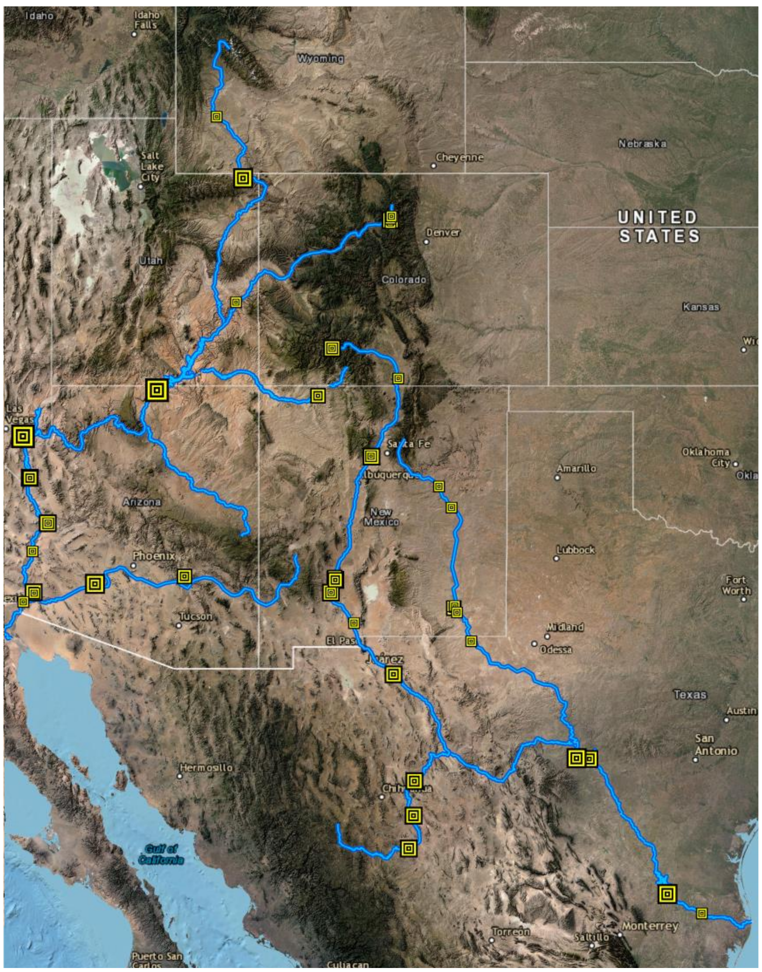
Sustainability of Engineered Rivers in Arid Lands:

Euphrates-Tigris and Rio Grande/Bravo



Lyndon B. Johnson School of Public Affairs
The University of Texas at Austin

Policy Research Project Report

190

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Sustainability of Engineered Rivers in Arid Lands: Euphrates-Tigris and Rio Grande/Bravo

Project Directed by

Aysegül Kibaroğlu

Jurgen Schmandt

A report by the
Policy Research Project on
Sustainability of Euphrates-Tigris and Rio Grande/Bravo
2016

The LBJ School of Public Affairs publishes a wide range of public policy issue titles.

ISBN: 978-0-89940-818-7

Cover design by Lauren R. Jahnke
Maps created by the Houston Advanced Research Center

Policy Research Project Participants

Graduate Students

Deirdre Appel, BA (International Relations and Public Policy), University of Delaware; Master of Global Policy Studies student, LBJ School of Public Affairs, The University of Texas at Austin

Jose Balledos, BS (Physics), University of San Carlos; Master of Global Policy Studies student, LBJ School of Public Affairs, The University of Texas at Austin (Fall term only)

Christine Bonthius, BA (Physical Geography), University of California, Las Angeles; Ph.D. student (Geography and the Environment), The University of Texas at Austin (Fall term only)

Ryan Brown, BA (International Relations and Economics) University of California, Santa Barbara; Master of Global Policy Studies student, LBJ School of Public Affairs, The University of Texas at Austin

Podie Chitan, BA (International Relations), ITESM Mexico City; Master of Public Affairs student, LBJ School of Public Affairs, The University of Texas at Austin

Marcos Duran, BA (Psychology), Southwestern University, Georgetown, Texas; Master of Public Affairs student, LBJ School of Public Affairs, The University of Texas at Austin

Sara Eatman, BS (Mechanical Engineering), University of New Mexico and BA (Humanities), Fort Lewis College; Master student, Environmental and Water Resource Engineering, Cockrell School of Engineering, The University of Texas at Austin (Spring term only)

Brian Jackson, BS (Biology and Chemistry), Denison University; Master of Public Affairs student, LBJ School of Public Affairs, The University of Texas at Austin

Anne Kilroy, BA (Psychology and International Studies), North Carolina State University; Master of Public Affairs student, LBJ School of Public Affairs, The University of Texas at Austin

Marimar Miguel, BA (Women's and Gender Studies), Texas A&M University; Master of Public Affairs student, LBJ School of Public Affairs, The University of Texas at Austin

Haytham Oueidat, BE (Civil and Environmental Engineering), Beirut Arab University; Master of Public Affairs student, LBJ School of Public Affairs, The University of Texas at Austin

Faith Martinez Smith, BA (Environmental Science), Westminster College; Master of Global Policy Studies and Master of Science student, The University of Texas at Austin

Melissa Stelter, BA (Sam Houston State University); Master of Global Policy Studies student, LBJ School of Public Affairs, The University of Texas at Austin

Rachel Weinheimer, BA (Classics), The University of Texas at Austin; Master of Global Policy Studies student, LBJ School of Public Affairs, The University of Texas at Austin

Technical Advisor

George Ward, Ph.D., Research Scientist, Center for Research in Water Resources, Cockrell School of Engineering The University of Texas at Austin

Project Directors

Aysegül Kibaroğlu, Ph.D., Visiting Professor, LBJ School of Public Affairs, The University of Texas at Austin; and Professor, MEF University, Istanbul

Jurgen Schmandt, Ph.D., Professor Emeritus, LBJ School of Public Affairs, The University of Texas at Austin; and Distinguished Fellow, Houston Advanced Research Center

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List of Acronyms

ASCE	American Society of Civil Engineers
CILA	Comisíon Internacional de Limítes y Aguas
CONAGUA	Comisíon Nacional del Agua
DSI	State Hydraulics Work (Turkey)
EPA	U.S. Environmental Protection Agency
ET	Euphrates-Tigris River Basin
FAO	United Nations Food and Agricultural Organization
GAP	Southeastern Anatolia Project
GWCD	Groundwater Conservation District
HARC	Houston Advanced Research Center
IBWC	International Boundary and Water Commission
MRGCD	Middle Rio Grande Conservancy District
OECD	Organization for Economic Cooperation and Development
PdN	Paso del Norte
POR	Period of Record
RG	Rio Grande/Bravo River Basin
RIA	Reservoir Impact Assessment
SERIDAS	Sustainability of Engineered Rivers in Arid Lands
TCEQ	Texas Commission for Environmental Quality
TWDB	Texas Water Development Board
USDA	United States Department of Agriculture
USGS	United States Geological Service

Foreword

The Lyndon B. Johnson School of Public Affairs has established interdisciplinary research on policy problems as the core of its educational program. A major element of this program is the nine-month policy research project, in the course of which one or more faculty members direct the research of ten to twenty graduate students of diverse disciplines and academic backgrounds on a policy issue of concern to a government or nonprofit agency. This “client orientation” brings the students face to face with administrators, legislators, and other officials active in the policy process and demonstrates that research in a policy environment demands special knowledge and skill sets. It exposes students to challenges they will face in relating academic research, and complex data, to those responsible for the development and implementation of policy and how to overcome those challenges

The curriculum of the LBJ School is intended not only to develop effective public servants, but also to produce research that will enlighten and inform those already engaged in the policy process. The project that resulted in this report has helped to accomplish the first task; it is our hope that the report itself will contribute to the second.

Finally, it should be noted that neither the LBJ School nor The University of Texas at Austin necessarily endorses the views or findings of this report.

Angela Evans
Dean

Acknowledgements

We thank the George and Cynthia Mitchell Family Foundation and Meredith Dreiss, daughter of Cynthia and George Mitchell, for their financial support of this project.

For insightful information and guidance, we thank the following individuals: Jennifer Cooper, LBJ School; Marilu Hastings, Mitchell Foundation; Sean McKaughan, Avina Foundation; Steve Niemeyer, TCEQ; Gerald North, Texas A&M University; Sally Spener, IBWC; Carlos Rincon, EPA Regional Office El Paso; Carlos Rubinstein, former Rio Grande Water Master; Chandler Stolp, LBJ School; and Michael Webber, The University of Texas at Austin. Lauren Jahnke copyedited and formatted the report.

Introduction

by Jurgen Schmandt and Aysegül Kibaroğlu

Policy Research Project on Sustainability of Euphrates-Tigris and Rio Grande/Bravo

This publication arose from a Policy Research Project on the sustainability of river systems. Our team of faculty members and graduate students studied water management issues in two river systems—Euphrates-Tigris (ET) and Rio Grande/Bravo-Conchos (RG). (The Rio Grande is called the Río Bravo in Mexico, hence we often use both names). See Figures I.1 and I.2 for maps of these two river systems. Occasionally we also refer to the Colorado River because it is managed together with the Rio Grande/Bravo by the same international agency, the International Border and Water Commission (IBWC). These rivers are part of a ten-river project called Sustainability of Engineered Rivers in Arid Lands (SERIDAS), described in the next section.

The ET/RG project took nine months to complete, from September 2015 to May 2016. It was directed by professors Aysegül Kibaroğlu, MEF University, Istanbul (International Relations), and Visiting Professor at the LBJ School; and Jurgen Schmandt, of the LBJ School and the Houston Advanced Research Center, or HARC (Water Policy and Sustainability Science). The team received advice on matters pertaining to hydrology and meteorology from Dr. George Ward, Center for Research in Water Resources at The University of Texas. Several experts on specific aspects of our research agenda visited with the team. This for-credit graduate course was organized as a policy research project that serves as an instrument for both learning and public service. The project team met for three hours each week, when necessary using Skype to connect with distant team members. Students organized their work in small groups or prepared individual case studies. The full team reviewed all contributions and helped draft the conclusion.

Both the ET and RG river systems are drought-prone and likely to face increased water scarcity as a result of climate change and reservoir sedimentation. Water demand will increase due to population growth in river stretches close to areas with highly productive irrigated agriculture. We sought to answer these questions:

1) How do water stakeholders prepare for future water scarcity?
2) How sustainable is water supply and demand in the river basins?

We placed these questions in the context of sustainability science: linking local to global conditions, studying issues using an interdisciplinary framework, integrating the experience of stakeholders, and providing sound scientific guidance to decision-makers for implementing step-by-step improvements. These principles were developed by the National Academy of Sciences, and have greatly changed the way we study the future sustainability of natural resources.[1]

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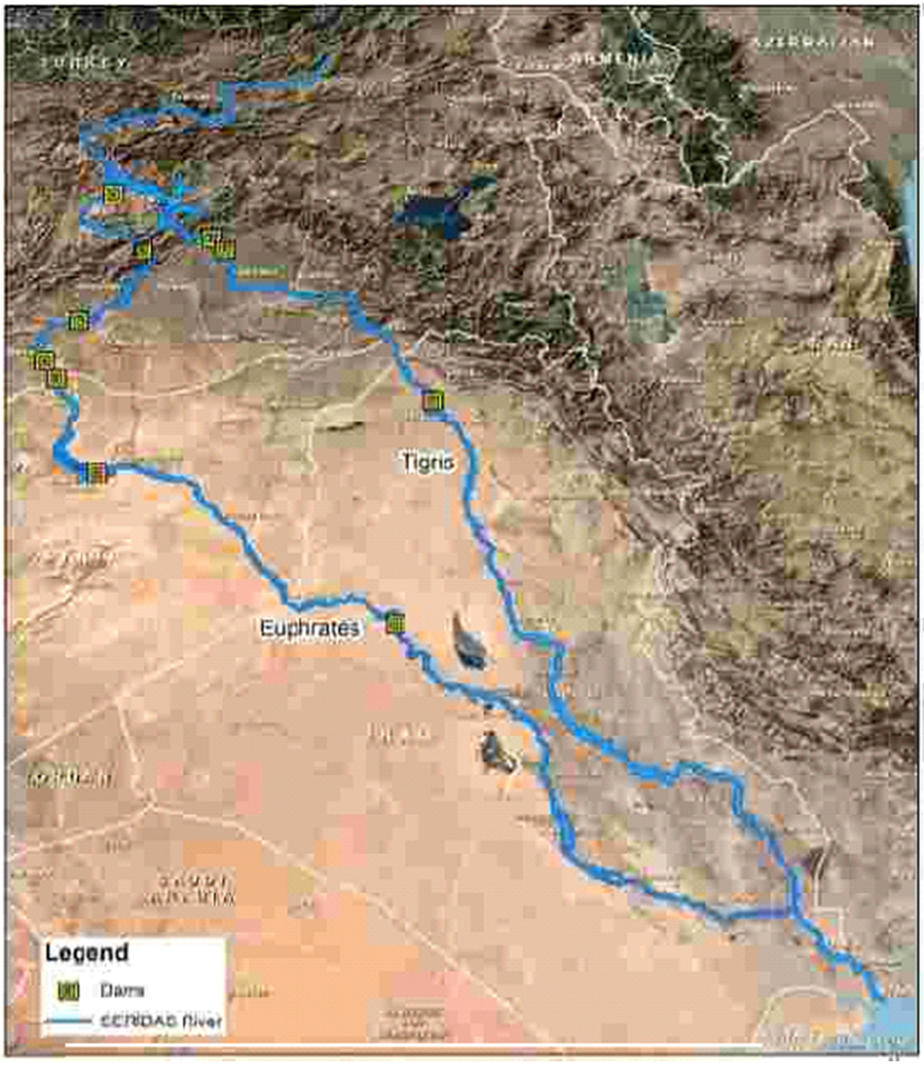
[1] National Research Council, *Our Common Journey: A Transition toward Sustainability* (Washington, D.C.: National Academy Press, 1999).

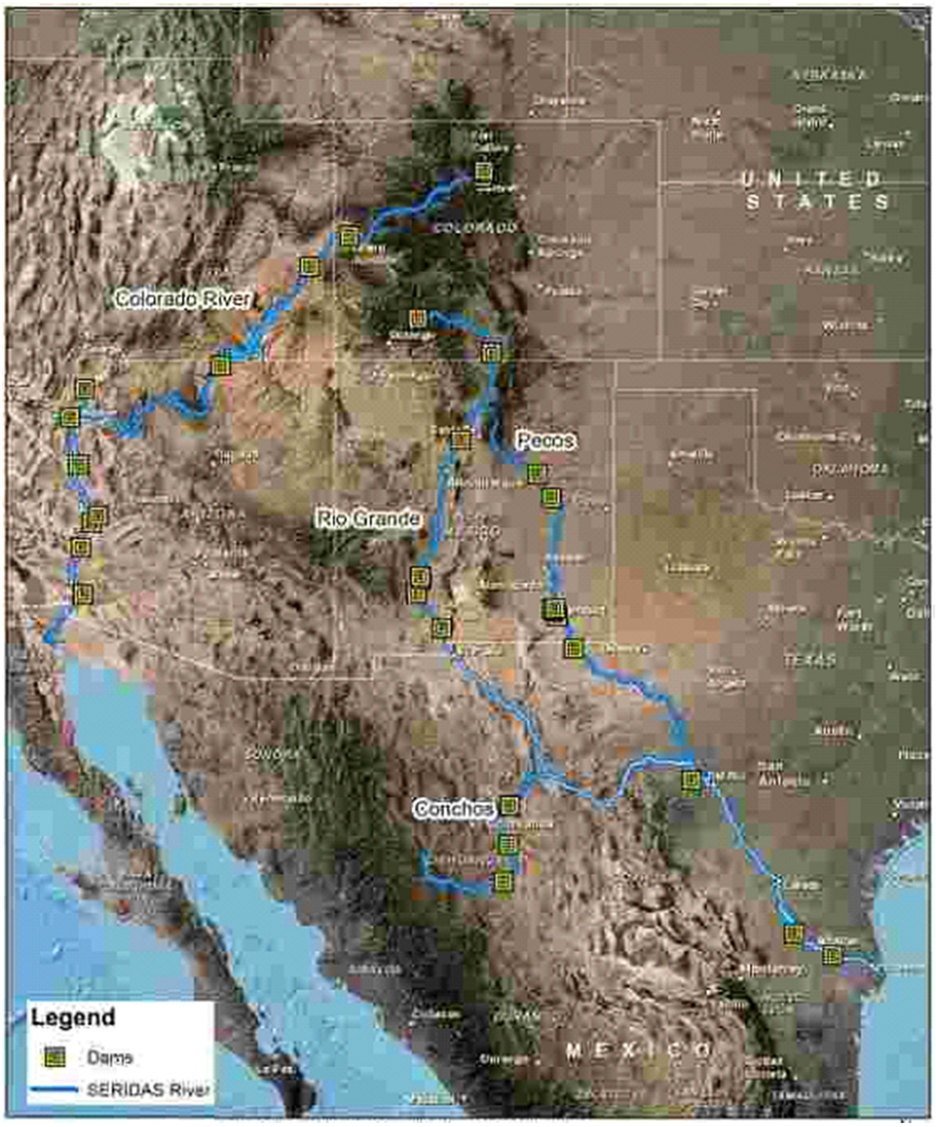
Figure I.1.
Euphrates and Tigris Rivers and Reservoirs



Source: HARC, compiled from GRanD Database, NID, GRDC, USGS, NASA, and ESRI data.

The common elements of the two river systems framed much of our research agenda: 1) reliable water supply (at least until recently) from snowpack in the mountainous source regions, 2) fertile downstream land from millennia of annual sediment accumulation during spring melts, 3) massively increased agricultural production as a result of modern large-scale river engineering (reservoirs and distribution networks), and 4) population growth in riparian cities next to irrigated lands. A major part of our work focused on studying the impacts of large reservoirs, both in the storage lakes and downstream. For each reservoir we asked how year-round water availability increased food production and enhanced the economic well-being of farmers and cities. We then turned to challenges that need to be faced: climate change/variation, reservoir sedimentation, groundwater over-pumping, growing urban demand, and reduced environmental flow.

Figure I.2.
Colorado and Rio Grande/Bravo Basins and Reservoirs



Source: HARC, compiled from GRanD Database, NID, GRDC, USGS, NASA, and ESRI data.

We took care to highlight differences between the river systems. In the case of the Euphrates-Tigris we asked, for example, how the emergence of a non-state actor—ISIS—and its control of strategic water infrastructure compels water stakeholders to search for new mechanisms for reliable water management. In the case of the Rio Grande we worked with water stakeholders in the Paso del Norte stretch of the river, covering parts of New Mexico, Texas, and Chihuahua. We conducted a survey of current water management arrangements and plans for coping with increased water scarcity in the future. We also reviewed more than 300 agreements between Mexico and the United States that were crafted in the decades following signing of the 1944 water treaty. These "minutes" address changing conditions in the Colorado and Rio Grande basins and we wanted to know if the minute process could be used to cope with increasing water scarcity.

Some important parts of our work took place outside the classroom. We organized two workshops, one on each of our river systems. The ET workshop was held at Ohio State University on April 21-22, 2016, and the RG workshop convened in El Paso, Texas, on May 27, 2016 (more information on these events can be found in Part IV of this report).

Overview of the SERIDAS Project

This section provides background information on the Sustainability of Engineered Rivers in Arid Lands project (SERIDAS) to which our PRP contributed.

Goals

Engineered rivers are the lifeblood of irrigated agriculture, produce electricity, and supply water for industry and cities in the river basins. By now most large rivers in the world have been engineered—equipped with multiple dams, bypass canals, and distribution channels. River engineering brings large benefits to farmers and cities. It also creates risks.

Members of the SERIDAS network study ten rivers, namely Colorado (U.S./Mexico), Euphrates-Tigris (Middle East), Júcar (Spain), Limarí (Chile), Murray-Darling (Australia), Nile (North Africa), Rio Grande (U.S./Mexico), São Francisco (Brazil), and Yellow (China) in order to find out how the rivers will do in 2040 and 2060 (see Figures I.3 and I.4). All share important characteristics: upstream mountains supply reliable stream flow from glaciers, snowpack, or rainfall. Large-scale water engineering has created important agricultural systems that support the economic well-being of basin populations and contribute to global food security. While physical conditions are similar, political, social, and economic features differ widely, as do arrangements for water governance.

Specifically, the SERIDAS projects asks how natural and social conditions in the ten river systems listed above will change by 2040 and 2060. By how much will future water scarcity damage basin economies, populations, and natural conditions? Or can water managers and users take steps to make the rivers and basins more sustainable?

The project applies the principles of sustainability science to the study of agriculture-intensive dryland river basins: linking global to local conditions, using integrative/interdisciplinary frameworks and working with stakeholders. It looks at both physical and social drivers of change—climate change/variation, reservoir sedimentation, surface-to-groundwater connection, and environmental flow on nature's side; and population and land use changes, as well as options for more efficient water use and better governance, on the social side.

History

Under EPA grant R824799, the Houston Advanced Research Center convened a Mexican-U.S. team for an interdisciplinary study of water supply and demand in the Lower Rio Grande, the 1,000-kilometer-long river segment on the U.S.-Mexico border that is dependent on Amistad and Falcón reservoirs. The research team spent several years on the project and found that the river would be dramatically changed by 2030. Most importantly, there would be one-third less river water:

- Each decade the Rio Grande loses 5 percent of reservoir storage to sediment buildup behind reservoir dams;
- The basin population will double by 2030, requiring a larger share of river water; and
- Environmental flow, already low, will decline even more.

Figure I.3.
The SERIDAS Rivers

Source: HARC, "Sustainability of Engineered Rivers in Arid Lands," http://www.harc.edu/work/SERIDAS.

There was one good piece of news: researchers found that farmers might be able to maintain the value of current harvests while using less water—provided they adopted more efficient irrigation methods and shifted to less water-demanding crops. And both agriculture and cities could make much progress with water conservation and repair of leaking distribution systems.[2]

The Rio Grande/Bravo results brought up more questions: Were they representative of rivers elsewhere? What are the prospects for engineered rivers in arid lands worldwide? How will the rivers do under the impacts of climate change, reservoir sedimentation, and population growth? The project resulted in the creation of SERIDAS to find answers.

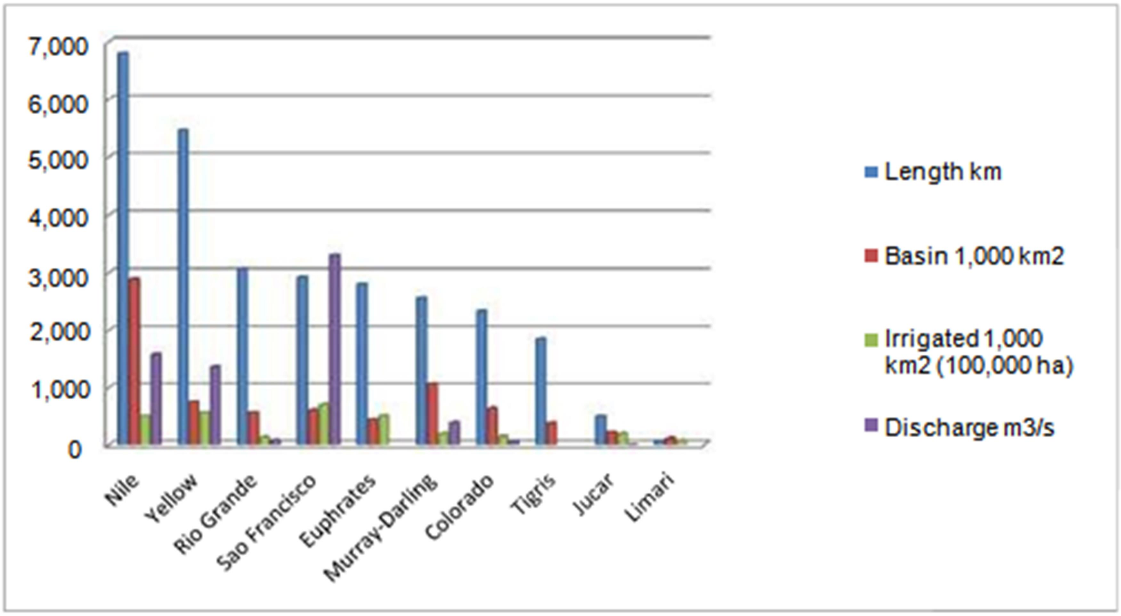
Work Done, Work Underway

The project team completed Phase I of the project—conducting the above-mentioned test study (Lower Rio Grande), developing study methodology, recruiting the study team, holding two international workshops (Austin, Texas, in 2014, and Hannover, Germany, in 2015), and

[2] For a detailed summary of the study results, see J. Schmandt, "Bi-national water issues in the Rio Grande/Rio Bravo," *Water Policy 4* (2002): 137-155. The full report is available at http://mitchell.harc.edu/archive/RioGrandeBravo/Report. An abstract is available on the EPA website at https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/857/report/F.

assessing past and current river conditions. The project team includes an expert for each of the rivers as well as specialists for key change factors. Phase II, currently underway, projects 2040 and 2060 conditions in the basins, recommends ways for using water more efficiently, and analyzes the impact of changed river conditions on global and regional water, food, and energy security.

Figure I.4.
SERIDAS River Characteristics



Source: HARC, compiled from data provided by the SERIDAS team.

Members of the SERIDAS Network

The SERIDAS project assembled a team of river experts to project water supply and demand for a group of heavily engineered rivers worldwide. A second group of team members was invited to advise the river experts on how to deal with future risks.

SERIDAS River Experts

- José Albiac, Researcher, CITA, Government of Aragon, Agricultural Economics (Júcar basin)
- Michael Cohen, Senior Research Associate, Pacific Institute (Colorado basin)
- Daniel Connell, Research Fellow, Environment and Development Program, Crawford School of Public Policy, Australian National University (Murray-Darling basin)
- Mohamed Taher Kahil, International Institute for Applied Systems Analysis, Laxenburg (Júcar basin)
- Aysegül Kibaroğlu, Department of Political Science and International Relations, MEF University, Istanbul (Euphrates-Tigris basin)

- Antonio Magalhães, Center for Strategic Studies, Brasilia, Economics (São Francisco basin)
- Alexandra Nauditt, Cologne University of Applied Science, Earth sciences (Limarí basin)
- David Pietz, University of Arizona, History (Yellow basin)
- Lars Ribbe, Cologne University of Applied Science, Hydro Informatics (Nile basin)
- Jurgen Schmandt, HARC and UT Austin (Rio Grande basin)
- George Ward, UT Austin (Rio Grande basin)

SERIDAS Issue Advisers

- Peter Gleick, Environmental Scientist, Co-founder of the Pacific Institute, energy and resources, food security
- Stephanie Glenn, Program Director, Hydrology and Watersheds, HARC, environmental science and engineering, groundwater connection
- Antonio Magalhães, Center for Strategic Studies, Brasilia, economics and poverty, sustainability
- Tony McLeod, Murray-Darling River Authority, water planning, river management
- Ari M. Michelsen, Resident Director, TAMU, AgriLife Research and Extension Center, agricultural economics
- Steve Murdock, Allyn R. and Gladys M. Cline Professor of Sociology, Rice University, sociology, demography
- Gerald North, University Distinguished Professor of Atmospheric Sciences and Oceanography, TAMU, climatology, climate change
- Lars Ribbe, Cologne University of Applied Science, hydro informatics, information tools for water governance
- Jurgen Schmandt, HARC and UT Austin, water policy, sustainability
- George Ward, UT Austin, hydrology, water budget, reservoir sedimentation

PART I.
RESERVOIR IMPACT ASSESSMENTS

Chapter 1. Methodology

by Haytham Oueidat

Overview

We divided the Euphrates-Tigris and Rio Grande/Bravo in river segments reaching from one reservoir to the next one. Each reservoir creates both a new hydrological sub-basin and a socio-economic impact region. The Reservoir Impact Assessment (RIA) approach allows us to find answers to multiple questions: What is the purpose of the reservoir—flood control, drought management, agricultural and municipal water supply, industry? What has been the impact on irrigated agriculture and city growth? How is the storage lake used? When is water released from the dam? How much? How is the water divided between users? How is the reservoir managed and maintained? In planning ahead, is there consideration of storage volume loss due to sedimentation? Or of the impact of climate change? What is the environmental impact?

RIAs are useful stepping stones for the assessment of conditions and prospects in the entire river basin. They allow for a close look at the benefits as well as problems in the hydrological and socio-economic sub-basin created by the reservoir and its hydrological and socio-economic region. We recommend to the members of the SERIDAS river network to include reservoir impact assessments in their studies.

The following was the suggested outline for the RIAs in this report. This was intended as general guidance since students were free to structure their RIAs according to data availability and personal preferences.

1. The dam
    a. History, planning, and financing
    b. Engineering details
    c. Rationale for location
    d. Goals and changes over time
    e. Maintenance
    f. Problems

2. The reservoir (lake, storage area, upstream of dam)
    a. Capacity (maximum volume)
    b. Size of allocation pools (irrigation, municipal, energy, environmental flow)
    c. Area covered
    d. Uses (recreation, fishing, cities, etc.)
    e. Drought incidence (frequency, minimal volume ever recorded)
    f. Storage loss due to sedimentation
    g. Description of area before the dam was built (people, cities, villages, etc.) and number of people displaced

3. The impact area (drainage area, sub-basin watershed downstream of dam)

a. Discharge from dam (average, maximum, minimum)
b. Size (river length plus riparian land receiving river water)
c. Distribution channels/canals/pipe lines (how does water reach irrigated land?)
d. Hydropower
e. Water use
f. Irrigation (normal and drought years)
    i. Municipal water supply (total and water use per capita over time)
    ii. Industry
    iii. Ecology, in-stream flow
    iv. Water left for discharge to next reservoir or the sea
g. Farming (crops, irrigation technologies, value of harvests, river water supplemented by ground water), cost of water
h. Irrigation districts
i. Population growth/decline

4. Governance
    a. Agency(ies)
    b. Compacts, treaties, agreements
    c. Rules for coping with drought/flooding
    d. Flexibility/success in coping with new conditions
    e. Planning for the future
    f. Whether impact of climate change is considered and how

Reasoning for Reservoir Impact Assessments

The unidimensional treatment of river streams complicates the evaluation of their influence on the environments through which they traverse. A great deal of insight would be inadvertently excluded, for instance, by contemplating the two basins included in this study with a purely hydrological "lens," or similarly a purely retrospective or political one would unveil the underlying motives of management up to now but would not highlight the correctness and fairness of water-related decisions or lack thereof to the different constituents of the basin.

A comparative analysis on that large a scale suggests that while similarities and contrasts will be derived from a macroscopic examination of the two rivers, this approach is likely to be superficial for failing to explore in detail the notable peculiarities of the system. Consequently, a multilevel methodology had to be adopted to facilitate the comparison of the two basins and to provide a set of common elements to investigate in each. This procedure, the RIA, involved a delicate scanning by geographic apportioning of the entire network in regions between one dam and another.

The following RIA focal points provide a working template and orient the individual reports that follow.

Geography

We divided the river into segments and joints to represent stream channels and reservoirs. Each analysis area was deliberately demarcated by two dams of the same series to define the nature of the relationship between the dam locations and various aspects of that node-to-node interface. Arguably occasional buffers upstream of the reservoir could also be included to slightly expand the study area—as reservoirs fill up they form widely stretched inundation zones that change in function with noticeable water level variations.

History

Every dam is an edifice purposely built in response to specific objectives of water planning and management, and while all were presumably conceived within different contexts and visions, some recursive goals and hurdles could be identified in seemingly dissimilar political environments from surveying the construction and maintenance processes as they occur in the life of the reservoir.

Hydrology and Socioeconomic Evaluation

Regions' social and economic characteristics are outlined along with a description of the hydrology and infrastructure in place. The hydrologic features should include data and text on irrigated lands, water supply, flood control, and/or energy production traced over 10- to 20-year intervals until the latest available information was published. The socioeconomic attributes comprise population and water demand data over the same timeline, and literature reviews on the region's economy, irrigated agriculture, and signs of urbanization.

Transboundary Governance

Every region is rich in interesting events that shaped its fate in history. A review of local governing bodies, stakeholder jurisdictions, and notable agreements and treaties could determine how or if the observed difficulties were resolved.

Problems Confronted

Any hydrological system is inherently faced with challenges internal and external to it. The control for sediment transport, salinity, flooding, droughts, and ecological damage cannot digress from accounting for growing population needs. This section should lead to observations on strategies devised to handle the effects of water scarcity.

The information will be reported in both metric and imperial units depending on the adopted custom in the corresponding literature for each basin. It is also important to note the impediments encountered while performing RIAs such as the absence of data on current conditions, which could in itself constitute an argument on the limitations of this methodology. Nonetheless, using RIAs to gather evidence for the characterization of international rivers could prove to be a robust instrument for its ability to expose and overlay in a single lot a range of common aspects and issues that would otherwise be addressed separately.

Chapter 2. Keban Dam

by Melissa Stelter

History, Planning, and Financing

The Keban Dam is located in Elazig province in Eastern Turkey. The region is mountainous and is bordered by the Hazar, Maden, Ak, and Karaboga Mountains. The dam is placed below the point where the Munzur, Peri, Murat, and Karasu rivers form the Euphrates river.[3] (See Figures 2.1 and 2.2 for maps.)

The construction of the Keban dam began in 1964 under the administration of the Euphrates Planning Authority, which was established in 1961. The goal of Keban Dam was to provide electricity and to promote urbanization and industrialization. Funding for the dam was provided by the Marshall Plan, France, Germany, Italy, and the U.S. Agency for International Development (USAID). Funding from the World Bank was withheld until Turkey negotiated flows with Syria.[4] However, Turkey was able to sign an agreement with USAID guaranteeing a flow of 350 cubic meters per second and this agreement was confirmed by Syria and Iraq.[5] Construction of the rockfill and concrete gravity dam was finished in 1974, after 10 years of construction; it was the first project of its size and the first project to result in displacement of people in Turkey.[6]

The Reservoir

The construction process was complicated due to the geological foundation of the region. The basement of the dam was karstic marble, meaning that the foundation contained caves. The accessible caves were filled with cement and the inaccessible caves were filled with grouting. However, it was still a possibility for leaking to occur on the left side of the dam. When the reservoir was filled to capacity, a whirlpool formed as water entered two previously undiscovered cavities, and a leak was also discovered at Keban Creek. The reservoir levels were reduced while repairs were completed. A concrete wall was constructed around the sinkhole and the cavities were filled. There is still a leak at Keban Creek but it is reduced and maintains a low and constant flow rate.[7]

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[3] Kenan Alpaslan, Ahmet Sesli, Ridvan Tepe, and Mehmet Ali T. Koçer, "Vertical and Seasonal Changes of Water Quality in Keban Dam Reservoir," *Journal of Fisheries Science*, 6(2) (2012): 252-262.

[4] Kerem Oktem, "When Dams Are Built on Shaky Grounds: Policy Choice and Social Performance of Hydro-Project Based Development in Turkey" (Dämme auf unsicherem Grund. Politische Strategien und soziale Auswirkungen von Wasserprojekten in der Südost-Türkei), *Erdkunde* 3 (2002): 310-325.

[5] Ayşegül Kibaroğlu, *Building A Regime for the Waters of the Euphrates-Tigris Rivers Basin* (The Hague: Kluwer Academic Publishers, 2002).

[6] Oktem, "When Dams Are Built on Shaky Grounds."

[7] Aziz Ertunç, "The Geological Problems of the Large Dams Constructed On the Euphrates River (Turkey)," *Engineering Geology* 51(3) (1999): 167-182.

Figure 2.1.
Location of the Keban Dam

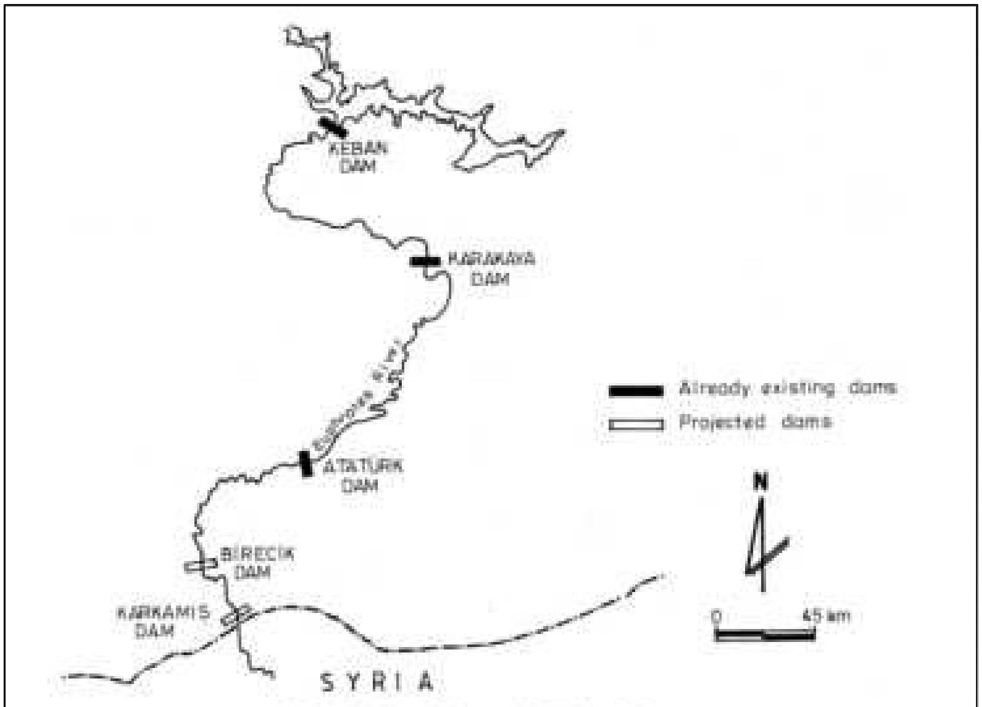
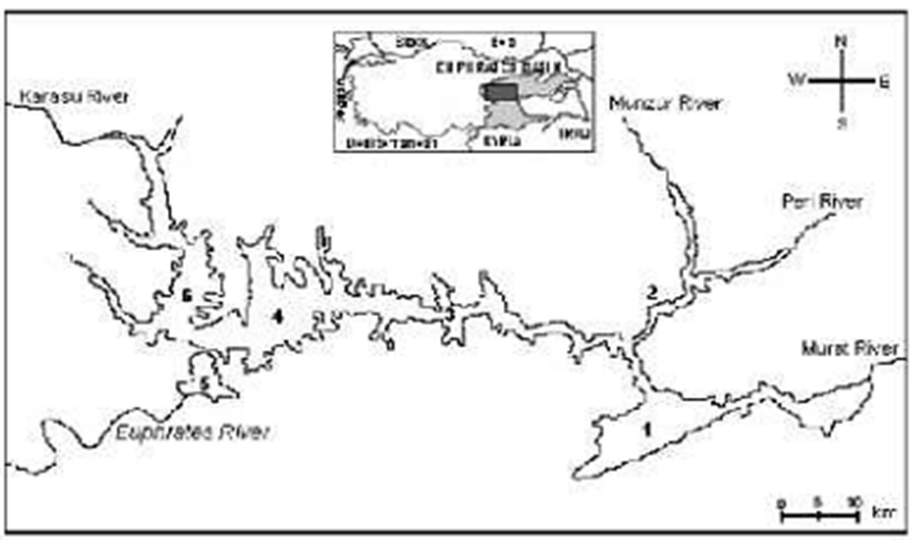


Fig. 1. Positions of dams on the Euphrates River.

Source: Aziz Ertunç, "The Geological Problems of the Large Dams Constructed On the Euphrates River (Turkey)," *Engineering Geology* 51(3) (1999): 167-182.

Figure 2.2.
Tributaries Leading to Keban Dam



Source: Aziz Ertunç, "The Geological Problems of the Large Dams Constructed On the Euphrates River (Turkey)," *Engineering Geology* 51(3) (1999): 167-182.

The Impact Area

This was the first project in Turkey that made it necessary to relocate people since the dam would flood certain lands, and the relocation process was inefficient and inequitable. The people who benefitted from the project were the owners of large tracts of land who received a payment and then moved to Western Turkey. The landless peasants could not benefit from this same type of compensation and, upon relocating to urban centers, struggled to find non-farm employment. An estimated 30,000 to 40,000 people were relocated as a result of this project. The provincial capital of Elazig doubled in population, which resulted in a housing shortage and poor living conditions.[8]

After completion, the dam began producing an estimated 6,000 gigawatt hours of energy each year. The dam has a crest elevation of 848 meters and a crest length of 1,097 meters. The height from the foundation is 207 meters and the height from the river bed is 163 meters. Maximum water surface elevation is 846.67 meters and the average water surface elevation is 845 meters. At normal surface-level elevation, the storage lake has a volume of 30,600 cubic meters. The completion of this dam changed the downstream flows. At Jarablus, Syria, the average flow rate from 1938 to 1973 was 30 billion cubic meters.[9] This flow rate average represents the flows up to the year before the completion of Keban dam, the first dam on this river. In the period after the construction of the Keban dam, the flows reduced to 24.9 billion cubic meters from 1974 to 1987. While the flow rates of the Euphrates changed after the construction of the dam, this water was not used for irrigation or municipal water consumption, it was solely for electricity. As a result, this dam's main effect on the region was displacing a portion of the residents in Elazig province.

There are also some concerns about downstream water quality due to water pollution. Sewage is discharged into the Keban Dam reservoir, leading to an increase in heavy metals in the water. An estimated 0.346 kilograms per square kilometer of chromium and lead are added to the water each year, along with 2.17 kilograms of cadmium and 1.08 kilograms of nickel. This not only degrades the quality of water that will be used downstream for irrigation purposes, but the fish, especially carp, consume these heavy metals and could then enter the food system if consumed.[10] In addition to environmental pollution, the dam led to siltation. Based on 2006 estimates by the General Directorate of State Hydraulic Works of Turkey, 14.7 percent of the Keban Dam volume was lost since closing.

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[8] Oktem, "When Dams Are Built on Shaky Grounds."

[9] Ercan Ayboga, "Report About the Impacts of the Southeastern Anatolia Project (GAP) and the Ilisu Dam on the Downstream Countries Iraq and Syria" (Initiative to Keep Hasankeyf Alive, 2009).

[10] Yakup Cuci, Halil Hasar, Mehmet Yaman, and U. Ipek, "Pollution in Keban Dam Lake: Trace Metals from Classical Activated Sludge System" *Bulletin of Environmental Contamination and Toxicology* 67(6) (Dec. 2001):906-912.

Chapter 3. Atatürk Dam

by Rachel Weinheimer

History of the Dam

Atatürk Dam was not Turkey's first major dam construction project; it was preceded by the Keban Dam (started in 1966 and in operation in 1974) and the Karakaya Dam (started in 1976 and in operation in 1987). It is, however, the main feature of Turkey's Southeastern Anatolia Project (GAP) and the sixth-largest dam in the world, with a volume of 48.7 billion cubic meters and standing at 169 meters high (see Figure 3.1). The dam was funded by the Turkish government and constructed by Turkey's State Hydraulic Works (known by the Turkish acronym DSI), spanning two provinces in Turkey's southeast, Adıyaman and Şanlıurfa. When fully realized, the total irrigated area will be approximately one million hectares.[11]

Construction began in 1983 and was completed in 1990. A tunnel system was constructed in 1997 and provides water through a system of irrigation networks and canal systems. In addition to irrigation, Atatürk Dam is an important source of energy in Turkey. The dam began producing energy in 1992 and produces 7.8 billion kilowatt hours per year, valued at US$468 million. The dam is maintained by DSI.

One of the major issues currently faced by the dam is competing objectives driving development in the GAP region. Though the Atatürk Dam was planned and constructed to provide both hydroelectric power and newly irrigated land, hydro-climatic conditions have constrained the dam's ability to operate at full capacity.[12] Turkey's southeast is not receiving enough rainfall for Atatürk Dam to function as planned, which forces the government to prioritize the dam's objectives in the region. Additionally, the dam's initial objectives of providing power and irrigating land have expanded to include improvement projects intended to transform the social and economic landscape of the Southeastern Anatolia region.[13] Some of these projects include literacy centers, health education, family planning education, and other initiatives meant to help close the gap in gender disparity in the region.

The Reservoir

The storage capacity of the Atatürk reservoir is 48.7 billion cubic meters, making it the 20th-largest reservoir in the world. While in its planning stages, the Atatürk reservoir was intended to supply irrigation water to 882,380 hectares of agricultural land, which corresponded to about 54 percent of the total GAP irrigation area. The irrigation system encompassed six irrigation

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[11] Ibrahim Yüksel, "South-Eastern Anatolia Project (GAP) Factor and Energy Management in Turkey," *Energy Reports 1* (2015): 151-155.

[12] Anna Brismar, "The Ataturk Dam Project in South-East Turkey: Changes in Objectives and Planning Over Time," *Natural Resources Forum* 26(2) (2002): 101-112.

[13] Leila M. Harris, "Water and Conflict Geographies of the Southeastern Anatolia Project," *Society & Natural Resources* 15(8) (2002): 743-759.

schemes: the Siverek-Hilvan scheme (160,105 hectares), the Bozova pumped scheme (69,702 hectares), the Suruc-Baziki scheme (146,500 hectares), the Mardin-Ceylanpinar scheme (334,939 hectares), and the Urfa-Harran scheme (141,535 hectares). The last two were regarded as the most important.[14]

The GAP region has been under a severe drought since 1998 with conditions expected to worsen. These conditions have significantly constrained the potential of the dam project to provide a steady supply of electricity. For continuous production, the reservoir must maintain a minimum operational water level of 525 meters. In October 2000, the water level dropped to only 526.59 meters, and in spring 2001 it still hovered very close to the minimum.[15]

Figure 3.1.
Map of Turkey with Location of Atatürk Dam and Reservoir

Source: Google, “Google Maps,” accessed April 2016, https://www.google.com/maps.

Resettlement of Reservoir Residents

The construction of the Atatürk Dam and subsequent inundation of the reservoir area displaced approximately 40,000 people[16] from dozens of villages in Adıyaman and Şanlıurfa.[17] The residents were given the choice of monetary compensation or a land allotment; over 95 percent

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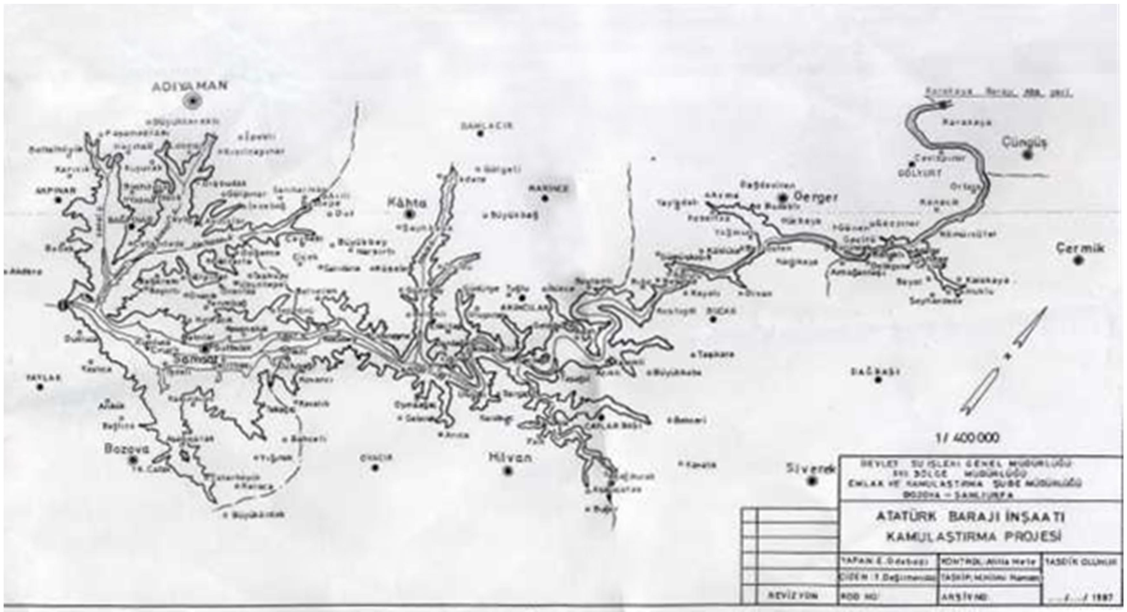
[14] Republic of Turkey Prime Ministry State Planning Organization, *The Southeastern Anatolia Project Master Plan Study, Final Master Plan Report,* vol. 2, 2nd ed., June 1990.
[15] Brismar, “The Ataturk Dam Project in South-East Turkey.”
[16] Jennifer Keiser, Marcia Caldas De Castro, Michael F. Maltese, Robert Bos, Marcel Tanner, Burton H. Singer, and Jürg Utzinger, “Effect of Irrigation and Large Dams on the Burden of Malaria on a Global and Regional Scale,” *American Journal of Tropical Medicine and Hygiene* 72(4) (2005): 392-406, http://www.who.int/water_sanitation_health/resources/ajtmhmalaria.pdf.
[17] John F. Kolars and William A. Mitchell, *The Euphrates River and the Southeast Anatolia Development Project* (Carbondale: Southern Illinois University Press, 1991).

chose monetary compensation. Figure 3.2 shows a 1987 map of the villages and cities that were flooded when the Atatürk Dam was built. Figures 3.3 and 3.4 show maps of the impact areas.

Figure 3.2.
Villages and Cities Flooded after Building of Atatürk Dam



Source: Turkish State Hydraulics Works (DSI), Archived map (1987), provided to author by DSI.

Figure 3.3.
Regional View of Atatürk Reservoir and Provinces of Adıyaman and Şanlıurfa

Source: Turkish State Hydraulics Works, "DSI," accessed January 2016, http://barajlar.dsi.gov.tr/.

Figure 3.4.
Euphrates River and Surrounding Regions Before Construction of Atatürk Dam in 1984

Source: O. Ozcan, B. Bookhagen, and N. Musaoglu, "Impact of the Atatürk Dam Lake on Agro-Meteorological Aspects of the Southeastern Anatolia Region Using Remote Sensing and GIS Analysis," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* XXXIX-B8 (2012): 305-310.

The Harran Plain is located in Şanlıurfa and represents approximately half of the irrigated area (141,855 hectares) created by the Atatürk Dam. In 1994, water reached the Harran Plain via the Şanlıurfa tunnels. As shown in Figures 3.5 and 3.6, irrigated areas increased 289 percent from 1993 to 2002.[18] In 2002, cotton accounted for over 85 percent of all crops grown on the plain, while cereals, maize, and vegetables accounted for the remainder. A canal system is also being built in order to provide irrigation to the Siverek-Hilvan plains, which will allow an additional 64,500 hectares of land to be irrigated.[19]

Irrigation Management and Organization in the Harran Plain

A case study conducted in 2009-2011 found that in the course of two decades, irrigation management and practice had fundamentally changed in Turkey.[20] The creation of the Atatürk Dam changed Harran Plains irrigation from small-scale (using groundwater) to large-scale (using surface water). In addition to this shift, DSI established irrigation associations, which work in a semi-autonomous fashion and are comprised of local authorities and farmer representatives who distribute water to farmers, operate and maintain canals, and collect fees. The case study showed that these associations voice similar concerns: farmers applying inappropriate irrigation practices and not adopting water-saving irrigation methods, and irrigation associations not using irrigation

[18] Mutlu Ozdogan, Curtis E. Woodcock, Guido D. Salvucci, and Hüseyin Demir, "Changes in Summer Irrigated Crop Area and Water use in Southeastern Turkey from 1993 to 2002: Implications for Current and Future Water Resources," *Water Resources Management* 20(3) (2006): 467-488.
[19] John F. Kolars and William A. Mitchell, *The Euphrates River and the Southeast Anatolia Development Project* (Carbondale: Southern Illinois University Press, 1991).
[20] Gül Özerol, "Institutions of Farmer Participation and Environmental Sustainability: A Multi-Level Analysis from Irrigation Management in Harran Plain, Turkey," *International Journal of the Commons* 7(1) (2013): 73-91.

fees to reduce water use and not enforcing sanctions against excessive water use. Though the associations are meant to work as a collective, opportunities for participation are mixed and institutional alignment is low. According to the case study, this low level of alignment has implications for the environmental sustainability of practices in the Harran Plain.

Figure 3.5.
Harran Plain, August 1993

Source: NASA, Satellite Images (1993), accessed February 2016, http://earthobservatory.nasa.gov/Features/HarranPlains/Images/ataturk_1993.jpg.

Figure 3.6.
Harran Plain, August 2002

Source: NASA, Satellite Images (2002), accessed February 2016, http://earthobservatory.nasa.gov/Features/HarranPlains/Images/ataturk_2002.jpg.

Demography

Though populations shifted during the construction of Atatürk Dam, the densities of these regions did not change substantially. In 1991, the population density (people per square kilometer) was 49. In the year 2000, this number rose to 50.3.[21]

Problems

Salinization

The Harran Plain, which is irrigated by the Atatürk Dam, faces excessive salinization as a result of the rising level of groundwater. The level of salinization in the area in 1987 was 5,500 hectares; in 1997 it stood at 7,498 hectares and in 2000 it had expanded to 11,403 hectares.[22] As a result, there have been high levels of aquifer and groundwater contamination. Additionally, well equipment has been corroded due to salty water.[23]

Health Concerns

Though Turkey has almost completely eradicated the presence of malaria within its boundaries, there were several epidemics throughout the 20th century,[24] some of which may correlate to dam projects. During the construction of Atatürk Dam's irrigation tunnel system to Şanlıurfa in the early 1990s, there was a sharp spike in the number of cases of malaria. The province of Şanlıurfa (with a population of one million in 1990) reported that malaria cases increased from 785 in 1990 to 5,125 in 1993.[25] Though the dam construction contributed to the number of cases, it was most likely not the sole factor in the rise of malaria. During this time, Turkey also accepted thousands of migrant workers who were found to be carrying and spreading the disease.

Security Issues

When dam construction commenced, militant Kurdish separatists (the PKK) staged multiple deadly attacks against construction workers, engineers, and crew associated with the dam project. In addition to attacks against people, approximately 1,100 vehicles and pieces of working machinery were destroyed.[26] These attacks prolonged the project's construction time and drove up the costs of completing the dam. Theft of the electricity generated by the Atatürk

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[21] Keiser et al., "Effect of Irrigation and Large Dams on the Burden of Malaria on a Global and Regional Scale."

[22] M. Irfan Yeşilnaçar and Ibrahim Yenigun, "Effect of Irrigation on a Deep Aquifer: A Case Study from the Semi-Arid Harran Plain, GAP Project, Turkey," *Bulletin of Engineering Geology and the Environment* 70(2) (2011): 213-221.

[23] Ibid.

[24] Serap Aksoy, Sedat Ariturk, Martine Y.K. Armstrong, K.P. Chang, Zeynep Dörtbudak, Michael Gottlieb, M. Ali Ozcel, Frank F. Richards, and Karl Western, "The GAP Project in Southeastern Turkey: The Potential for Emergence of Diseases," Emerging Infectious Diseases 1(2) (1995): 62-63, http://wwwnc.cdc.gov/eid/article/1/2/pdfs/95-0207.pdf.

[25] Ibid.

[26] Paul A. Williams, "The common and uncommon political economies of water and oil 'wars,'" *ASAM Review of International Affairs* 3(1) (2003): 13-28.

Dam is also a concern. The illicit use of the energy causes mechanical failures and power outages in the region.[27]

Loss of Historical Heritage

The land of modern-day Turkey was host to millennia of civilization. When lands are inundated in Turkey, it is almost inevitable that cultural heritage sites will be lost. When the Atatürk Dam was built and its reservoir filled, the ancient city of Samosata was flooded. Samosata was one of the largest Greco-Roman cities along the Euphrates in Asia Minor and one of the four cities of the Commagenian Kingdom. It was also inhabited by Assyrians and Hittite whose relief carvings dating to the 8th century B.C. had been discovered. The relics and history of this site now lie below approximately 120 meters of water.[28]

Transboundary Water Agreements and the Atatürk Dam

Binational issues related to Atatürk Dam were first addressed in the 1987 protocol between Turkey and Syria. The protocol was developed by the Turkish-Syrian Joint Economic Commission on July 17, 1987, and at the time was considered provisional.[29]

The text of Article 6 of the protocol reads as follows:

> During the filling up period of the Atatürk dam reservoir and until the final allocation of the waters of Euphrates among the three riparian countries the Turkish side undertakes to release a yearly average of more than 500 m3/sec at the Turkish-Syrian border and in cases where monthly flow falls below the level of 500 m3/sec, the Turkish side agrees to make up the difference during the following month.

Two years later, the Protocol of 1989 was signed between Syria and Iraq. The impounding of the Atatürk Dam created flow issues on the Euphrates River which necessitated a water allocation agreement between Euphrates riparians Syria and Iraq. A bilateral accord between Syria and Iraq was developed, according to which 58 percent of the Euphrates water coming from Turkey would be released to Iraq by Syria.

[27] Ulaş Demircan, "6 İldeki Kaçak Elektrik Kullanım Oranı 4 Atatürk Barajı'na Bedel," 2015, http://onedio.com/haber/6-ildeki-kacak-elektrik-kullanim-orani-4-ataturk-baraji-na-bedel-674657.
[28] David L .Kennedy, "Drowned Cities of the Upper Euphrates," *Aramco World* 49(5) (Sept.-Oct. 1998), http://archive.aramcoworld.com/issue/199805/drowned.cities.of.the.upper.euphrates.htm.
[29] Cecilia Tortajada, Dogan Altinbilek, and Asit K. Biswas, "Impacts of Large Dams: A Global Assessment" (Berlin, Heidelberg: Springer-Verlag, 2012).

Chapter 4. Tabqa Dam

by Anne Kilroy

Because the Euphrates is the major source of freshwater in the arid nation of Syria, plans for damming the Euphrates near the Turkish border had been considered since the country was a French Mandate.[30] After Syria's independence, the country adopted the paradigm of hydraulic mission, which sought to maximize the potential utility of the river's resources by constructing large-scale water development projects. With financial and technical assistance from the Soviet Union and West Germany, Tabqa Dam was finally completed in 1973.[31] The initial goals for the dam included generating 1,100 megawatts (MW) of electricity, irrigating over 1.5 million acres of land, and providing a source of drinking water for Aleppo, the country's largest city.[32,33]

Figure 4.1.
Tabqa Dam

Source: Steve White, "ISIS chiefs hiding in an enormous dam where UK, US, and Russia refuse to bomb," *Mirror*, January 21, 2016, http://www.mirror.co.uk/news/world-news/isis-chiefs-hiding-enormous-dam-7219847.

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30 M. El-Khatib, "The Syrian Tabqa Dam: Its Development and Impact," *The Geographical Bulletin* 26 (1984): 19-28.

31 Ibrahim Kaya, "The Euphrates-Tigris Basin: An Overview and Opportunities for Cooperation Under International Law," *Arid Lands Newsletter* 44 (Fall/Winter 1998).

32 Carla Hunt, "Last boat to Tabqa," *Saudi Aramco World* 25(1) (1974): 8-10.

33 Central Bureau of Statistics (CBS), "Syria, Aleppo Sub District Population," 2008, http://www.cbssyr.sy/index-EN.htm.

At the time it was completed, the Tabqa Dam was the largest dam ever constructed, measuring 196 feet (60 meters) high, 2.7 miles (4.5 kilometers) across, and 1,680 feet (512 meters) wide at the base.[34] Today Tabqa remains the world's largest earth-filled dam, built with over 1.5 billion cubic feet of compacted gravel, sand, clay, dirt, and an impermeable core.[35] This massive structure damming the flow of the Euphrates River led to the creation of the man-made Lake Assad, the largest reservoir in Syria.[36] (See Figure 4.2.)

Figure 4.2.
Lake Assad

Source: Earth Snapshot, "Lake Assad and Nearby Agriculture, Syria," June 2009, http://www.eosnap.com/image-of-the-day/?s=%22lake+assad%22.

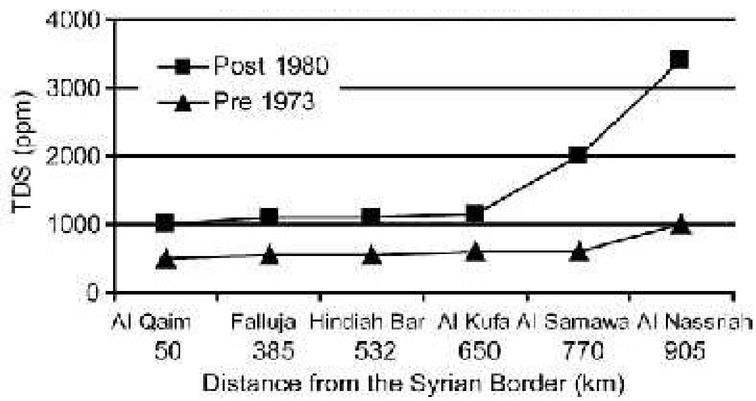
Located 40 kilometers west of the city of Ar Raqqah, Tabqa was the first modern Syrian dam built on the Euphrates. The dam is located in a central area that experiences low levels of rainfall, making the surrounding areas reliant on irrigation for agricultural production. At 1,007 feet (307 meters) above sea level, the location of the dam was ideal not only for satisfying water demand but also for flood prevention.

Despite the economic and agricultural benefits, the long-term effects of damming the river have revealed several negative externalities, especially for Iraq. When Syria temporarily blocked the Euphrates after closing of the dam, the flow of the river downstream was inevitably reduced, but further declines in water quantity due to evaporation, sedimentation, reduced precipitation, and variations in upstream flow exacerbated this effect. What little flow continues downstream is then polluted by high levels of gypsum and dissolved solids, as the salinity of the Euphrates as it

[34] Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.
[35] Hunt, "Last boat to Tabqa."
[36] FAO, "AQUASTAT."

enters Iraq has more than doubled since the dam was constructed.[37] When the flow of the Euphrates was completely dammed to fill the lake in 1974, Iraq complained that its flow of the Euphrates had been so severely depleted that it threatened to bomb the dam a year later.[38] (See Figure 4.3.)

Figure 4.3.
Salinity of the Euphrates within Iraq



Source: K.hayyun A. Rahi and Todd Haliham, "Changes in the salinity of the Euphrates River system in Iraq," *Regional Environmental Change* 10 (Feb. 2009):27-35.

Furthermore, high levels of sediment accumulation in the river have threatened the structural integrity of the dam. As a result of deforestation, desertification, and climate change, the amount of sediment flowing through the Euphrates is increasing. Even before the construction of the dam, scientists estimated that, on average, 140 million tons of sediment would build up at the base each year.[39] The composition of the earth-fill dam and the subsequent weight of the lake formed behind it places a great deal of pressure on the fragile dirt core, and too much pressure or an overflow from the lake will cause the dam to fail. As such, the dam requires a substantial amount of annual maintenance and repairs in order to remain structurally sound, but over the last several decades the prioritization of this upkeep has often taken a back seat to national security agendas. As a result, the neglected Tabqa Dam is considered to be at high risk for collapsing, and non-state actors have strategically prioritized occupying territory surrounding the dam because government forces would not dare to conduct air strikes in the area in fear of releasing a devastating flood.[40]

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[37] Khayyun A. Rahi and Todd Haliham, "Changes in the salinity of the Euphrates River system in Iraq," *Regional Environmental Change* 10 (Feb. 2009):27-35.
[38] Kaya, "The Euphrates-Tigris Basin."
[39] El-Khatib, "The Syrian Tabqa Dam: Its Development and Impact."
[40] David Michel, Amit Pandya, Syed Iqbal Hasnain, Russell Sticklor and Sreya Panuganti , "Water challenges and cooperative response in the middle east and North Africa" (Brookings, Nov. 2012, p. 14), http://www.brookings.edu/research/papers/2012/11/water-security-middle-east-iwf.

The Reservoir

On an average day, Lake Assad is 50 miles (80 kilometers) long and 5 miles (8 kilometers) wide. The waters of the reservoir are used for hydropower generation and irrigation but also for fishing and water transportation. The reservoir has an annual discharge of 6.8 billion cubic meters per year and a maximum capacity of 2.8 cubic miles (11.7 cubic kilometers), although the actual capacity is currently only 2.3 cubic miles (9.6 cubic kilometers), equal to about 82 percent capacity.[41] The reservoir has a maximum surface area of 240 square miles (610 square kilometers), although the actual surface area is currently only 173 square miles (477 square kilometers). Much of this decrease in capacity is due to reduced rainfall and high levels of evaporation from the basin and further exacerbated by an increase in global temperatures.[42]

The waters of Lake Assad irrigate about 644,000 hectares of agricultural land, which is slightly less than half of all irrigated land in Syria. This represents only about 20 percent of the original goal.[43] The dam produces 800 MW of hydroelectric power annually, which is over 50 percent of Syria's hydropower production and 10 percent of Syria's total energy production.[44] Although the Tabqa has not yet fulfilled its original goal of generating 1,100 MW/year, the number of villages receiving electricity increased from 241 in 1970 to 1,173 in 1978.

The impact region surrounding the Tabqa Dam and Lake Assad is one of the oldest continuously inhabited regions in the world, with the first evidence of civilization dating as far back as 7,000 BCE. When the Syrian government announced plans to flood the area in order to create a reservoir, many archaeologists protested and flocked to the area to excavate what they could before the lake was filled. The creation of Lake Assad also displaced 60,000 people in 43 villages. An estimated two-thirds of those who were relocated elsewhere and promised proportional compensation never received their remuneration.[45]

The Impact Area

The construction of the Tabqa Dam was a pivotal moment for the Syrian economy. At the time of its completion, the Syrian government was seeking to reduce its dependency on foreign food imports and set out to achieve agricultural self-sufficiency. Today, food exports total nearly 20 percent of all of Syria's merchandise exports, and as a result the country's socioeconomic structure relies heavily on the agricultural sector. After the construction of the dam, implementation of various irrigation networks boosted Syria's share of agriculture in GDP from

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41 FAO, "AQUASTAT."

42 Colin P. Kelley, Shahrzad Mohtadib, Mark A. Canec, Richard Seagerc, and Yochanan Kushnir, "Climate change in the fertile crescent and implications of the recent Syrian drought," *Proceedings of the National Academy of Sciences* 112(11) (March 17, 2015): 3241-3246.

43 FAO, "Irrigation in the Middle East Region in Figures," AQUASTAT Survey, 2008, http://www.fao.org/docrep/012/i0936e/i0936e00.htm.

44 Dogan Altinbilek, "Development and management of the Euphrates-Tigris basin," *International Journal of Water Resources Development* 20(1) (2001): 15-33.

45 G. Meyer, "La Réinstallation De La Population Touchée Par Le Barrage De l'Euphrate En Syrie," *Barrages Internationaux Et Coopération* (1995): 283-303.

21 percent in 1986 to 34 percent in 1992.[46] At last measure in 2007, the agricultural value added to Syria's GDP was still substantial at 18 percent, and nearly 15 percent of the country's population remains employed in the agricultural sector.[47]

In the Tabqa region, water irrigates over 1.4 million hectares of arable land, and the amount of land equipped for irrigation has been increasing at an average rate of 3.2 percent over the last 11 years. A majority of irrigation water (58 percent) comes from groundwater, while 42 percent comes from surface water.[48] However, irrigation experts estimate that the efficiency of irrigation methods is less than 60 percent due to outdated and wasteful distribution methods.[49] An estimated 80 percent of irrigated farms use flood irrigation, wasteful not only for the large quantities of water it requires but also for the runoff that pollutes the water downstream.[50]

The increase in agricultural productivity has led to a drastic increase in water withdrawals. According to the Syrian Central Bureau of Statistics, Syria's total water withdrawal (including losses) was over 19 billion cubic meters in 2007. The Gravity Recovery and Climate Experiment (GRACE) satellite mission observed that water in the Euphrates-Tigris was being reduced at a rate of 20.5 cubic kilometers during a seven-year period from 2003-2009. The total amount of water withdrawn during this period is equal to the size of the Dead Sea. One explanation for this trend is attributed to the annual evaporation on Lake Assad, estimated to be upwards of 1.3 cubic kilometers due to Syria's high summer temperatures (and now exacerbated by the effects of climate change) and the large number of square kilometers of surface area of the waters on Lake Assad.

The effect of a diminishing water supply combined with a growing population (Syria's population has grown from 3 million in 1950 to over 22 million in 2012) resulted in a reduction in water availability per capita from over 5,550 cubic meters per person per year in 1950 to less than 760 cubic meters per person per year in 2012.[51] When a historic drought hit the region in 2007, the effects were so severe that an estimated 1.5 million herders and farmers from northeastern Syria were displaced, and the vast majority of them resettled in urban areas in hopes of finding employment.[52] By the end of that year, the flow of the Euphrates River had decreased to approximately 70 percent of its normal flow by the time it crossed into Iraq and employment in the Syrian agricultural sector had dropped by 33 percent.[53] It is estimated that 1.3 million

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46 World Bank, National Accounts Data, World Development Indicators, http://data.worldbank.org/data-catalog/world-development-indicators.
47 Ibid.
48 Marwa Daoudy, "Asymmetric Power: Negotiating Water in the Euphrates and Tigris," *International Negotiation* 14(2) (April 2009):361-391.
49 Altinbilek, "Development and management of the Euphrates-Tigris basin."
50 FAO, "Syrian Arab Republic Joint Rapid Food Security Needs Assessment (JRFSNA)," 2012 , http://www.fao.org/giews/english/otherpub/JRFSNA_Syrian2012.pdf.
51 Peter H. Gleick, "Water, drought, climate change, and conflict in Syria," *Weather, Climate, and Society* 6(3) (2015): 331-340.
52 Andrew Freedman, "Seeds of war: Global warming helped trigger Syria's bloody civil war," *Mashable* , March 3, 2015.
53 Francesca de Châtel, "Leaving the land: The impact of long-term water mismanagement in Syria," in *Water Scarcity, Security and Democracy: A Mediterranean Mosaic*, eds. F. de Châtel, G. Holst-Warhaft, and T. Steenhuis (Cornell University and Global Water Partnership Mediterranean, 2009), 87.

people were affected by the drought and that 800,000 "severely affected" people lost their livelihoods and basic food supports.[54] By 2010, the UN estimated that 3.7 million people, or 17 percent of Syria's population, was food insecure.[55]

Governance

After violent conflict between Iraq and Syria was narrowly avoided regarding the amount of water released to the Iraqi border, Iraq and Syria agreed to a share of 60 percent and 40 percent of the river's resources. In 1990, Syria and Iraq met in Baghdad to revisit their previous agreement on the proportion of water to be released to Iraq, and Syria increased its share of the flow to 42 percent. However, both agreements focused primarily on issues of water quantity and did not consider issues of water quality. The agreements also failed to consider the variability in upstream flow to be released by Turkey and did not include a strategy for drought management in the basin, contributing to the devastating effects of the drought of 2007.

Furthermore, because regional water institutions in Syria and Iraq have little administrative or legal capacities with which to execute water infrastructure repairs, these neglected and dilapidated irrigation systems and dams are significantly contributing to the water deficit in the region. Often, Syrian water stakeholders rival one another while navigating their state's bureaucratic administration system.[56] Administrative districts in Syria are also divided in terms of agro-climatic zones, which distorts the reality of water situations on the ground because water management districts are not organized by the amount of irrigated water supplied to the area but only by the amount of annual precipitation.[57] This kind of organizational structure is ripe with opportunities for corruption and unequal distribution of water resources because they can continue to allocate water to the areas with the lowest rainfall even if those areas are already receiving the most water.

Conclusion

The Tabqa Dam is central to the Syrian economy, particularly with respect to its agricultural sector and its renewable energy sector. However, the Syrian government has not been able to properly maintain the infrastructure in the basin, and as a result, the country faces high levels of water insecurity due to non-state actors controlling the dam. Securing the Tabqa Dam from ISIS forces and repairing the infrastructure of the dam should be a top priority, as millions of lives in the region are being directly threatened by water and food insecurity.[58]

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[54] Mahmoud Solh, "Tackling the drought in Syria," *Nature Middle East* 206 (September 27, 2010), http://www.natureasia.com/en/nmiddleeast/article/10.1038/nmiddleeast.2010.206.

[55] The UN Refugee Agency (UNHCR), "Syria Emergency," 2011, http://www.unhcr.org/en-us/syria-emergency.html.

[56] S. Smets, "Baseline Water Sector Report: GTZ Modernization of the Syrian Water Sector Support to Sector Planning and Coordination and State Planning Commission" (Damascus: State Planning Commission and German Technical Development Corporation, 2009).

[57] Timothy Mitchell, *Rule of Experts; Egypt, Techno-Politics, Modernity, 1st Ed.* (University of California Press, 2002).

[58] Kelley et al., "Climate change in the fertile crescent and implications of the recent Syrian drought."

Chapter 5. Mosul Dam

by Haytham Oueidat and Ryan Brown

The Mosul Dam is located 50 kilometers north of Mosul, the second-largest city in Iraq, and is the country's largest dam (see Figure 5.1). Construction began in 1981 and the reservoir was filled in 1986. The purpose of the dam is to regulate flooding, irrigate agriculture in Northern Iraq, and to provide electricity and water to Mosul.

Figure 5.1.
The Mosul Dam

Source: CBS News, "Fears grow about Mosul Dam catastrophe," March 9, 2016, http://www.cbsnews.com/news/fears-about-mosul-dam-catastrophe-grows.

The main hydroelectrical station, Mosul 1, has an installed capacity of 750 megawatts and contains four 187.5 megawatt Francis-turbine generators. The Mosul regulation dam, Mosul 2, is downstream and functions to regulate tail waters of the larger dam, with an installed capacity of 62 megawatts. A pumped hydro facility, Mosul 3, is upstream and has capacity of 240 megawatts. The entire Mosul dam project has a capacity of 1,052 megawatts.[59]

Planning was difficult because the geology of prospective sites was not ideal for dam construction. Five separate engineering teams chose five different sites for the dam from the 1950s to the 1970s. When the location finally was chosen, the dam was built on a foundation of gypsum, which dissolves when in contact with water. Therefore, the dam must constantly be

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[59] U.S. Army Corp of Engineers "Iraqi dam assessments," June 2003, http://www.envirozan.info/EZDocs/Dams/IraqiDamAssessments.pdf.

"grouted" with concrete and other materials in order to plug any holes. Grout material is constantly pumped into the base, and over 50,000 tons have been injected into the foundation since the dam's opening. Downstream sinkholes have formed at various times and must be maintained. (Long-run maintenance is discussed in the governance section below.) During the planning stage, engineers advised that the foundation be thoroughly grouted prior to building the superstructure. Instead, in order to speed up construction, the foundation was blanket-grouted 25 meters deep around the foundation and in a 150-meter curtain directly below the dam.[60]

The rush to build the dam may have been part of the larger goal of the Ba'ath party to *arabize* Northern Iraq. The dam was built, at a total cost of $1.5 billion, in order for Saddam Hussein to maintain control in Northern Iraq during the Iran-Iraq War.[61] Hussein was able to maintain regional support by providing electricity, irrigated land, and running water to the people surrounding Mosul.

The initial flooding of the reservoir submerged several archaeological sites, harming the cultural heritage of not only the region, but also the world. Today, in addition, a failure of the dam would destroy a number of Assyrian heritage sites downstream.[62]

The Mosul Dam has been called the "most dangerous dam in the world" due to the erosion of its foundation. A collapse of the dam would result in Mosul being flooded under 20 meters of water within two hours, and an estimated 500,000 deaths and 500,000 people displaced.[63] Flood water would reach Baghdad's six million residents within three to four days, and potentially flood Baghdad International Airport.[64] The flooding would shut down the Iraqi power grid, destroy irrigated agriculture, and leave internally displaced persons (IDPs) susceptible to armed militant groups such as ISIS.[65] Preparing for a flood will require coordinated efforts for evacuation, which are discussed in the governance section below. In addition, the engineering plans for the dam are evaluated below.

The Reservoir

The reservoir, Lake Dahuk (Figure 5.2), has a capacity of 11.1 cubic kilometers and covers an area of 380 square kilometers—8.1 cubic kilometers of the capacity is considered in the active

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[60] Julie R. Kelley, Lillian D. Wakeley, Seth W. Broadfoot, Monte L. Pearson, Christian J. McGrath, Thomas E. McGill, Jeffrey D. Jorgeson, and Cary A. Talbot, "Geologic Setting of Mosul Dam and Its Engineering Implications," U.S. Army Corps of Engineers- Engineer Research and Development Center, ERDC TR-07-10, September 2007, http://el.erdc.usace.army.mil/elpubs/pdf/tr07-10.pdf.

[61] Wikipedia, "Mosul Dam," https://en.wikipedia.org/wiki/Mosul_Dam,

[62] Kristin Romey, "This Crumbling Dam Could Wipe Out Cultural Treasures," *National Geographic*, March 2, 2016, http://news.nationalgeographic.com/2016/03/160302-Iraq-Mosul-Dam-Islamic-State-Archaeology-Nineveh-Nimrud-Assyria-ISIS-ISIL/.

[63] "The Mosul Dam: A watery time-bomb, the most dangerous dam in the world," *The Economist*, February 13, 2016, http://www.economist.com/news/middle-east-and-africa/21692903-most-dangerous-dam-world-watery-time-bomb.

[64] The Embassy of the United States- Baghdad, Iraq, "Mosul Dam Overview," February 28, 2016, http://iraq.usembassy.gov/022816.html.

[65] Ibid.

pool, meaning that it is used for power generation and downstream releases, and the remaining 2.96 cubic kilometers are inactive (dead) storage.

Sedimentation is an issue for Lake Dahuk, yet no detailed assessment has been carried out since its planning stage. A 2013 study indicated that the annual reduction rate in the dead and live storage capacities of the reservoir is 0.786 percent and 0.276 percent respectively, and that the useful life of the Mosul Dam reservoir is about 125 years.[66] This useful life estimate only takes into account sedimentation and not the potential for dam failure.

The number of Iraqi citizens displaced by the dam construction is unknown at this time. Accurate population data for Iraq, provided by the U.N., is only available for 1987, and therefore any analysis of migration pre-or post-dam construction is an estimate and therefore beyond the scope of this study. Downstream cities and villages are threatened by a potential dam collapse. As well, a number of archaeological sites were flooded when the dam opened in 1986 and many sites are threatened by a potential collapse.

Figure 5.2.
Lake Dahuk

Source: Thair M. al-Taiee and Anass M.M. Rasheed, "Simulation Tigris River Flood Wave in Mosul City Due to Hypothetical Mosul Dam Break," *Damascus University Journal* 25 (2009), http://www.hidropolitikakademi.org/wp-content/uploads/2015/07/Damascus-University-Journal-Flood-Wave-in-Mosul-City-Due-to-a-Hypothetical-Mosul-Dam-Break.pdf.

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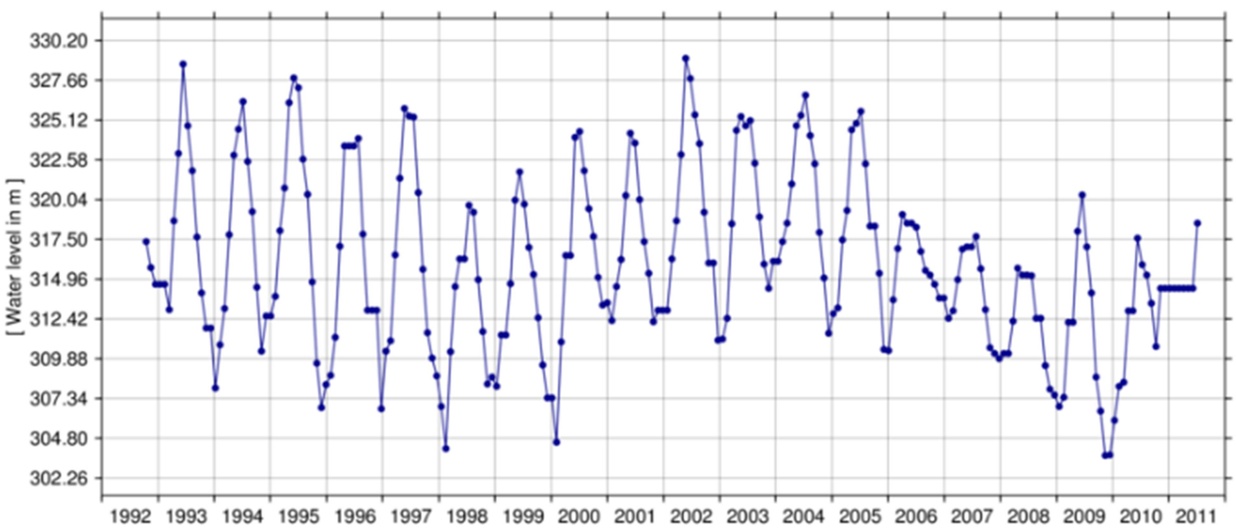
[66] Issa E. Issa, Nadhir Al-Ansari1, Govand Sherwany, and Sven Knutsson, "Sedimentation Processes and Useful Life of Mosul Dam Reservoir, Iraq," *Engineering* 5 (2013): 779-784.

Northern Iraq climate is classified as semi-arid, sub-tropical Mediterranean. This region has experienced reduced moisture-carrying westerly winds from the Mediterranean Sea and increased temperature, both likely due to the effects of climate change.[67] These regional climate trends have reduced the ability for vegetation to grow, and thus have effected agricultural production in the region.[68]

Figure 5.3 is a historic time series showing the water levels of Lake Dahuk. The lowest level was 303 meters above sea level, coinciding with the droughts of 1997, 1999, and 2009. The reservoir's dead storage capacity of 2.96 cubic kilometers corresponds with a level of 300 meters. This suggests that at times of very severe drought, the dam was depleted to its physically limiting threshold.[69]

Figure 5.3.
Mosul Dam Lake Historic Water Levels, 1992-2011



Source: Database for Hydrological Time Series of Inland Waters (DAHITI), "Mosul Dam Lake," Technische Universität München, 2014, http://dahiti.dgfi.tum.de/en/118/time_series/.

Impact Area

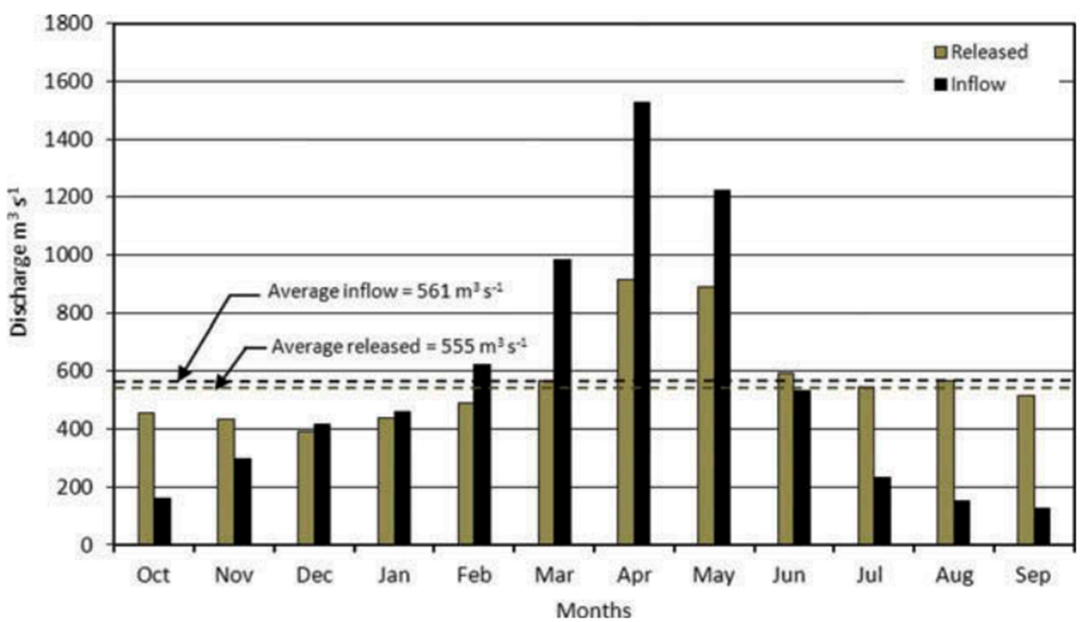
The al-Mosul plateau is Iraq's breadbasket, providing 70 percent of the country's grain production. The 1999-2000 droughts in Iraq were considered the worst in 50 years by a U.N.

67 Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian Drought."
68 Ahmad S. Muhaimeed and Al-HednySuhad M, "Evaluation of long-term vegetation trends for northeastern of Iraq: Mosul, Kirkuk and Salah Al-Din," *Journal of Agriculture and Veterinary Science,* 5 (2013): 67-76, http://iosrjournals.org/iosr-javs/papers/vol5-issue2/K0526776.pdf?id=8064.
69 Issa E. Issa, Nadhir Al-Ansaria, and Sven Knutssona, "Sedimentation and New Operational Curves for Mosul Dam, Iraq," *Hydrological Cycles Journal,* 58 (2013): 1-11, https://pure.ltu.se/portal/files/43957787/mosul_dam.pdf.

estimate.[70] During this drought, the region received only 20 percent of its normal rainfall, reducing the average flow of the Tigris by 20 percent.[71] This resulted in 75 percent smaller crops of wheat, barley, and rice. In the event of drought or Mosul Dam's failure, Iraq is threatened by famine due to its reliance on irrigated agriculture.

The dam's average inflow is 561 cubic meters per second and the average outflow is 555 cubic meters per second. The maximum and minimum inflow and outflow vary as noted in Figure 5.4.[72] The dam is located 50 kilometers north of Mosul, in Ninewa province. The lake extends roughly another 40 kilometer upstream to meet its inlet, which is in proximity to the borders of both Turkey and Syria. The upstream trail of the Tigris is captured within mountainous ranges unfolding at the entry point of the inundation pond. The main single-sided drainage area becomes the left bank of the reservoir and is comprised of seven valleys summing up to 1,241 square kilometers.

Figure 5.4.
Maximum, Minimum, and Mean Inflow and Outflow



Source: Issa E. Issa, Nadhir Al-Ansaria, and Sven Knutssona, "Sedimentation and New Operational Curves for Mosul Dam, Iraq," *Hydrological Cycles Journal* 58 (2013): 1-11, https://pure.ltu.se/portal/files/43957787/mosul_dam.pdf.

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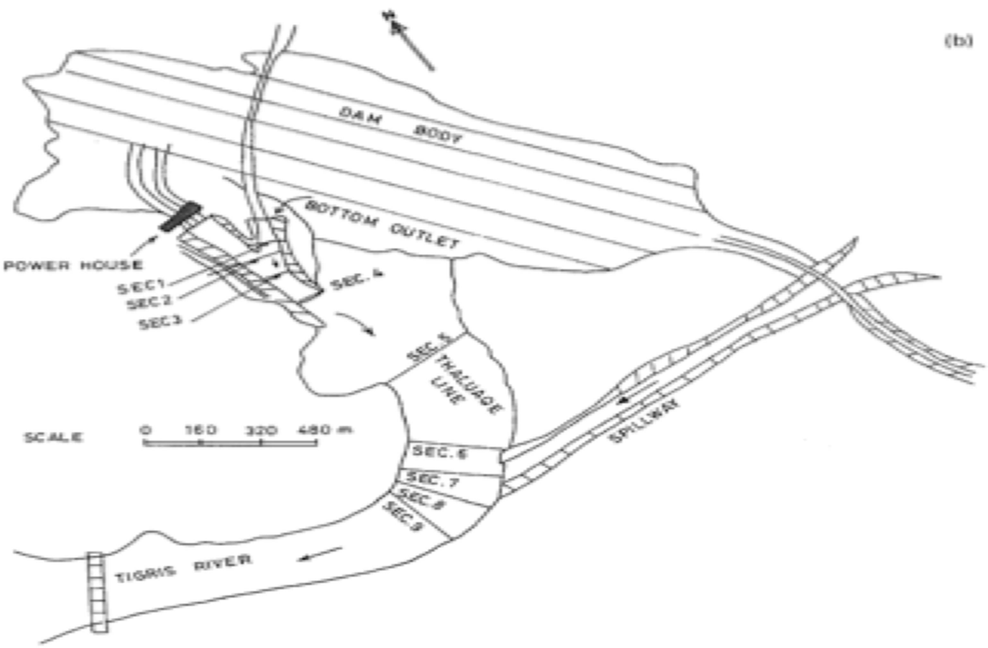
[70] Food and Agriculture Organization of the United Nations Near East Regional Office and the National Drought Mitigation Center, USA, "A Review of Drought Occurrence and Monitoring and Planning Activities in the Near East Region," May 2008, http://www.ais.unwater.org/ais/pluginfile.php/516/course/section/175/Drought%20Occurrence%20and%20Activities%20in%20the%20Near%20East.pdf.

[71] Ibid.

[72] Ibid.

The dam consists of two power-generating units that service 1.7 million people with electricity. The first is an inverted tunefork bottom outlet-combining outflow from the lake and the powerhouse.[73] The dam services the needs of Ninewa's irrigation sector through the Al-Jazeerah pumping station at a rate of 45 cubic meters per second. The pumping station is located at the inlet of the reservoir and allows water to flow south downstream to agricultural areas. According to the Iraq Information Portal an estimated 47 percent of cropland was lost from the drought in 2009 that farmers are still unable to afford replenishing.[74] As stated previously, this region provides 70 percent of Iraq's grain production.

Figure 5.5.
Mosul Dam Infrastructure Components



Source: Nadhir Al-Ansari and Omar Rimawi, "The Influence of the Mosul Dam on the Bed Sediments and Morphology of the River Tigris," *Human Impact on Erosion and Sedimentation-Rabat Symposium,* April 1997, https://www.researchgate.net/publication/253015364_The_influence_of_the_Mosul_Dam_on_the_bed_sediments_and_morphology_of_the_River_Tigris.

Mosul's reliance on the reservoir water and economy is poorly documented. Around 39 percent of Ninewa province is rural and the population count of 2.8 million inhabitants constitutes 9

[73] Nadhir Al-Ansari and Omar Rimawi, "The Influence of the Mosul Dam on the Bed Sediments and Morphology of the River Tigris," *Human Impact on Erosion and Sedimentation-Rabat Symposium,* April 1997, https://www.researchgate.net/publication/253015364_The_influence_of_the_Mosul_Dam_on_the_bed_sediments_and_morphology_of_the_River_Tigris.

[74] Joint Analysis and Policy Unit (JAPU), "Ninewa Governorate Profile," April 2016, http://www.iau-iraq.org/gp/print/GP-Ninewa.asp.

percent of the total Iraqi population.[75] Surprisingly, only 87 percent of the residents have access to improved drinking water.[76]

Governance

The Ministry of Water Resources was established after the 2003 invasion of Iraq and is responsible for the management of Iraq's dams and irrigation canals. Although the main framework is centralized, many times local communities are relied upon for management. Autonomous entrepreneurial groups have worked with the state commissions since the restructure of the ministry's sectoral administrations in 2003.

There are no apparent policies on drought management in the region. From the indicators seen above we can deduce that reservoirs are accepted to be "operational until dry." GRACE imagery revealed a reduction of almost 70 percent in groundwater storage from 2007 until 2009, corresponding to years of record drought and a lack of viable management techniques.[77]

Failure of the Mosul Dam could occur at any time, but the World Bank has hired an Italian firm, Trevi Group, to permanently plug the foundation, at a cost of $300 million.[78] Emptying the reservoir is not considered an option because Northern Iraq is dependent on the Mosul Dam for drinking water and irrigated agricultural production.

A second option, aiding the stability of the foundation, is to build a 200-meter cutoff slurry wall below the dam. This plan is risky because a cutoff wall at this depth has never been attempted and the estimated cost is $3 billion.[79]

A third option is much more feasible, and offers a potential venue for cross-border cooperation between Iraq and Turkey: water could be stored in the mountainous regions of Turkey. The high altitude and narrow geography of this area would lessen the surface area of the reservoir, thus reducing evaporation losses. In turn, Iraq would pay for this storage with oil and gas exports, providing energy security for fossil fuel-poor Turkey and secure an income stream for cash-strapped Iraq.[80] The United States would benefit by subsidizing this process, as it would mitigate the substantial cost of a humanitarian disaster caused by a dam failure. This plan would call for the decommissioning of the Mosul Dam, but a cooperative framework such as this would exploit regional synergies while also promoting cooperation on other venues.[81]

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[75] Ibid.
[76] Ibid.
[77] Katalyn A. Voss, James S. Farmiglietti, Min-Hui Lo, and Sean C. Swenson, "Groundwater Depletion in the Middle East from GRACE with Implications for Transboundary Water Management in the Tigris-Euphrates-Western Iran Region," *Water Resources Research,* 49 (2013): 904-914.
[78] Azzam Alwash, "The Mosul Dam: Turning a Potential Disaster into a Win-Win Solution," Wilson Center: Middle East Program, April 6, 2016, https://www.wilsoncenter.org/publication/the-mosul-dam-turning-potential-disaster-win-win-solution.
[79] Ibid.
[80] Ibid.
[81] Aysegul Kibaroğlu and Sezin I. Gursoy, "Water-Energy-Food Nexus in A Transboundary Context: The Euphrates-Tigris River Basin As A Case Study," *Water International* 40(5-6) (2015): 824-838.

In preparation for a potential dam failure, Iraq must first establish an education campaign to give credibility to its evacuation routes and alert system. Iraqi media is highly politicized and local residents may not believe state communication platforms. The alert system must respond quickly to dam failure, use multiple communication channels, and, most importantly, be trusted by local residents.[82] International cooperation will be required to respond to a humanitarian crisis caused by flooding. Aid actors will have to utilize a variety of delivery methods to provide water, food, shelter, sanitation, medical, and livestock assistance. These efforts will be further complicated by the destruction of infrastructure and the presence of violent non-state actors.[83]

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[82] The Embassy of the United States- Baghdad, Iraq, "Mosul Dam Overview," February 28, 2016, http://iraq.usembassy.gov/022816.html?utm_source=Sailthru&utm_medium=email&utm_campaign=New%20Campaign&utm_term=%2ASituation%20Report.

[83] Ibid.

Chapter 6. Middle Rio Grande and Cochiti Dam

by Sara Eatman

Introduction

It is clear from looking at a map of New Mexico, with all of the major cities and a swath of irrigated agriculture hugging the banks of the Rio Grande, that the river is critical to the development of the region. The history and laws related to use of the Rio Grande water have determined how this resource has been used, and therefore shaped the development of the region. An agricultural tradition dating back to pre-Columbian times persists, although development has significantly changed the river itself. The three states and two countries that rely on the Rio Grande are only going to put increasing pressure on the available water supplies as the population grows and climate impacts supplies. The fish and wildlife that depend on the river, especially the endangered silvery minnow, have shaped recent changes on how the river is managed and will require coordination among all users to manage this resource into the future.

Early History

The Pueblo people irrigated the Rio Grande valley as early as 10 A.D. using a system of acequias, or main-stem diversion canals, and secondary channels, or laterals, that served each family or farm. The community shared responsibility for maintenance of the acequias.[84] Maize, beans, and melons were planted in the fertile bottom lands of the Rio Grande.[85]

Spanish expeditions into New Mexico began in the 1520s and 1530s as a joint venture of Franciscan missionaries and Spanish military. Early outposts were established at the Pueblos of northern New Mexico in 1598.[86] The missionaries settled inside or near to the Pueblos in order to have access to Pueblo people for conversion and as a labor force. The settlers used the existing irrigation canal structures and extended the system, relying heavily on native labor.

Through the 17th century, Spanish settlers spread across the middle Rio Grande basin. However, the colony remained small, reaching a population of between 2,000 and 2,500. The area was remote; over 1,600 miles from Mexico City, and neither the Native Americans nor the climate were reliably hospitable.[87] In 1680 the Pueblo Revolt drove the Hispanic colonists out of the middle Rio Grande to exile in El Paso del Norte. The Pueblo fighters gained significant ground when they cut off the water supply to the remaining colonists sheltered in Santa Fe through control of the acequia.[88]

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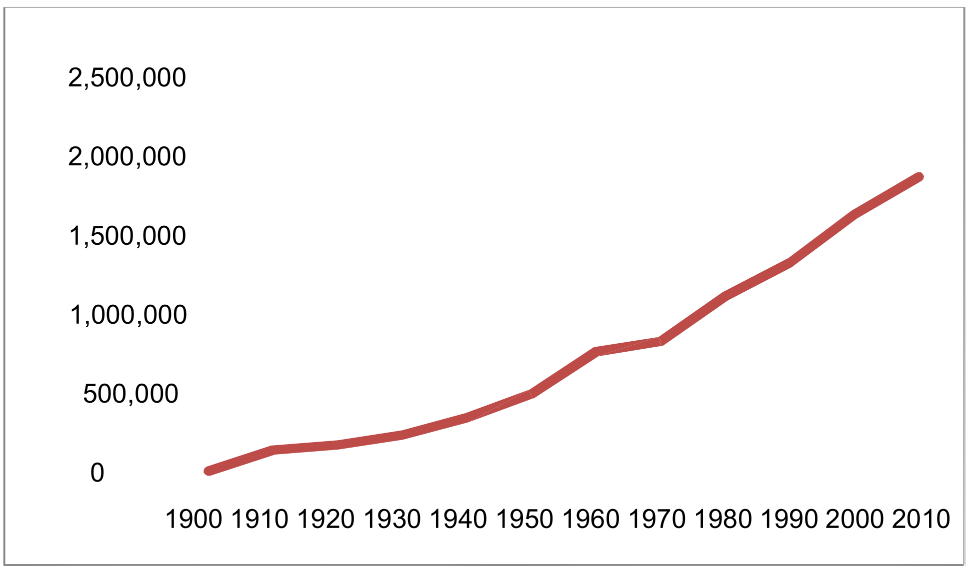
[84] James R. Bartolino and James C. Cole, *Ground-Water Resources of the Middle Rio Grande Basin, New Mexico* (U.S. Dept. of the Interior, U.S. Geological Survey, 2002).
[85] Carleen Lazell and Melissa Payne, *Historic Albuquerque: An Illustrated History* (HPN Books, 2007).
[86] Michael C. Meyer, *The Course of Mexican History*, 7th Ed. (Oxford University Press, 2003).
[87] Lazell and Payne, *Historic Albuquerque*.
[88] New Mexico Office of the State Historian, "Historical-Events-and-Timeline," accessed March 11, 2016, http://newmexicohistory.org/historical-events-and-timeline.

The Spanish colonists took over a decade to return, but they returned and reestablished the colonies along the Rio Grande throughout the 18th century. In 1821, Mexico won independence from Spain, and in 1848 Mexico ceded New Mexico to the United States under the Treaty of Guadalupe Hidalgo.[89] Although the middle Rio Grande Valley was largely settled and farmed, it wasn't until the railroad passed through New Mexico in 1890 that the population grew significantly (see Figure 6.1). At the time New Mexico gained statehood in 1912, the population was approximately 350,000. At this point, strains on the water supply began to show, and active management became critical.

Figure 6.1.
Population of New Mexico, 1900-2010



Source: Bureau of Business and Economic Research University of New Mexico, "Historical Demographic Tables and Maps," http://bber.unm.edu/historical-comparisons.

Water Law in New Mexico

The doctrine of prior appropriation governs water law in New Mexico. Based on Spanish water law, the doctrine states that the first person who puts the water to beneficial use has the right to appropriate water. Beneficial use is assumed to be consumptive use for the purpose of irrigation, livestock, municipal, industrial, or domestic purposes. Water rights can be transferred as long as there is no impact on other claims. If a water right is not put to beneficial use for four years, it reverts to the public.

Water rights are issued based on their priority date, and those issued before the 1907 enactment of the New Mexico Water Code are considered "vested" so are not required to have a permit unless the use or withdrawals associated with the right are changed. Junior water use permits may not impair senior water rights, and in dry years junior users may receive limited water or no

[89] Meyer, *The Course of Mexican History,* 246.

water at all.[90] Because agricultural users don't typically pay volumetrically for their water, and because their claims are based on how much water they can put to beneficial use, there is little incentive to conserve.[91]

The Office of the State Engineer (OSE) is the administrative entity that administers water allocations. Water rights priorities are registered with the state, and the OSE has the responsibility to adopt administrative rules that do not interfere with any existing adjudications (certain Pueblo water rights, for instance) and enforce the priority system. Water allocations are based on "administrable water rights" that were compiled from any adjudicated rights (which are limited), surveys, licenses, and permits demonstrating the seniority, location, quantity, and beneficial use. The majority of water rights have not been adjudicated, but are fulfilled based on OSE's best information.[92] This limits the ability of some claimants to transfer or sell their water rights, and makes the existence of a water market infeasible.[93]

The interaction between shallow groundwater and surface water has been long-established in New Mexico water law. The Office of the State Engineer's authority to administer surface water rights extends to shallow groundwater rights that are understood to be hydraulically connected to the river. In some cases, a water right holder may be permitted to drill a supplemental well to compensate for impairment of their surface water right. These decisions are made on a case-by-case basis in order to account for geologic/hydrologic differences from site to site.[94]

Pueblo water rights are not subject to state water law, and have been adjudicated for Pojoaque Basin pueblos, Taos Pueblo, and the Navajo Nation. The settlements include some guaranteed deliveries, inter-basin transfers, groundwater-surface water interactions, and agreements not to make priority calls on water in some cases.[95] In 1938, the federal government, New Mexico, Colorado, and Texas signed the Rio Grande Compact, which established annual delivery obligations between the states based on gauged flows at specified locations throughout the basin.[96] Beginning in Colorado each state's delivery to their downstream neighbor was indexed based on the flows in river and key tributaries. The treaty includes provisions for a debit and credit system to carry over across years, water quality requirements, inter-basin transfers, and reservoir storage operations so as to "remove all causes of current and future controversy between [the states]."[97] The Rio Grande Compact is discussed in more detail later in this report. However, between signing of the compact and 1966, Colorado did not comply and accumulated a debt of one million acre-feet of water to New Mexico. As a result, New Mexico accumulated a

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[90] Jim Bartolino and J. C. Cole, "Ground-Water Resources of the Middle Rio Grande Basin, New Mexico" (USGS, 2002).

[91] Winthrop Quigley, "Rising to Challenge of New Mexico's Falling Water Supply," *Albuquerque Journal* (March 23, 2015), http://www.abqjournal.com/558815/news/rising-to-challenge-of-new-mexicos-falling-water-supply.html.

[92] New Mexico Office of the State Engineer, "2016 Middle Rio Grande Regional Water Plan," Section 4 – Legal, accessed March 11, 2016, http://www.ose.state.nm.us/Planning/RWP/region_12.php.

[93] Quigley, "Rising to Challenge of New Mexico's Falling Water Supply."

[94] New Mexico Office of the State Engineer, "2016 Middle Rio Grande Regional Water Plan."

[95] New Mexico Office of the State Engineer, "Interstate Stream Commission, Indian Water Rights Settlements," accessed March 11, 2016, http://www.ose.state.nm.us/Legal/settlements_IWR.php.

[96] New Mexico Office of the State Engineer, "Rio Grande River Compact NM OSE/ISC," accessed March 11, 2016, http://www.ose..statenm.us/Compacts/RioGrande/isc_RioGrande.php.

[97] Ibid.

500,000 acre-foot debt to Texas. In 1966, New Mexico and Texas sued Colorado to force compliance, and the case was eventually heard by the U.S. Supreme Court. The lawsuit continued until 1985, when reservoirs were filled and Colorado's water debt was erased. The debt that New Mexico had accumulated to Texas was not erased, and debts and different interpretations of the Compact have failed to prevent conflict between the parties.[98]

Middle Rio Grande Conservancy District

The early 20th century brought both flooding and drought, and resulted in an overall reduction in irrigated acreage in New Mexico's Rio Grande Valley. In 1923 the Middle Rio Grande Conservancy District (MRGCD) was formed as a local political subdivision in order to coordinate and manage irrigation and drainage from Cochiti Reservoir to San Marcian, just upstream of Elephant Butte Reservoir (see Figure 6.2). Deforestation and development in the southern Colorado since the late 1800s had increased the silt washing into the Rio Grande. When sediment-laden water reached the wider, slower reaches of the Middle Rio Grande the silt settled out and resulted in higher stream bed and water tables. This caused shallow flooding along the river banks and resulted in a loss of over 60,000 irrigated acres.[99]

The MRGCD began an infrastructure improvement project in 1928 that mitigated flood risks through the use of levees, increased irrigation capabilities with improved and extended delivery canals, and recovered flooded farmland with a drainage canal system. One storage dam at El Vado was built, and four main irrigation diversions were built at Cochiti, Angostura, Isleta, and San Acacia to serve irrigators along the inner basin (shown in Figure 6.3).[100] These projects were credited with the development of 118,000 acres, 59,159 of which were irrigated, and 20,700 of which were Indian lands.[101]

MRGCD was criticized for rushing the projects and for taking some shortcuts in construction. Conversely, the cost of the projects was passed on to farmers through assessments of the benefit received, which were prohibitively high for some farmers. As the nation faced the depression, the MRGCD struggled financially.[102]

Major flooding in 1941 focused New Mexican attention on flood control, and federal assistance was provided through the Bureau of Reclamation and the Army Corps of Engineers. The MRGCD shared responsibilities with these two federal agencies under the Rio Grande Comprehensive Plan of 1950: The Bureau of Reclamation took responsibility for El Vado dam and the main channel of the Rio Grande between Velarde (near Taos) all the way to Elephant Butte. The Army Corps of Engineers took over maintenance of Cochiti Dam, and the MRGCD maintained the three remaining diversion dams and all of the irrigation facilities.

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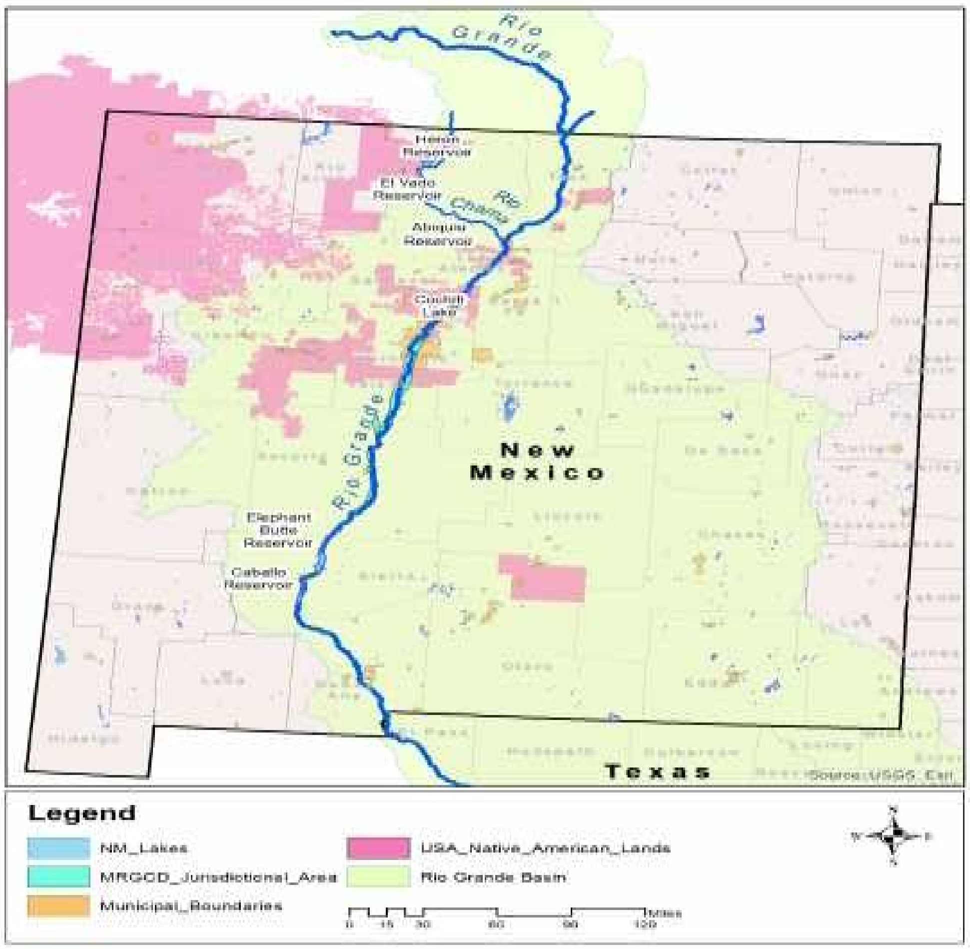
[98] David S. Brookshire, Hoshin Gupta, and Olen Paul Matthews, *Water Policy in New Mexico: Addressing the Challenge of an Uncertain Future* (RFF Press, 2013).
[99] Middle Rio Grande Conservancy District, "The Rio Grande: A Ribbon of Life and Tradition," accessed March 11, 2016, http://www.mrgcd.com/History.aspx,.
[100] Ibid.
[101] Ira G. Clark, *Water in New Mexico: A History of Its Management and Use, 1st Ed.* (Albuquerque: University of New Mexico Press, 1987).
[102] Ibid.

Figure 6.2.
Rio Grande Basin, Major Lakes, Native American Lands, and Middle Rio Grande Conservation District Jurisdictional Area



Source: Middle Rio Grande Conservation District.

The MRGCD still manages upkeep of the irrigation and drainage systems, and farmers that used those systems paid annual fees based on irrigated area. The District manages distribution of water to users within its area, and does so proportionally based on land area. Additionally, the District delivers water to six Pueblos. The MRGCD negotiates with the Pueblo "majordomos" to meet water needs, and are typically served by the same mechanism as other water users in the District. Some of the Pueblos have established "prior and paramount" water rights through the court system, and receive water preferentially in drought.[103] The MRGCD has revised their mission to include not only maintenance and operations of the irrigation, drainage, and flood control infrastructure, but also the management of parks, paths, and open space around the many waterways that thread across the Middle Rio Grande.[104]

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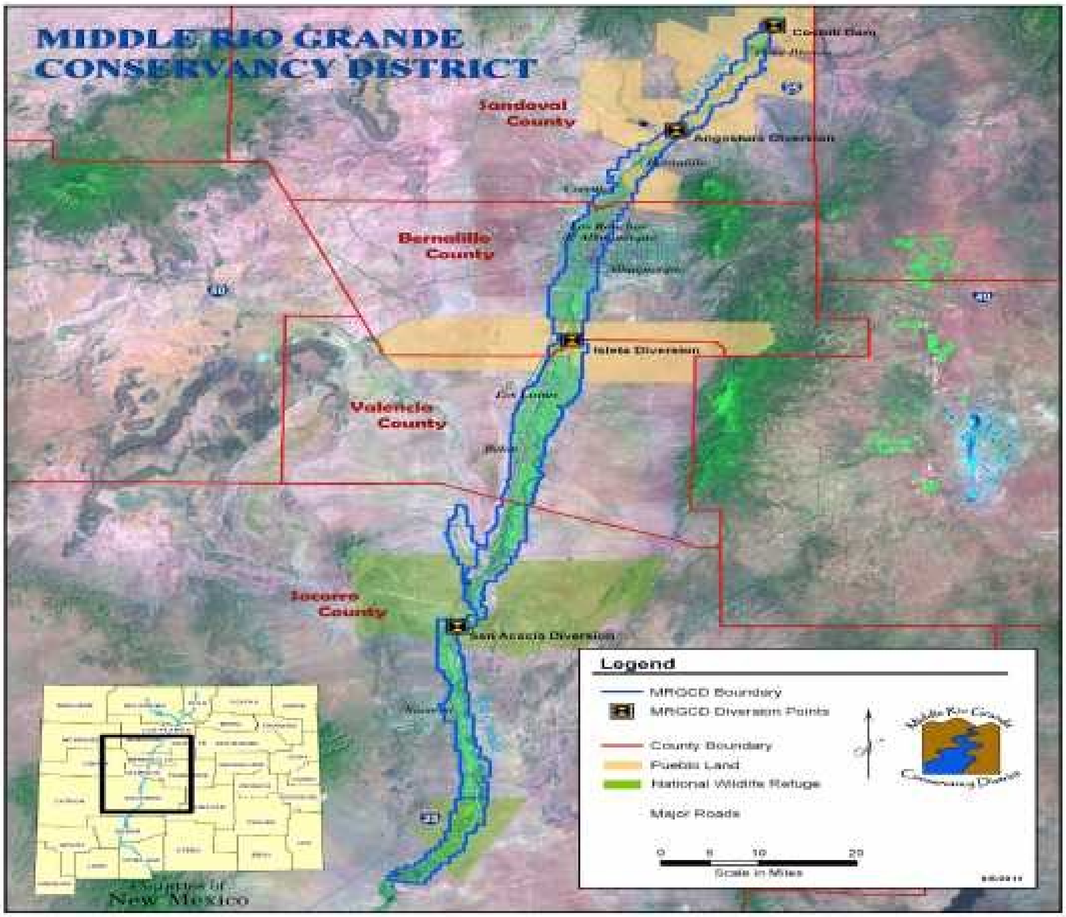
103 Middle Rio Grande Conservancy District, "Water Distribution Policy of the Middle Rio Grande Conservancy District," accessed April 21, 2016, http://www.mrgcd.com/Water_Distribution_Policy.aspx.
104 Middle Rio Grande Conservancy District, "The Rio Grande: A Ribbon of Life and Tradition."

Figure 6.3.
Middle Rio Grande Conservancy District



Source: Middle Rio Grande Conservancy District.

San Juan - Chama Diversion Project

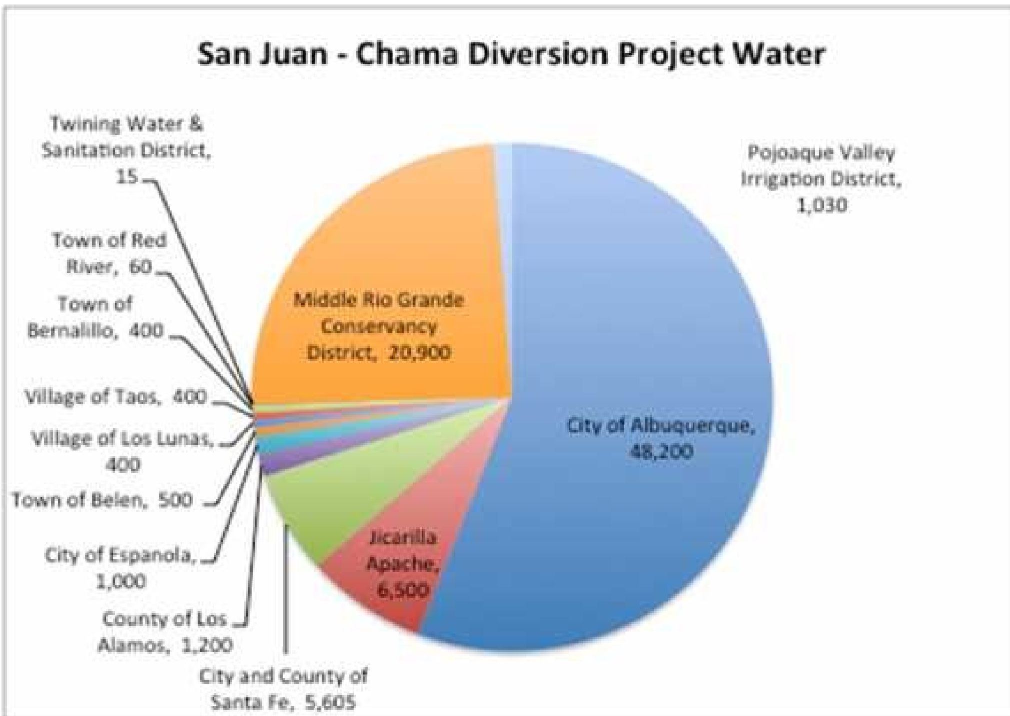
The San Juan - Chama Diversion Project, a trans-mountain transfer from the Colorado basin to the Rio Grande basin, was authorized in 1962. The Bureau of Reclamation began construction in 1964 and the tunnels were completed in 1970.

Under the Colorado River Compact, New Mexico was allocated 11.25 percent of the Upper Basin of the Colorado River's estimated annual flows (or 840,000 acre-feet per year on average).[105] The San Juan - Chama project delivers a portion of New Mexico's allocation (110,000 acre-feet per year on average) across the continental divide to the Rio Grande basin through a system of diversion structures and 26 miles of tunnels. Water is diverted from the Blanco, Navajo, and Little Navajo Rivers (tributaries of the Colorado) to the Rio Chama, a tributary of the Rio Grande, and stored in Heron and El Valdo reservoirs. The reliable yield,

[105] League of Women Voters, "The Colorado River Compact and the San Juan - Chama Project," accessed March 11, 2016, http://www.lwvnm.org/Water/SJCBackground.pdf.

approximately 86,000 acre-feet per year, is contracted by municipalities and irrigators along the Rio Grande (see Figure 6.4). The Corps of Engineers receives an annual allocation of about 5,000 acre-feet per year to maintain Cochiti Reservoir for recreation, fish, and wildlife.[106] San Juan - Chama water must be accounted for separately from the native flows in the Rio Grande and must be used within New Mexico.[107]

Figure 6.4.
Contracted Amounts for San Juan - Chama Water



Source: U.S. Bureau of Reclamation.

El Vado Reservoir

The El Vado Dam was built as a part of the Middle Rio Grande Conservancy District works in 1935, and rehabilitated by the Bureau of Reclamation in the 1950s. The MRGCD uses El Vado to store native Rio Chama water for the "prior and paramount" water rights held by the six Pueblos served by MRGDC (Kewa, Cochiti, San Felipe, Santa Ana, Sandia, and Isleta). The reservoir stores water in the spring runoff season and releases water during the irrigation season and, in some cases, water to meet New Mexico's obligation to Texas under the Rio Grande Compact.

[106] U.S. Bureau of Reclamation, "Project Details - San Juan-Chama Project," accessed March 11, 2016, http://www.usbr.gov/projects/Project.jsp?proj_Name=San+Juan-Chama+Project.
[107] U.S. Bureau of Reclamation, "Calendar Year 2014 Report to the Rio Grande Compact Commission," March 2014, http://www.usbr.gov/uc/albuq/water/RioGrande/rpts/Final2014RGCCReport.pdf .

Heron Reservoir

Heron Reservoir was authorized in 1962 and constructed on Willow Creek, a tributary of the Rio Chama, in 1971. The Bureau of Reclamation constructed Heron reservoir to store imported water from the Colorado River Basin as a part of the San Juan - Chama Diversion Project. The Azoteca Tunnel delivers an average of 94,200 acre-feet from a San Juan River tributary into Heron Lake each year, as compared with an average of 15,000 acre-feet of native flow. The storage capacity is 401,320 acre-feet, which is reserved for the San Juan - Chama water, while the native inflows are metered and an equivalent amount is released at the dam. As shown in Figure 6.4, the majority of the water is contracted by Albuquerque and other smaller municipal entities, and a smaller portion is under contract to the MRGCD and Pojoaque Valley Irrigation Districts.

Cochiti Dam

The federal Flood Control Act of 1960 authorized construction of a flood and sedimentation control dam at Cochiti, replacing the irrigation diversion dam, which had been constructed by the MRGCD in 1935. The original project didn't include any water rights to fill or maintain a permanent pool. However, after the San Juan - Chama Diversion Project authorization, there was additional water available in the basin, and in 1964 the project's authorization was amended to include a permanent pool for recreation, fish, and wildlife. This authorization does not designate Cochiti to store water for the purpose of supplying downstream water users.[108]

Under this authorization, Cochiti Reservoir was operated with equal amounts of inflow and outflow under normal conditions. Storage capacity, beyond the permanent pool, can be used to mitigate downstream flood damage. The Rio Grande slows and widens downstream from Cochiti Dam, which causes sediment to be deposited. This causes the riverbed to rise over time, and increases wetland area and shallow flooding along the banks. Sediment control is accomplished by slowing down the water from tributaries feeding the reservoir, which allows particles to drop out within the reservoir and limits sedimentation in the riverbed downstream.[109]

The entire Cochiti Dam site and inundation area are within the Pueblo of Cochiti, and the project was vocally opposed by the Pueblo of Cochiti members from the initial dealings with the federal government in the 1960s.[110] The location of the lake, between Santa Fe, Albuquerque, and Los Alamos, was selected so that New Mexicans from metropolitan areas could access the lake for recreation, and thereby encourage economic development. Along with the dam construction, there were plans to build the Town of Cochiti Lake, which was a proposed development open to up to 40,000 non-native residents (compared with the Pueblo's population of about 1,000

[108] U.S. Bureau of Reclamation, "Project Details - San Juan-Chama Project."

[109] U.S. Army Corps of Engineers, "Albuquerque District / Missions / Civil Works / URGWOM," accessed March 11, 2016, http://www.spa.usace.army.mil/Missions/CivilWorks/URGWOM.aspx.

[110] Cochiti Pueblo, "The Official Website of the Cochiti Pueblo," accessed March 11, 2016, http://www.pueblodecochiti.org.

people). The Town of Cochiti Lake was developed in the 1970s, but only about 400 houses were built.[111]

Figure 6.5.
Cochiti Dam Water Wars

Source: Thomas Blog, "Waterworks," accessed March 11, 2016, http://santafereview.com/waterwars/review/blog.html.

The reservoir was opposed by the Pueblo's governing body because the inundation area included a significant portion of the Pueblo's traditional farmland. After the reservoir was constructed, even more farmland was flooded due to seepage near the dam. After filing for damages in 1976 and initiating multiple lawsuits over the subsequent decades, the Pueblo succeeded. The Army Corps of Engineers issued a formal apology to the Cochiti Pueblo Indians in 2001.

Because the Cochiti Dam's primary function is flood and sediment control, it is operated with the intent that inflows are equal to the outflows until the capacity of the downstream channel has been exceeded. The permanent recreation pool has been maintained at 50,000 acre-feet since the dam was constructed. Annually, the lake captures approximately 970 acre-feet (1,200,000 cubic meters) of sediment. The reservoir has capacity for an additional 545,000 acre-feet that can be used for flood control.[112]

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[111] Regis Pecos, "The History of Cochiti Lake from the Pueblo Perspective," *Natural Resources Journal* 47 (June 2007): 639-653.
[112] U.S. Army Corps of Engineers, "URGWOM."

Growth and Environmental Concerns

The majority of municipal water demands in New Mexico are met with groundwater, while agricultural users rely mainly on surface water. The Middle Rio Grande planning area includes Sandoval, Bernalillo, and Valencia counties and approximately coincides with the study area (excluding Socorro County). Based on the 2010 Middle Rio Grande Regional Water Plan, demand across the region is 431,640 acre-feet per year; 129,126 of which is met with groundwater, and 302,514 of which is met with surface water. However, the source and usage are closely linked: 83 percent of surface water was used for agriculture and 68 percent of groundwater was used to meet municipal needs.[113]

The region has seen increasing demands and water scarcity due to drought and climate change. The ability of the OSE or others to set aside some portion of the Rio Grande for environmental purposes has been disputed as a "beneficial use."[114] Since the 1990s, environmental issues have been the primary drivers of changes in how water is managed on the Rio Grande. In 1994 the Silvery Minnow was listed as endangered. The resulting lawsuits on behalf of the minnow required restoration of their habitat, but did not specify any environmental flow requirements. The federally mandated restoration of the minnow's habitat has required cooperation between local, state, and federal agencies to ensure that the river "flows continuously" according to the mandate. However, in 1996 the Middle Rio Grande Conservancy District diverted all of the flow from the Rio Grande into their irrigation canals, which killed 10,000 minnows, or 40 percent of their remaining population.[115]

Conclusions

The Middle Rio Grande basin was fully allocated to users as early as the 1920s, and has been preserved as a resource primarily used for agriculture. In this way, the Rio Grande is the link to over a thousand years of agrarian culture in the river valley, and the seniority of agriculture as a beneficial water use has limited urbanization. Although the Cochiti Dam doesn't serve to manage the Rio Grande as a water supply, it does allow for greater development downstream as a result of flood control. The most significant boon to municipal growth may not be a dam, but the tunnels of the San Juan - Chama project, linking the Rio Grande Valley to the Colorado River basin.

Figure 6.6 shows that the water conveyed by the Rio Grande, both native Rio Grande water and the San Juan - Chama Project water, has allowed for significant agricultural and municipal development in an otherwise arid region.

Management of the Rio Grande has at times been collaborative in response to environmental issues (or the litigation that results from those environmental issues). With the weight of the Endangered Species Act, the silvery minnow may force the most significant changes in the future of the Middle Rio Grande.

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[113] New Mexico Office of the State Engineer, "2016 Middle Rio Grande Regional Water Plan.".

[114] Bartolino and Cole, "Ground-Water Resources of the Middle Rio Grande Basin, New Mexico."

[115] Greg Hanscom, "A Tiny Fish Cracks New Mexico's Water Establishment," October 11, 1999, http://www.hcn.org/issues/164/5305.

Figure 6.6.
Impact Area of Cochiti Dam, as Shown by the Visibly Irrigated Area Comprising the MRGCD Jurisdiction

Source: Middle Rio Grande Conservation District.

Chapter 7. Elephant Butte and Caballo Dams

by Brian Jackson and Marcos Duran

Introduction

The Paso de Norte (PdN) region is experiencing historic population growth in each of its component regions, El Paso, Cuidad Juárez, and Las Cruces. Typical of the American southwest, there is an excess of evaporation over precipitation throughout the region, leaving the PdN dependent on surface water transported from upstream regions. The Elephant Butte reservoir was constructed to control the flooding and drought patterns of the region and provide a steady water supply to create a rich farming and agricultural economy in the region. Caballo reservoir was added later to also allow for year-round hydropower generation at Elephant Butte.

The mission of the U.S. Bureau of Reclamation was to build infrastructure that would capture every gallon of water in the west and use it in agricultural or urban centers to promote the regional growth and economy. The growth of the PdN region is intimately tied to the success of the reservoir system. Sedimentation, population growth, and climate change now threaten the water future of the region.

Figure 7.1.
Elephant Butte Dam

Source: U.S. Bureau of Reclamation.

History

At the turn of the 20th century, westward expansion to the Pacific coast was anything but complete. The U.S. government was actively promoting westward expansion through the Homestead Act of 1862 and the underlying belief in manifest destiny and the ideology of rain follows the plow.[116] The explorations of John Wesley Powell, the first head of the U.S. Geologic Survey, and initiatives by new state representatives from western states like Francis Newall of Nevada led to passage of the Reclamation Act of 1902 authorizing the creation of the Bureau of Reclamation. Theodore Roosevelt created the hydrologic mission to create and expand productive farmlands by bringing water through irrigation and flood control to turn the west into the new growth area of the United States.

Planning and Goals

In recognition of the 1906 IBWC convention with Mexico and under the authority of the Reclamation act of 1902, Congress reauthorized the Reclamation Act in 1906. Among the first projects as a result of the reauthorization was the Elephant Butte Dam.[117] Elephant Butte was built to regulate the water flow through New Mexico to El Paso, Texas. Prior to the construction of the dam, irrigation was difficult due to the destructive forces of the Rio Grande when it flooded.

Construction and Maintenance

Construction began in 1911 and the dam was completed in 1916. As a hydroelectric dam, Elephant Butte Dam provides electricity for much of the surrounding area. It is able to produce electricity year-round and during drought because of Caballo Dam, which lies 25 miles downstream from Elephant Butte. Caballo was built in 1936 for two primary reasons: to allow for the year-round production of electricity from Elephant Butte, and to compensate for the loss of storage volume at Elephant Butte due to sedimentation.

The Bureau of Reclamation maintains the dam itself, and the Elephant Butte Irrigation District is responsible for maintenance of the diversion canals and irrigation infrastructure.

Hydrologic Region

Irrigated Land

According to the Bureau of Reclamation, the Elephant Butte and Caballo reservoir systems combine to irrigate 196,557 acres of farmland in Sierra and Dona Aña Counties in New Mexico and El Paso and Hudspeth Counties in Texas, as of 1991.[118] A review of the USDA Census of Agriculture shows that the number of irrigated acres in the Paso del Norte region has been

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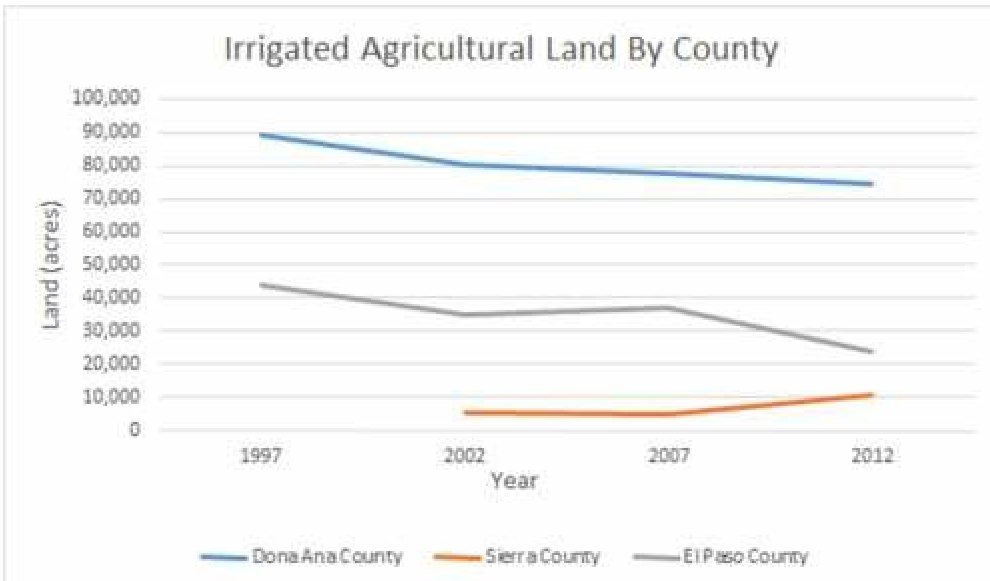
116 Marc Reisner, *Cadillac Desert: The American West and Its Disappearing Water, Revised Edition* (New York, N.Y.: Penguin Books, 1993).
117 Robert Autobee, "The Rio Grande Project" (Denver, Colorado: Bureau of Reclamation History Program, 1993).
118 U.S. Department of the Interior, Bureau of Reclamation, "Summary Statistics. Vol. 1, Water, Land, and Related Data" (Denver.: Bureau of Reclamation, 1985).

decreasing for the past two decades. In 1997 Dona Ana, Sierra, and El Paso counties accounted for a total of 133,230 acres of irrigated land. By 2012, the three counties only accounted for 109,085 acres. This trend conforms to the dry period which began in the early 2000s and continued until 2013. However, the census data does not explain whether water scarcity is the reason for this decrease in acreage, or whether it is due to changes in crops, agricultural practices or urbanization.

Figure 7.2.
Irrigated Land Over Time



Source: USDA, "USDA Census of Agriculture," https://www.agcensus.usda.gov/.

Water was plentiful after the construction of the dam. Water levels oscillated between 1-1.5 million acre-feet of water throughout the 1920s. The first dry period occurred during the Dust Bowl Era, 1934 and 1935. At this time water levels dropped below 500,000 acre-feet of water. Water scarcity reached unprecedented levels when the drought of record occurred in 1945 and continued until the late 1950s. In the mid-1950s water levels went as low as 100,000 acre-feet of water in the reservoir. After the drought of record, the water supply stabilized, but water levels in the lake did not recover until the floods in 1979, which brought the water back to above 1 million acre-feet. The mid 1980s began a decade of plentiful water. The dam was frequently discharging water as the lake filled up to the flood pool. This trend reversed beginning in the early 2000s as drought again set into the region. It was in 2011 that the region experienced the most severe drought since the drought of record in the 1950s. Though more precipitation followed in 2013, lake levels have not recovered. On June 25, 2016, Elephant Butte Lake stood at 16 percent full, at 315,000 acre-feet.

Socioeconomic Region

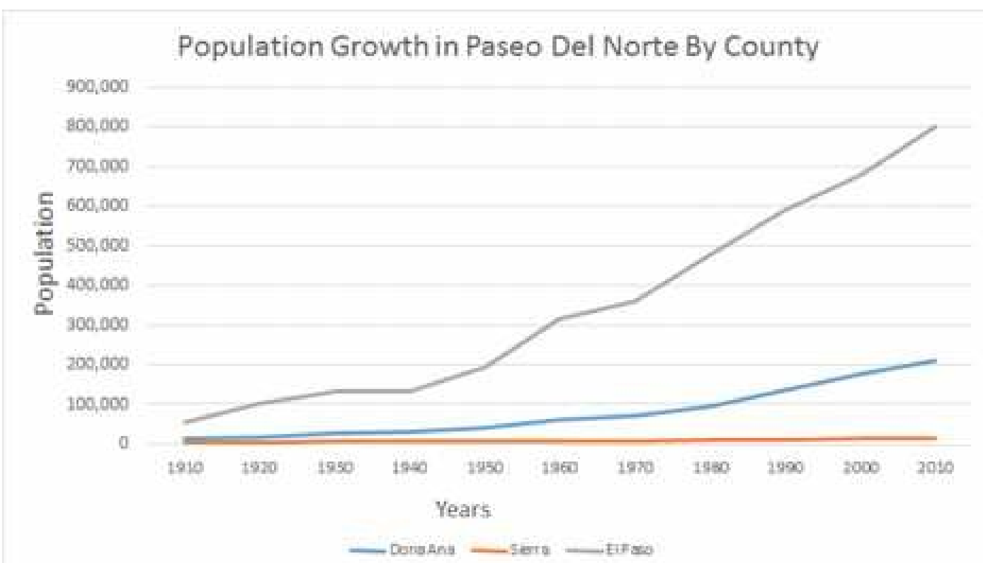
Population

The Paso del Norte population in New Mexico and Texas numbers over 1 million people. Most of the growth has occurred in El Paso County. Prior to the construction of the Elephant Butte Dam, El Paso's population was just over 50,000 people. Without proper infrastructure, there were years when the river was nearly dry upon reaching the City of El Paso. After the dam was constructed at Elephant Butte the population doubled to over 100,000 people by 1920. The population grew slower in the following decades until the decade between 1950-1960, when the population increased from 195,000 to 314,000 people. Growth accelerated again during the 1990s and 2000s, and by 2010 the region was home to over 800,000 residents.

Dona Ana County, where the city of Las Cruces, New Mexico, is located, has generally experienced more moderate growth than El Paso County. In 1910 over 12,000 people lived in the county. After the construction of the dam, the population only rose to 16,000 by 1920. The county did not exceed 100,000 people until the 1980s. By 2010 its population was just over 200,000 people.

Finally, Sierra County continues to be sparsely populated. In 1910 it had 3,500 people living in its boundaries, and in 2010 it still had not exceeded 12,000 people.

Figure 7.3
Population Growth in Paso del Norte (U.S. Portion), by County



Source: Bureau of Business & Economic Research, University of New Mexico, "Total Population: 1900 to 2010 for New Mexico and Counties," accessed February 28, 2016, http://bber.unm.edu/visualizations/migrated/census/cenhist.htm,.

Economy

The New Mexico dairy industry is the largest component of the agricultural industry in New Mexico, generating $1.32 billion in economic activity,[119] and dependent on the Rio Grande for water. The Juárez-El Paso-Las Cruces region produces cotton, pecans, vegetables, alfalfa, grapes, and other high-value crops.[120]

Water Demand

From 1990 to 1995, water demand in the Middle Rio Grande increased from 1,830,628 acre-feet to 2,104,873 acre-feet. This represents an increase of 15 percent in water demand in the region. Water demand remained stable through the 1990s but began to decrease after 2000. In 2005, total water demand was 1,905,965 acre-feet. In 2010, on the eve of the new drought of record, it shrank to 1,773,521 acre-feet. It is clear from this data that the region does decrease its water demand during drought. From 1995 to 2010 water demand shrank by nearly 16 percent. Both urban areas and agriculture adjust their use of water during drought, however surface water is used almost primarily by agriculture, with urban areas changing the amount of groundwater they pump in drought.[121,122] The ratio of surface water use to groundwater use remains fairly stable over time, with surface water accounting for roughly two-thirds of overall water usage.

Problems

Sedimentation

Kent Collins and R. L. Ferrari conducted a survey for the Bureau of Reclamation in 1999 by comparing sonograms to image the lake bottom along original 1915 topographic transects of the Elephant Butte reservoir. They found that 611,442 acre-feet of sediment have accumulated along the bottom of the reservoir. That represents a rate of sedimentation of 7,253 acre-feet per year over the life of the dam. However, they noted that using data from 1988 they found a sedimentation rate of 3,719 acre-feet per year. This indicates that sedimentation is correlated to inflows, therefore when inflows are low during drought years, sedimentation is similarly low.[123]

The Bureau of Reclamation monitors the inflow of sediments from the top of the reservoir to maintain an estimate, based on flow, of the sedimentation of Elephant Butte reservoir, but has

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119 Victor E., Cabrera, R. Hagevoort, D. Solís, R. Kirksey, and J.A. Diemer, "Economic Impact of Milk Production in the State of New Mexico," *Journal of Dairy Science* 91(5) (2008): 2144-2150.

120 Adriana Evangelina Perez, "Satellite Detection of Land Use Changes in the Rio Grande Valley from Elephant Butte Dam, NM, to Fort Quitman, TX," Master's Thesis, The University of Texas at El Paso, 2000.

121 John W. Longworth, Julie M, Valdez, Molly L, Magnuson, Elisa Sims Albury, and Jerry Keller, "New Mexico water use by categories," Technical Report 54 S (Santa Fe, New Mexico: New Mexico State Engineer Office, 2010).

122 Molly A. Maupin, J.F. Kenny, S.S. Hutson, J.K. Lovelace, N.L. Barber, and K.S. Linsey, "Estimated use of water in the United States in 2010," U.S. Geological Survey Circular 1405, 2014, http://pubs.usgs.gov/circ/1405/.

123 Kent Collins and R.L. Ferrari, "Elephant Butte Reservoir: 1999 Reservoir Survey," http://www.usbr.gov/pmts/sediment/projects/ReservoirSurveys/Reports/Elephant%20Butte%20Reservoir%201999%20Reservoir%20Survey.pdf. (Denver, Colo: U.S. Dept., of the Interior, Bureau of Reclamation, Sedimentation and River Hydraulics Group, Water Resources Services, Technical Service Center, 2000).

not replicated the Collins and Ferrari survey since 1999. The Bureau of Reclamation should re-survey the reservoir transects to make a current model of sedimentation and storage capacity.

Flooding

Elephant Butte is part of a network of dams, weirs, and channels designed to capture and control flood waters. As such, lake levels have rarely reached the flood pool level, which is 2 million acre-feet. The first time this occurred was in 1944, and it did not occur again until the mid-1980s.[124]

Droughts

Lake levels slowly filled throughout the beginning of the 20th century. The first period of drought after the construction of the dam remains to this day the drought of record. For over a decade, from 1945-1957, the central valley of New Mexico experienced prolonged drought.[125] During this period, lake levels were decimated. Following this drought lake levels began to stabilize. From 1979-2003 the Elephant Butte Irrigation District was able to supply the region with a “full” supply (i.e., 790,000 acre-feet) of surface water.[126] However, in 2003 another prolonged dry period began, and in 2011 the region experienced the most severe drought since the 1950s. This dry period continued until 2013.[127]

Climate Change

In a review, Hurd and Coonrod estimated economic impacts of climate change on water resources in the Upper Rio Grande. They found that, under the relatively dry scenario, the region can expect a loss of approximately 0.2 percent of the estimated Gross State Product (GSP) of $60 billion. Runoff change was estimated to fall by 28 percent and annual direct economic damages in 2080 were estimated at $100 million using a hydro-economic model of the watershed.[128]

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[124] Texas Water Development Board, “Elephant Butte Lake Historical Levels,” Water Data for Texas, accessed February 28, 2016, http://waterdatafortexas.org/reservoirs/individual/elephant-butte.

[125] South Central Climate Science Center, “Drought History for the Central Valley of New Mexico,” accessed February 28, 2016, http://www.southcentralclimate.org/content/documents/factsheets/Drought_History_NMCD05.pdf.

[126] Terrence Henry, “A History of Drought and Extreme Weather in Texas,” November 29, 2011, accessed February 28, 2016, https://stateimpact.npr.org/texas/2011/11/29/a-history-of-drought-and-extreme-weather-in-texas/.

[127] New Mexico Governor’s Drought Task Force, “Monitoring Working Group Monthly Agenda & Status Reports Archive,” accessed February 27, 2016, http://www.nmdrought.state.nm.us/dtf_workgroup_report_archives.html.

[128] Brian Hurd and Judie Coonrod, “Hydrological and Economic Consequences of Climate Change in the Upper Rio Grande Region,” *Climate Research* 53(2) (2012): 103-118.

Chapter 8. La Boquilla Dam

by Deirdre Appel

Introduction

Due to massive water use in the Paso del Norte area, the Rio Grande/Bravo downstream from Fort Quitman, Texas, is reduced to a small river. The river is revived by a tributary from Mexico, the Conchos. Therefore, we include a reservoir assessment for La Boquilla Dam in the Conchos sub-basin.

This chapter begins with a section on the history, planning, goals, and construction of the reservoir and dam. The hydrological and socio-economic regions created by the reservoir are explored in further detail followed by an analysis of governance covering the reservoir and how it may affect the region. The paper concludes with options for dealing with increased water scarcity.

Figure 8.1.
Conchos River Basin

Source: Sierra Rios, "Rio Conchos," http://www.sierrarios.org/GuidedTrips/RaftTripInfo_Conchos.html.

The Rio Conchos is one of the most important rivers in Northern Mexico and is highly important for South Texas. The Rio Conchos begins high in the Sierra Madre Occidental, moves through the central plains of Chihuahua, and finds its confluence with the Rio Bravo/Rio Grande just above Texas' Big Bend National Park. It is an essential ribbon of life in the arid desert.

The Conchos river basin lies in the state of Chihuahua, Mexico, and covers about 26,400 square miles. The Conchos basin accounts for roughly 14 percent of the total area of the Rio Bravo basin and 35-40 percent of the surface flow of the lower Rio Grande.[129] The river is a lifeline for municipal, agricultural, and industrial water needs in Chihuahua. Once the river meets the Rio Grande/Bravo, it satisfies these same demands for Texas and other eastern Mexican states like Coahuila, Nuevo Leon, and Tamaulipas. A list of major cities in the Rio Conchos basin and their populations over time is displayed in Table 8.1.

Table 8.1.
Major Cities in the Rio Conchos Basin

Locality	1995 Population	2000 Population	Estimated 2020 Population	% Change (2000-2020)
Chihuahua	609,059	677,852	957,347	41
Hidalgo de Parral	95,913	103,285	136,048	32
Delicias	93,447	99,137	124,996	26
Camargo	37,572	39,189	47,881	22
Jiménez	30,992	32,966	42,121	28
Meoqui	25,066	27,288	34,838	28
Ojinaga	18,063	18,342	20,353	11
Saucillo	15,454	15,679	17,917	14

Source: Mary E. Kelly, "The Rio Conchos: A Preliminary Overview" (Austin, Tex.: Texas Center for Policy Studies, 2001), http://www.texascenter.org/publications/rioconchos.pdf, 6.

There are several reservoirs in the Rio Conchos basin. A list of major reservoirs in the Conchos basin is shown in Table 8.2. La Boquilla reservoir (also known as Lake Toronto), built during the Mexican revolution in 1910, is the largest and oldest reservoir on the river. It was completed in 1916—the same year as Elephant Butte Reservoir. Today, the reservoir is used to generate hydropower and meet irrigation demands. The remainder of this paper will focus on the La Boquilla reservoir.

History of the Dam and Reservoir

Planning and Goals

Construction for La Boquilla began during the Mexican Revolution in 1910. The reservoir, the largest in Chihuahua, is used to supply water downstream to irrigation districts and when supply levels are high enough, the reservoir is also used to generate hydropower. The reservoir, however, did not always serve this need. Initial construction was born out of a desire to provide electric power to nearby mining districts and was put forth by a privately owned construction company. In the early 20th century, the purpose of the reservoir was to supply electric power to the Parral mining district about 50 miles from a power house just below the La Boquilla Dam.[130]

[129] Mary E. Kelly, "The Rio Conchos: A Preliminary Overview" (Austin, Tex.: Texas Center for Policy Studies, 2001), http://www.texascenter.org/publications/rioconchos.pdf.
[130] Edwin Jr. Duryea, and H.L. Haehl, "A Study of the Depth of Annual Evaporation from lake Conchos, Mexico", Transactions of the American Society of Civil Engineers, 30:1 (1916): 1829-1901.

In fact, the Canadian owners of the dam refused to submit to a project that would use the water needed by their hydroelectric dam for irrigation use.[131]

Table 8.2.
Major Reservoirs in the Conchos Basin

River	Reservoir	Year Completed	Storage Capacity Mm^3 (MAF)	Uses
Florido	San Gabriel	1981	255 (0.21)	Irrigation
Florido	Pico de Aguila	1993	50 (0.045)	Irrigation
Conchos	La Boquilla	1916	2903 (2.34)	Irrigation, hydroelectricity
Conchos	La Colina	1927	24 (0.195)	Irrigation, hydroelectricity
San Pedro	F. Madero	1949	348 (0.28)	Irrigation, sediment control
Chuvíscar	Chihuahua	1960	26 (0.021)	Municipal, irrigation, flood control
Conchos	Luis L. León	1968	337 (0.29)	Irrigation, flood control

Source: Mary E. Kelly, "The Rio Conchos: A Preliminary Overview" (Austin, Tex.: Texas Center for Policy Studies, 2001), http://www.texascenter.org/publications/rioconchos.pdf, 7.

Note: Mm^3 means million cubic meters; MAF means million acre-feet.

Construction and Maintenance

At the time of construction, the La Boquilla Dam was said to be one of the largest masonry dams in the world—at 79.5 meter high and containing about 300,000 cubic yards of masonry, the dam was extraordinary for its time. Though construction began in 1910, the project saw many interruptions and halts due to the ongoing revolution. One engineer noted, "The political conditions of this country have added greatly to the troubles of engineering and construction."[132]

The storage capacity of La Boquilla rests at 3336 million cubic meters[133] while the mean natural runoff is around 1,153 cubic hectometers annually.[134] The reservoir has an evaporation rate of 253.1 cubic hectometers per year and a water extraction rate of roughly 1.034.3 cubic hectometers per year.[135] Additional statistics on the reservoir are displayed in Table 8.3.

131 Luis Aboites Aguilar, "The Transnational Dimensions of Mexican Irrigation 1900-1950," *Journal of Political Ecology* 19 (2012): 70-80.
132 Engineering and Contracting: The Construction of La Boquilla Dam, Mexico, Difficulties due to Revolutions.
133 Conaqua, "Subdirección General Técnica (SGT)," IMTA-BANDAS, https://www.imta.gob.mx/bandas.
134 Alberto Guitron, H. Pasell, J. Valdés, J. Aparicio, and J. Echeverría, "Water Sustainability and the Conchos," Second International Symposium on Transboundary Waters Management, http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=966981.
135 Ibid.; Mexican Institute of Water Technology (IMTA), "Surface water distribution between Fort Quitman and Falcon Dam," 2003.

Table 8.3.
La Boquilla Reservoir Statistics

Total capacity	2,903 cubic hectometers
Conservation capacity	2,744 cubic hectometers
Sediment capacity	159 cubic hectometers
Design flood flow	11,000 cubic meters per second
Intake flow	50 cubic meters per second
Dam length	270 meters
Maximum height	80 meters

Source: Alberto Guitron, H. Pasell, J. Valdés, J. Aparicio, and J. Echeverría, "Water Sustainability and the Conchos," Second International Symposium on Transboundary Waters Management, http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=966981.

Impacts of the Reservoir in the Region

Dams and reservoirs render enormous impacts upon the communities they serve. Benefits range from agriculture to industry to electricity. They also function as powerful economic development catalysts for the region. This has been the case of the la Boquilla Dam and Reservoir. While the purpose of the dam and reservoir in its original form was to generate hydroelectric power to support mining projects in a remote region of Mexico, the reservoir's impact has permeated sectors beyond hydroelectricity. The reservoir has supported the growth of irrigation district 005 in Delicias and had a ripple effect for development of the state of Chihuahua more broadly.

Hydrologic Region

The reservoir of La Boquilla, one of the largest in the world at the time, helped open up more than 100,000 new hectares of land for irrigation and cultivation. In 1927 the Mexican government decided to move forward with an irrigation project on the Rio Conchos that would help develop new irrigation districts in the northern lands of Mexico. Using the waters from the La Boquilla reservoir, Delicias was created. The maximum irrigated area of Delicias is 76,171 hectares while the total irrigated area from 1988-2000 wavers around 63,000 hectares.[136] Water volume used in this district between 1988-2000 was 1,049 cubic hectometers.

The construction of the La Boquilla Dam and Reservoir in the early 1900s helped spur the development of Delicias, Chihuahua through irrigation projects promoted by the government of Plutarco Elías Calles (1924-1928).[137] At the onset of irrigation development, the owners of the dam refused to submit to any projects that would use the water needed by their hydroelectric plant for irrigation purposes. They contended that they had been awarded this right to water use during the government of Porfirio Diaz and any other such uses of the water would be considered

136 Comisión Nacional del Agua, "Programa Hidraulico de Gran Vision, Estado de Chihuahua (1996-2020)," 1997, http://www.sequia.edu.mx/planhidra/.
137 Luis Aboites Aguilar, "The Transnational Dimensions of Mexican Irrigation 1900-1950," *Journal of Political Ecology* 19 (2012): 70-80.

illegal. The company instead used the water released from the dam to make two additional hydroelectric plants on the river—Colina in 1928 and Rosetilla in 1930. The government then turned to the reservoir created by Boquilla Dam as their source for irrigating the northern borderlands. And thus, the irrigation region of northern Mexico was born.

Similar to the rest of the region, the hydrological region of Chihuahua has experienced abnormally dry conditions over the past decade. In fact, Chihuahua's precipitation is one of the lowest in the country. The limited precipitation coupled with high temperatures has maintained moderate drought conditions in this area. Table 8.4 shows the average monthly precipitation.[138]

Table 8.4.
Normal Monthly Precipitation in Chihuahua, 1971-2002

In Millimeters

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
17	13	7	7	12	39	112	108	75	31	16	21	456

Source: National Water Commission of Mexico, "Statistics on Water in Mexico, 2010 Edition," June 2010, http://www.conagua.gob.mx/english07/publications/EAM2010Ingles_Baja.pdf.

Socio-Economic Region

As mentioned above, the Delicias Irrigation District was made possible by the waters of the La Boquilla dam and reservoir. It was not until 1960, however, that the Chihuahua State Congress recognized Delicias as a city. This incorporation made Delicias the fourth most populous city in the state. Population continued to grow during this time and the district continued to blossom as an agricultural center. Today is serves more as a manufacturing hub, attracting migrants for that purpose. Nonetheless, the area continues to see an increase in population. Population figures for Delicias, Chihuahua, and Mexico are shown in Table 8.5 and Figure 8.2.

Table 8.5.
Population in Delicias, Mexico, 1990-2015

1990	1995	2000	2005	2010	2015
87,412	94,001	98,615	108,187	118,071	129,500

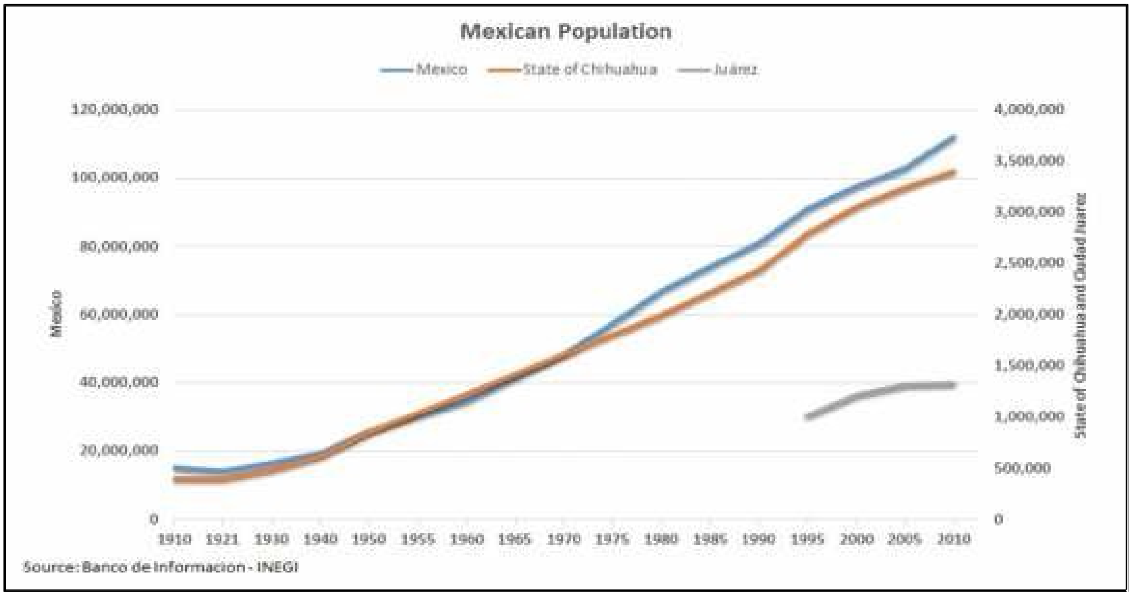
Source: INEGI, "Instituto Nacional de Estadística, Geografía e Informática," http://www.inegi.org.mx/.

The state of Chihuahua, where the La Boquilla dam is located, has one of the greatest regional disparities in Mexico, with the state's income range wider than in any other Mexican state. This income disparity is fueled by the range of occupations within Chihuahua—occupations which the reservoir supports. Incomes tend to be higher in the districts with higher economic productivity.

[138] National Water Commission of Mexico, "Statistics on Water in Mexico, 2010 Edition," June 2010, http://www.conagua.gob.mx/english07/publications/EAM2010Ingles_Baja.pdf.

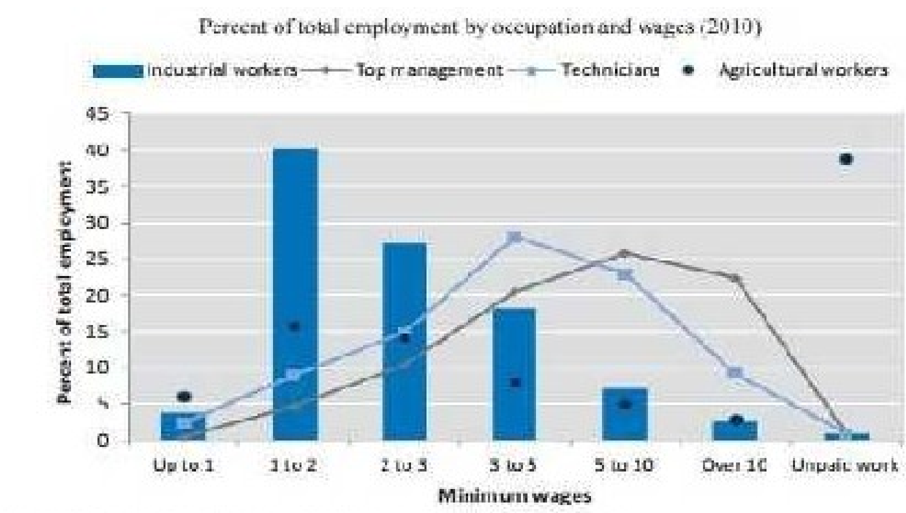
Management employees have earnings that fall between the two top income categories, while professional and technicians fall in the second and third income categories.

Figure 8.2.
Population in Mexico, Chihuahua, and Juárez



Source: OECD, "OECD Territorial Reviews: Chihuahua, Mexico 2012," April 13, 2012, http://www.oecd-ilibrary.org/urban-rural-and-regional-development/oecd-territorial-reviews-chihuahua-mexico-2012_9789264168985-en;jsessionid=5rasoliqks5p5.x-oecd-live-03.

Figure 8.3.
Wage Inequality by Occupation in Chihuahua



Source: OECD, "OECD Territorial Reviews: Chihuahua, Mexico 2012," April 13, 2012, http://www.oecd-ilibrary.org/urban-rural-and-regional-development/oecd-territorial-reviews-chihuahua-mexico-2012_9789264168985-en;jsessionid=5rasoliqks5p5.x-oecd-live-03.

Forty-four percent of all industrial workers, however, earned less than three times the minimum wage (US$8.80/day). If the proportion is extended to three times the minimum wage (US$13.20), the rate is 71 percent of all industrial workers. For agricultural workers, the situation is even more grim—40 percent of employees in farming go unpaid and an additional 36 percent of farmers earn less than three times the minimum wage.[139] These discrepancies in income are displayed in Figure 8.3.

Despite the manufacturing and agriculture jobs created by the availability of water and the established industries that followed, marginalized neighborhoods persist, gender inequalities remain, and indigenous populations' human development index (HDI) levels fall 26 percent below those of the nonindigenous population.[140]

While the state of Chihuahua is characterized by income inequality and regional disparities, in terms of education, Delicias, the municipality in which La Boquilla is located, experiences an above average trend (8.7 percent) for total population with a university degree, while the state's average is 7.5 percent. Due to concentrations such as this, over 90 percent of Chihuahua's university degrees are located in 10 percent of its municipalities, which are Chihuahua City, Juárez, Delicias, Parral, Cuauhtémoc, and Nuevo Casas Grandes.[141]

The reservoir triggered a tremendous amount of activity in Chihuahua's development, especially in sectors such as agriculture and mining. Farming represents the largest source of jobs and income for just over 220,000 farmers. Agriculture continues to have a large share of the state economy. A rise in growth rates in both these sectors was the trend since construction of the reservoir until about the 1990s. During the 1990s, however, agriculture and mining saw a decline in growth rates.[142] Rather it was industries such as manufacturing, service, construction, and transportation that experienced substantial growth. There is no doubt, of course, that agriculture continues to be an important economic generator in the irrigation districts around La Boquilla where crops such as maize, winter wheat, alfalfa, cotton, and pecans are produced. A changing economic base, however, should be noted. This change can be explained by the devaluation of the Mexican peso, competition from U.S. products, inefficient production methods, and the persistent drought.

Governance and Treaties Covering the Reservoir and Region

The irrigation politics at the time of dam construction were characterized by an emphasis on the northern region. The government aimed to increase population close to the border with the United States. After years of debate regarding what role the government would play in such affairs, the 1926 Irrigation Law broke the model of previous governments and contended direct government intervention was unavoidable. This was the stance that the U.S. had taken with the

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[139] OECD, "OECD Territorial Reviews: Chihuahua, Mexico 2012," April 13, 2012, http://www.oecd- ilibrary.org/urban-rural-and-regional-development/oecd-territorial-reviews-chihuahua-mexico-2012_9789264168985-en;jsessionid=5rasoliqks5p5.x-oecd-live-03.
[140] Ibid.
[141] INEGI, "Sistema Estatal y Municipal de Bases de Datos (SIMBAD), Instituto Nacional de Estadística, Geografía e Informática, Mexico," 2005, accessed 15 June 2011, http://sc.inegi.org.mx/sistemas/cobdem/.
[142] Kelly, "The Rio Conchos: A Preliminary Overview."

establishment of the Bureau of Reclamation. Yet despite the converging positions between the two countries, there is no reference to the Bureau of Reclamation in the 1926 Irrigation Law.

Mexican emphasis on the northern border was designed to take advantage of the tributaries of the Rio Grande/Rio Bravo, particularly the Conchos and Salado rivers. The aim was to utilize these waters before they emptied into the main course and were at the disposal of the U.S. This standpoint on division is a product of the 1906 Water Convention. Regardless of whether these interpretations hold true or not, the Mexican irrigation policy of this time derived from this strategic thought process.

In addition to the strategy surrounding the development of irrigation districts around the reservoir, the Mexican government promoted the idea of repatriation of Mexicans living in the United States to live and work in new irrigation districts in the planned northern region. This policy of repatriation created the influx of thousands of Mexicans back into northern Mexico who brought back with them new agricultural knowledge and practices. Actively recruited by the Comision Nacional de Agua (CNA), they were a catalyst for development of agriculture in the region.

But in order to have these thriving irrigation districts, the Mexican government needed water to provide. They were able to do this by using the reservoir created by the La Boquilla Dam. But the agreement process between the Mexican government, foreign-owned companies, and the United States was not easy. There has been speculation that the strong opposition from the Canadian owners of the dam was not due to an aversion to water use by agriculture but rather an agreement with Texas farmers.[143] Farmers in Texas were anxious that irrigation in Chihuahua would limit access to water for their own crops. Despite the apprehension, the CNA was able to reach an agreement with the Canadian hydroelectric company under which the water from the Toronto Lake would be used collaboratively for both agriculture and electricity. With this agreement, the Mexican government was able to allocate more water from the Conchos, held in the reservoir, to development of a new irrigation zone.

As time moved on, the two countries came together in 1944 in attempts to collaborate on strategy and arrive at a more formal agreement regarding water sharing. The Rio Conchos and its sub basin reservoirs play a major role in meeting the allocations under the 1944 Water Treaty. Prolonged drought in the region and an increasing use of surface water, however, have highlighted shortcomings in the management of water, both nationally and bi-nationally. The decade between 1993-2003 saw immense challenges due to the persistent drought. Reservoir recovery has not yet been possible and the reservoir continues to rest shy of its storage capacity. Scarcity remains an issue as population and economic development exacerbated the situation even further.[144] In addition to these national effects, drought has caused deep tensions bi-nationally as well. These issues are addressed further in the following Drought and Governance section.

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[143] Luis Aboites Aguilar, "The Transnational Dimensions of Mexican Irrigation 1900-1950," Journal of Political Ecology, 19 (2012): 70-80.
[144] Guitron et al., "Water Sustainability and the Conchos."

Problems: Drought and Governance, Sanitation and Sedimentation

Drought and Governance

The prolonged drought in northeast Mexico has reduced stream flows and reservoir storage levels among other secondary socio-economic impacts. The northern states of Mexico, such as Chihuahua, are particularly vulnerable to drought shocks. The reservoirs in this basin reached some of the lowest points in their history, especially La Boquilla. Due to the drought, the Mexican National Water Commission has concluded there is little if any opportunity to build a new reservoir on the Conchos basin. There has, however, been discussion of increasing the height of the dam at La Boquilla to increase storage capacity. Figure 8.4 displays the range of storage levels in the La Boquilla reservoir from 1977 to 1999.

Figure 8.4.
Historical Reservoir Storage Levels at La Boquilla

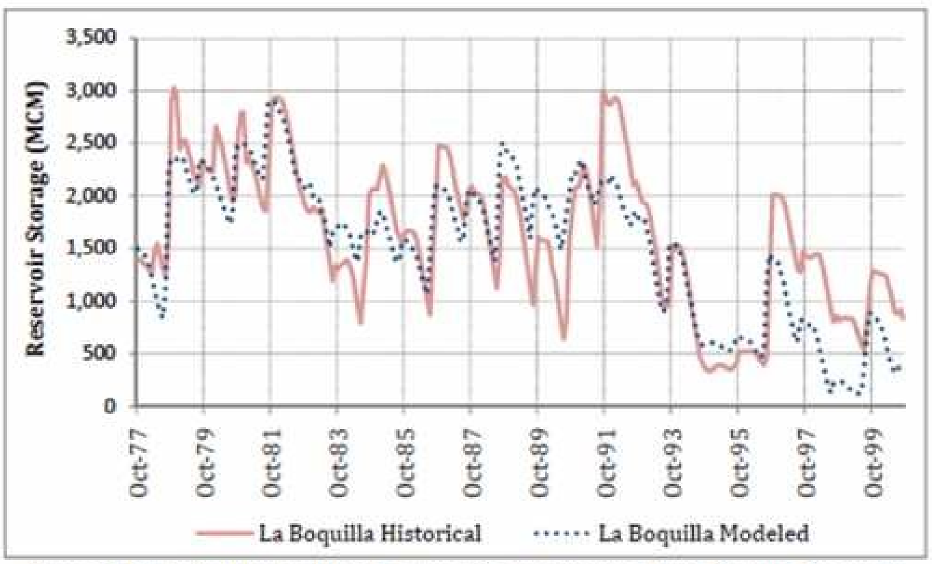

Figure 31 Historical and Modeled Reservoir Storage Volumes for La Boquilla Reservoir

Source: Constance L. Danner, Daene C. McKinney, Rebecca L. Teasley, and Samuel Sandoval-Solis "Documentation and Testing of the WEAP Model for the Rio Grande/Bravo Basin," The University of Texas at Austin, 2006, https://www.crwr.utexas.edu/reports/pdf/2006/rtp06-08.pdf.

The persistent drought and low storage levels of the reservoir have led to disagreements over binational allocations as well. There is debate whether Mexico now owes a large amount of water to the U.S. under the 1944 Water Treaty that governs the allocations of the Rio Grande/Bravo and Colorado. On the Texas side, farmers and stakeholders claim that Mexico has been in violation of the treaty while those on the Mexican side argue this is not the case. In addition to instances of low levels, there is also disagreement over what constitutes allocations of conserved water as well. According to Minute 309 as negotiated by the IBWC, conserved waters should be released to the Rio Bravo from the Rio Conchos. The lack of agreement, however, on what constitutes "savings" has led to a lack of enforcement of this matter. Farmers in the

Delicias District of Chihuahua have been reluctant in releasing supplemental water to the United States.

Diana Liverman, a researcher at the University of Arizona, notes that communities built around large reservoirs in arid regions tend to be more vulnerable to drought in the long term because reservoirs permit a level of irrigation that is unsustainable in the environment when reservoir levels decline. This has been the case with La Boquilla. During drought years, farmers and communities in the irrigation districts face grave hardships. Recent data from CNA shows that irrigation in this area sees drastic reductions during drought periods.[145] The clamor has seized attention in both Washington, D.C., and Mexico City. As population growth and industrialization continue to pressurize the already delicate drought situation, focus will sharpen on how best to address the challenges facing the Conchos and allocations between the two nations.

Options for Dealing with Water Scarcity

As this reservoir assessment notes, the waters of the Rio Conchos, including those of La Boquilla, are vital to the economic wellbeing of both Mexico and the United States. The Conchos—a major tributary for the Rio Grande—is not only the source of water for 1.3 million people in Chihuahua but provides water to 200 hectares of fields in other districts and border towns as well as 100,000 hectares of fields in irrigation districts and border towns in the U.S.[146] The codependency between the U.S. and Mexico requires that measures are taken to allow for a more stable future characterized by increased water scarcity.

In addition to binational measures, national measures must also be taken. Climate change is expected to increase the frequency and severity of droughts in the region. Preventative initiatives for the future should be explored before severe consequences become reality. With increased water scarcity, water pumping will increase as reservoir levels and aquifer recharge rates decrease. The following recommendations are suggested for the La Boquilla/Chihuahua region to mitigate this future.

1) Make information more readily available and accessible. More information regarding how much water is in streams, aquifers, and watersheds in the basin must be shared and incorporated in planning and policy on both sides of the border. This information should include changing patterns in water demands and current water use practices. Texas, especially water users in the Lower Rio Grande basin, must acknowledge their intertwined and mutually dependent relationship with the Conchos. Efforts should be made in eliminating the information gaps and promoting feedback loops in Conchos basin management.

2) Localize water policy. While it is important that institutions such as the IBWC exist, policymakers should not lose sight of the importance of locally driven policy-making. In order to address water scarcity in this reservoir and region, the Chihuahua water management system must be strengthened. Policy makers should explore a multi-level approach incorporating international, national, and local actors while further decentralizing water

[145] Kelly, "The Rio Conchos: A Preliminary Overview."
[146] Brian Thomson, "Saving water, saving the river: Chihuahua, Mexico," June 7, 2006, http://wwf.panda.org/wwf_news/?69260/Saving-water-saving-the-river-Chihuahua-Mexico.

policy. This will strengthen the local management and regulation systems in the water sector.[147]

3) Invest in new technology and more efficient farming practices. Chihuahua's main use of water remains agriculture yet only low levels of technology are employed in the sector. There is a range of farms from small to large that operate in the district. Depending on the size of the farm, the farming practices differ drastically with large farms using more efficient measures. Farming practices remain sub-optimal in the reservoir region. To address water scarcity, the excessive water use, cultivation methods that encourage erosion, overstocking, and non-optimal mixes of crops should be eliminated. Large farms often adopt and utilize the most recent technology; it is small farms that must be addressed. If modernizing agriculture is to be addressed, so too must farmers' access to credit in order to fund these changes.

[147] OECD, "OECD Territorial Reviews: Chihuahua, Mexico 2012."

Chapter 9. Amistad and Falcón Dams

by Marimar Miguel

The Rio Grande river is named the Río Bravo in Spanish because of the heavy and dangerous currents it carries. However, this would not come to mind when looking at the current state of the river from Elephant Butte to Fort Quitman. Because of the municipal and agricultural use, the river is knee high, at best. Further downstream, once the Rio Conchos makes contact with the Rio Grande as its largest tributary, the currents pick up again and the downstream area allows for the increasing population of South Texas and Northern Mexico to continue growing.

This chapter looks at the history, impact, and future of two dams, the Amistad and Falcón Dams, in the lower Rio Grande that play a major role for economy and water policy of the region. This analysis divides the river into segments defined by reservoirs. Below Fort Quitman, Amistad and Falcón reservoirs define the physical water region and the sociocultural impact region of the river.

Amistad Dam

Open since late 1969, Amistad Dam is located about 150 miles west of the city of San Antonio in a semi-arid region of Texas.[148] Located in Val Verde County, the dam serves as the connection between Del Rio, Texas, and Ciudad Acuña, Coahuila, in Mexico. Amistad Dam is the Rio Grande's largest dam and reservoir. The dam is 32,022 feet long (9,760 meters) and 254 feet (77.4 meters) high. The reservoir extends 75 miles up the Rio Grande. The surface area measures 65,000 acres (26,300 hectares) and has a volume of 3,124,260 acre-feet (3,886,578,000 cubic meters).[149]

History

The history of Amistad Dam cannot be narrated without mentioning that the geographical region where the dam was built was inhabited by the Coahuiltecan tribes that lived in the caves and canyons of the region and along the Rio Grande.[150] As the state of Texas began to be settled and the westward expansion began, the native people were displaced from their land in an effort to settle the American West. There was a rich, pictorial history on the walls of the caves that were documented prior to the building of the dam, but with its construction, they were inundated and many of those histories were lost.[151]

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[148] M.C. Peel, B.L. Finlayson, and T.A. McMahon, "Updated world map of the Köppen-Geiger climate classification," *Hydrology and Earth System Sciences* 11(5) (2007): 1633-1644, doi:10.5194/hess-11-1633-2007.
[149] International Boundary and Water Commission (IBWC), "Amistad Dam," http://www.ibwc.state.gov/Organization/Operations/Field_Offices/amistad.html.
[150] J.W. Powell, "7th Annual Report of the Bureau of Ethnology, 1885-1886" (Washington: GPO, 1891), 68.
[151] Handbook of Texas Online, "Amistad Reservoir," accessed March 02, 2016, http://www.tshaonline.org/handbook/online/articles/roa10.

Figure 9.1.
Satellite View of Amistad Dam and Reservoir

Source: Created by author using ARC GIS, April 2016.

Planning and Goals

Pursuant to the Mexico-U.S. Water Treaty of 1944, Amistad and Falcón Dams were built to provide conservation, storage, and regulation of the flows of the Rio Grande. With flood control in mind, the dam was built to help prevent displacement and loss of life as floods in the 1950s had done to the people of the area. Power generation was also one of the major functions of the dam. Two hydroelectric plants, one on each side of the border, generate up to 323 million kilowatt hours to be divided by the United States and Mexico.[152] With two major tributaries, the Devils River and the Pecos River, the dam site was strategically placed in its current location to retain flows that feed into the Rio Grande. Minutes 207 and 210 of the International Boundary and Water Commission (IBWC) review the recommendations for construction of the dam by both countries after assessments from the U.S. Army Corps of Engineers and the Mexican Ministry of Hydraulic Resources.

[152] IBWC, *Amistad Dam and Reservoir Project,* n.d.. http://www.ibwc.state.gov/Files/amistad_dam_and_reservoir_project.pdf.

Costs

Upon agreeing to the construction of the dam, the cost was divided among the two nations based on the proportion of conservation capacity of the reservoir.[153] The United States paid for 4/7 of the dam, which was about US$43.8 million, and Mexico paid for 3/7 of the dam, which was the equivalent of about US$34.2 million, totaling approximately US$78 million.[154]

Construction/Engineering

The dam was planned as a concrete channel section and an earth embankment, with each country's share of principal quantities as follows:

- Principal quantities of the work allocated to the U.S. are 6 million cubic yards of earth embankment construction, 1.3 million cubic yards of rock excavation, the placing of approximately 900,000 cubic yards of concrete, and the furnishing and installing of 10 million pounds of structural steel, including the 16 Tainter gates.

- Principal quantities of the Mexican work are 7.5 million cubic yards of earth embankment construction, 1.8 million cubic yards of rock excavation, the placing of about 765,000 cubic yards of concrete, and the furnishing and installation of 3 million pounds of structural steel.[155]

Amistad construction began in 1963 and was completed in early 1969. The dam was dedicated in 1969 by U.S. President Richard Nixon and Mexican President Gustavo Diaz Ordáz. As stated by President Nixon in his remarks at the dedication ceremony, the previous name of the Diablo Dam (rooted in the name of the Rio Grande River's tributary) was ominous and therefore the name of Amistad (meaning "friendship" in Spanish) was taken to represent the furtherance of an ideal friendship that the two nations hoped to share.[156]

Maintenance

Amistad Dam is maintained by the Mexico and U.S. sections of the International Boundary and Water Commission. A binational project established in 1848 as temporary joint commission to survey, map, and demarcate the boundaries of the United States and Mexico is the root to what would become the IBWC. The International Boundary Commission (IBC) was established in 1889 and evolved into the commission that exists today.[157] In an effort to stabilize the river flows, the IBWC has been involved with transboundary dam projects since the signing of the

[153] Ibid.
[154] Ibid.
[155] Ibid.
[156] Richard Nixon, "Remarks at the Dedication of the Amistad Dam on the Rio Grande," September 8, 1969, in Gerhard Peters and John T. Woolley, *The American Presidency Project,* http://www.presidency.ucsb.edu/ws/?pid=2224.
[157] IBWC, "History of the International Boundary and Water Commission," http://www.ibwc.state.gov/About_Us/history.html.

1944 Water Treaty. It is tasked with boundary preservation and demarcation, water conveyance, water quality management, and resource and asset management.[158]

Geography

Amistad Dam is located at the edge of the South Texas brush country, the Texas Hill Country, and the canyon-rich area of Texas. The semi-arid climate of the region calls for special attention to water usage because of the high humidity and long, hot months.

Flood Control

One of the most compelling reasons for construction of Amistad and Falcón Dams was flood control. With villages and towns being destroyed by powerful rainfall, the dams were designed to prevent future destruction of the lands. Water released by the dams' floodgates helps mitigate the possibility of severe river flooding on both sides of the border. In the summer months, during the Gulf of Mexico's hurricane season, the monitoring of the pool levels for both of the dams is increased to quickly initiate emergency management.

Recreational Use

Amistad reservoir provides an ideal environment for camping, swimming, fishing, and other water-based activities. With temperatures reaching well over 100° F in the summer months, water activities are popular to provide relief from the heat. Texas Parks and Wildlife monitors the shoreline of the reservoir and is tasked with the monitoring of the habitat for use in recreational activities. Per the most recent report, the reservoir's habitat led to lower aquatic vegetation coverage. Largemouth bass and shad sunfish, along with channel, blue and flathead catfishes, striped bass, and smallmouth bass all attract the fishing population that visits the reservoir.[159] With hundreds of fishing competitions held per year, it is difficult to deny the importance of the recreational use of the reservoir. On the Mexican side, the reservoir serves as one of the major attractions for Ciudad Acuña, Coahuila, as both a historic site and a recreational space.

Falcón Dam

Falcón Dam, finished in 1954, is located just south of the city of Laredo, Texas, in a semi-arid region of the Texas.[160] The dam serves as the boundary between Falcón Heights, Texas, in the Texas counties of Starr and Zapata, and Nueva Ciudad Guerrero, Tamaulipas, Mexico. The Falcón Dam is the last major engineered structure downstream on the Rio Grande, and as the lowest international storage dam before reaching the Gulf of Mexico estuary, it is a significant marker for use in the purpose of water allocation between the U.S. and Mexico per the Treaty of 1944. The dam is 26,294 feet long (8,014 meters) and 150 feet (45.72 meters) high, leading to a

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158 IBWC, "Strategic Plan: FY 2010-2016," http://www.ibwc.state.gov/Files/Strategic_Plan.pdf.
159 Texas Parks and Wildlife Department, "2014 Fisheries Management Survey Report," 2015.
160 Peel et al., "Updated world map of the Köppen-Geiger climate classification."

reservoir 60 miles long and 11 miles wide with a surface area of 83,653 acres (33,854 hectares).[161]

History

The area of Falcón Heights and Falcón, Texas, and the number of lives lost in this area, both by flooding and displacement, are crucial to the history of Falcón Dam. Dating back to the 1700s, the Ramirez and Falcón families were influential in the subsistence of the village of Falcón, Texas. The flooding of the villages and towns along the river prior to the building of Falcón Dam and after its construction have played a major role in the sentiment toward the U.S. government by the people of the region.[162] IBWC Minutes 182 and 187 deal with the history and governance of Falcón Dam and reservoir.

Figure 9.2.
Satellite View of Falcón Dam and Reservoir

Source: Created by author using ARC GIS, April 2016.

[161] IBWC, "Falcon Dam and Power Plant Brochure," n.d.
[162] Patsy Jeanne Byfield, *Falcon Dam and the Lost Towns of Zapata* (Austin: Texas Memorial Museum, 1966).

Planning and Goals

Pursuant to the Water Treaty of 1944, Falcón Dam was built to achieve the purpose of providing conservation, storage, and regulation of the flows of the Rio Grande by being the lowest major international storage dam to be built on the river.[163] The previously planned site of Salineño was not economical, and recommendations from the Joint Engineering Conference called for the Falcón Heights area to be used as the site for construction.

Considering the major functions of Falcón Dam to maximize transboundary waters for the two nations for agricultural, private, and industrial use, as well as minimize flood damage as a result of previous damage to the city of Zapata and the region, the recommendations made for construction of the dam by both countries after assessments from the U.S. Army Corps of Engineers and the Mexican Ministry of Hydraulic Resources were deemed adequate to start construction.

Construction

The dam was planned as a concrete channel section and an earth embankment, with the features of the dam as follows:

- Type: rolled earth fill embankment;
- Earth fill: 12.6 million cubic yards;
- Riprap: 360,000 cubic yards;
- Concrete: 282,000 cubic yards; and
- Reinforcing steel: 10,300 tons.[164]

The dam construction began in 1950 and went through early 1953. The Falcón Dam dedication took place in October 1953 on the dam itself by President Dwight D. Eisenhower and President Adolfo Ruiz Cortines.[165] Shortly after, the dam began to fill and the electricity generation began. The name of the dam has origins in recognition of Margarita de la Garza Falcón, who was the wife of the founder of the city of Falcón, Texas. The total U.S. share of the cost was around $35 million.[166]

While planning for the dam had assumed it would take several years to reach capacity, the first hurricane of 1954, Hurricane Alice, provided enough rainfall to fill the reservoir in a few days and prevent major flooding in the Lower Rio Grande Valley.

Maintenance

Like Amistad Dam, Falcón Dam is maintained by both the U.S. section and the Mexican section of the IBWC. Many of the same functions for maintenance that occur with Amistad Dam occur

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[163] IBWC, "Minute 197," 1951, http://www.ibwc.gov/Files/Minutes/Min197.pdf.

[164] IBWC, "Falcon Dam and Power Plant Brochure."

[165] Texas Archive, "Falcon Dam Dedication," 1953, http://www.texasarchive.org/library/index.php/2013_00972.

[166] IBWC, "Falcon Dam and Power Plant Brochure."

with Falcón Dam. The IBWC monitors the total conservancy capacity biweekly to determine the shares of the parties involved.[167]

Geography

Falcón Dam is located in the middle of the Texas brush plains and the coastal plains of the Rio Grande Valley and the state of Tamaulipas, Mexico. The climate of the region is semi-arid, and like Amistad Dam calls for special attention to water usage because of the high humidity and long, hot months. The area's brush land is dominated by mesquite-acacia savanna with grassy areas, depending on the wet and dry seasons of the region.

Flood Control

Prior to construction of the Falcón Dam, flooding in the Lower Rio Grande Valley had been frequent, causing widespread damage to communities and farms in the region. Both Amistad and Falcón Dams are essential to the safety and well-being of the communities below the location of the dams.

Recreational Use

Both Amistad and Falcón Dams are available for recreational use, including camping, swimming, fishing, and other water-based activities. Like in the Amistad reservoir, water activities on Falcón Lake provide relief from the heat to citizens and tourists on both sides of the U.S.-Mexico border.

The flooded terrestrial vegetation that is prominent in the reservoir sets the stage for a different landscape than the Amistad reservoir. Trees and brush that would normally thrive on dry land have survived largely under water, making it a unique ecosystem. Per the most recent report, the composition of the reservoir included largemouth bass, which provided for more than 90% of the total fishing effort, gizzard and threadfin shad, alligator gar, blue and channel catfish, white bass, black crappie, and largemouth bass.[168]

The Impact Area of Both Dams

The distance between Amistad Dam and Falcón reservoir measures 330 miles. From Falcón reservoir to the Laguna Madre discharge in the Gulf of Mexico is 280 miles. In both river segments water is shared between the U.S. and Mexico. The river supplies the water needed for the sustainability of the region.[169]

The flow from the Rio Grande below Fort Quitman and the Rio Conchos account for two-thirds of the Rio Grande flow entering Amistad reservoir. Quick changes in weather and flows has

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[167] Texas Water Development Board, "Water Data for Texas," http://waterdatafortexas.org/reservoirs/individual/falcon.

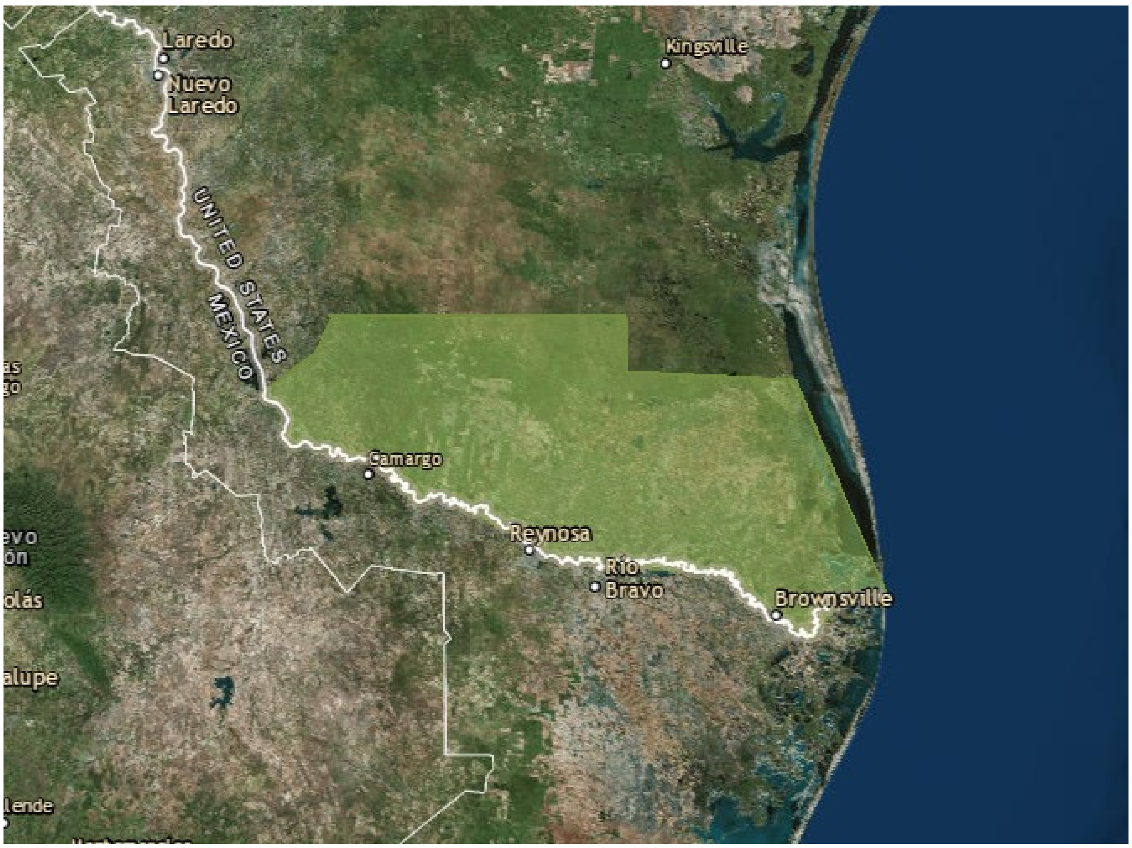
[168] Texas Parks and Wildlife Department, "2013 Fisheries Management Survey Report- Falcón Reservoir," 2014.

[169] IBWC, "2010 Basin Highlights Report for the Rio Grande Basin in Texas," April 2010, http://pecosbasin.tamu.edu/ media/381534/2010%20basin%20highlights.pdf.

caused high salinity and increased variability in the amount of water in the reservoir conservation pool.[170]

In the deltaic floodplain of the Lower Rio Grande Valley, south of Falcón Dam, the water is distributed by multiple irrigation channels, including the resacas, river channels that become more common as the river approaches the Gulf of Mexico.

Figure 9.3.
Satellite View of the Lower Rio Grande Valley Region of Texas



Source: Created by author using ARC GIS, April 2016.

Dam Discharge

Discharges from Amistad and Falcón Dams are typically higher during irrigation season, however, there are variations in flows from the Rio Grande dams based on weather patterns and flow activity of the tributaries. Table 9.1 shows significant discharges, followed by a time series of the historical means for the two dams until 2011 in Figures 9.4 and 9.5.

[170] Ibid.

Distribution of River Water and Diversion Dams

From Falcón Dam to the Gulf of Mexico, the water is distributed using river channels and the irrigation channels that support the economy of the U.S. and Mexican communities in the basin.

Below the Amistad and Falcón Dams, there are two more dams that serve the purpose of providing and regulating irrigation waters.[171] The Anzalduas Dam is located in the city of Mission in the Lower Rio Grande Valley. The purpose of building the dam was to divert U.S. floodwaters to the interior floodway and the diversion of waters to Mexico's main irrigation canal.[172] The other one, Retamal Dam, is located south of the city of Donna in the Lower Rio Grande Valley, which allows Mexico to divert its share of floodwaters to its interior floodway and limit the flows at Brownsville-Matamoros to the safe capacity of the Rio Grande.[173]

Hydropower

The Amistad Dam powers two hydroelectric power generating plants. For both the United States and Mexico, there are about 161 million kilowatt hours generated by each plant.[174] The Falcón Dam powers two hydroelectric power generating plants, as well, one on the U.S. side and the other on the Mexican side. For both the U.S. and Mexico, there are about 3,000 to 10,500 kilowatt hours generated by each plant.[175] The Western Area Power Administration (WAPA) administers energy generated in the U.S. by the dams. Unlike major plants, the remote location of the dams from major grids allows WAPA to draft tailored contracts to specific clients.[176]

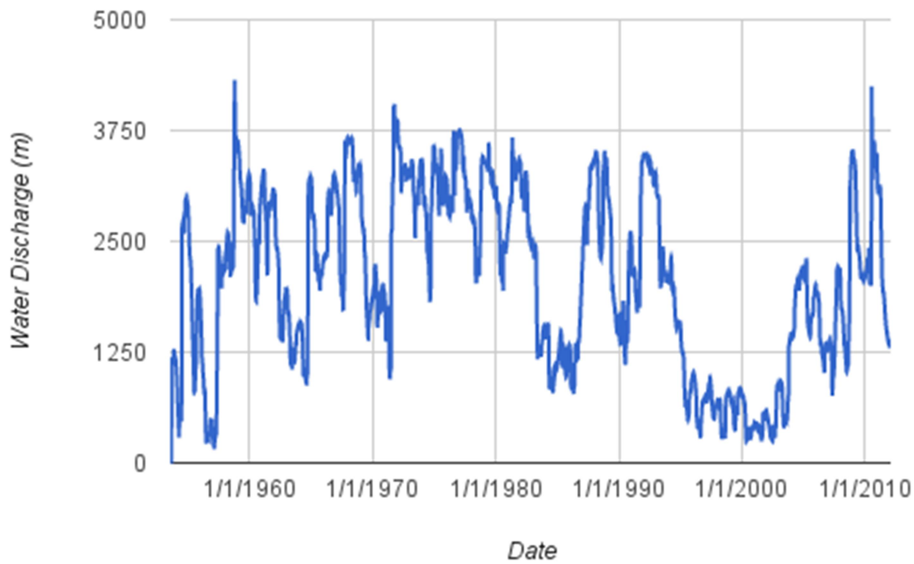
Table. 9.1.
Significant Discharges from Amistad and Falcón Dams

	Falcón Dam		Amistad Dam	
	Date	Discharge (m^3/s)	Date	Discharge (m^3/s)
Average		2070.871		3143.973
Minimum	8/20/1953	1.8	5/31/1968	1.2
Maximum	10/18/1958	4300.7	9/22/1974	5990.7

Source: IBWC, "Falcón and Amistad Historical Mean Daily Discharge," http://www.ibwc.gov/Water_Data/Reports/RG_Storage_Conditions.htm#.

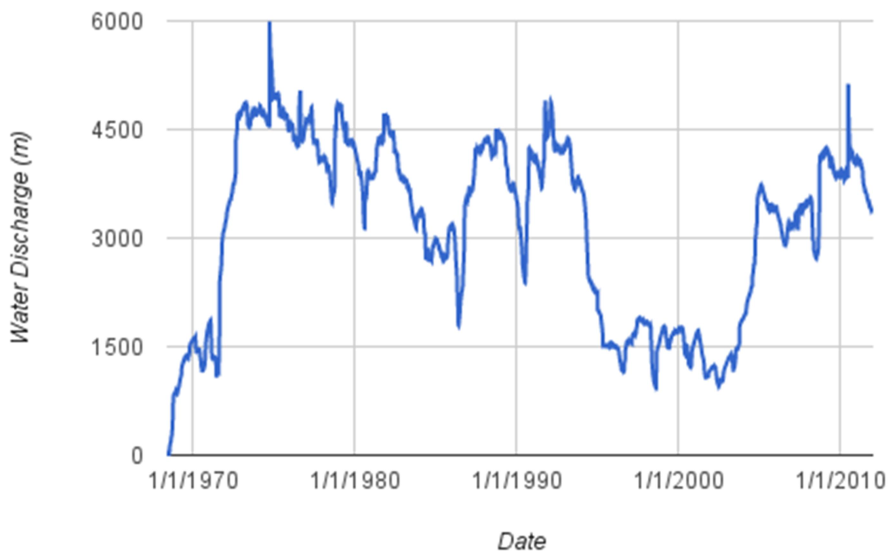
171 IBWC, "Diversion Dams and Related Structures*,"* http://www.ibwc.gov/Mission_Operations/Diversion_Dams.html.
172 Ibid.
173 Ibid.
174 IBWC, "Amistad Dam and Power Plant Brochure."
175 IBWC, "Falcon Dam and Power Plant Brochure."
176 Western Area Power Administration, "Doing Business with WAPA," https://www.wapa.gov/DoingBusiness/Pages/doing-business.aspx.

Figure 9.4.
Falcón Dam Historical Mean Daily Discharge



Source: IBWC, "Falcón Dam Historical Mean Daily Discharge," http://www.ibwc.gov/Water_Data/Reports/RG_Storage_Conditions.htm#.

Figure 9.4.
Amistad Dam Historical Mean Daily Discharge



Source: IBWC, "Amistad Dam Historical Mean Daily Discharge," http://www.ibwc.gov/Water_Data/Reports/RG_Storage_Conditions.htm#.

Water Use and Irrigation Data

Per the Water Treaty of 1944, the joint use of international waters should be prioritized in the following way: "1) Domestic and municipal uses, 2) Agriculture and stock-raising, 3) Electric power, 4) Other industrial uses, 5) Navigation, 6) Fishing and hunting, and 7) Any other beneficial uses which may be determined by the [International Boundary and Water] Commission."[177]

The Texas Water Development Board is legislatively directed to plan for, and to assist financially, the development and management of the water resources of Texas.[178] In 2013, for example, 527,620 acre-feet of Rio Grande water were used for irrigation on the U.S. side of the border.[179]

Ecology

The basin between Amistad Dam and the Gulf of Mexico is ecologically highly diverse. The region holds one of the last remaining Sabal palm tree habitats, hence the previous nomenclature of the Rio De Palmas (River of Palms). There are over 150 species of birds, making the region ideal for the annual birding festival, which attracts visitors from around the world.[180]

The modifications of the river and the effects of urbanization have resulted in many species of animals and native plants becoming endangered and/or extinct. The ocelot and the jaguarondi are two species that are endangered. The upper limit of their tropical habitat lies in the Rio Grande basin. The border fence fragments the habitat of animals and plants of the region.[181] The expansion of the border fence, beginning in 2006, has had a significant impact on the environment of the region.[182]

Farming

Agribusiness is a large source of income for the middle and lower sub-basin of the Rio Grande/ Rio Bravo. Furrow irrigation is still the most common practice, but the Texas AgriLife Extension Project provides training and best practices to improve efficiency of water use.[183]

In the areas along the river between Amistad and Falcón Dam, the dry pasture provides excellent grazing grounds for cattle. Further south, the land is used for irrigated farming. In the Lower Rio Grande Valley, the production of sugarcane and citrus fruits make up almost half of all crops in

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177 Treaty Between the United States of America and Mexico, "Utilization of Waters of Colorado and Tijuana Rivers of the Rio Grande" (Washington, D.C.: Stat. 1219, TS 944, 1944), Article 3.

178 Texas Water Development Board, "Agriculture and Irrigation Data," https://www.twdb.texas.gov/conservation/agriculture/irrigation/.

179 Texas Water Development Board, 2014, "Water Use Survey - Historical Summary Estimates by Basin."

180 U.S. Fish & Wildlife Service, "Lower Rio Grande Valley Species List."

181 Lindsay Eriksson and Melinda Taylor, "The Environmental Impacts of the Border Wall between Texas and Mexico," 2008, https://law.utexas.edu/humanrights/borderwall/analysis/briefing-The-Environmental-Impacts-of-the-Border-Wall.pdf.

182 Secure Fence Act of 2006. 2006-H.R. 6061.

183 Texas A&M AgriLife Extension, "Irrigation District Engineering and Assistance," http://idea.tamu.edu/.

the region.[184] The Rio Grande Valley area, including the sister region across the river in Mexico, had its early beginnings thanks to agribusiness. Prior to the use of irrigation technologies, the majority of the land in the region was used for cattle grazing. However, the ability to divert and control the waters flowing in the Rio Grande enabled the 4,000-plus square miles to be used for agriculture, giving rise to migration and economic development in the region. The region quickly became a market for farmers, and, as such, transitioned to an agrarian economy.

Ground Water and Water Supply

The presence of brackish groundwater has resulted in the construction of desalination plants in Webb, Hidalgo, and Cameron counties in Texas. The strain of municipal and agricultural water demand has encouraged the region to research the possibility for more desalination plants for both groundwater and ocean water to supplement drinking water supplies for the area.[185]

While the region does use groundwater pumping to supplement surface water supply, the costs associated with desalination and pumping are high, so that river water remains the principal source for irrigation, municipal use, and drinking water. Increasing water quality issues call for special attention to the availability and sustainability of water supply from the Rio Grande.[186]

Water Quality

Water quality concerns along the river reach far beyond the pollution caused by maquiladoras and cities. Studies have documented bacteria concerns since 1996 for the basin down to the delta in the Laguna Madre. The parameters of concern vary by river section as shown in Table 9.2.

The water quality of each sub-section of the river limits the use of that river section, particularly the recreational use, as high levels of bacteria and the presence of toxic substances in the water compromise human use.

Irrigation Districts

There are 31 irrigation districts on the U.S. side of the Rio Grande and five irrigation districts on the Mexican side of the river. There is insufficient data available to assess the efficiency of water distribution from the river to the districts

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[184] Ibid.

[185] IBWC, "2010 Basin Highlights Report for the Rio Grande Basin in Texas."

[186] IBWC, *Binational Study Regarding the Intensive Monitoring of the Rio Grande Waters in the Vicinity of Laredo, Texas and Nuevo Laredo, Tamaulipas Between the United States and Mexico*, 2000, http://ibwc.state.gov/Files/Binatl_Study_NL_Pub.pdf.

Table. 9.2.
Water Quality of Rio Grande Segments

Segment	Segment Name	Parameter(s) Impaired	Parameter(s) of Concern
2305	International Amistad Reservoir	No impairment	Nitrate
2304	RG below Amistad International Reservoir	Bacteria	Toxicity in ambient water
2303	International Falcón Reservoir	No impairment	Toxicity in ambient water Total phosphorus Ammonia Nitrate Orthosphosphorus
2302	RG below Falcón Reservoir	Bacteria	Mercury in edible tissue Depressed dissolved oxygen Ammonia
2301	Rio Grande Tidal	No impairment	Bacteria Chlorophyll-a

Source: IBWC, "Basin Highlights Report for the Rio Grande Basin in Texas," 2010, http://pecosbasin.tamu.edu/media/381534/2010%20basin%20highlights.pdf.

Population and Economy

While the population is growing faster closer to the Gulf of Mexico, the demographics of the region between Amistad and Falcón dams are similar. A majority of the racial makeup is white with over 80% of the population identifying as Hispanic or Latino.[187] Many school districts are underperforming and a few of the counties in the region are listed as the poorest in the nation.[188]

The economy of the region is based mostly on agriculture, although in the years since the free trade agreements between the U.S. and Mexico, many companies have relocated to the border region, making some of the growth rates as high as 39.3% between 1995 and 2005.[189] Using subsidiary plants known as maquiladoras, private companies manufacture and assemble raw products into finished items to be shipped to their home countries. The maquiladora industry brought substantial growth to the region, but like many of the poorly regulated industries along the river in this region, it is widely suspected and occasionally documented that maquiladoras contribute to the degradation of the water quality in the Rio Grande Basin through illegal dumping of hazardous waste.[190]

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[187] U.S. Census Bureau, "Fact Finder," http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.

[188] U.S. Census Bureau, "2011 American Community Survey*,"* https://www.census.gov/programs-surveys/acs/data.html.

[189] CNN Money, "10 Fastest Growing U.S. Cities," 2012, http://money.cnn.com/galleries/2012/real_estate/1204/gallery.US-Cities/7.html.

[190] Texas Natural Resource Conservation Commission, *Regional Assessment of Water Quality in the Rio Grande Basin including the Pecos River, the Devils River, the Arroyo Colorado and the Lower Laguna Madre* (Austin, Tex.: Texas Natural Resource Conservation Commission, 1996).

Water Demand

As we move south along the river basin, the rate of growth of the population is exponential.[191] The river's ecology and supply are burdened with the ecological stress placed on the river waters by urbanization of the region, particularly in the cities of Laredo, McAllen, and Brownsville, along with their sister cities, Nuevo Laredo, Reynosa, and Matamoros. The section below Falcón Dam known as the Rio Grande Valley is a metro region that includes these cities. With an increase in the population, the demand for water for agricultural purposes and municipal use will continue to grow.

According to the 2016 Regional Water Demand Projections for 2020-2070, Region M, which covers Amistad and Falcón dams down to the Gulf of Mexico, the water demand is projected to be as shown in Table 9.3.

Table. 9.3.
Future Water Demand for Region M, 2020-2070

Demand Category	2020	2030	2040	2050	2060	2070
Irrigation	1,144,135	1,093,749	1,040,789	983,283	924,558	924,558
Livestock	4,986	4,986	4,986	4,986	4,986	4,986
Manufacturing	10,433	11,292	12,147	12,898	13,896	14,971
Mining	17,051	16,480	14,952	12,823	10,458	10,361
Municipal	311,591	368,997	427,611	488,449	550,830	612,127
Hydro Power	16,972	19,842	23,340	27,605	32,806	38,916
Region M Total	1,505,168	1,515,346	1,523,825	1,530,044	1,537,534	1,605,919

Source: Texas Water Development Board, *2016 Regional Water Plan - Water Demand Projections for 2020-2070 Regional Summary,* http://www2.twdb.texas.gov/ReportServerExt/Pages/ReportViewer.aspx?%2f Projections%2f2-demand_region&rs:Command=Render.

The table shows that irrigation demand will go down while municipal use will go up, as the population is projected to grow. Based on the allocation priorities as set forth by the Water Treaty of 1944, municipal use has precedence over any of the other potential uses of the water available from the river.[192]

The lack of growth projections for Mexican cities below Amistad Dam leaves us with the conservative estimate that the Mexican counterparts of U.S. cities will grow at least at the same rate. As a result of security problems, demographic shifts in the population, and changes in industrial employment, there have been many re-adjustments in the projections of population in recent years. In 1995, NAFTA promised to bring many jobs for the border regions, but some of

[191] U.S. Census Bureau, "Fact Finder."
[192] Water Treaty of 1944, Article 3.

the industries that moved in created fewer jobs than expected, and the economic landscape is constantly changing.[193]

Governance

Both sides of the river infrastructure are maintained by the binational agreement between the United States and Mexico, specifically by the International Boundary and Water Commission, which was created in 1944 to execute the terms set forth by the Water Treaty of February 1944.[194]

Binational Treaty

The 1944 Water Treaty stipulates that the water in the Rio Grande along the U.S.-Mexico border be allocated to the two countries based on a formula. Mexico is entitled to two-thirds of the water reaching the Rio Grande from certain tributaries originating on its side and the United States the remaining one-third. Annually 350,000 acre-feet of Conchos water is to be delivered to the United States.[195] In exchange, Mexico receives water from the Colorado river. Each country is entitled to half of the water that was not specifically allocated by the Treaty between Fort Quitman and the lowest international storage dam (currently Falcón Dam). Below the lowest international storage dam, both countries are entitled to one-half of the flows in the main channel.[196]

Water Master Program

The Texas Commission on Environmental Quality administers the water rights in Texas south of Amistad Lake. Water distributions south of the Amistad reservoir vary from year to year as established by the Water Treaty of 1944 in its proportionality clauses in Article 3.[197] The Water Master program is tasked with monitoring stream flows, reservoir levels, and water use in the Lower Rio Grande Valley region of the State of Texas.[198]

Nongovernmental Initiatives

There are several organizations that provide additional insight to policymakers and engage the community members of different areas of the Rio Grande basin on the U.S. side of the river. The Basin Advisory Committee pulls in key stakeholders to ensure issues and concerns in the community are addressed.[199] The Texas Stream Team are volunteers who work to ensure the

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[193] Vicente Lopez, "Lecture: IMIP – Juarez Municipality," Paso del Norte Water Task Force Workshop, University of Texas – El Paso, El Paso, Texas, May 2016.
[194] Treaty Between the United States of America and Mexico, "Utilization of Waters of Colorado and Tijuana Rivers of the Rio Grande" (Washington, D.C.: Stat. 1219, TS 944, 1944), Article 2.
[195] Treaty of 1944, Article 4.
[196] Ibid.
[197] Ibid.
[198] Carlos Rubinstein, "The Texas Water Master Program," Lecture, The LBJ School of Public Affairs, Austin, Texas, October 6, 2015.
[199] IBWC, "2010 Basin Highlights Report for the Rio Grande Basin in Texas."

information produced by the water governance agencies is available to the general public to maximize engagement.

The Friends of the Rio Grande was an initiative in 2009 that harnessed organizing talent and engaged community members to promote environmental awareness along the Rio Grande. The partnerships developed through this outreach initiative made it possible to host various engagement meetings in schools, museums, and local organization meetings, among other places.[200]

Is Impact of Climate Change Considered?

The region's cities have strategic plans for managing the growth of their city. Many cities have adopted measures to conserve water by providing resources through fairs and awareness events, while others have set schedules for garden watering to ensure the most efficient use of water by the inhabitants. Texas state agencies hesitate to attribute declines in water supply explicitly to climate change.

On the Mexican side, CONAGUA, the Mexican National Water Commission, has issued development plans for cities and agriculture along the border.[201]

Conclusion

The population in the Rio Grande basin from the Amistad Dam and reservoir to the Gulf of Mexico is growing and will continue to grow, requiring increased municipal water supply. This calls for action at all levels of government on the U.S. and Mexican sides of the border. The analysis set forth in this chapter serves as a starting point to assessing the realities of water supply and demand in a rapidly growing region.

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200 Ibid.

201 Comisión Nacional del Agua, "Plan Nacional de Desarrollo 2013-2018," Programa Nacional Hídrico, http://www.conagua.gob.mx/conagua07/contenido/documentos/PNH2014-2018.pdf.

Chapter 10. Reservoir Impact Assessment Findings

Marcos Duran and Melissa Stelter

Euphrates-Tigris Basin

History

All of the dams reviewed in this report were completed prior to 1990 and, with the exception of the Keban Dam, they all support agricultural activities, produce hydropower, and are utilized to regulate flow. The Mosul and Tabqa dams are also used for municipal water use. The hydropower benefits of these dams contribute to the entire country and the local regions benefit from flood control, municipal water, and irrigation for agriculture.

Governmental Agreements

The region frequently faces disputes regarding flow rates. Of the dams covered in this report, some are international and some are upstream of the international boundary. Most of these dams were constructed with the assistance of international engineering support and financial assistance from foreign countries and development agencies. In some cases, the involvement of foreign cash is what facilitated international agreements regarding river flow rates. These agreements are frequently violated and there are few repercussions. Prolonged tensions and repeated violations have led to threats of hostilities, though nothing has yet resulted from these conflicts.

Many dams were constructed on karstic soil, which has been an issue in both the construction and maintenance of these dams. Some dams require constant maintenance to fill sinkholes and cracks that compromise the safety of the dam and, as with Mosul dam, threaten the lives and livelihood of at least a million people downstream in addition to essential national infrastructure.

Effects of the Dams

The construction of these dams led to displacement of whole villages. Governments commonly offered financial compensation to land owners, but many residents did not own land and were forced out of their homes without compensation. Without any money to resettle or agricultural land to replace what they lost, many displaced people were much worse off as they didn't have the necessary skills to enter the workforce. Once the upstream reservoirs were filled, many archeological sites were destroyed.

After the completion of these dams, the region gained affordable and reliable power, and most dams expanded agricultural production in the region and a few provided drinking water to nearby municipalities. The boon to agriculture has helped develop more rural regions of Turkey, Syria, and Iraq raise the standard of living, and has helped develop more modern cities through providing plentiful food and energy.

Challenges

These regions are still not fully industrialized so pollution levels remain relatively low. Siltation is a concern in the region, but it has not yet resulted in serious problems. Salinization of soils and reduced water availability will increase as the region uses more water and as climate change worsens. The structural integrity of these dams will be a continuing challenge as many are built upon problem-ridden foundations.

Rio Grande/Bravo-Conchos Basins

Four RIAs were completed for dams in the Rio Grande/Bravo-Conchos basins. Beginning at Cochiti Dam in the middle Rio Grande basin, the Rio Grande flows down to Elephant Butte and Caballo dams. Together, these two dams regulate water flow downstream through the Paso del Norte region. It is at this point that the Rio Grande becomes the transnational boundary between Mexico and the United States. The river is fully allocated and its flow nearly terminates before Fort Quitman. Below Fort Quitman, water from the Conchos River replenishes the channel. La Boquilla Dam lies on the Conchos River in Mexico and is an important water source in the region. From Fort Quitman onward the Rio Grande/Bravo passes through the Amistad and Falcón dams, eventually finding its way to the Gulf of Mexico.

History of the Dams

The two oldest dams that were examined are Elephant Butte Dam and La Boquilla Dam—both were finished in 1916. La Boquilla was originally intended primarily to produce hydroelectric power for nearby mining districts but it also served to open up additional land for irrigation. Elephant Butte was designed to address erratic and unreliable surface water flows but it also doubled as a hydroelectric power source. In 1936, Caballo Dam was completed just below Elephant Butte. This companion reservoir created additional water storage capacity and also allowed Elephant Butte to release water year round in order to generate electricity. North of Elephant Butte, Cochiti Dam was constructed in 1928 and helped manage irrigation needs between the Cochiti and Elephant Butte dams. However, in 1960 Cochiti dam was rebuilt to mitigate flooding and prevent some sedimentation from reaching and filling the reservoir at Elephant Butte.

The Amistad and Falcón dams were constructed in a joint effort by the United States and Mexico as agreed upon in the 1944 treaty. Falcón was built first in 1953 and Amistad followed in 1969. Both dams are operated in tandem. They were designed to mitigate flooding, increase agricultural production, and supply drinking water to cities.

Displacement of People

Several dams generated resentment by displacing peoples. Cochiti Dam was built in an area that was traditionally cultivated by the Pueblo people. The Pueblo people sued the Army Corps of Engineers because seepage from the Cochiti Dam flooded their agricultural area. When Amistad Dam was built the Coahuiltecan, another indigenous people, were displaced and their pictorial history was inundated and lost. Lastly, when Falcón Dam was built local people were displaced.

To this day the history of displacement affects attitudes towards the United States and Mexico in the region.

Floods and Droughts

The Rio Bravo/Grande basin has historically been characterized by erratic water flows. Droughts and floods were common enough that economic advancement in the area was continually disrupted, especially by raging floods. Today, after the construction of the dams, flooding is rarely a concern. This has led to consistent cultivation and increased population in the region.

Although the issue of flooding seems to have been greatly mitigated by the construction of the dams, extended droughts are still a concern. A review of water levels along the Rio Grande/Bravo show erratic increases and decreases over time. Since the early 2000s, extended drought has strained the region, especially the Elephant Butte Reservoir. Extended droughts have also hit Mexico and La Boquilla dam. The basin seems to lack a coordinated plan for drought conditions.

Socioeconomic Region and Water Use

Agriculture accounts for the majority of water use in the river basin. In the case of La Boquilla Dam, the importance of the mining districts it was created to supply electricity for faded and many people began to populate and cultivate the surrounding area. Furthermore, because of the reservoir at Elephant Butte, land has been consistently cultivated all the way to El Paso. In fact, hardly any of Elephant Butte's water is used for municipal use as the cities in the region primarily rely on groundwater sources. This is different from the region around Amistad and Falcón, which do use surface water for municipal use.

The population along the Rio Grande/Bravo basin has greatly increased over time. This growth has been slower in New Mexico, between Elephant Butte and El Paso. In contrast, the City of El Paso itself has grown rapidly in recent decades, and so has the city of Juárez. Likewise, in the Lower Valley of the Rio Bravo, Amistad and Falcón supply water to growing populations. These communities, which lie along the U.S. Mexican border, have enjoyed rapid growth due to free trade agreements between the two countries. However, it is likely that these developments would not have occurred without the infrastructure of the dams in place to provide protection from floods and provide a steady and regulated supply of water.

In Mexico, the population along the border has increased drastically since the construction of the dams. However, a review of the growth in the state of Chihuahua, where la Boquilla Dam and Juárez reside, suggests that population growth in the basin is comparable to the population growth rate of the country of Mexico as a whole. This is further evidence that even though the dams are essential to the communities along the border, constructing the dams in and of themselves did not necessarily serve as the impetus for the influx of peoples to the region.

Intergovernmental Conflict

The basin is governed by both interstate and international agreements. In the case of the Rio Grande Compact, the interstate agreement between Colorado, New Mexico, and Texas, there is a history of upstream riparians accruing water debts to states downstream. This illustrates the difficulty of enforcing interstate agreements. These states were able to use the mechanism of a higher court, the Supreme Court of the United States, to try to resolve their conflicts. However, history shows that the rains sometimes return quicker than these mechanisms can resolve water conflicts. In the future, this poses serious questions as to the effectiveness of governing agreements in the basin during drought conditions.

On the international stage, there have also been water debts accrued by Mexico to the United States. However, in the matter of international agreements, there is no higher authority to mitigate between the two riparians. Therefore, we see very little progress on water debt issues in the basin.

The increase of conflict between state and national governments during times of drought is further evidence that a comprehensive plan for managing drought conditions is needed between all parties in the basin.

Intergovernmental Cooperation

One interesting aspect of dam construction in the region is the cooperation between Mexico and the United States. Through the mechanism of the International Boundary and Water Commission (IBWC) established by treaty between the two countries, dam projects were designed and constructed together. The costs and responsibilities of these dams were not always shared equally, but were often stipulated specifically in the minute system used by the agency in the implementation of its duties. Because of this, the IBWC may exemplify a way that riparian states can build diplomatic capacity while executing joint projects along their borders, specifically through the construction of dams to help regulate the flow of surface water.

Basin Issues

Sedimentation has become an issue in the Rio Grande/Bravo basin. Sedimentation decreases a reservoir's capacity over time. The general response to sedimentation issues in the region has been to construct additional dams to make up for lost capacity. This occurred with the construction of Caballo Dam just south of Elephant Butte Dam. Additionally, Cochiti Dam was constructed in such a way that it would reduce sedimentation inflow from tributaries. It is important to note that in recent decades the rate of sedimentation seems to have slowed in the Upper Rio Grande Basin as rainfall has decreased.

Another concern is evidence that growing use of groundwater along the banks of the Rio Grande in New Mexico has disrupted natural flows between surface water and shallow ground water. Texas is currently suing New Mexico, arguing that New Mexico has overdrawn ground water and thereby reduced the surface water available to be allocated to Texas. This suggests that surface water agreements may need to establish controls on ground water usage in order to be effective.

Finally, climate change models predict that the region will see reduced surface water flows in the future. Currently, with the existence of water debts between riparians, and the over-appropriation of water seen in some states, the region does not seem prepared to proactively address the possibility of increased water scarcity. Since most water debts and subsequent litigation occurs as a result of drought years and reduced water flows, it can be estimated that tensions between riparians will increase in the future. Furthermore, relations between states and countries seem to indicate that the status quo will not be changed until tensions increase substantially.

Comparison of Reservoir Assessments from ET and RG Basins

Dam Costs and Benefits

The benefits of the dams in both basins are self-evident. In both the ET and RG Basin, the dams serve as an essential water source for agriculture, hydropower, and drinking water. Though there are some differences to the extent that surface water is used for drinking water, nearly every dam is utilized to provide electricity.

During the construction of most dams in the ET and RG basins, construction costs were shared between multiple governments. In the case of the ET basin, foreign money was used to incentivize cooperative agreements between countries in the region over the allocation and flow of water. In the RG basin, the United States and Mexico shared the costs of building dams along the international border. The U.S. paid for the costs of building Elephant Butte and Cochiti, but La Boquilla dam in interior Mexico was initially built and owned by a Canadian mining company.

One unfortunate trend that the RIA reveals is the displacement of peoples in the region where dams are constructed. These peoples are often marginalized even before dam construction. In the U.S. native peoples suffered with the construction of Cochiti Dam and Amistad Dam. Other marginalized peoples were displaced during the construction of Falcón. In the ET basin, local, often unskilled workers, were displaced in order to construct the dams. Often these marginalized groups are worse off after the dams are constructed, since they struggle to enter the workforce due to lack of skills. Furthermore, even when landowners are compensated for any potential damages, these marginalized groups often do not benefit from the government programs, since they are too poor to own land.

Dam Management

In the RG basin, dam management seems to produce minimal concern. Even though the dams are growing older, the dams seem to be adequately maintained. The dams were well planned and constructed to withstand raging floods. However, in the ET basin, some dams are in serious need of repair. Many of the dams were built on questionable foundations and constantly need attention to repair cracks and sinkholes.

Intergovernmental Agreements and Issues

In the RG basin, there are both interstate and international agreements that govern the allocation of water throughout the basin. There are also intergovernmental agreements in the ET basin. In both cases, these agreements are often violated. This leads to tension between governments.

However, despite the use of diplomacy, threat of violence, or litigation, disputes are rarely settled.

Basin Challenges

Sedimentation continues to be a problem for most dams in both basins. Neither basin has found a solution to this issue. However, in the case of the richer RG basin, additional dams are sometimes built to make up for lost reservoir capacity and also to prevent sedimentation from reaching areas further downstream.

Neither the RG nor the ET basin seem to have developed policies to adequately address drought conditions. As temperatures continue to grow in the future, this may cause greater conflict between governments in both regions. Climate change may reduce what has traditionally been regarded as normal precipitation and water flow. Given the difficulty of enforcing current agreements, it may prove difficult to amend agreements or make new ones.

PART II.
WATER ISSUES IN THE EUPHRATES-TIGRIS BASIN

Chapter 11. War on the Euphrates-Tigris: How the Syrian Conflict Started (and Will End) with Water

by Anne Kilroy

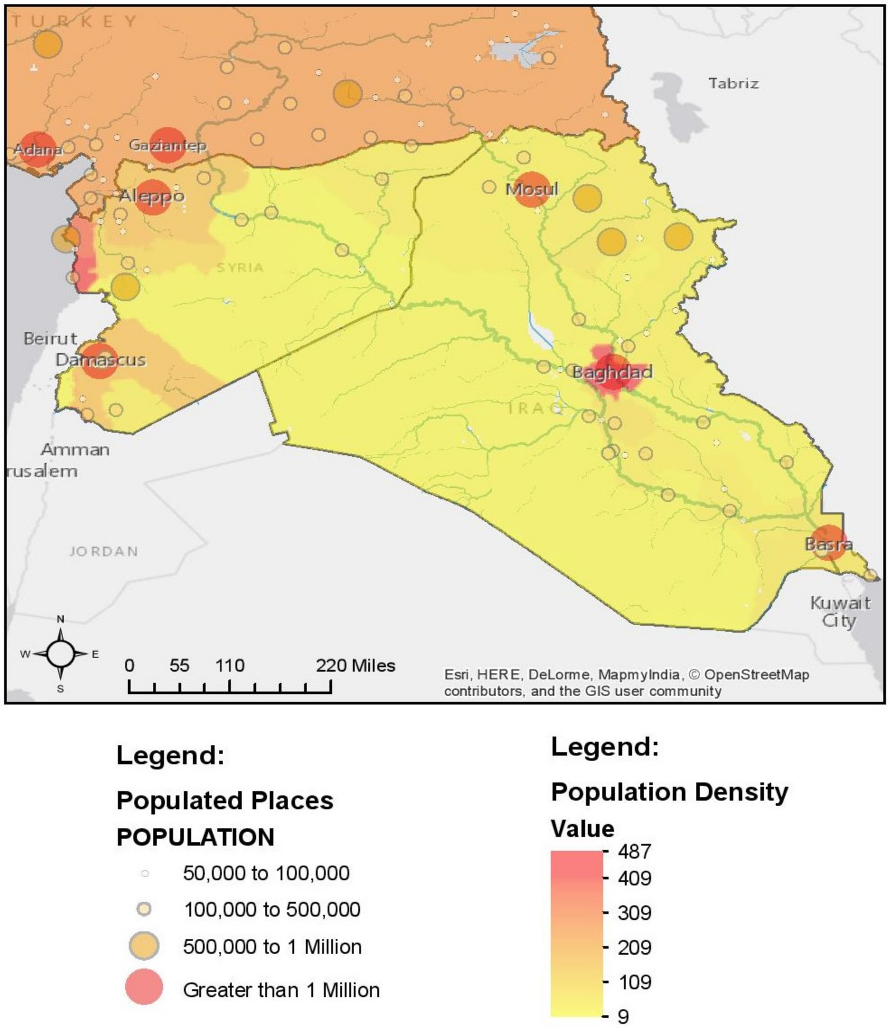
Introduction

The impact of the Euphrates-Tigris river basin on the stability, development, and livelihood of the Middle East is huge. The Euphrates flows for 3,000 kilometers and contains 580,000 square kilometers of drainage area, while the Tigris is 1,850 kilometers long and has a drainage area of 370,000 square kilometers. The nearly 1 million square kilometer basin created by the two rivers is shared among six countries and is home to more than 54 million people in Iran, Iraq, Syria, and Turkey (see Figures 11.1 and 11.2). The Euphrates and Tigris provide nearly 100 percent of Iraq's surface water supply, 65 percent in Syria, and 28.5 percent in Turkey. With these waters making such a significant impact on the livelihood of so many Middle Easterners, it is not hard to imagine how the current crisis in Syria and the Levant can be traced back to the way these rivers were managed.

Figure 11.1
The Euphrates-Tigris River Network

Source: Bernhard Lehner, Kristine Verdin, and Andy Jarvis, "New Global Hydrography Derived From Spaceborne Elevation Data," Eos 89(10) (March 2008): 93-94.

Figure 11.2
Population of the Euphrates-Tigris Basin



Source: Center for International Earth Science Information Network (CIESIN), Columbia University, and Centro Internacional de Agricultura Tropical (CIAT), "Gridded Population of the World, Version 3 (GPWv3): Population Density Grid," NASA Socioeconomic Data and Applications Center (SEDAC), 2005, http://dx.doi.org/10.7927/H4XK8CG2.

Population growth and agricultural expansion in the last several decades have increased water demand in the region. Climate change, salinization, sedimentation, and excessive extractions due to overzealous water development policies have significantly diminished the available water supply. Although the riparian governments have primary control over agricultural and hydrological development, their focus on sovereign rights of river water has prevented them from implementing an equitable, functional, and sustainable basin-wide water management policy. As a result, water scarcity became pronounced during the multi-year drought in the late 2000s and significantly contributed to the outbreak of the Syrian Civil War that currently has displaced over 11 million people.

The lack of efficient water development oversight in the basin made the region especially vulnerable to drought, and the lack of a basin-wide drought response plan made the effects of the drought much more severe. Without relief from federal agencies, feelings of discontent spread among citizens as sectarian groups clashed with one another in the competition for resources. Once the region succumbed to wide-ranging civil warfare, non-state actors like ISIS were able to effectively seize and control territory by targeting water infrastructures. The humanitarian crisis is so severe that the availability of drinking water has declined by an additional 50 percent, and villages and water officials in the region have willingly surrendered to these groups in exchange for access to water.[202] If Syria, Iraq, and Turkey hope to ever regain control of the region and avoid another tragedy like this in the future, they must recognize water's central role in the conflict and cooperate on an effective and cohesive water management strategy.

Historical Context

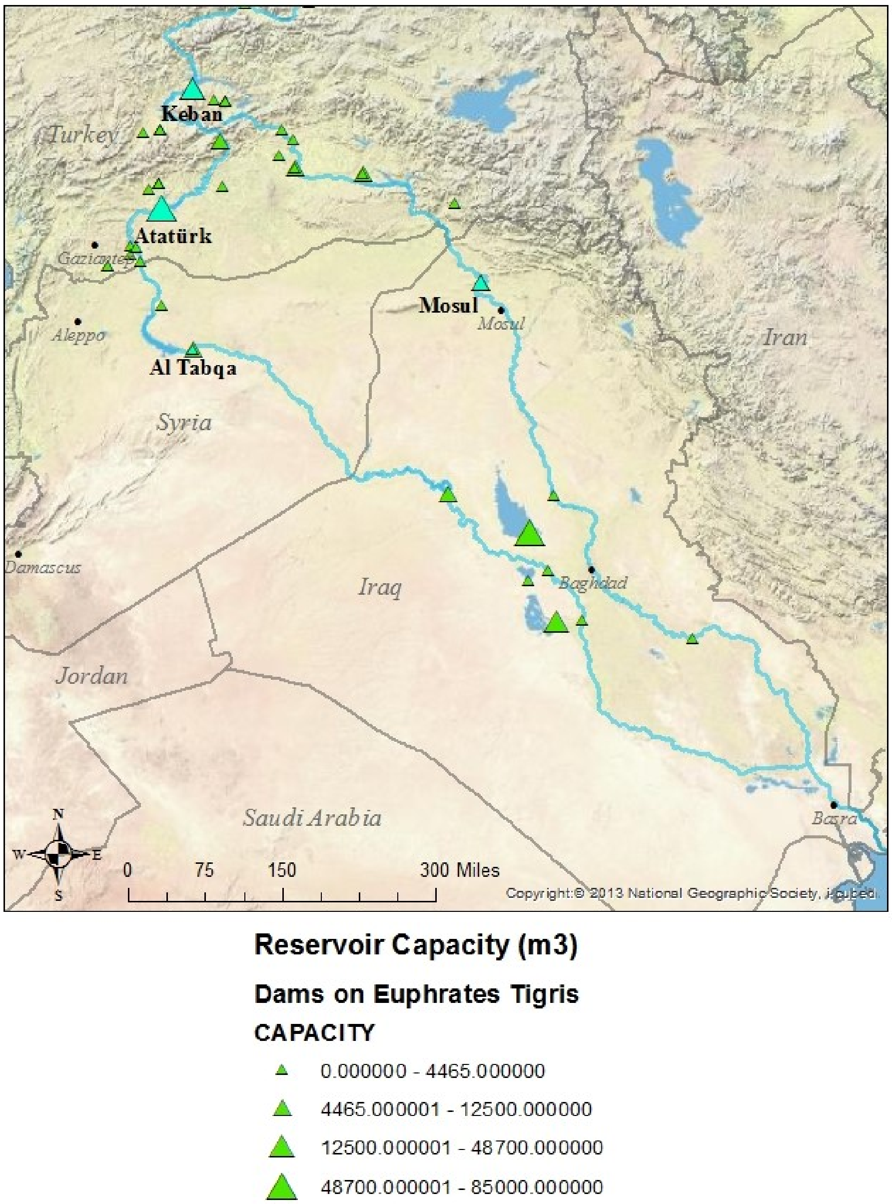
From a purely utilitarian perspective, the three riparian countries have sound social and economic justifications for utilizing the resources of the river for their respective domestic interests. During the Cold War, Syria, Iraq, and Turkey sought to reduce their dependency on foreign imports through large-scale hydropower and irrigation development projects. With the waters provided by the Euphrates and Tigris being the only sources of freshwater in the country, the riparians developed the basin with an expansive irrigation network. In the 1950s, Iraq was the first of the three to invest heavily in modern flood control and irrigation infrastructure on the Euphrates-Tigris, with the aim of decreasing its dependency on foreign food imports through investments in domestic agricultural production. Syria followed suit and launched a series of policies aimed at achieving agricultural self-sufficiency, an ambitious goal for a country where over half of the total land is classified as desert or steppe and crop irrigation was (at the time) almost completely dependent on rainfall. Turkey was last to catch on, and initially invested primarily in hydroelectric power generation projects along the river in hopes of reducing its dependence on foreign oil. By the late 1970s, Turkey had shifted its focus towards regional development and began investing in irrigation and water retention with a series of projects known as the Southeastern Anatolia Project (GAP).[203] See Figure 11.3 for location of dams on Euphrates and Tigris.

However, during this resource-conquering period known as the Hydraulic Mission, the water development goals of the riparians were inherently competitive and contradictory. While the flows of the river were dammed upstream, the downstream riparians were extracting the remaining flows at unsustainable rates. From 1975 to 2005, Syria's water consumption increased from 3.74 cubic kilometers per year to 16.76 cubic kilometers per year.[204] Similarly, Iraq's water consumption jumped from 40.56 cubic kilometers per year in 1975 to 66 cubic kilometers per

202 European Commission, "Elements for an EU Regional Strategy for Syria and Iraq as well as the Da'Esh Threat," June 2015, http://ec.europa.eu/echo/files/news/20150206_JOIN_en.pdf.
203 M. Dohrmann and R. Hatem, "The Impact of Hydro-Politics on the Relations of Turkey, Iraq, and Syria," *The Middle East Journal* 68(4) (2008).
204 Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

year by 2000[205] (see Figure 11.4). By 2003, the overdevelopment had resulted in a water deficiency in the Euphrates basin of 12 cubic kilometers per year.[206]

Figure 11.3.
Dams on the Euphrates-Tigris



Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

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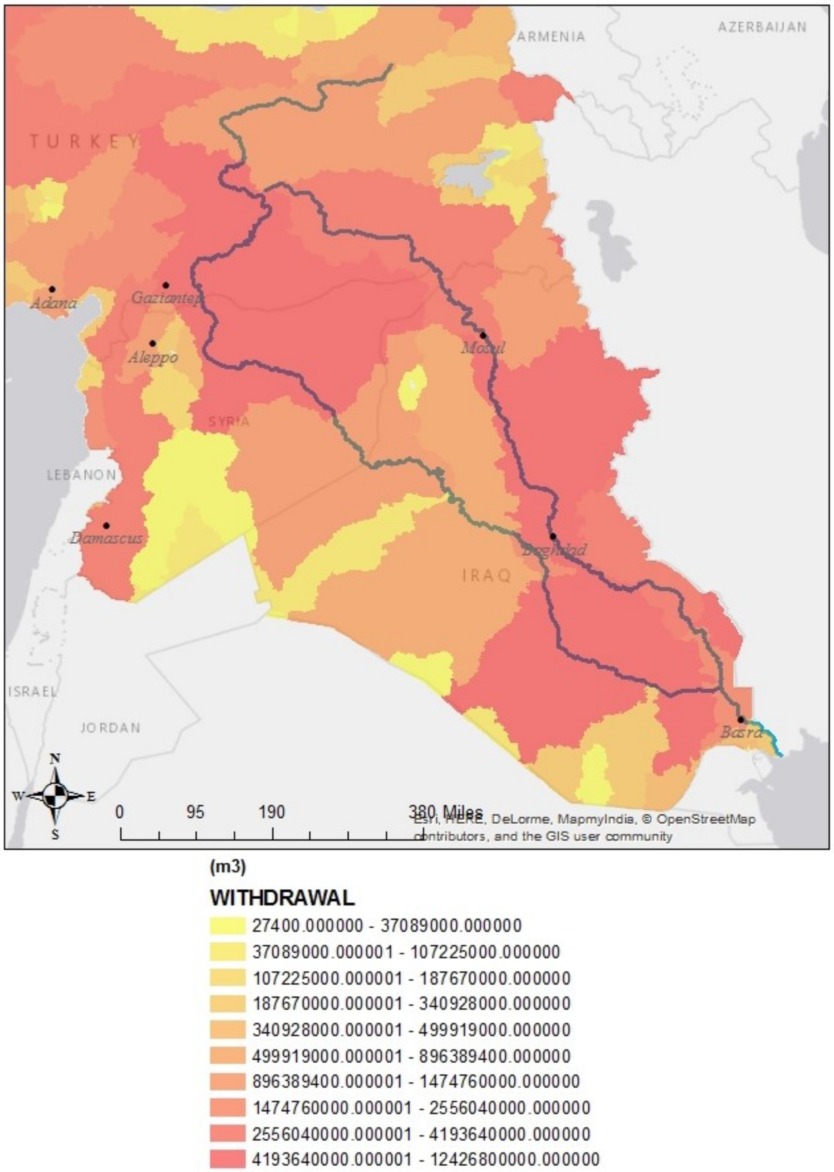
205 Ibid.

206 Dogan Altinbilek, "Development and management of the Euphrates–Tigris basin," *International Journal of Water Resources Development* 20(1) (2014): 15-33.

Figure 11.4.
Water Withdrawal in the Euphrates-Tigris Basin



Source: F. Gassert, M. Luck, M. Landis, P. Reig, and T. Shiao, “Aqueduct Global Maps 2.0,” Working Paper, World Resources Institute, 2013, http://wri.org/publication/aqueduct-global-maps-20.

The repercussions of these disjointed projects were exacerbated by inefficient and destructive irrigation practices that have reduced both water quantity and water quality in the region. The three countries have often come close to open conflict with one another over the water supply (or lack thereof) entering their countries. While this did not happen, after nearly 60 years of negotiations, they remain unable to reach a consensus on how to sustainably manage the basin.

Competitive Policies

Attempts to collaborate on a basin-wide water management strategy are complicated by the differences in terms of resource and organizational capacities between the riparians (see Table 11.1 for differences in basin area).[207] Both the Euphrates and Tigris rivers originate in the temperate, humid, mountainous region of Southeastern Turkey, which receives an average 400-600 millimeters of rainfall per year. As a result, snowmelt in Turkey accounts for 60-70 percent of the runoff for the rivers, and Turkey provides the Euphrates with 90 percent of its mean annual discharge of 32 billion cubic meters. Turkey is also responsible for 40 percent of the annual flow of the Tigris, which discharges 52 billion cubic meters per year.

Once the rivers reach Eastern Syria and Northwestern Iraq, the climate of the basin is much the opposite. Midstream, the arid and semi-arid lands are dry, hot, and poorly drained. The Mesopotamian Plain receives less than 200 millimeters of rainfall per year and summer temperatures can climb above 50 degrees Celsius, contributing to high levels of evaporation and salinization on the rivers. Syria contributes only 10 percent of the Euphrates' annual discharge, leaving the waters of the Euphrates in Iraq entirely dependent upon the leftover discharge from its upstream neighbors. Iraq, however, contributes 51 percent of the flow of the Tigris, but Syria hardly contributes to the Tigris at all and is thus similarly at the mercy of the discharge supplied by its neighbors (see Table 11.1 for riparian contributions to the waters of the Euphrates and Tigris).

Table 11.1.
Euphrates-Tigris Basin Area by Country

	Area of Country in Basin (km^2)	As Percent of Total Area of the Basin	As Percent of Total Area of Country
Iraq	407,880	46.40%	93.10%
Turkey	192,190	21.80%	24.50%
Iran	166,240	18.90%	9.50%
Syria	96,240	11.00%	52.10%
Saudi Arabia	16,840	1.90%	0.80%
Jordan	220	0.03%	0.20%

Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

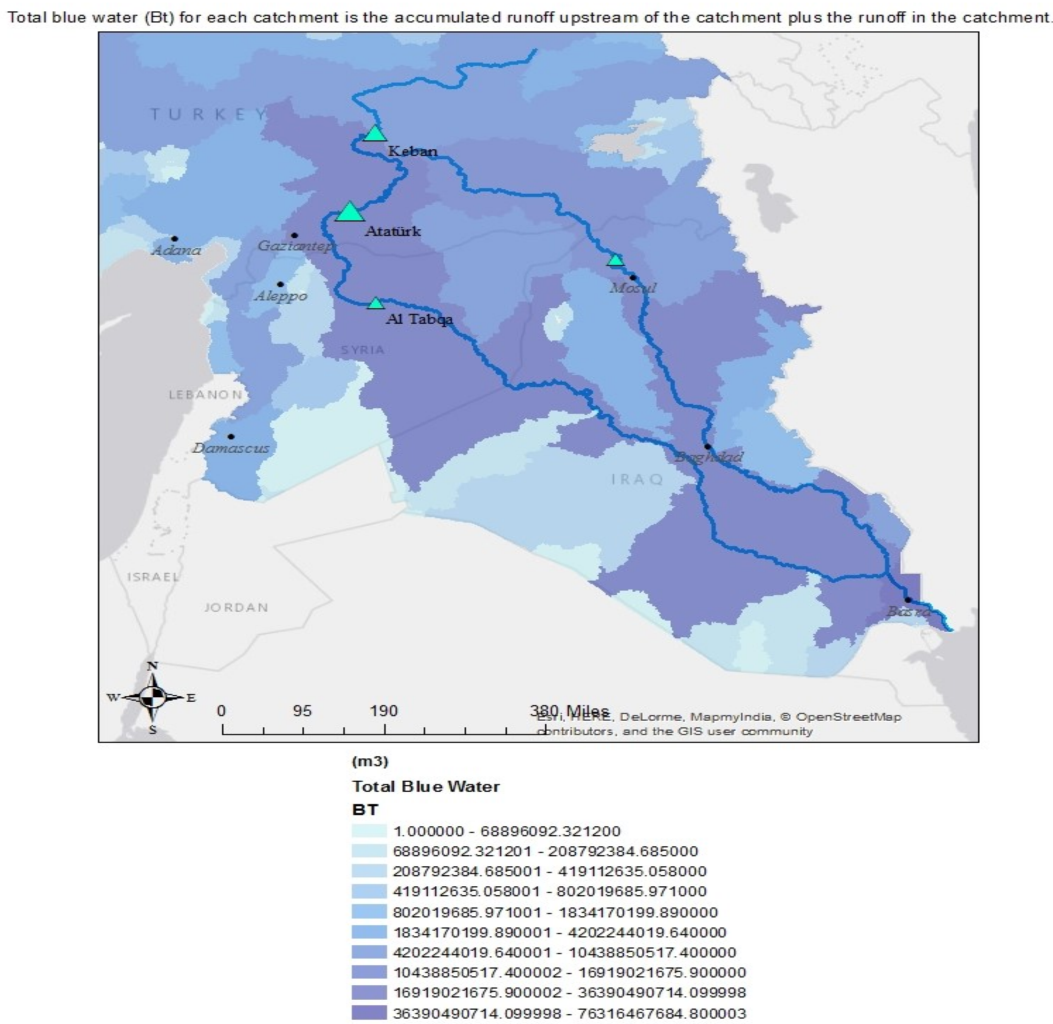
The prospect of effective basin-wide management is also complicated by differences in each riparian's economic dependence on the waters supplied by the Euphrates and Tigris. Because of the country's relatively small size and lack of freshwater diversity, Syria only has 16.8 cubic kilometers of total renewable water resources (defined as "the maximum theoretical yearly amount of water actually available for a country at a given moment"), while Iraq has 89.86 cubic kilometers and Turkey 211.6 cubic kilometers (see Figure 11.5 for Total Blue Water).[208] Of these

207 Ayşegül Kibaroğlu, *Building A Regime for The Waters of the Euphrates-Tigris River Basin* (Boston: Kluwer Law International, 2012), 259-260.

208 United Nations Environment Program, "The UNEP Environmental Data Explorer," as compiled from FAO, AQUASTAT, 2016, http://ede.grid.unep.ch.

resources, Syria and Iraq are extremely dependent upon water that originates outside of their countries' borders (see Table 11.2).

Figure 11.5.
Total Blue Water in Cubic Meters



Source: F. Gassert, M. Luck, M. Landis, P. Reig, and T. Shiao, "Aqueduct Global Maps 2.0," Working Paper, World Resources Institute, 2013, http://wri.org/publication/aqueduct-global-maps-20.

The two rivers constitute 28.5 percent of all surface water supply in Turkey, 65 percent in Syria, and nearly 100 percent of all supply in Iraq. For all of these reasons, the three countries value the water of these rivers in varying degrees due to their potential for hydropower generation and agricultural irrigation, both of which are key components of each country's economic strategy.

Table 11.2.
Renewable Water by Source (Internal/External, Surface Water/Groundwater)

Cubic kilometers	Total Internal Renew-able Water	Total External Renew-able Water	Total Renew-able Water	Ground-water Inflow	Ground-water Outflow	Total Renew-able Ground-water	Surface Water Inflow	Surface Water outflow	Total Renew-able Surface Water	Depen-dency*
Syria	7.13	9.67	16.82	11.13	0.34	n/a	28.52	31.73	n/a	0.72
Iraq	35.20	54.58	89.86	0.08	n/a	3.28	61.33	n/a	88.58	0.61
Turkey	227.00	-14.20	211.60	0.00	11.00	67.80	1.80	60.12	171.80	0.02

Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

* Percent of total renewable water resources originating outside the country.

These dissimilarities in terms of resource endowments and dependence on the rivers have produced national water policy perspectives that are often in opposition of one another. Because institutional frameworks in the basin are mostly administered using a top-down approach, water and irrigation authorities within a district have little choice but to adopt the perspectives taken at the national level, regardless of their contradiction with the realities of the basin. This has further contributed to inefficient and ineffective management practices in the basin, as irrigation associations have little legal capacity for building or maintaining infrastructure that will ensure sustainability.[209]

Unchecked Inefficiencies

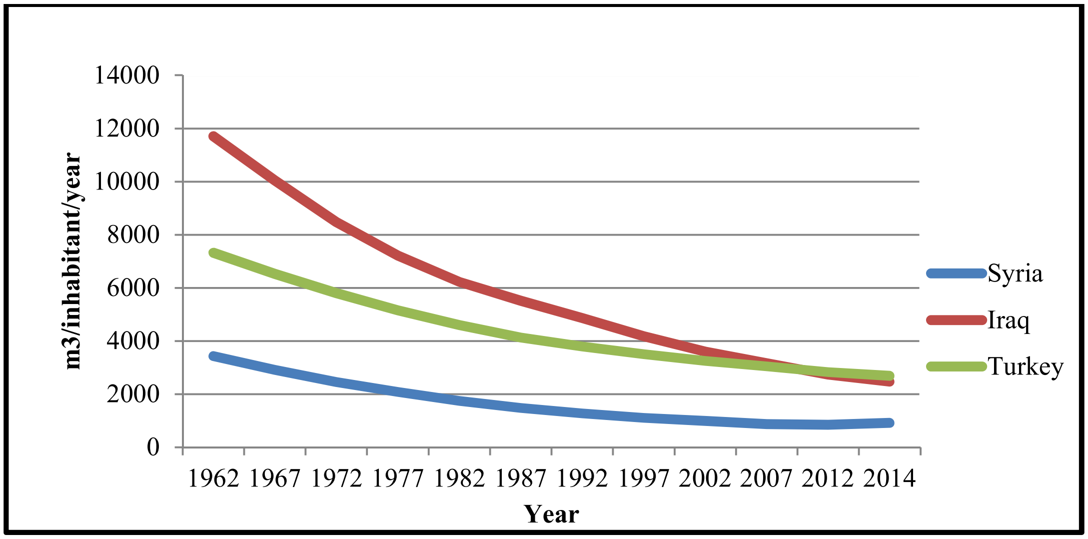
While development projects of the Hydraulic Mission period were seen as fostering economic and agricultural development on the domestic level, these uncoordinated and overly aggressive projects have had a negative impact on the basin as a whole. As agricultural production increased under state-run economic policies, the governments actively encouraged its citizens to contribute to the country's agricultural production by providing subsidies for ecologically damaging fertilizer and diesel fuel for high-intensity irrigation. The lack of an effective water-pricing model in the region provides no incentive for implementing water-saving techniques and fails to generate an adequate source of revenue that could help finance water-saving techniques. The irrigation network that the governments built has also proven to be extremely inefficient, poorly designed, and wasteful. As a result, the amount of water consumed in the basin has outpaced the rate at which the water can be renewed.

In Syria, for example, the country's annual renewable water availability per capita has been slashed from over 5,550 cubic meters per person per year in 1950 to less than 760 cubic meters

[209] Ayşegül Kibaroğlu, "Euphrates-Tigris River Basin Report," Sustainability of Engineered Rivers in Arid Lands, Houston Advanced Research Center, 2014, http://www.harcresearch.org/sites/default/files/Project_Documents/Reports1-EuphratesTigris.pdf.

per person per year in 2012 (see Figure 11.6).[210] However, this decline in available water per capita is not solely due to increasing populations. From 2003 to 2009, GRACE Satellite findings showed an alarming decrease in total groundwater storage in the Euphrates-Tigris basin. The satellite detected a decrease of 144 cubic kilometers, which is nearly equivalent to the total volume of the Dead Sea (average volume of the Dead Sea is 147 cubic kilometers).[211]

Figure 11.6
Total Renewable Water Resources Per Capita



Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

The construction of dams and artificial reservoirs for water storage also increases the surface area of the water subject to evaporation. Increasing global temperatures due to climate change exacerbate this problem, as higher temperatures lead to a decline in soil moisture and higher levels of evaporation. The GRACE Satellite study estimated that 20 percent of all water loss observed from 2003 to 2009 could be attributed to surface water evaporation.[212] One study estimated that if the three countries could coordinate a joint reservoir operation, they could potentially minimize water loss due to evaporation and save up to 6-7 cubic kilometers per year.[213]

In addition to this substantial decrease in surface water, the availability of groundwater in the region has also rapidly declined. Of the 144 cubic kilometers of water loss that the GRACE satellites observed, nearly 63 percent can be attributed to groundwater extraction.[214] Since the

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210 Peter Gleick, "Water, Drought, Climate Change, and Conflict in Syria," *Weather, Climate, and Society,* 6(3) (2015): 331-40.
211 Katalyn Voss, J. Famiglietti, M. Lo, C. de Linage, M. Rodell, and C. Swenson, "Groundwater Depletion in The Middle East from Grace with Implications for Transboundary Water Management in The Tigris-Euphrates-Western Iran Region," *Water Resources Research* 49(2) (2013): 904-914.
212 Ibid.
213 Altinbilek, "Development and management of the Euphrates-Tigris basin."
214 Voss et al., "Groundwater depletion in the Middle East."

1960s, many farmers have resorted (legally or otherwise) to using their own diesel motor pumps to extract water from wells. The lack of oversight or enforcement from water agencies typically means that farmers are extracting water at rates that exceed the available supply, contributing to the alarming rate of groundwater depletion in the last several decades. In 1994 the FAO estimated that wells accounted for 80 percent of irrigated land in the basin.[215] A 2012 FAO study indicated that half of all of the wells in the basin extract groundwater.[216] The number of groundwater wells increased from around 135,000 in 1999 to nearly 230,000 in 2010.[217] This is especially problematic for the basin's long-term water supply because groundwater resources take significantly longer than surface water to replenish and renew once the water has been extracted.

Furthermore, the irrigation networks constructed and utilized on a daily basis in the three riparian countries are typically wasteful and inefficient, especially in Syria and Iraq. In 2011, *Iraq Business News* reported that up to 50 percent of the country's water resources are wasted due to seepage, leakage, and irrigation system inefficiencies.[218] In Syria, up to 40 percent of all water consumed is actually lost due to seepage and evaporation.[219] As a result of technical deficiencies and poor planning around unstable subsoils, many irrigation canals have collapsed.[220] An estimated 21 dams in Syria are in need of "immediate" repair, and one even collapsed in 2003 (see Figure 11.7 for map of irrigated area).[221]

Because regional water institutions in Syria and Iraq have little administrative or legal capacities with which to execute repairs, these neglected and dilapidated systems are significantly contributing to the water deficit in the region. Each riparian has many water institutions, and while many of their responsibilities overlap, there is little coordination or communication between them. Often, they rival one another while navigating their state's bureaucratic administration system.[222] Administrative districts are often divided in terms of agro-climatic zones, which distorts the reality of water situations on the ground because water management districts are not organized by the amount of irrigated water supplied to the area but only by the amount of annual precipitation.[223] This kind of organizational structure is ripe with opportunities for corruption and unequal distribution of water resources because they can continue to allocate water to the areas with the lowest rainfall even if those areas are already receiving the most

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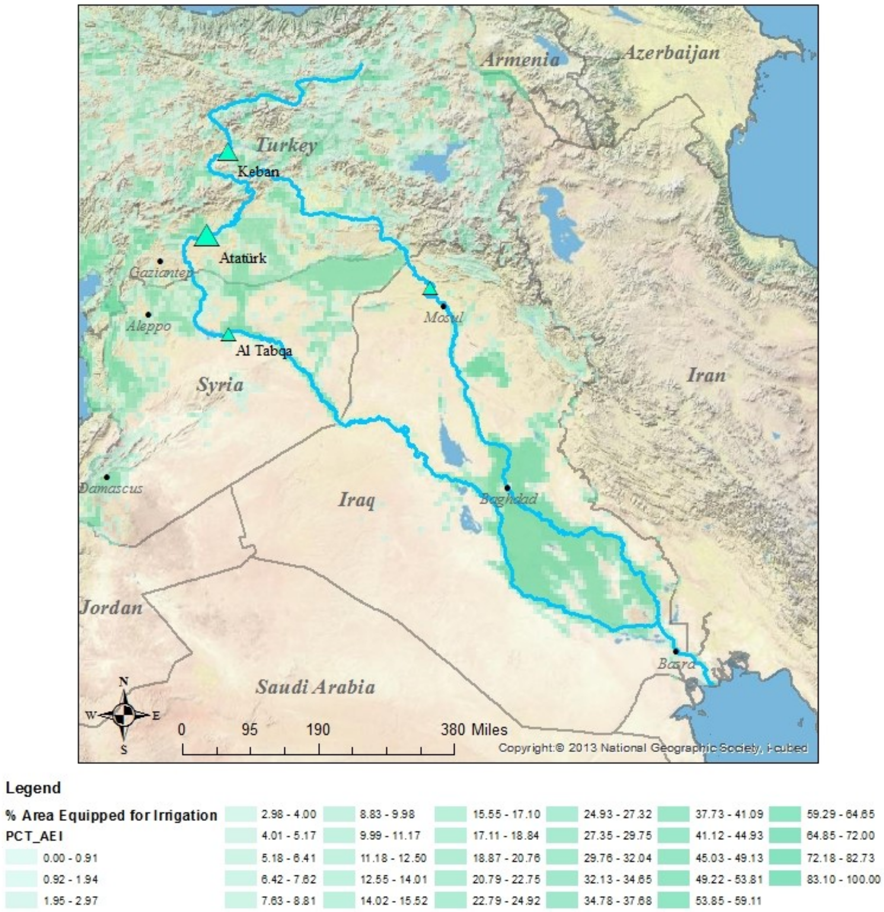
215 Francesca de Châtel, "The Role of Drought and Climate Change in The Syrian Uprising: Untangling The Triggers of the Revolution," *Middle Eastern Studies* 50(4) (2014): 521-535.
216 FAO, "Syrian Arab Republic Joint Rapid Food Security Needs Assessment (JRFSNA)," 2012 , http://www.fao.org/giews/english/otherpub/JRFSNA_Syrian2012.pdf.
217 de Châtel, "The role of Drought and Climate Change in The Syrian Uprising."
218 Iraq Business News, "Half of Iraq's Water Is Wasted," March 22, 2011, http://www.iraq-businessnews.com/2011/03/22/half-of-iraqs-water-is-wasted/.
219 Frederick Lorenz and Edward J. Erickson (eds.), *Strategic Water: Iraq and Security Planning in The Euphrates-Tigris Basin* (Quantico, VA: Marine Corps University Press, 2013).
220 Ibid.
221 Ibid.
222 S. Smets, "Baseline Water Sector Report: GTZ Modernization of the Syrian Water Sector Support to Sector Planning and Coordination and State Planning Commission" (Damascus: State Planning Commission and German Technical Development Corporation, 2009).
223 Timothy Mitchell, *Rule of Experts; Egypt, Techno-Politics, Modernity*, 1st Ed. (University of California Press, 2002).

water. A collaborative, international water management scheme would no doubt increase accountability, data accuracy, and transparency, and allow for a more equitable and sustainable allocation of the rivers' resources.

Figure 11.7.
Irrigated Lands in the Euphrates-Tigris Basin



Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

These structural inefficiencies are especially problematic considering agriculture accounts for an overwhelming majority of the basin's total water consumption (see Table 11.3 and Figure 11.8). An estimated 80 percent of irrigated farms use flood irrigation, which is wasteful not only for the large quantities of water it requires but also for the runoff that pollutes the water downstream (see Table 11.4).[224] In 2004, Altinbilek estimated that the application of water-saving techniques in irrigation could help reduce water demand by as much as 20 percent.[225,226]

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[224] FAO, "Syrian Arab Republic Joint Rapid Food Security Needs Assessment."
[225] Altinbilek, "Development and management of the Euphrates–Tigris basin."
[226] FAO, "Syrian Arab Republic Joint Rapid Food Security Needs Assessment."

Table 11.3
Water Withdrawal by Sector

	Agricultural	Municipal	Industrial	Total Withdrawal (km^3)	Total Withdrawal Per Capita (m^3)	2015 Population
Syria (2005)	87.53%	8.80%	3.67%	16.76	862.8 m3	18,502,000
Iraq (2000)	78.79%	6.52%	14.70%	66	2,646 m3	36,423,000
Turkey (2003)	73.82%	15.46%	10.72%	40.1	576.9 m3	78,666,000

Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

Table 11.4.
Irrigation Methods, in Hectares

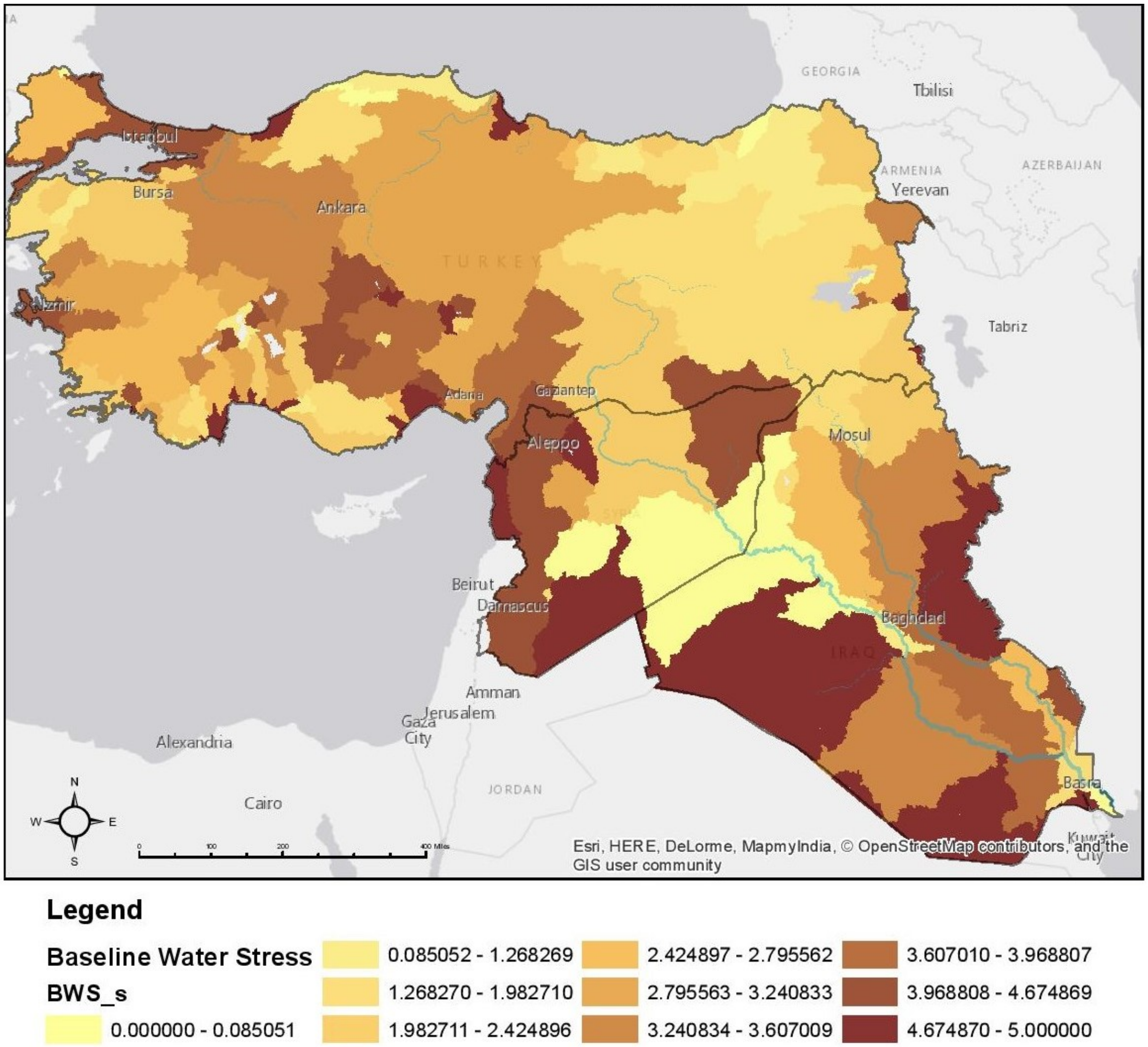
	Surface Irrigation		Sprinkler Irrigation		Localized Irrigation		Total Area Equipped for Irrigation
Syria (2010)	1,043,000	77.78%	187,100	13.95%	110,900	8.27%	1,341,000
Iraq (2003)	7,432,000	85.43%	280,000	3.22%	420,000	4.83%	8,700,000
Turkey (2012)	4,690,000	87.83%	500,000	9.36%	150,000	2.81%	5,340,000

Source: Food and Agriculture Organization of the United Nations (FAO), "AQUASTAT," 2016, http://www.fao.org/nr/water/aquastat/main/index.stm.

Salinization, another side effect of building dams, has also significantly reduced the quality of the water in the Euphrates and Tigris rivers. According to the World Health Organization, water with salinity levels exceeding 1,000 parts per million (ppm) is unfit for human consumption, and salinity levels exceeding 2,000 ppm are unsuitable for crop irrigation. In the Euphrates, the upstream salinity levels are relatively low at 260 ppm but increase dramatically to 1,100 ppm by the time the waters reach the Syrian border.[227] In the city of Nassiriyah, 225 miles southeast of Baghdad, salinity levels peak at 4,000 ppm. A similar trend has been observed on the Tigris, where salinity levels upstream average 275 ppm but jump to 2,250 ppm in Ali al-Sharki just before merging with the Euphrates at the Shatt al-Arab.[228] See Figure 11.9 for a representation of the return flow ratio on the Euphrates-Tigris rivers, where the red areas receive higher quantities of runoff and thus require more intensive water treatment.

[227] FAO, "AQUASTAT."
[228] Ibid.

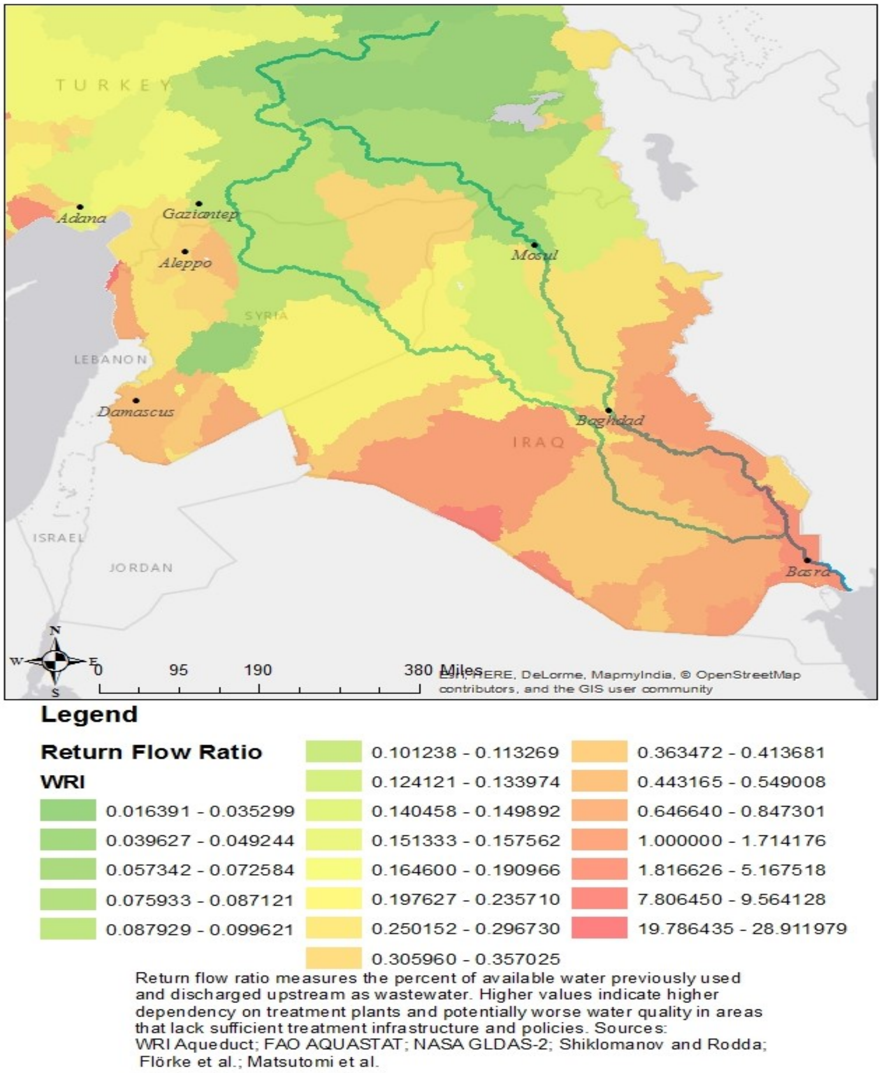
Figure 11.8.
Baseline Water Stress Score



Baseline water stress measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow. Higher values indicate more competition among users

Source: F. Gassert, M. Luck, M. Landis, P. Reig, and T. Shiao, "Aqueduct Global Maps 2.0," Working Paper, World Resources Institute, 2013, http://wri.org/publication/aqueduct-global-maps-20.

Figure 11.9.
Return Flow Ratio



Source: F. Gassert, M. Luck, M. Landis, P. Reig, and T. Shiao, “Aqueduct Global Maps 2.0,” Working Paper, World Resources Institute, 2013, http://wri.org/publication/aqueduct-global-maps-20.

Evaporation, salinization, agricultural runoff, and the dumping of untreated sewage in the Euphrates and its tributaries have increased nutrient levels and coliform bacteria counts in the water in all three riparian countries.[229] In the first half of 2010 there were 360,000 reported cases of diarrhea due to polluted water in Iraq, where the ailment is the second largest cause of death for children less than five years old.[230] Since the outbreak of civil war, a typhoid outbreak has threatened the lives of thousands of internally displaced people in the neighborhood of the Yarmouk refugee camp, near Damascus.

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229 Kibaroğlu, “Euphrates-Tigris River Basin Report.”
230 UNICEF, “World Water Day 2011 (22 March),” 3, http://iq.one.un.org/documents/155/UNICEF%20media%20advisory%20and%20facts.pdf.

Failed Negotiations

Despite a growing water supply deficit, diplomatic efforts to implement a trilateral basin management strategy have been thwarted by competition over water rights, opposing regional alliances, and political mistrust. Historically, Syria and Turkey have had a less-than-amicable relationship that is based on Syria's reliance on water supplied from Turkey and Turkey's opinion that they should have full rights to the water within their borders. Contradictory alliances during the Cold War, the Arab-Israeli wars, and conflicts with Kurdish forces have also fueled political mistrust and competition. As a result, the riparians have come to view water security as an issue of national security and sovereignty, which has resulted in decades of unsuccessful negotiations.[231]

The Joint Technical Committee

In 1964, after the Hydraulic Mission led to fierce competition among riparians over water rights, Iraq insisted that a minimum downstream flow of 350 cubic meters per second be released from Turkey while dams were impounding upstream, provided the river's flow was "adequate." This led to the establishment of the Joint Technical Committee, which was to be responsible for measuring each country's water needs in order to facilitate an agreement on equitable water allocations.[232] Although the Joint Economic Commission and the Joint Technical Committee met 16 times between 1981 and 1992, the organization failed to produce any serious bilateral agreements. Most discussions ended in stalemates due to rivalrous regional alignments and fundamental disagreements regarding the extent of the basin.

Although all three parties did meet in Baghdad in 1965 and again several times throughout the 1970s, no trilateral agreement was reached, and Syria and Turkey unilaterally planned and executed their own impoundment programs for their respective reservoirs.[233] The failure of the riparians to agree on a trilateral solution implied that two parties could meet to discuss water allocations in terms of their own respective interests and irrespective of the needs of the excluded third party. As a result, these disjointed and uncoordinated development projects continued to compete for resources along the basin without regard to sustainability or impact on the basin as a whole.

In 1987, for example, Syria and Turkey met regarding the ongoing development of dams in Turkey and the two parties agreed on a monthly average flow of 500 cubic meters per second. However, actual flows from Turkey fluctuated after the agreement was made. During the filling of the Ataturk dam in 1990, for example, Turkey reduced water flow to Iraq and Syria from 500 cubic meters per second to 165 cubic meters per second without warning. While the agreement stated that Turkey could make up for any monthly deficit in future periods, the unpredictability of flow levels from Turkey caused serious problems for Syria and Iraq, even though Iraq was not a party to the agreement.

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[231] Lorenz and Erickson (eds.), *Strategic Water*.

[232] Ayşegül Kibaroğlu and W. Scheumann, "Euphrates-Tigris river system: Political rapprochement and transboundary water cooperation," in *Turkey's water policy: National frameworks and international cooperation*, Aysegul Kibaroğlu, Annika Kramer and Waltina Scheumann, eds. (Heidelberg: Springer, 2011), 277-299.

[233] Ibid.

In 1990, Syria and Iraq met in Baghdad to revisit their previous agreement on the proportion of water to be released to Iraq, and Syria increased its share of the flow from 40 percent to 42 percent. However, this policy failed to consider the variability in upstream flow to be released by Turkey and did not include a strategy for drought management. As a result, it is widely accepted that "the JTC meetings… did not make an effective contribution to the settlement of the regional water dispute" because the agreements were bilateral in nature and failed to adopt an integrated approach to the aspects of water needs that extend beyond a stated minimum quantity requirement.[234]

Recent Negotiations

Efforts to re-launch negotiations in the 1990s and early 2000s were also largely unsuccessful due to the dramatic shifts of political and military power in both Syria and Iraq and the rise in violence with non-state actors in the region. Those years were plagued with violence and political unrest, and water resource management took a back seat to national security issues. By 2008, much of the basin's critical infrastructure was in disrepair and each country's capacity for efficient water resource management was considerably diminished.[235]

In December 2009, Turkey and Syria issued a bilateral memorandum of understanding that permitted Syria to extract 1.25 billion cubic meters of water annually from the Tigris. After nearly 40 years of unilateral basin development, this was the first agreement that included measures for demand management, drought planning, irrigation efficiencies, and water conservation.[236] Although the High Level Strategic Cooperation Council that facilitated this agreement made some promising progress during that same year, relations between Syria and Turkey quickly dissolved after Turkey sided with Syrian opposition forces against Bassar-Al Assad's regime when civil war broke out in 2011.[237] Furthermore, while this memorandum was the first to include policies on water demand management and drought planning, Syria was already in the midst of the worst drought in observable record.

Opposing Perspectives

Much of the reason they were not able to ever agree on a comprehensive policy was rooted in each riparian's contrasting beliefs regarding each country's entitlement to the waters of the river. Turkey took the stance that, as the upstream riparian responsible for 90 percent of the discharge of the Euphrates and 40 percent of the Tigris, downstream states do not have "rights" to water that is generated and contained within Turkey's borders.[238] Iraq cited historical and ancestral development of the river as a basis for sovereign or "acquired right" to water on the Tigris and refused to consider the Euphrates and Tigris as a single basin, nor did they accept Turkey's offer

[234] Aysegül Kibaroğlu, "Transboundary water governance in the Euphrates Tigris river basin," *E-International Relations,* July 22, 2015, http://www.e-ir.info/2015/07/22/transboundary-water-governance-in-the-euphrates-tigris-river-basin/.
[235] David Michel, Amit Pandya, Syed Iqbal Hasnain, Russell Sticklor, and Sreya Panuganti, "Water challenges and cooperative response in the Middle East and North Africa," The Saban Center at Brookings, 2012, http://www.brookings.edu/~/media/Research/Files/Papers/2012/11/iwf%20papers/Water%20web.pdf.
[236] Kibaroğlu, "Transboundary water governance in the Euphrates Tigris river basin."
[237] Ibid.
[238] Ibid.

to supply a surplus to the Tigris to make up for the scarcity on the Euphrates.[239] On the other hand, Syria and Turkey argued that the Euphrates-Tigris should be viewed as one single watercourse system and basin because the two rivers merge at Shatt-al-Arab and also at the man-made Thartar Canal.

The riparians also disagreed on how to define the river basin in terms of international law. Turkey defined the rivers as transboundary watercourses, which should be utilized and allocated among three parties based on water need, while Syria and Iraq viewed the rivers as international rivers that must be shared.[240] Syria and Iraq accused Turkey of prioritizing control over a majority of the Euphrates waters upstream instead of considering the rivers to be collective international property.[241] Syria disagreed on the definition of the basin and insisted that the Euphrates and Tigris rivers be allocated as "international watercourses" instead of shared as "transboundary rivers," the former of which implies water-sharing based on quotas and declared demands in accordance with international law.[242] As a result of these fundamental disagreements, much of the negotiation process never got past the introductory stages, and water losses in each country continued to compound.

Most importantly, these agreements failed to implement a cooperative method of monitoring water supply and demand, which made it impossible to execute any water-sharing agreement. Inaccurate and unshared data collection on water resource management was partly due to competitive politics but also due to issues of national security. When states depend on other states for water supplies in times of shortages and there are few alternative sources of water, the resource is more likely to become an issue of national sovereignty and security.[243] Because of the mistrust among the riparians, reliable data on water demand and use within the three riparians is not made public, and water is such a sensitive topic it is almost rarely discussed openly.[244] As a result, water ministries and irrigation districts in the basin often produce contradictory results, in the event that they exchange data at all. This lack of reliable data in tandem with a complicated administration system leads to a lack of transparency and accountability and opens the door for corruption among the complex network of water authorities and irrigation associations.

The Drought

As a result of wasteful water use practices, this arid region became even more vulnerable to drought and water shortages, and without functional water institutions or international agreements, the riparian governments had no formal drought mitigation strategy. This lack of foresight had devastating consequences when the agriculturally-dependent region fell victim to the worst drought in observable record in 2007. Average rainfall in Syria dropped to 66 percent

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239 Altinbilek, "Development and management of the Euphrates–Tigris basin."

240 Aysegül Kibaroğlu and Waltina Scheumann, "Evolution of transboundary politics in the Euphrates-Tigris river system: New perspectives and political challenges," *Global Governance: A Review of Multilateralism and International Organizations* 19(2) (2013): 279-305.

241 Altinbilek, "Development and management of the Euphrates–Tigris basin."

242 Ibid.

243 Gleick, "Water, Drought, Climate Change, and Conflict in Syria."

244 de Châtel, "The role of Drought and Climate Change in The Syrian Uprising."

of the long-term average during the 2007-2008 season, and some areas saw no rain at all.[245] By the end of that year, the flow of the Euphrates River had decreased to approximately 70 percent of its normal flow by the time it crossed into Iraq[246] and employment in the Syrian agricultural sector had dropped by 33 percent.[247] It is estimated that 1.3 million people were affected by the drought and that 800,000 "severely affected" people lost their livelihoods and basic food supports.[248] By 2010, the UN estimated that 3.7 million people, or 17 percent of Syria's population was food insecure.[249]

Even more so than its basin neighbors, the consequences of the drought for the Syrian economy were devastating because of the country's near complete reliance on the flows of the Euphrates-Tigris as well as its rapid decline in groundwater resources.[250] The long-term average wheat harvest in Syria is typically around 4.7 million tons, of which 3.8 million tons is consumed internally. By contrast, the wheat yield for the 2007-2008 season came in at just 2.1 million tons.[251] After consecutive seasons without crop yields, problems with agricultural productivity continued because farmers had no seeds with which to plant future harvests. As a result, the average yield of basic crops declined 32 percent in irrigated areas and up to 79 percent in non-irrigated (rain fed) areas.[252] By 2010, yields for wheat and barley, Syria's two major cash crops, dropped by 47 percent and 67 percent, respectively.[253]

As a result, Syria was forced to import wheat for the first time in over 15 years.[254] The region was also forced to absorb the brunt of world-wide food inflation. In just the first year of drought, wheat, rice, and feed prices more than doubled.[255] In an effort to alleviate the budget deficit and to increase their presence on a global economic stage, Syria abolished diesel and fertilizer subsidies in 2008. Diesel was essential to Syrian farmers, not only for transporting harvest to the markets but also for extracting groundwater from wells for irrigation. Overnight, the price of diesel jumped from $0.14 per liter to $0.53, instantly putting thousands of farms out of

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245 Ibid.

246 Martin Chulov, "Iraq: Water, water nowhere," *World Policy Journal* 6(4) (2009): 31-41.

247 de Châtel, "The role of Drought and Climate Change in The Syrian Uprising."

248 Mahmoud Solh, "Tackling the drought in Syria," *Nature Middle East* 206, (September 27, 2010, http://www.natureasia.com/en/nmiddleeast/article/10.1038/nmiddleeast.2010.206

249 The UN Refugee Agency (UNHCR), "Syria Emergency," 2011, http://www.unhcr.org/en-us/syria-emergency.html.

250 Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian drought."

251 de Châtel, "The role of Drought and Climate Change in The Syrian Uprising."

252 Wadid Erian, "Drought vulnerability in the Arab Region: Case study; Drought in Syria—Ten years of scarce water (2000–2010)," ACSAD and ISDR, 2011, http://www.unisdr.org/files/23905_droughtsyriasmall.pdf.

253 Ibid.

254 de Châtel, "The role of Drought and Climate Change in The Syrian Uprising."

255 Integrated Regional Information Networks, "Syria: Drought blamed for food scarcity," February 22, 2009, http://www.irinnews.org/news/2009/02/22/drought-blamed-food-scarcity.

commission.[256] The regime's failure to put in place economic measures to alleviate the effects of drought was a critical driver in propelling the massive mobilizations of dissent.[257]

Climate Change

Significant decreases in precipitation in the region in the last decades, mostly due to a combination of natural variability and a long-term drying trend, are consistent with trends of global warming.[258] Climate change is considered a "threat multiplier" in the intelligence community, particularly in states that have fragile governments but experience rapid population growth, as is the case in the Euphrates-Tigris basin.[259] Every standard deviation of change in climate toward warmer temperatures or more extreme rainfall increases interpersonal violence and intergroup conflict by measured amounts.[260] Furthermore, it is estimated that increasing global temperatures, decreasing precipitation rates, and increased surface evaporation will decrease the surface runoff in the basin in Turkey by 23.5 percent on the Euphrates and 28.5 percent on the Tigris, implying a high risk for future conflicts in the region if the riparians cannot formulate an adequate drought-response strategy.[261]

However, it is not beneficial to blame the current crisis in the Levant entirely on climate change or drought and downplay the role of the governments in causing this conflict. For starters, when controlling for natural drying trends and climate change, researchers have concluded that the drought in the Middle East was largely due to human factors, such as exploitative policies, inefficient practices, and inadequate drought preparation.[262] Secondly, the governments' initial encouragement of agricultural production and subsequent lack of support or relief for their agricultural industries in the wake of the drought has resulted in catastrophic socioeconomic consequences for the citizens of the basin. As a result, citizens in the basin revolted against their respective authorities and sent the region into political chaos. In the midst of the chaos, ISIS was able to capitalize on the precious resource and utilize water as a means of exercising effective control over the region.

Mass Migrations

The lack of preventative measures or strategic planning with regards to drought forced millions of people out of their livelihoods and out of their homes. This massive migration of people displaced by the drought intensified historical ethnic tensions in the region and fueled anti-

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256 Francesca de Châtel, "Leaving the land: The impact of long-term water mismanagement in Syria," in *Water Scarcity, Security and Democracy: A Mediterranean Mosaic*, F. de Châtel, G. Holst-Warhaft and T. Steenhuis, eds., Global Water Partnership, 2009.

257 Suzanne Saleeby, "Sowing the seeds of dissent: Economic grievances and the Syrian Social Contract's unraveling," *Jadaliyya*, February 16, 2012.

258 Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian drought."

259 Andrew Freedman, "Seeds of war: Global warming helped trigger Syria's bloody civil war," *Mashable*, March 3, 2015.

260 Solomon Hsiang, Marshall Burke, and Edward Miguel, "Quantifying the influence of climate on human conflict," *Science* 341 (6151) (Sept. 2013).

261 Deniz Bozkurt and Omer L. Sen, "Climate change impacts in the Euphrates-Tigris basin based on different model and scenario simulations," *Journal of Hydrology* 480 (2013): 149-161.

262 Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian drought."

government sentiments. Before the Syrian government withdrew their subsidies, political instability, violence, and water insecurity in Iraq had already been forcing millions of Iraqis away from their homes and into neighboring countries like Syria and Turkey. Between 2003 and 2007, an estimated 1.5 million Iraqi refugees migrated to Syria alone.[263] An additional 1.5 million herders and farmers from northeastern Syria were internally displaced due to the drought, and a vast majority of them concentrated in urban areas in hopes of finding employment.[264]

By 2010, the year before the Syrian uprising, internally displaced Syrians and Iraqi refugees compromised 20 percent of the country's entire urban population. While Syria's population has expanded rapidly (from 3 million in 1950 to 22 million in 2012), the population growth in Syria's urban centers exceeds that of the national average. From 2002 to 2010, Syria's urban population increased dramatically, from 8.9 million to 13.8 million.[265]

Furthermore, rapidly increasing populations in urban areas can do even more damage to the water supply downstream, due to inefficient and ineffective wastewater treatment methods poorly managed by the government.[266] This forced even more rural farmers downstream to relocate to urban centers for employment. Once they arrived, these urban areas did not have the available infrastructure to accommodate such large migrations, and the areas were plagued with poor living conditions, overcrowding, and rampant crime.[267] Socioeconomic crises like these fuel anti-government sentiments and weaken the legitimacy of state powers, increasing the chances for ethnic conflicts and military coups.[268] As such, it is no coincidence that the nonviolent protests that sparked the Civil War occurred within these urban areas.

While Syrians in the Dara'a province initially took to the streets in 2011 over the arrest of 15 children, later demonstrations emphasized their complaints over well licensing and groundwater use policies mandated by the government. Furthermore, citizens in Dier ez-Zour complained specifically about the lack of help from the government in dealing with the drought, mandating which crops to grow, and monopolizing their choice in crops. This was not a hyperbolic complaint, as 60-70 percent of villages in Deir ez-Zor and Hassakeh were deserted by 2009. Syrian citizens faced unemployment, forced migration, poverty, and food scarcity. They followed the trend of the Arab Spring and made their grievances with the government known.

Ethnic and Sectarian Conflict

Since their establishment after the fall of the Ottoman Empire, the three governments have managed their nationalized water sector while remaining largely fragmented along secular and ethnic lines. The massive population shift that resulted from the drought was thus especially problematic for the Euphrates-Tigris basin because it is home to a diverse array of ethnic and

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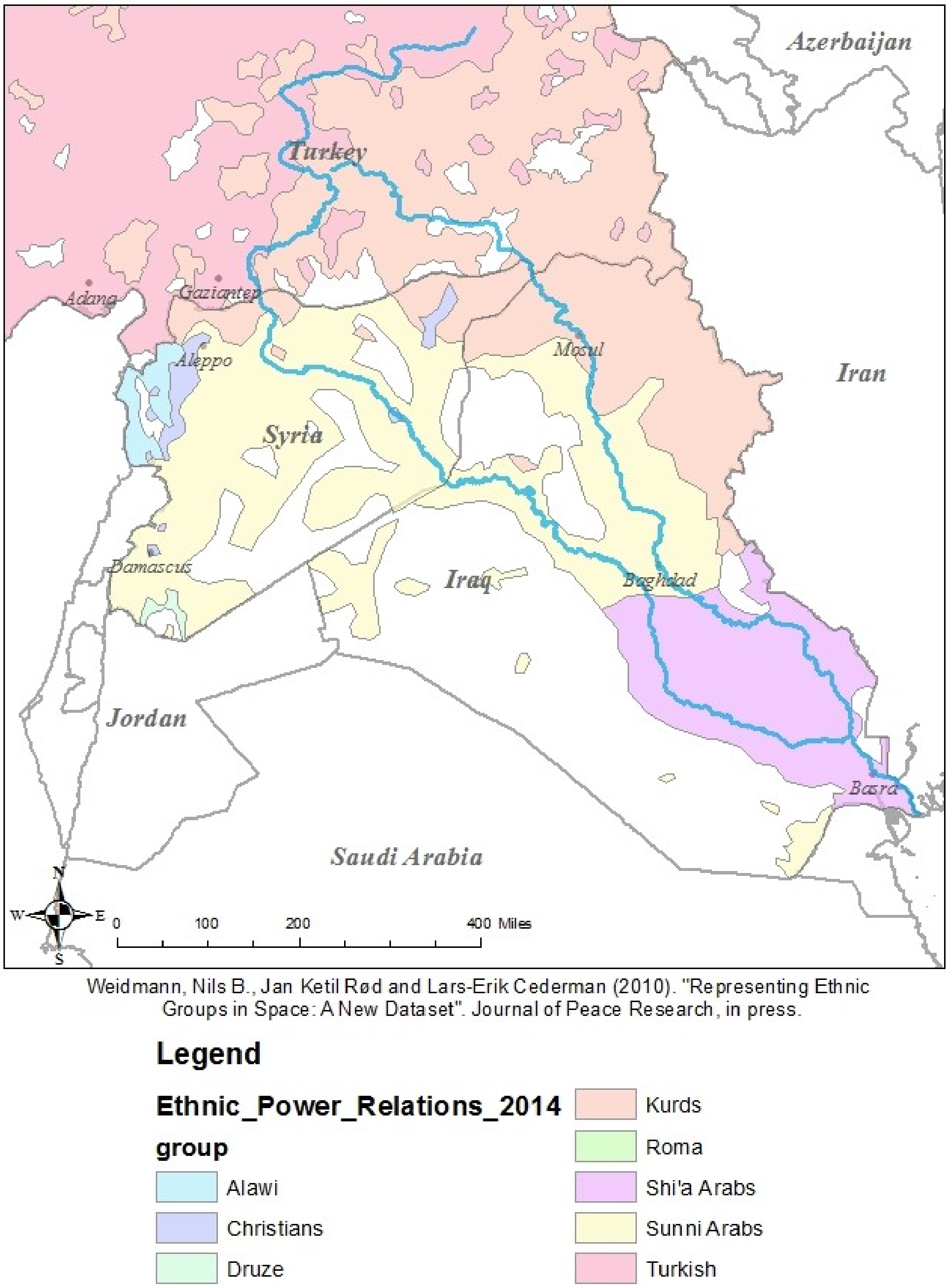
[263] Alyssa Martino, "Water scarcity is helping radicalize the Middle East," *Vice*, April 25, 2015.
[264] Freedman, "Seeds of war: Global warming helped trigger Syria's bloody civil war."
[265] U.S. Census Bureau, International Database (U.S. Census Bureau, Washington, D.C., 2014), http://census.gov/population/international/data/idb/informationGateway.php.
[266] Timothy Mitchell, *Rule of Experts; Egypt, Techno-Politics, Modernity*.
[267] Ali Massoud, *Years of drought: A report on the effects of drought on the Syrian Peninsula* (Berlin: Heinrich - Böll - Stiftung - Middle East Office, 2010).
[268] Sarah Mitchell, "Cross-Border Troubles? Interstate River Conflicts and Intrastate Violence," Department of Political Science, University of Iowa, 2014.

religious groups, many of which have extremely volatile relationships with other groups in the region (see Figure 11.10 for map of ethnic groups in the region). Because the water crisis has affected the region in varying degrees, the mass displacement and unemployment of millions of people in the face of a historic drought has incited feelings of ethnic marginalization and political discontent among the citizens in the region.

Figure 11.10.
Main Ethnic Groups in the Euphrates-Tigris Basin Region



Source: Nils B. Weidmann, Jan Ketil Rød, and Lars-Erik Cederman, "Representing ethnic groups in space: A new dataset," *Journal of Peace Research* 47 (4) (July 2010): 491-499.

For example, the majority of the inhabitants in the Euphrates-Tigris basin are ethnic Kurds, who have a long-standing animosity towards the Turkish government. Part of this animosity stems from the displacement of thousands of native Kurds during the Southeastern Anatolia Project and their subsequent treatment by the Turkish government. Between 1988 and 1997, 11,000 Kurds were displaced following the construction of the Ataturk Dam alone,[269] and up to 78,000 primarily Kurdish people were displaced with the construction of the Ilisu Dam.[270] In Syria, Sunni and Kurdish farmers who were disproportionately affected by the drought were forced into the poor living conditions of Syrian cities that were primarily controlled by the rival Alawite religion, intensifying the level of dissatisfaction within Syria's major cities.[271] Similarly in Iraq, where military and government power has shifted from Sunni to Shia control, Sunni farmers felt that they had been deprived of basic services by their new government, including access to water.[272] Eventually, Sunnis launched a rebellion against the Shia government in 2013, opening the door for non-state actors to seize large swaths of territory in the region.

The EU's regional strategy for the conflict in Syria emphasizes that "there will not be lasting peace in Syria if the specific grievances of all ethnic and religious groups are not equally addressed and the country's multi-ethnic and multi-religious character is not maintained."[273] When regional water issues are related to asymmetries between ethnic groups, the potential for widespread violent conflict is especially high.[274] Because water is not only essential for life and food but also for economic and industrial development, water scarcity is and has always been a driving factor of sectarianism, a side effect of the drought that has served as a catalyst for radical groups such as ISIS.[275] As water resources diminished and entire villages were forced to migrate, real and perceived inequalities in water, irrigation, and land allocation exacerbated sectarian tensions and contributed to the radicalization that gave rise to ISIS.

ISIS: Fueled by Water

ISIS's Prioritization of Water Infrastructure

By March 2011, civil war had officially broken out in Syria due in part to water scarcity and the effect of one of the worst droughts in the region's history. ISIS seized the opportunity to control territory in the conflicted region by joining the fight against the Assad regime. Various accounts of major ISIS battles report that ISIS's strategy to besiege a city starts with seizing control of the police and municipal buildings, followed by securing core infrastructure such as water and electricity, quickly giving them complete control over all of the resources within the region.[276] Maps of ISIS-held territory indicate that they are strategically positioning themselves along the

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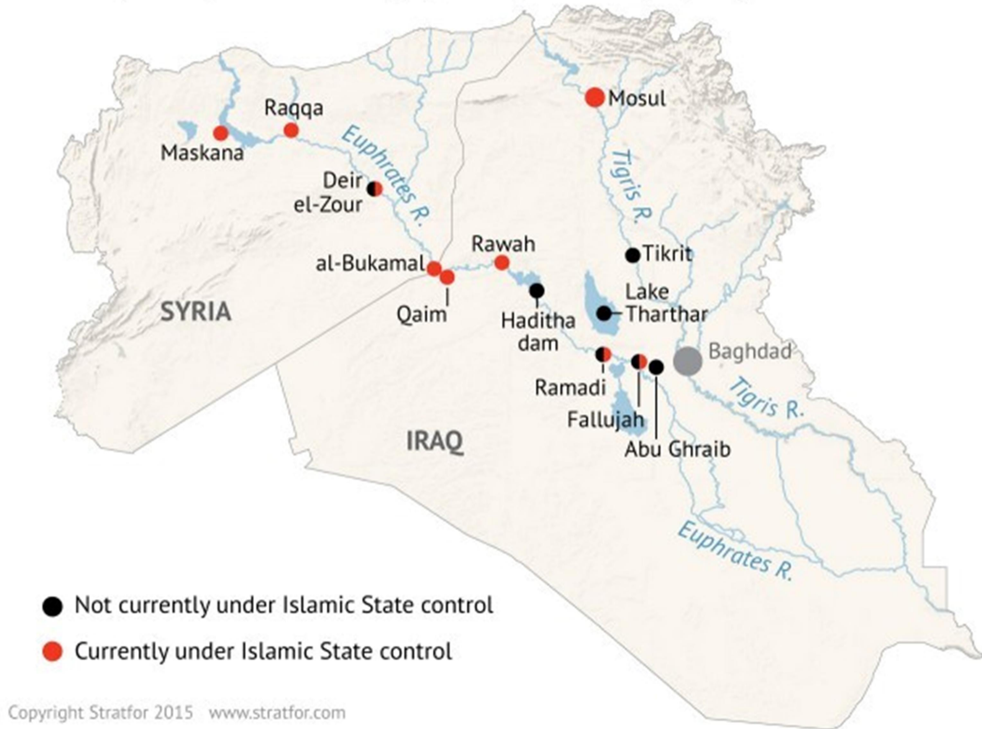
[269] Cecilia Tortajada, *Evaluation of Actual Impacts of the Ataturk Dam* (Mexico: Third World Centre for Water Management, 2002).
[270] Timothy Mitchell, *Rule of Experts; Egypt, Techno-Politics, Modernity*.
[271] Ahmed Hashim, "The Islamic State: From al-Qaeda affiliate to caliphate," *Middle East Policy* 11(4) (2014): 69-83.
[272] Ibid.
[273] European Commission, "Elements for an EU Regional Strategy for Syria and Iraq as well as the Da'Esh Threat."
[274] Timothy Mitchell, *Rule of Experts; Egypt, Techno-Politics, Modernity*.
[275] Marcus Moench, "Water and the Potential for Social Instability: Livelihoods, Migration and the Building of Society," *Natural Resources Forum* 26(3) (2002): 195-204.
[276] Hashim, 2014.

rivers in the basin (see Figures 11.11 and 11.12). Within a year of the outbreak of civil war, ISIS and Syrian rebel forces controlled most of the country's major dams, including the Tishrin Dam, the Tabqa Dam, and the Baath Dam.[277] Since 2013, ISIS has launched over 20 major attacks on Syrian and Iraqi water infrastructure.[278]

Figure 11.11
Sites of Islamic State Water Manipulation



Source: Stratfor, "The Water Wars Waged by the Islamic State," Nov. 25, 2015, https://www.stratfor.com/weekly/water-wars-waged-islamic-state. Republished with permission of Stratfor.

The Beirut Center for Middle East studies also confirmed that ISIS considers controlling the dams and rivers in the basin to be "a weapon more important than oil."[279] Once ISIS gains control over the water, they weaponize the resource by deliberately flooding towns, polluting bodies of water, destroying desalinization plants, and shutting off electricity and irrigation pipelines to the civilian populations. In 2014, for example, ISIS was able to shut down Fallujah's Nuaimiyah Dam, and the subsequent flooding destroyed 200 square kilometers of Iraqi fields and villages.[280]

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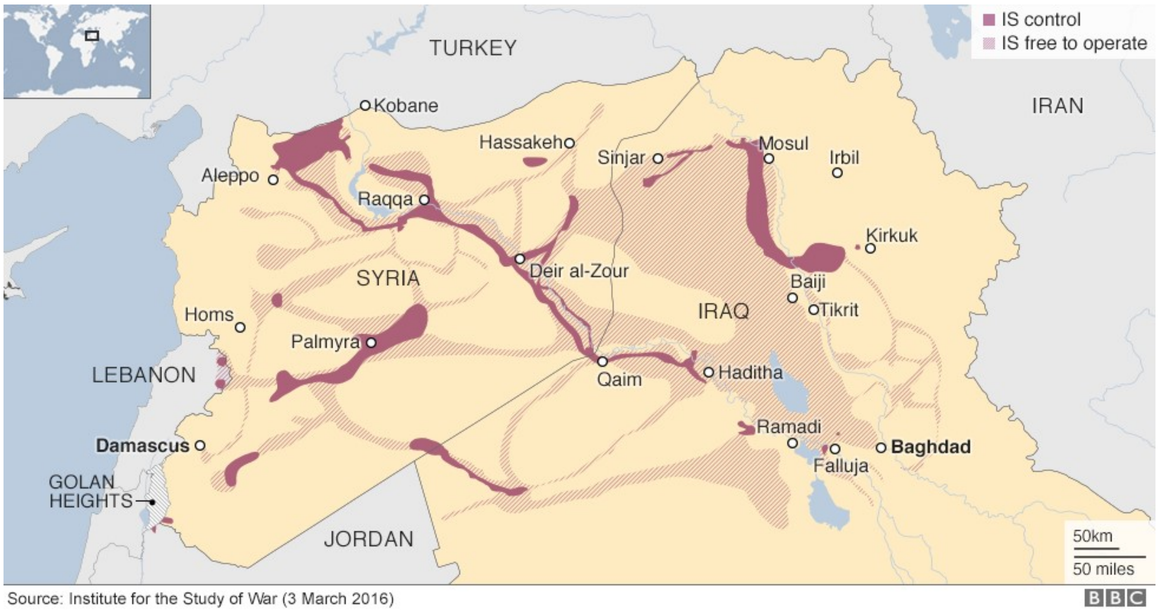
277 Hashim, 2014.
278 Ambika Vishwanath, "The Water Wars Waged by The Islamic State," *Stratfor*, November 25, 2015.
279 Walaa Hussein, "How IS Uses Water as Weapon of War", *Al-Monitor*, May 11, 2015.
280 Vishwanath, 2015.

Figure 11.12
ISIS-Controlled Territorry, 2016



Source: Institute for the Study of War, "ISIS Sanctuary Map," 2016, http://www.understandingwar.org/backgrounder/isis-sanctuary-map-july-1-2016.

Controlling the water in war-stricken Syria has also been used as a recruitment strategy for ISIS, as they utilize water provisions as a system of rewards and punishments for civilians, which enables them to hold and maintain territory far more effectively than other terrorist organizations like Al-Qaeda. Additionally, fears of potential water contamination and chemical warfare downstream are not far-fetched. In December 2014, reports came from the Balad district of Salahaddin Governorate (south of Tikrit) that ISIS deliberately contaminated water with crude oil, while reports of poisoned water supplies came from Aleppo, Deir ez-Zor, Raqqa, and Baghdad.[281]

Impact of ISIS

When ISIS took over the Ramadi Dam in 2015, the flow of water in the Euphrates River reaching Babel, Karbala, Najaf, and Qadisiyah provinces dropped below 50 percent of its normal rate and forced many the Arabs living in the Anbar province to flee.[282] The restrained flow of the Euphrates River has also had a serious impact on the southern marshlands in the Dhi Qar Province, causing large swaths of ecologically rich wetlands to be completely dried up and threatening a cholera outbreak due to increasing levels of salinization and poor sanitization.

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[281] Tobias von Lossow, "Water as weapon: IS on the Euphrates and Tigris," ISN, Center for Security Studies, *International Relations and Security Network*, February 1, 2016.
[282] Joanna Paraszczuk, "ISIS is waging a 'water war' in southern Iraq." Radio Free Europe/Radio Liberty, *Business Insider*, June 28, 2015.

UNICEF reports that the average availability of drinking water in the region has declined by 50 percent,[283] and some highly populated areas, such as Aleppo and Hamah, have seen their average water availability decline by as much as 80 percent.[284] The IAU reported that in the first six months of 2010, there were over 360,000 diarrhea cases as a result of polluted drinking water and poor hygiene practices, and 8 percent of the rural population use saline shallow village wells as a main source of drinking water.[285] With ISIS controlling virtually all of the water supply in the area, the number of casualties due to waterborne diseases is expected to increase dramatically. As a result of the threatened and polluted water supply, typhoid fever has erupted in the refugee camp of Yarmouk outside of Damascus.

Conclusion

The riparians must recognize that their inability to effectively manage their infrastructure or protect their citizens from the consequences of water shortages has played a significant role in the outbreak of conflict in the Middle East. The lack of effective oversight and management has set up the states for economic and social failure and paved the way for radical non-state actors to effectively seize and maintain territory by controlling the basic resource that is essential to all life. In order to retake the region and save the lives of millions of people, riparians must put their sovereign differences aside and cooperate on an effective and cohesive water management strategy that results in equitable and sustainable distribution. If these governments continue to debate water rights as if they were economic commodities and thereby neglect the logistics of sustainable supply and demand management, the region may never know peace.

While the consequences of resource scarcity often disproportionately affect disadvantaged and impoverished groups, "the water wars will not spare anyone." However, the main difference between waging wars over water and the current situation of fighting wars with water is that two states fighting over water have typically eventually ceded in some kind of arrangement. Even the most optimistic international diplomats cannot hope for this kind of outcome with ISIS. If Syria, Iraq, and Turkey hope to ever regain control of the region and avoid another tragedy like this in the future, they are going to have to cooperate on a cohesive, sustainable, and equitable water management strategy.

283 USAID, "Syria – Complex Emergency Fact Sheet," USAID (September 21, 2015): 1-8.
284 Ibid.
285 UN Security Council, "Report of the Secretary-General on the implementation of Security Council resolutions 2139 (2014), 2165 (2014) and 219, (2014)," Dec. 2015, http://reliefweb.int/report/syrian-arab-republic/report-secretary-general-implementation-security-council-resolutions-7.

Chapter 12. The Energy-Water-Food Nexus and the Syrian Civil War

by Ryan Brown

Introduction

The generally held belief, offered by Western media, is that the Syrian civil war and the rise of non-state actors such as ISIS were either an uprising in reaction to the brutality of the Bashar al-Assad regime or a byproduct of the 2003 U.S. invasion of Iraq. Both of these viewpoints, though partly valid, offer only a superficial look at the internal politics of Syria. There is no arguing that Syria is a failed state, but this failure was a result of the inability of Bashar al-Assad's authoritarian regime to adapt to three crises that he inherited after assuming power in 2000. First, Syria was approaching peak oil and natural gas production, and thus needed to plan for a reduction of a substantial revenue stream. Second, ineffective water policy that prioritized self-sufficiency in wheat production, rather than sustainability, depleted the water table in a drought-prone region. Third, climate change was increasing the regional frequency and intensity of drought, yet Syria did not plan accordingly. The inflexible Syrian state was subject to what has been defined as the "resource curse," where its reliance on oil wealth to provide services and maintain stability created weak institutions that promoted unsustainable energy and water policy. This chapter examines the role of energy and water policy mismanagement, which led to a myriad of internal crises including drought, famine, migration, and ultimately civil conflict.

The chapter first describes the domestic situation prior to the conflict—declining state revenues from fossil fuel extraction and simultaneously decreased access to water and depressed agricultural production. Second, the academic literature is examined to explain why weak institutions formed and how leadership continued with status quo policies rather than adapting to changing circumstances. Third, energy and water policies are studied to show how states dependent on resource wealth are unsustainable in the long run.

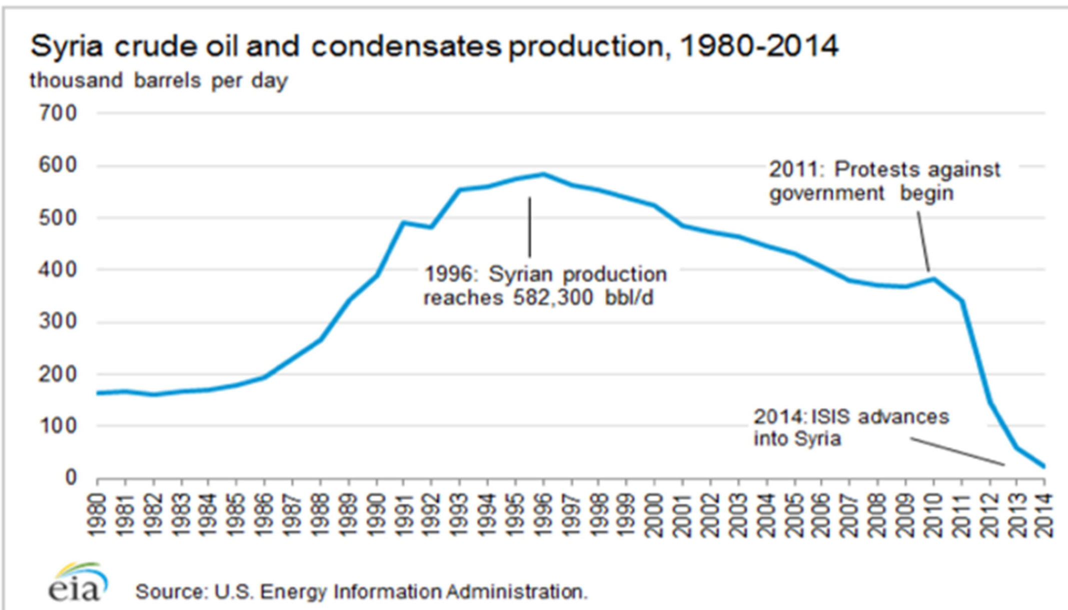
Peak Oil Production and Declining Revenues

Syrian oil production started in the 1980s and peaked at nearly 600,000 barrels per day in 1996, or 0.5 percent of world production (see Figure 12.1). Oil production follows a bell-shaped curve consistent with economic theories regarding exhaustible resources. Due to the finite nature of any resource, the rate of production grows, peaks, and then declines. The exhaustibility of a country's resources assumes that no new reserves are found and no new technology is discovered that would unlock previously unobtainable reserves.

Syria became a net oil importer in 2009. This should not have been a surprise, as a 2005 International Monetary Fund (IMF) report estimated that the state would become a net importer in 2010 and that gross revenues would peak in 2006.[286] Even though production was declining, prior to the conflict proceeds from oil exports still made up roughly a quarter of government spending, which was possible due to high prices on the world market.[287]

Starting during the regime of Bashar's father, Hafez al-Assad, oil revenues were spent on irrigation projects used to promote agricultural self-sufficiency and also to subsidize consumer goods. The state subsidized the refined petroleum product, gasoil, and also paid a production subsidy to farmers. These policies created market distortions making consumers dependent on low priced oil and farmers dependent on state purchases of agricultural production above world prices. Both policies drained foreign reserves that were obtained from the sale of fossil fuels. As oil revenues declined and population increased, continued state subsidies were no longer realistic.

Figure 12.1
Syrian Peak Oil Production



Source: U.S. Energy Information Administration (EIA), "Country Report: Syria," last updated June 2015, https://www.eia.gov/beta/international/analysis.cfm?iso=SYR.

In addition, rather than using oil revenues to diversity Syria's energy mix, the state used oil to produce electricity. This created an unsustainable domestic reliance on oil for electricity generation, which ideally would have been exported to benefit the Syrian people. As shown in

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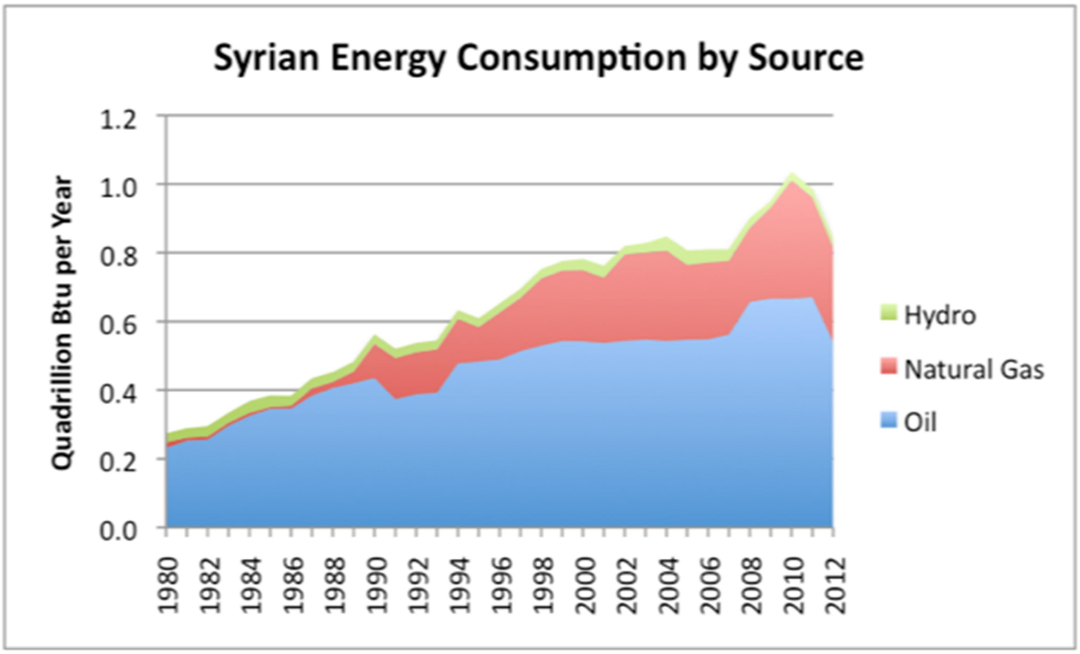
286 International Monetary Fund, "IMF Country Report No. 05/356, Syrian Arab Republic: 2005 Article IV Consultation-Staff Report; and Public Information Notice on the Executive Board Decision," October 2005, https://www.imf.org/external/pubs/ft/scr/2005/cr05356.pdf.

287 Jamal Mahamid, "Syria's frail economy, before and after the revolution," *Al Arabiya English*, April 1, 2013, http://english.alarabiya.net/en/perspective/alarabiya-studies/2013/04/01/Syria-s-frail-economy-before-and-after-the-revolution.html.

Figure 12.2, 94 percent of Syria's electricity production was fossil fuel-based. Hydroelectric power played a small role, providing about 6 percent of Syria's electricity. Beginning in the 1990s, there was some transfer to natural gas for electricity production, but this only exemplifies the inability of the state to adapt, relying once again on an exhaustible resource. Syria became a net natural gas importer in 2008.[288] Now that Syria had to import oil and natural gas to provide electricity, the state was forced to purchase fossil fuels from abroad, putting the state in debt and reducing its ability to provide services to its citizens.

Figure 12.2
Syrian Energy Mix



Source: Jamal Mahamid, "Syria's frail economy, before and after the revolution," Al Arabiya English, April 1, 2013, http://english.alarabiya.net/en/perspective/alarabiya-studies/2013/04/01/Syria-s-frail-economy-before-and-after-the-revolution.html.

2006-2010 Drought

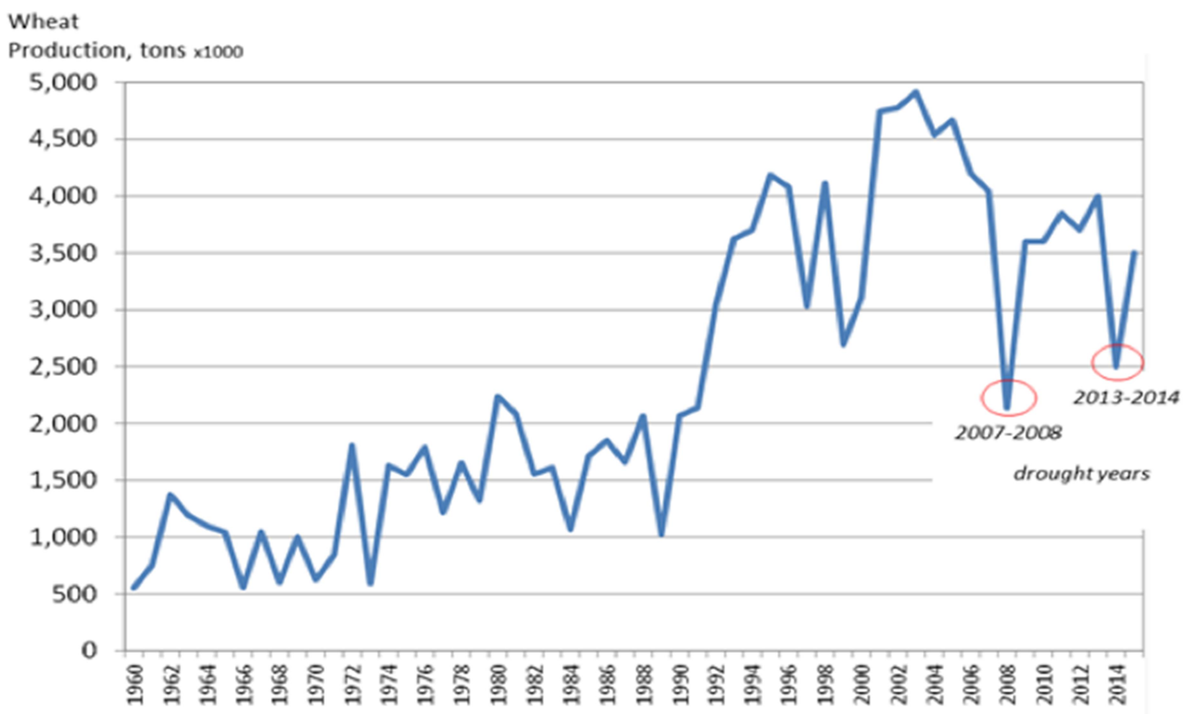
The 2006-2010 drought was the most severe in the recorded history of Syria, and preceded the beginning of the civil war.[289] Precipitation rates during this period were half of the historic long-term average.[290] The rural economy was severely affected as crops failed and much of the region's livestock died. Northeast Syria, where most of Syrian agricultural production occurred, was hit dramatically hard, with 75 percent of crops failing. A UN Food and Agricultural Organization report stated that the provinces of al-Raqqah, al-Hasakah, and Dair al-Zur were

[288] Ibid.
[289] Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian Drought."
[290] Vivian Tou'meh, "Drought exhausts affected communities in Syria," International Federation of Red Cross and Red Crescent Societies, August 19, 2014, http://reliefweb.int/report/syrian-arab-republic/drought-exhausts-affected-communities-syria.

plagued by "total crop failure" during the 2007-2008 growing season.[291] Syria's economy was crippled due to the droughts, creating substantial hardship and forcing farmers to migrate in search of employment.

Prior to 2007, agriculture accounted for 25 percent of the country's gross domestic product.[292] During the drought, farmers in the northeast region lost 90 percent of their income and 80 percent of their livestock.[293] In 2007-2008, the drought reduced yearly wheat production to 2.1 million tons, compared to the long-term average of 4.7 million (see Figure 12.3). Syria was forced to import wheat, its staple crop, for the first time in 15 years.[294] Internally displaced persons from these regions largely moved to Syria's cities, increasing the country's urban population by 20 percent and turning these cities into centers of unemployment and unrest. An estimated 1.5 million Syrians moved from rural to urban centers or left the country all together.[295]

Figure 12.3.
The Effects of Drought on Syrian Wheat Production



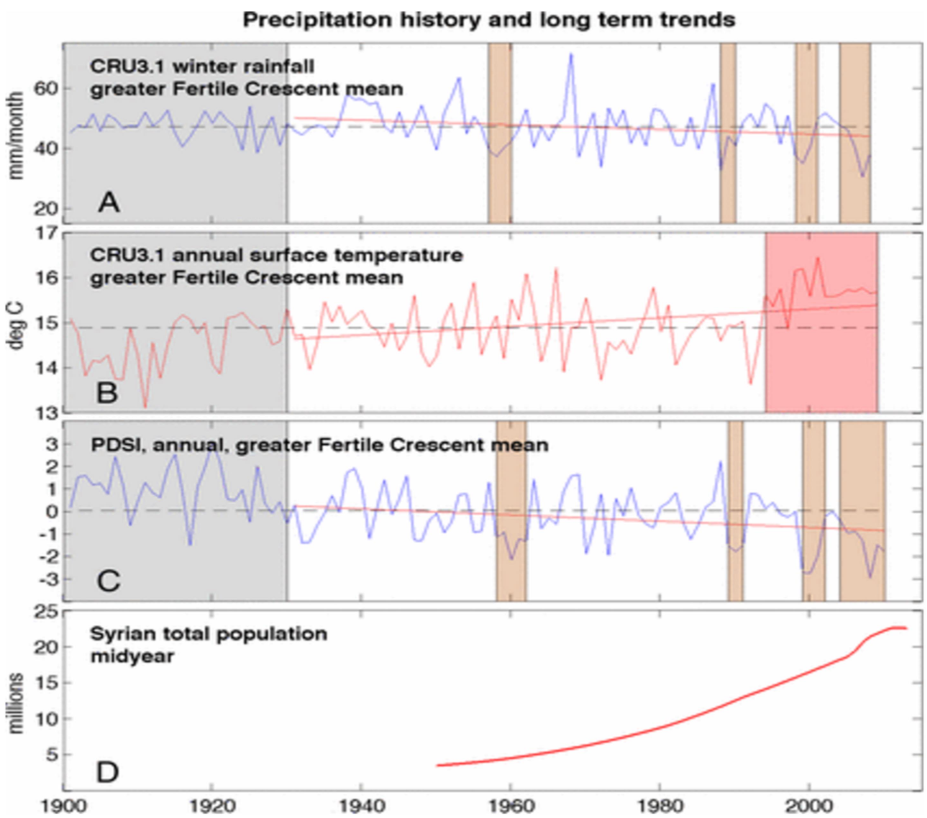
Source: United States Department of Agriculture, Foreign Agricultural Service, "Commodity Intelligence Report," July 23, 2015, http://www.pecad.fas.usda.gov/highlights/2015/07/Syria/Index.htm.

291 Fred H. Lawson, *Global Security Watch: Syria* (Santa Barbara: ABC-CLIO, 2013), 49.
292 Ibid.
293 Tou'meh, "Drought exhausts affected communities in Syria."
294 Ibid.
295 Lawson, *Global Security Watch: Syria*.

Climate Change Intensified Water Scarcity

Arid regions such as the Middle East, which are prone to drought, are increasingly at risk due to the effects of climate change. In Syria, westerly winds bringing moist air from the Mediterranean have decreased, while temperatures have increased.[296] Less moisture in the air reduces precipitation and higher temperatures increase reservoir evaporation, both of which reduce the amount of water available for human consumption or agricultural use. Figure 12.4 shows these trends culminating in a negative Palmer Drought Severity Index (PDSI), with a negative three indicating severe drought.[297] Climate change made the drought three times as likely to occur as compared to natural variability and intensified the drought's severity.[298]

Figure 11.4.
Climate Trends in the Fertile Crescent



Source: Colin P. Kelley, Shahrzad Mohtadib, Mark A. Canec, Richard Seagerc, and Yochanan Kushnir, "Climate change in the fertile crescent and implications of the recent Syrian drought," Proceedings of the National Academy of Sciences 112(11) (March 17, 2015): 3241-3246.

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[296] Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian Drought."

[297] Climate Prediction Center, National Weather Service, "Drought Indices Explanation," http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/wpdanote.shtml

[298] Kelley et al., "Climate change in the Fertile Crescent and implications of the recent Syrian Drought."

The Resource Curse and Authoritarian Regimes

An often-cited article by Jeffrey Sachs and Andrew Warner defines what is known in economic literature as the resource curse.[299] Many countries that are endowed with abundant natural resources grow slower economically than natural resource-scarce countries.[300] A variety of potential causes exist for the squandering of resource revenues, including corruption, weak institutions, and a lack of fiscal linkage to productive industries. Resource revenues are more likely to be consumed, either by corrupt or inept leadership, rather than invested properly. Often, resource revenues are used to maintain control of the citizenry instead of investing in the human or physical capital of the state.

Political scientist Michael L. Ross built upon the theory of the resource curse when he looked at the reasons why resource-rich authoritarian regimes are unlikely to become democracies. He defines the effects of resource wealth, which are discussed below and then applied to the Syrian state.

Resource-rich governments use low taxes and directed spending to maintain power and reduce calls for accountability; this can be described as the *rentier effect*.[301] The fiscally weak Syrian regime could not properly respond to the drought or declining oil production, and therefore was unable to continue to pay for consumer or production subsidies. Without the benefit of low priced consumer goods or proper access to water, the support of Syrian citizens could no longer be bought off.

States with substantial oil revenues tend to spend heavily on internal security, using coercion to control its people. Ross defines this as the repression effect. States that are dependent on oil revenues are prone to instability when oil production dips. The market distortions, created by unsustainable policies, create dependency and once government revenues can no longer fund state-sponsored programs, the dependency turns to desperation and eventual civil unrest. The authoritarian state must then resort to coercive force to maintain power.[302]

Syria also suffered from the modernization effect, where resource-rich states do not invest in the social or cultural changes required for proper development. These changes would include occupational specialization, urbanization, and education.[303] Production subsidies in the agricultural sectors reduce the likelihood for these changes to occur. For example, these subsidies motivated Syrians to go into the agricultural sector because they were paid higher than world market price for their production, and thus were not motivated to learn other trades or move to urban areas. In addition, children are likely to be put to work in the field rather than sent to school in this situation. Overall, these agricultural subsidies stunted the development of the Syrian economy.

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[299] Jeffrey D. Sachs and Andrew M. Warner, "The Curse of Natural Resources," *European Economic Review* 45 (2001): 827-838.

[300] Jeffrey D. Sachs and Andrew M. Warner, "Natural Resource Abundance and Economic Growth, Working Paper 5398," December 1995, National Bureau of Economic Research, http://www.nber.org/papers/w5398.

[301] Michael L. Ross, "Does Oil Hinder Democracy?" *World Politics* 53 (2001): 325-361.

[302] Ibid.

[303] Ibid.

The following sections will look at the ineffective policies aimed to maintain the rentier effect and how those policies hastened the decline of the Syrian state, eventually forcing the regime to use violence to maintain control.

Promotion of Agricultural Self Sufficiency led to Water Scarcity

The Syrian economy has traditionally been agricultural, and 90 percent of the state's water is used in irrigation.[304] When oil production took off in the 1980s, the regime of Hafez al-Assad chose to invest to increase agricultural production with the hope of attaining food self-sufficiency. State policies directed toward the agricultural sector made sense politically, as rural citizens, who worked in this sector, made up the base of Ba'ath party power.[305]

The water scarcity of Syria is largely a result of Ba'ath party policies promoting food self-sufficiency via the expansion of irrigation.[306] These policies served the short-run goal of maintaining the Ba'ath party's base of power, but in the long run, unsustainable water policy produced drought and hardship for those involved in agriculture. Simply put, the goal of food self-sufficiency produced a negative externality: water scarcity.

In addition, the Ba'ath party's focus on subsidizing and promoting agriculture produced a culture of dependence, where farmers relied on state assistance to maintain their livelihoods. The culture of dependence was inherent in the creation of a civil society based solely on promoting agriculture policy. The government created a pro-Ba'ath sub-elite, called the Peasants' Union, which was able to mobilize the rural areas. This group lobbied for support of the agricultural sector and even campaigned against groundwater pumping limitations.[307] The current Assad regime was caught in a dilemma when it promoted unsustainable water management in order to keep the support of the Peasants' Union, but over the long run, these same policies magnified water quantity issues and worsened the poverty in rural areas.

The policies of both the current and former Assad regimes laid the groundwork for the humanitarian crisis. The other states in the region were able to adapt to the change in water availability, and large-scale migration and malnutrition happened only in Syria.[308] Fifty years of unsustainable water management created a situation where the state could not respond properly to the drought.

Strategic Crop Subsidies

Syria sets prices and quantities of seven "strategic crops" including wheat, barley, cotton, sugar beet, tobacco, and lentils. The state buys these goods from domestic producers above the world

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[304] Jessica Barnes, "Managing the Waters of Ba'ath Country: The Politics of Water Scarcity in Syria," *Geopolitics* 14 (2009): 510-530.
[305] Aysegül Kibaroğlu and Sezin Iba Gürsoy, "Water-energy-food nexus in a transboundary context: the Euphrates-Tigris river basin as a case study," *Water International* 40 (2015): 824-838.
[306] Barnes, "Managing the Waters of Ba'ath Country: The Politics of Water Scarcity in Syria."
[307] Ibid.
[308] Francesca De Chatel, "The Role of Drought and Climate Change in the Syrian Uprising: Untangling the Triggers of Revolution," *Middle Eastern Studies* 50 (2014): 521-535.

market price in order to increase production and promote self-sufficiency.[309] For example, the state will pay farmers 60 percent above the world price for its main staple crop, wheat.[310] This policy promoted wheat production and successfully achieved self-sufficiency in the country's staple crop, but the long-term effects of such a market distortion were water table depletion and an agricultural sector reliant on subsidies funded by an exhaustible resource.

The inability to respond to the reduction in annual precipitation was due to a tradition of unsustainable water policy featuring unregulated water table access and large-scale state irrigation projects. Syria subsidized the production of many strategic crops in order to create self-sufficiency and increase production, depleting the water table in the process. Further, the state subsidized the price of domestically consumed oil, promoting increased pumping of groundwater. The effects of climate change further magnified the effects of the drought. The natural occurrence of drought in the region was intensified by unsustainable water policy by Syria coupled with the natural process of desertification, a result of climate change.

Removal of Gasoil Subsidies

The Syrian state subsidized the price of its domestically consumed petroleum product, gasoil. It is used for transportation, heating, and agricultural purposes. These subsidies kept fuel prices low for Syrian citizens but created a dependence on low price oil that was difficult to break after oil production dropped since its peak in 1996. The Assad regime has been forced to spend its foreign reserves to maintain price stability in order to mitigate civil unrest, but in the context of declining oil revenues, the policy was unsustainable.

Syria made efforts to reduce gasoil subsidies in order to aid the budget shortfall and liberalize the economy preparing for WTO accession. In 2008, the state tripled the price of gasoil from US$0.15 to US$0.45 per liter, while the Syrian state imported the refined product for $1 per liter, costing the state US$9 billion per year.[311] To put this number in perspective, the Syrian GDP in 2007 was only $40 billion.[312] The gasoil subsidy alone cost the Syrian government nearly a fourth of its GDP. In addition, the subsidized gasoil price created a black market for smuggling the product to neighboring states, such as Lebanon.[313] The Syrian government then increased the price of state-provided gasoil hoping to provide the state with more fiscal security while also reducing the motivation for black market operations.

Higher gasoil prices were a hardship for the average Syrian citizen and potentially lead to unrest. The government hoped to aid in the cost of this vital living expense by raising public sector salaries by 25 percent.[314] The agricultural sector was particularly susceptible to a price increase as gasoil is used for irrigation pumps and transport of produce. In response, the Assad regime

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309 Barnes, "Managing the Waters of Ba'ath Country: The Politics of Water Scarcity in Syria."
310 Ibid.
311 Khaled Yacoub Oweis, "Syria slashes oil gas subsidy, tripling price," *Reuters*, May 3, 2008, http://www.reuters.com/article/us-syria-subsidies-idUSL0319586220080503.
312 The World Bank, "Syrian Arab Republic, Data," http://data.worldbank.org/country/syrian-arab-republic.
313 Alexander's Gas & Oil Connections, "Syria can no longer afford fuel subsidy," December 15, 2007, http://www.gasandoil.com/news/2008/01/ntm80365,.
314 Oweis, "Syria slashes oil gas subsidy, tripling price."

announced that it would increase production subsidies for strategic crops, such as wheat and cotton.[315] In 2009, direct cash transfers by the Agricultural Support Fund mitigated the impacts of the increase in gasoil price and the liberalization of Syria's fertilizer market.[316] The Assad regime attempted to reduce the market distortions in the gasoil market but furthered government intervention in the labor and strategic crop markets. These are the actions of a regime desperately hoping to maintain power.

Conclusion

The Syrian state was highly reliant on oil proceeds to maintain control. The state used fossil fuel revenues to subsidize consumer goods rather than creating sustainable energy and water policies. A reduction in revenues due to peak oil production made state subsidies unsustainable. Investments in irrigation and production subsidies to promote self-sufficiency in wheat production depleted water tables. This depletion coupled with the effects of climate change led to a crippling drought causing famine and internal instability. The state responded with violence because it was unable to continue with policies used to maintain control.

After taking control in 1999, the Bashar al-Assad regime should have invested in sustainable energy production and realistic water management, but this was not possible due to the weak institutions and corrupt practices typical of resource-rich authoritarian states. In the short run, the state was able to maintain control, but over the long term, it was inevitable that the state would fail. Currently, oil and natural gas extraction are almost non-existent and overcrowded urban centers are even less likely to provide access to food and water for their residents. Today, this failed regime faces a loss of autonomy to external forces, such as Russia and Iran, or the threat to be overthrown by non-state actors such as ISIS.

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[315] Ibid.

[316] International Monetary Fund, "Syrian Arab Republic: 2009 Article IV Consultation-Staff Report; and Public Information Notice," IMF Country Report: Syria No. 10/86, March 2010, http://www.imf.org/external/pubs/ft/scr/2010/cr1086.pdf.

Chapter 13. Shifting Demographics as a Result of Dam Construction in Southeast Turkey

by Rachel Weinheimer

Introduction and Problem Statement

The Southeastern Anatolia Project (in Turkish, *Güneydoğu Anadolu Projesi* or GAP) was started in 1976 and has yet to reach full completion. The primary objective of this system of 22 dams was to generate hydroelectric power to most of Turkey and irrigate 1.7 million hectares of land in Turkey's most underdeveloped region. The construction of these dams saw sizeable shifts in Turkey's population, both in terms of populations displaced due to flooding and those attracted to the massive project seeking work.

This chapter explores various aspects of the effects on the population in Southeast Turkey caused by the dam. The demographics of the region are mapped and then correlated to provinces that experienced the most impact. One of the cornerstones of the analysis in this project involved correlating population decrease and growth within a given time period (1990-2010) in the dam region. As part of this analysis, rural and urban demographic shifts are also calculated.

Has the region witnessed an increase or decrease in population since the beginning of GAP construction in the early 1990s? The hypothesis is that the region decreased in population, which would indicate a negative correlation between the dam projects in Southeast Turkey and the economic success of dams in the region.

Southeast Region of Turkey

Turkey has a population of approximately 78 million people.[317] Out of this total, approximately 8.25 million people live in Turkey's Southeast Anatolia Region. Figure 13.1 shows the nine provinces in Southeast Turkey where GAP is located. Several provinces lie on the international border between Syria and/or Iraq.

Turkey does not collect statistics on the ethnicity or identity of its population, but it's well known that this area is home to a mix of Kurdish, Turkish, and Arabic populations.[318] It's important to note that the majority of Kurds also identify as Turks and most are fully conversant in Turkish, which is the official language of Turkey. In order to approximate Kurdish ethnic identity within Turkey, a map was constructed with recent (June 2015) voting data depicting the percentage of people at the provincial level who voted for Peoples' Democratic Party (in Turkish, *Halkların Demokratik Partisi* or HDP). The HDP represents a left-wing party that sympathizes with minority and Kurdish issues. As can be seen in Figure 13.2, the HDP's voting base is concentrated exclusively in Turkey's Southeast. It follows that the GAP region is

[317] Turkish Statistical Institute, "Main Statistics; Populations Statistics; Population of Provinces by Years" (Excel file), accessed May 2016, http://www.turkstat.gov.tr/Start.do.
[318] Helen Chapin Metz, ed. *Turkey: A Country Study* (Washington, D.C.: GPO for the Library of Congress, 1995).

primarily located within Kurdish-majority areas, but the Kurdish population extends beyond the provinces of the GAP region.

Figure 13.1.
Southeastern Anatolia Project Provinces, Turkey

Source: Created by author.

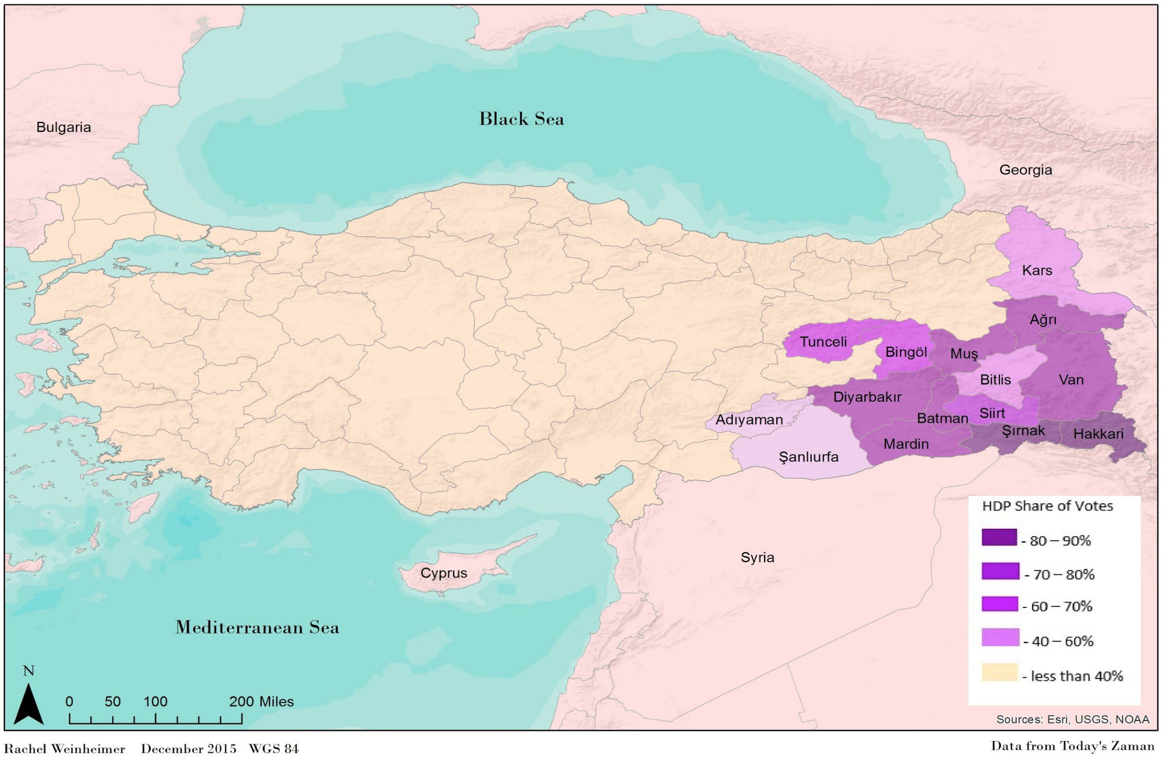
Shifting Demographics

Figure 13.3 displays Turkey's shifts in demographics during the two-decade period when dam construction was most active. The map shows percent changes in population between 1990 and 2010, when dam-building had the most impact on the region.[319] During these two decades, the GAP region experienced a dramatic growth in population. Turkey's major western cities (Istanbul, Antalya, Izmir, and Bursa) also experienced exceptional growth during this period.

Table 13.1 is a graphical presentation of Figure 13.3. Since data was not available below the provincial labels, this table was constructed to include shifts from rural to urban populations during Turkey's dam-building period in the provinces most impacted by the GAP.

[319] It should also be noted that although the dam-building regime continues to impact this region, the map and table only take into account the population up to the year 2010. Beginning in 2011, neighboring Syria devolved into civil war, which caused millions to flee from violence. At the time of this writing, Turkey has accepted over 2.5 million refugees, many of whom were settled in refugee camps in the provinces of Gaziantep and Kilis, which would encompass the GAP region.

Figure 13.2.
June 2015 HDP Election Results

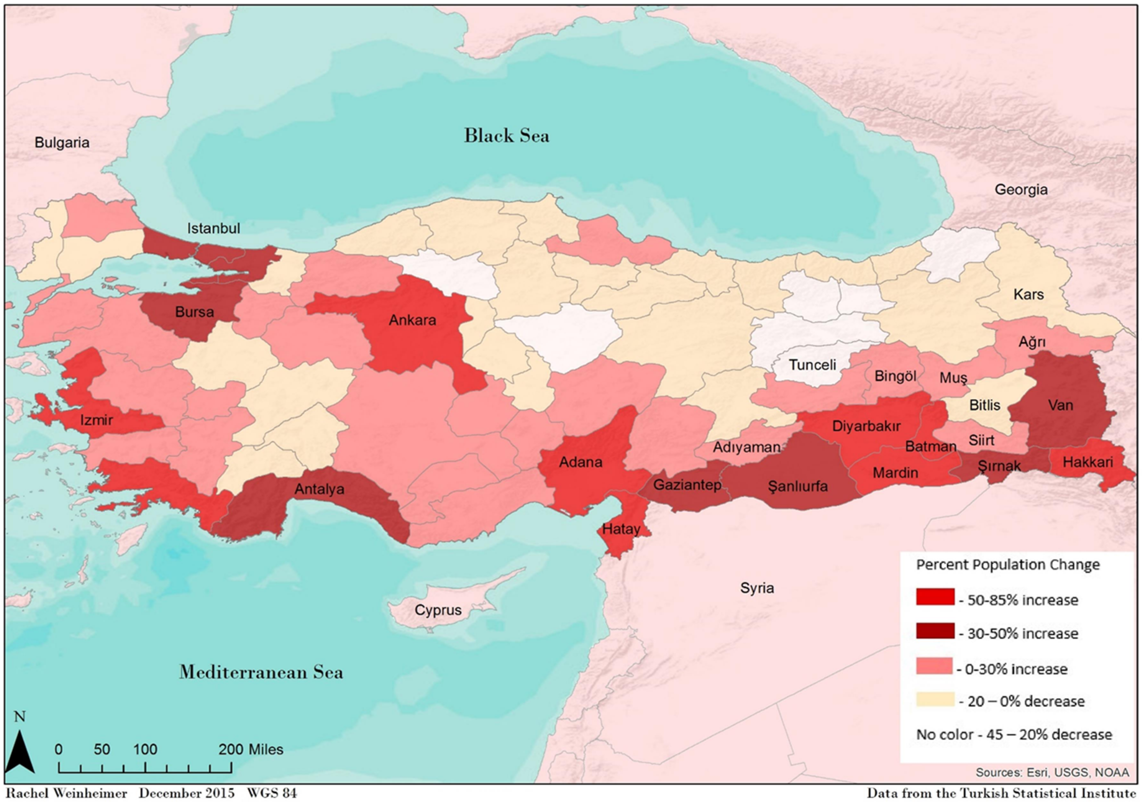


Source: Created by author.

Though Table 13.1 captures the trends of Turkish population growth and urbanization, this is not to say that growth or decline can be solely attributed to the dam project. Of particular note is civilian displacement due to violence in Turkey's southeast. From August 1984 until the present, Turkey has experienced waves of internal violence attributed to clashes between Turkish Security Forces and the separatist guerilla movement *Partia Karkaren Kurdistan* (PKK).[320] Residents in the southeast are commonly caught in the crossfire of either police or terrorist violence, and an estimated two million civilians were displaced in the early 1990s.[321] These populations were often forced from their homes and fled to larger cities (both in the southeast and Turkey's west), which would also affect the urban to rural shift. These trends are well-documented in contemporary Turkish press and government statements.[322,323]

[320] Christopher Panico, "Forced Displacement of Ethnic Kurds From Southeastern Turkey," *Human Rights Watch/Helsinki* 6(12) (October 1994), https://www.hrw.org/sites/default/files/reports/TURKEY94O.PDF.
[321] Ibid.
[322] Kenneth Katzmann, "Terrorism: Middle Eastern Groups and State Sponsors," CRS Report for Congress, August 1998, http://www.globalsecurity.org/intell/library/reports/crs/Cterror2.htm.
[323] U.S. Congress, Commission on Security and Cooperation in Europe, "Situation of Kurds in Turkey, Iraq and Iran: Briefing of the commission on security and cooperation in Europe" (Washington, D.C.: Commission on Security and Cooperation in Europe*,* 1993).

Figure 13.3
Percent Population Change 1990-2010



Source: Created by author.

Table 13.1.
Shifts in Population 1990-2010

	Total 1990	Urban 1990	Rural 1990	Total 2010	Urban 2010	Rural 2010	Total Change (%)	Urban Change (%)	Rural Change (%)
Adıyaman	513,131	219,304	293,827	590,935	347,236	243,699	15	58	-17
Şanlıurfa	1,001,455	551,124	450,331	1,663,371	922,539	740,832	66	67	65
Mardin	557,727	249,032	308,685	744,606	428,899	315,707	34	72	2
Gaziantep	1,140,594	821,127	319,467	1,823,898	1,587,489	236,409	60	93	-26
Siirt	243,435	110,139	133,296	300,695	181,410	119,285	24	65	-11
Diyarbakır	1,094,996	600,640	494,356	1,528,958	1,090,172	438,786	40	82	-11
Turkey	56,473,035	33,326,351	23,146,684	73,722,988	56,222,356	12,500,632	31	69	-24

Source: Turkish Statistical Institute, "Main Statistics; Populations Statistics; Population of Provinces by Years" (Excel file), accessed May 2016, http://www.turkstat.gov.tr/Start.do.

Connecting Demographic Shifts to the Dam Project

Due to the dams, there was also a dramatic shift in the physical environment of Southeast Turkey, specifically in terms of land use and land cover. The photographs in Figures 3.5 and 3.6 in Chapter 3 show how the construction of the Atatürk Dam altered the landscape of the adjacent area from 1993 to 2002, creating fertile land for irrigation known as the Harran Plains.

In general, populations tended to increase in areas that enjoy higher percentages of irrigated lands, compared to rates prior to dam construction. Though it can be argued that the dams promote agricultural expansion, the inverse could reasonably be expected to be true, in that population growth was driven by agricultural expansion. The accepted theory is summarized by Meyer and Turner:

> "...given sustained growth in population, agricultural land use expands and intensifies, involving conversion and modification of land cover. Sustained population decline has the opposite effect. The lessons are that agricultural land uses and covers have much to do with the character of the economy, but that a key element of demand in the economy is the level of population."[324]

In Turkey's case, those settled in irrigation areas gained the most, while those living in the future reservoir area were forced to move. The government offered cash or land as compensation, and the vast majority chose cash.[325]

Demographic Engineering

Demographic engineering is defined as the state-directed movement of ethnic groups.[326] The motivations for these actions vary; some have no qualitative component, such as instances of resettlement after a natural disaster. Others involve state-directed expulsions against the will of certain populations, such as ethnic or religious minorities. The means vary as well, and can involve both incentives (land, cash, jobs) or forced expulsion.

Turkey's GAP has been accused in both print media and academic articles of engendering a component of demographic engineering. The widely-publicized story of Hasankeyf, a Kurdish-majority town with historical significance slated to be flooded by the end of the Ilısu project's (the final component of the GAP) completion, illustrates this point. Though the flooding of Hasankeyf remains a deeply controversial issue and appears frequently in Turkish and international headlines,[327] demographic engineering does not appear to be the primary purpose of

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[324] William B. Meyer and B. L. Turner II, "Human Population Growth and Global Land-Use/Cover Change," *Annual Review of Ecology and Systematics* 23(1) (1992): 55.

[325] Ryo Fujikura and Mikiyasu Nakayama, "The long-term impacts of resettlement programmes resulting from dam construction projects in Indonesia, Japan, Laos, Sri Lanka and Turkey: A comparison of land-for-land and cash compensation schemes," *International Journal of Water Resources Development* 29(1) (2013): 4-13.

[326] John McGarry, "'Demographic Engineering': The state-directed movement of ethnic groups as a technique of conflict regulation," *Ethnic and Racial Studies* 21(4) (June 1998): 613-638.

[327] Harte, Julia, "New Dam in Turkey Threatens to Flood Ancient City and Archaeological Sites," *National Geographic*, February 2014, http://news.nationalgeographic.com/news/2014/02/140221-tigris-river-dam-hasankeyf-turkey-iraq-water/

the GAP. Though arguments have been published that the flooded reservoir sites will disrupt PKK logistics and movement,[328] economic development remains the primary purpose of the dam regime. That said, the PKK has used terror tactics to slow or halt the completion of the Ilısu dam and little progress is currently being made on the project due to regional violence and security threats.[329]

Conclusion

Mapping of the GAP region shows that Turkey experienced sizeable population shifts during the two-decade period of dam construction. Despite an uptick in regional violence during this time, Turkey's southeast experienced population growth and urbanization. This disproves my initial hypothesis. In future studies, Turkey's urbanization trends could be further analyzed in order to deduce possible explanations for these trends. Field research and the use of surveys, in particular, would benefit the current body of literature that exists on this topic.

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[328] Yavuz, Ramazan, "PKK'ya karşı planlanan o barajlardan ikisi tamam," *Milliyet,* October 26, 2011, http://www.milliyet.com.tr/pkk-ya-karsi-planlanan-o-barajlardan-ikisi-tamam-/gundem/gundemdetay/26.10.2011/1455488/default.htm.

[329] Agence France-Presse, "Kurdish militants threaten to attack Turkey dams," July 12, 2015, http://news.yahoo.com/kurdish-militants-threaten-attack-turkey-dams-134949094.html.

Chapter 14. Alternative Irrigation Management Practices in the Euphrates-Tigris basin of Turkey

by Melissa Stelter

This chapter reviews current irrigation management practices in the Euphrates-Tigris river basin of Turkey and discusses other management tools that could be implemented in this region. The lessons learned from various regions of Turkey and case studies from other countries are applied to the Tigris-Euphrates basin. This information helps to develop an equitable and efficient plan to price water in a way that accounts for the economic best use of water and encourages farmers to conserve water while cultivating crops for which they have a competitive advantage in the global market.

Background

Geography of the Euphrates-Tigris Basin

Both the Euphrates and the Tigris Rivers originate in Eastern Turkey. The Euphrates is fed by snowpack in the mountainous region between the Black Sea and Lake Van and its river basin covers 879,790 square kilometers, 22 percent of which is located within Turkey. The river forms from the confluence of the Murat and Karasu tributaries. Downstream, after joining the Tigris River, both form the Shatt Al-Arab River, which drains into the Persian Gulf.[330]

History

The Euphrates-Tigris river basin is managed by the General Directorate of State Hydraulics Works (DSI). Its functions gained in importance from the GAP project. The DSI was created in 1954 to manage both hydropower and irrigation water. The GAP project was established in 1977 to develop the water resources of the southeast Anatolia region to improve social welfare. GAP led to the construction of 22 dams and 1.8 million hectares of irrigated land in the region.[331]

In the early 1960s the DSI began transferring the management of irrigation schemes and fee collection to local irrigation districts or water user associations. The transfer rates accelerated in the 1990s and it has since been found that irrigation managed by local water user associations or irrigation districts have more success in assessing and collecting fees.[332] This element of local management is important to policy and administrative decisions because the fees assessed to farmers are determined by each water user association and the revenues are allocated in different ways.

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330 FAO, "Eurphrates-Tigris Basin," March 1, 2016, http://www.fao.org/nr/water/aquastat/basins/euphrates-tigris/index.stm, (2009).
331 T. Özhan, "New Action Plan for Southeastern Turkey," *SETA 10* (2012).
332 B. Cakmak, A. Kibaroğlu, B. Kendirli and Z. Gokalp, "Assessment of the irrigation performance of transferred schemes in Turkey: A case study analysis," *Irrigation and Drainage* 59(2) (2010): 138-149.

Benefits

The rapid construction of dams and expansion of irrigation networks has proven successful as 65 percent of villages in the Şanlıurfa-Harran Plains region increased their income while non-irrigating villages saw only a 46 percent increase in income. Miyata and Fujii also found that villages with irrigation saw an increase in their access to different types of food, that women had more leisure time, and that villages with irrigation were more likely to grow high-value crops like cotton.[333] These improvements in social welfare, income, and health are one important result of the GAP program.

Necessity, Challenges, and Considerations

Irrigation in Southeast Turkey is necessary because the majority of rain falls from October to March, outside of the summer growing season. These irrigation services are not free of charge to the farmers; Turkey currently attempts to cover the costs of operations and management through a fee, based on crop type and the amount of land in production. However, fees are thought to fall short in covering the costs by about ten dollars per decar. In addition to raising inadequate funds, this method does not promote the economical use of water or efficient on-farm water applications.[334] Despite concerns about revenue shortfalls, farmers are seeing their profit margins decrease as water prices are increasing in proportion to their declining income. Due to this, they are less likely to invest in better irrigation infrastructure that could both boost water use efficiency and farmer incomes.[335]

To further increase the conflicting interests of farmer welfare and economic efficiency, there have been decreases in stream flows and less precipitation resulting in reduced groundwater recharges[336] while water use per capita has increased from 98 liters per day to 270 liters per day in the last two decades.[337] Compounding the issue of increased water-use-per-capita, the population of Turkey is growing at 2.2 percent per year and the estimated population in 2025 will exceed 91 million people.[338] The diminishing water resources, increasing demand, growing population, and the tremendous benefits of irrigation necessitate government intervention to protect this resource and ensure that it is utilized to increase the welfare of farmers. To address these issues, I will review different policy options to balance these multiple and incongruent goals.

When considering what plans to implement, there are several issues to consider. The Agriculture Reform Implementation Project removed some supports for farmers that resulted in higher fertilizer costs and subsequently less fertilizer use. Cultivated area declined and, as profits fell,

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333 S. Miyata and T. Fujii, "Examining the socioeconomic impacts of irrigation in the Southeast Anatolia Region of Turkey," *Agricultural Water Management* 88(1-3) (2007): 247-252.

334 O. Ünver and R. K. Gupta, "Water Pricing: Issues and Options in Turkey," *International Journal of Water Resources Development*, 19: 2 (2003): 311–330.

335 B. Çakmak, M. Beyríbey and S. Kodal, "Irrigation Water Pricing in Water User Associations, Turkey," *International Journal of Water Resources Development* 20(1) (2004): 113-124.

336 S. Topcu, "Water for agriculture: a major and inefficient consumer," in *Turkey's Water Policy*, Aysegül Kibaroğlu et al., eds. (Heidelberg: Springer, 2011): 93-116.

337 Miyata and Fujii, "Examining the socioeconomic impacts of irrigation."

338 Çakmak, M. Beyríbey and S. Kodal, "Irrigation Water Pricing in Water User Associations."

farmers began using traction (livestock or manual labor to plow fields) over machinery to cultivate their fields. This has resulted in increased poverty rates in the rural regions of the Southeast. While a change in irrigation policy cannot address the effects of the Agriculture Reform Implementation Program, it is essential to protect the revenue of small farmers. In addition to concerns about farmer welfare, the water used for irrigation is also used in hydroelectric energy production.[339] Water releases from dams on the Euphrates-Tigris River are influenced by the country's energy needs and so at time there may be too much or too little water supplied to farmers.[340] These issues further emphasize the need for more efficient irrigation techniques and management practices.

Current Practices

A survey conducted on the GAP region by Aksit and Akcay provides background information on current practices and how they are viewed by farmers. At present, 22.6 percent of farmers use sprinkler irrigation,[341] which is 75-85 percent efficient.[342] They use this more expensive but efficient form of irrigation because they are required to do so by the DSI. Of those that didn't use sprinkler irrigation, about 6.2 percent used flood irrigation, 29.4 percent used furrows, and 41.8 percent used basin irrigation. The traditional irrigation methods (basin and flood) were employed for several reasons. Farmers typically lacked level land or equipment to level their land as is required for more sophisticated irrigation techniques, so it saved labor to utilize these less efficient but more easily implemented irrigation schemes. Farmers also didn't know that these methods improved yields over non-irrigated farming. However, of those who irrigated, only 18.3 percent learned how to do so from an extension agent, indicating that there is a dearth of irrigation knowledge in these villages.[343]

On average, farmers spent between one-third to one-fourth of their total expenditures on irrigation costs and only 38 percent felt that these charges were too high; 21 percent stated this was fair, and 41 percent stated that prices were too low. When discussing the collection of payments and the consequences of late payments, 37.5 percent felt that, in the case of late payments, the water supply should be stopped; 38.1 percent suggested high fines and 9 percent suggested that the land be confiscated. Compared to the current 10 percent late fee, these consequences are very harsh, but stricter punishments for late payments could improve efficiency. When asked about how water should be charged, 96 percent approved of the current method, which is based on the size of the land and the crop type, and only 3.4 percent approved of volumetric charges.[344]

[339] H. Lemel, "Hurdles in Confronting the World Food Crisis: Underutilization of Irrigation Infrastructure in Turkey," *African and Asian Studies* 8 (2009).
[340] C. Koç, "A Study On The Role And Importance Of Irrigation Management In Integrated River Basin Management," *Environmental Monitoring and Assessment*, 187(8) (2015): 488.
[341] B. Aksit and A.A. Akcay, "Socioculturels Aspects of Irrigation Practices In South-Eastern Turkey," *Water Resources Development* 13(4) (1997): 523-540.
[342] A. Ertek and H. Yilmaz, "The Agricultural Perspective On Water Conservation In Turkey," *Agricultural Water Management*, 143 (2014): 151-158.
[343] Aksit and Akcay, "Sociocultural Aspects of Irrigation Practices In South-Eastern Turkey."
[344] Ibid.

The survey provides good insight into the current practices and perceptions of farmers. Farmers typically adopt more efficient irrigation techniques if they are required to do so by the DSI, they are willing to pay more for their water, and are supportive of harsher penalties for late payments. However, they are lacking adequate education on irrigation methods and are skeptical of volume-based pricing. These insights will guide my selection of different policy tools.

Proposed Solutions

Agriculture Extension

The first need to be addressed is the lack of education about different irrigation techniques. The survey by Aksit and Akcay provides excellent information about how farmers learn about irrigation, and offers guidance as to what type of extension support the farmers are seeking. The results indicate that the majority would prefer training (44 percent) and field demonstrations (39 percent) while only 2.9 percent would like written materials or information delivered via television. Approximately 11.2 percent would like a combination of these services. Most farmers would prefer training during the winter (48.4 percent) which is a convenient time compared to summer (19.2 percent), spring (14.3 percent), or autumn (4.8 percent). One troubling result is that 84 percent agree that women should not be trained and that only male children should benefit from extension services (91 percent).[345] As with the low support for volumetric-based pricing, this might be an area where the ideal decision does not have popular support. While the men who responded to these surveys might prefer for women to not be included in extension programs, these services should be available to all citizens in the region. An increase in extension programs will not likely lead to an increase of pressurized (drip or sprinkler) irrigation, but it will provide farmers with accurate information. These irrigation extension programs, in tandem with other interventions, will ensure that individual farmers properly implement new irrigation techniques.

Water Pricing

In addition to providing more agriculture extension services to educate farmers, I will review the effects of water pricing and subsidies to improve irrigation technology as means for promoting water conservation and aiding farmers. Ideally, the price for water should cover the costs of operations and management, opportunity costs, and environmental effects of water abstraction. By assigning a price to water, users are made more aware of the value of water and are encouraged to use water efficiently. As mentioned in the above cited Unver article, the DSI has the legal right to charge for water based on article 26 of DSI law which states that “all expenditures done to operate the scheme are paid by the beneficiaries themselves (except flood protection facilities, reclamation facilities, and facilities which make navigation convenient).” The article also suggests that the implementation of water pricing would allow for the development of a water market within the basin and encourage nighttime irrigation that is more efficient. One of the largest challenges to implementing a volume-based pricing scheme is the installation of water meters. This could be accomplished through government mandate or

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345 Aksit and Akcay, “Sociocultural Aspects of Irrigation Practices In South-Eastern Turkey.”

subsidy. In the development of new irrigation schemes, water metering should be a pre-requisite.[346]

The price for water can be implemented in different ways and the literature indicates that an increasing block price model is the most effective pricing structure. Increasing blocks charge users based on the amount of water they use. Use quantities are divided into blocks and when a consumer moves from one block to the next, the price per unit jumps upwards. This has been shown to be effective for reducing water use without overburdening small farmers in Israel.[347] The other alternative is a uniform price. When comparing these two pricing structures, Bar-Shira found that a switch from a uniform price to a block rate resulted in a 7 percent reduction in water use while maintaining the same average price as a uniform structure. In addition to these decreases, the following year resulted in an additional 62 to 81 percent reduction. The block price doubles the reduction in used water when compared to the uniform price.[348] In addition to reducing applied water, Medellín-Azuara found that doubling the price of water in California reduces applied rates by 33 percent, increased infrastructure investment by 12 percent, and yielded a total reduction of 17.7 percent in applied water use.[349] In short, block rate prices reduce consumption at less cost to the producer and encourage investment in improved irrigation technology.

While an increasing block rate structure is more efficient and better for small farmers, it does lead to a decrease in farmer income. Although a switch from an area-based fee to volumetric pricing could, depending on the price, lower income, it would likely affect larger farms and possibly benefit smaller farms. The article by Bar-Shira finds that, in general, small farmers do better under block-rate prices versus a uniform pricing system.[350] Another potential issue is that, while water pricing models promote efficiency and capital investment in irrigation infrastructure, these improvements in efficiencies reduce the return flows from the soil to the water basin.[351] These issues will be addressed in a later section but the overall effect of block rate pricing is to more effectively promote water conservation at a lower cost to farmers, while encouraging investment.

Subsidies

Any irrigation method will improve yields and hopefully improve incomes, but the more expensive and efficient irrigation systems of sprinkler irrigation and drip irrigation should be promoted. Sprinkler irrigation systems are 75 to 85 percent efficient in their water use and drip irrigation, in addition to being 90 percent efficient, can deliver fertilizer to the plants and results in a reduced dependency on fungicides.[352] When compared to the water use efficiency of surface

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346 Ünver and Gupta, “Water Pricing: Issues and Options in Turkey.”

347 Z. Bar-Shira, I. Finkelshtain, and A. Simhon, “Block-Rate Versus Uniform Water Pricing In Agriculture: An Empirical Analysis,” *American Journal of Agricultural Economics* 88: 4 (2006): 986-999.

348 Ibid.

349 J. Medellín-Azuara, R.E. Howitt, and J.J. Harou, “Predicting Farmer Responses to Water Pricing, Rationing and Subsidies Assuming Profit Maximizing Investment in Irrigation Technology,” *Agricultural Water Management* 108 (2012): 73-82.

350 Bar-Shira et al., “Block-Rate Versus Uniform Water Pricing In Agriculture.”

351 Medellín-Azuara et al., “Predicting Farmer Responses.”

352 Ertek and Yilmaz, “The Agricultural Perspective On Water Conservation In Turkey.”

irrigation (40 percent), these methods are clearly better and, if Turkey switches to a volumetric pricing system, these systems could save money. To promote on-farm technology, the government could provide subsidies. In the article by Medellin-Azuara, they find that in California, a 50 percent subsidy of irrigation capital results in a 1 percent increase in land use, a 44 percent increase in capital investments, a 16 percent increase in effective water use, and $130 million increase in revenue.[353] While the aim of these policies would be to increase farm revenue, the secondary goal of promoting water conservation must be considered. Seeing as subsidies increase effective water use, over-abstraction of surface water must be monitored. Overall, it is estimated that the adoption of pressurized (drip and sprinkler) irrigation systems would boost water use efficiency by 50 percent,[354] raise farm income, increase crop yields, and reduce applied water.[355]

Water Masters

In Texas, the lower Rio Grande is managed by state employees commonly called "water masters." While the water from the Rio Grande is allocated by water rights, which is not the case in Turkey, the water master program could be applicable to Turkey. Under this system, a water master, appointed by the Texas Commission on Environmental Quality, interprets the rules of the state and assists in allocating water resources according to the landowner's water rights. A farmer will purchase the right to abstract a certain amount of water annually but, in the event of a drought, the water master has the power to reduce the amount of water received. Farmers pay an annual fee based on their allocated water rights and, if there is a water shortage, no portion of this fee is refunded.[356]

On a daily basis the water master will receive requests for water allotments and then, after confirming that the farmer has a right to that water, the water master will release the appropriate amount of water to satisfy that day's needs. An additional volume of water is released to account for losses in conveyance due to absorption into the soil or evaporation.[357] This system is similar to one that Unver suggested for Turkey: "Therefore, volumetric charges would allow a water market to develop directly. Each tertiary would be entitled to a given total volume of water in a season, and to a given maximum volume in peak periods. Sales of water within a tertiary would be direct and simple. Sales between tertiaries, or between the irrigation management organization, would be dependent on irrigation system capacity constraints, but would not be difficult to manage, once volume measurement and systems were in place."[358]

His suggestion is a mix of a volumetric based price and water rights allocated to each irrigation district rather than to the individual farmer. Each irrigation district purchases an allotment of water and then sells that water to its farmers. By putting the irrigation districts in charge of requesting water allocations and then selling this water to its farmers, this system is taking on

353 Medellín-Azuara et al., "Predicting Farmer Responses."
354 Ertek and Yilmaz, "The Agricultural Perspective on Water Conservation in Turkey."
355 M. Dagnino and F. A. Ward, "Economics of agricultural water conservation: Empirical analysis and policy implications," *International Journal of Water Resources Development* 28(4) (2012): 577-600.
356 Carlos Rubenstein, Former Rio Grande Water Master, telephone interview*,* February 12, 2016.
357 Ibid.
358 Ünver and Gupta, "Water Pricing: Issues and Options in Turkey."

characteristics of the water master system in the Rio Grande. This proposal could be an effective extension of the DSI's initiative to transfer management to the irrigation districts. However, this plan would require more training for irrigation district employees and capital investment for water meters.

Recommendations

The shortcomings of both the subsidization of irrigation infrastructure and water pricing plans are that farmers have to pay more and that improved efficiency reduces return flows to the river. These are important concerns that can be mitigated through a well-formed program. The current area-based fee is insufficient in covering the operations and management costs, does not promote efficient on-farm water use, and does not account for the economic value of water. Based on conservation gains and improvements in efficiency seen through pressurized irrigation systems and water pricing models, I suggest that Turkey implement a block-rate water-pricing schedule alongside a subsidy program for improved irrigation methods.

The subsidy could be distributed as a loan, a lump-sum transfer, or farmers could finance their irrigation improvements through an additional fee or per-unit price increase on their water. The implementation of water meters could be mandated by the government and administrated by the water user associations or it could be bundled with the infrastructure development subsidies. The investment in irrigation technology will boost yields and incomes for small farmers and alleviate stress on the nation's water resources. With the addition of water metering, the associations can assess a volumetric price and farmers will have more information and control over their water use.

Because the main goal of the GAP program is to improve farmer income, I suggest that block-rate prices are implemented at a rate that does not immediately affect average farmer income. Block rate prices are shown to redistribute more of the costs to higher income farmers, so even without a constraint to maintain the current financial burden, a block-rate system will be more equitable than the current area-based fee. After farmers are provided an opportunity to adjust to the new pricing system and have been granted time to adopt more efficient irrigation practices, prices could be raised to cover the true operations and management costs of each irrigation district. This will require cooperation from the irrigation districts and the water user organizations in addition to guidance in setting the price.

Farmers will oppose the implementation of a block-rate fee, as noted in the Aksit and Akjay survey, however they also stated that they were either happy with the current price of water or that it was too low. A system that does not drastically affect their incomes will be an area of compromise between the interests of farmers and promoting an efficient and equitable system. The survey also found that the 10 percent fee for late payments was judged to be an inadequate deterrent. While this would not likely affect water use rates, in the interest of maintaining a well-run system, an increased penalty or an alternative and more effective penalty for late payments should be assessed.

In addition to implementing the block-rate in an incremental manner and creating a program to mitigate the cost of irrigation infrastructure updates, there is a clear need for more agriculture extension work. By conducting more in-person training and field demonstrations, the extension service can ensure that farmers using both traditional and pressurized irrigation techniques are doing so in the most water-efficient and cost-effective manner. These trainings should be available to men, women, and children who are engaged in agricultural work.

The GAP project continues to elevate the social welfare and incomes of farmers in the Southeast Anatolia region, but with increased demand and reduced supply in the Euphrates-Tigris basin, the DSI must implement new policies to promote efficiency in water use. A properly implemented water-pricing model can maintain farmer income levels for a given period while they are provided the opportunity to improve their irrigation systems through government subsidies. With proper education by the agriculture extension service and increased pressure from the water pricing system, more farmers will adopt efficient irrigation techniques that will boost their income and reduce their ecological footprint. These practices, in conjunction with a management similar to that suggested by Unver or the water master system of the Rio Grande will prepare the Euphrates Tigris basin for climate change, improve water efficiency, and help farmers to deal with a reduced water supply.

PART III.
WATER ISSUES IN THE RIO GRANDE/BRAVO BASIN

Chapter 15. Toward a Sustainable Management of the Rio Grande/Bravo and Colorado Rivers: Treaties, Institutions, and Minutes

by Podie Chitan

Introduction

The 1944 Treaty for the Utilization of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Treaty) may be viewed as the product of decades of institution-building.[359,360] This process encouraged more cooperation in U.S.-Mexico cross-border water relations than we might otherwise have seen. This argument will be constructed through the juxtaposition of the spirits of the Harmon Doctrine of 1896 and a series of synchronous institutions that served as direct or indirect precursors to the 1944 Treaty.

We set up an analytical framework that highlights the importance of gradual and pragmatic institution-building to bilateral cooperation, all the while admitting the "discounting effect of a "state of nature" brand of realism in international relations. We then provide an extensive review of the antecedents to the 1944 Treaty as a possible explanation for 1) the spirit in which said Treaty was concluded and 2) the institutions created by the Treaty: the International Boundary and Water Commission (IBWC; in Spanish Comisión Internacional de Límites y Aguas, CILA) and the minute process.

We then employ its analytical framework to analyze post-1944 developments as they relate to the 1944 Treaty and the IBWC. These developments, made possible by the Treaty's minute process, will be viewed as analogous to the pre-1944 institution-building as discussed in the section on antecedents.

We suggest that continued and incremental cooperation, through the IBWC's minute process, will encourage a brand of cooperation that is "functional" and relies progressively less on selfish interpretations of "sovereignty" and "national interest." We conclude with a discussion of a "new 21st Century Minute"[361] and its benefits to transboundary water relations between the U.S. and Mexico.

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[359] Christer Jönsson and Jonas Tallberg, "Institutional Theory in International Relations," 2001, accessed February 25, 2016, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.471.8432&rep=rep1&type=pdf.
[360] Institution-building is defined as "social practices consisting of easily recognized roles coupled with clusters of rules or conventions governing relations among the occupants of these roles," and explains that "These institutions may or may not involve organizations," which are understood as "material entities possessing physical locations (or seats), offices, personnel, equipment, and budgets."
[361] Building on Steven Ingram's contribution to the subject. See Stephen Ingram, "In A Twenty-First Century Minute," *Natural Resources Journal* 44 (2004): 163-211, http://lawschool.unm.edu/nrj/volumes/44/1/06_ingram_minute.pdf.

Analytical Framework

While an exposition of political philosophy is not the primary objective of this chapter, the following discussion serves to position and streamline our analysis. First we present working definitions of the three theories that we consider most relevant to the arguments advanced in this chapter. It is important to note that none of these theories represent "absolute truths." For example, Jack Donnely argues that "Rather than a general theory of international relations, realism is best seen as a philosophical orientation or research program that emphasizes—in an insightful yet one-sided way—the constraints imposed by individual and national egoism and international anarchy."[362] Hence, our decision to use *historical institutionalism*, *international relations functionalism*, and *realism* is simply an attempt to take advantage of their respective "relative truths," their analytical strengths, as it relates to the 1944 Treaty, the IBWC, and the minute process. Together, the three theories constitute our analytical framework.

- *Historical institutionalism.* "Today's sovereignty norms and practices are the result of an institutionalization process over more than three centuries, with salient elements of path dependency as well as historical contingency.... Yet such path-dependent patterns of development, in which initial choices preclude future options, do not exclude variations in the practices of sovereignty."[363]

- *International relations functionalism.* "The classic functionalist approach to world order is based on the assumption that states can create a peaceful world society through gradualistic and pragmatic cooperation with one another in technical and economic sectors of activity. Functionalism offers an alternative model of international order to the power politics approach to international relations which is characteristic of realism. The idea is to eliminate nationalism which is seen as the root cause of war by attacking national sovereignty."[364]

- *Realism.* Skepticism toward international laws, institutions, and ideals that attempt to transcend or replace nationalism.[365] The following passages from Thomas Hobbes' *Leviathan* are discussed by Charles Covell and are instructive of classical realist thought as it applies to the "state of nature."[366]

> To this war of every man, against every man, this also is consequent; that nothing can be unjust. The notions of right and wrong, justice and injustice have there no place. Where there is no common power, there is no law: where no law, non in justice... It is consequent also to the same condition, that there

[362] Jack Donnelly, *Realism and International Relations* (Cambridge: Cambridge University Press, 2000): *eBook Collection*, EBSCO*host,* accessed February 25, 2016.
[363] Jönsson and Tallberg, "Institutional Theory in International Relations."
[364] Robert Weiner, "Lecture, University of Massachusetts, Boston," 2010, http://ocw.umb.edu/political-science/international-relations/lectures-assignments/polSci%20220/lectures%20and%20assignments/Lecture10.pdf.
[365] Frank W. Wayman and Paul Dieh, quoted in Jack Donnelly, *Realism and International Relations* (Cambridge: Cambridge University Press, 2000).
[366] For the sake of our analytical tool, we believe the extreme form of realism exhibited in a 'state of nature' where there are no laws but the laws of nature (*jus naturale*) is illustrative. The extremes described here are by no means intended to disparage realism as a theory of international relations.

> be no propriety, no dominion, no mine and thine distinct; but only that to be every man's, that he can get: and for so long, as he can keep it.[367]
>
> I need not say anything in this place; because the law of nations, and the law of nature, is the same thing. And every sovereign hath the same right, in procuring the safety of his people, that any particular man can have, in procuring the safety of his own body. And the same law, that dictateth to men that have no civil government, what they ought to do, and what to avoid in regard of one another, dictateth the same to commonwealths, that is, to the consciences of sovereign princes and sovereign assemblies; there being no court of natural justice, but in the conscience only.[368]

The present analytical framework is built on the premise/qualitative research hypothesis that a history of gradual institution-building and cooperation (functionalism), and the path dependency occasioned by the creation of norms and customs (historical institutionalism) provides the "conscience" that takes the sovereigns from their "state of nature" by placing constraints on the unbridled self-interest-driven nature of the sovereign through things such as customs and institutions.

The chapter also demonstrates the following:

- The future of the 1944 Treaty depends on a continuation of meaningful incremental gains.
- The minute process allows for such gains to be made where formal treaty revision is unlikely.
- A 21st Century Policy Minute would introduce a modern policy framework; and could revitalize the IBWC's role in the sustainable management of international rivers.

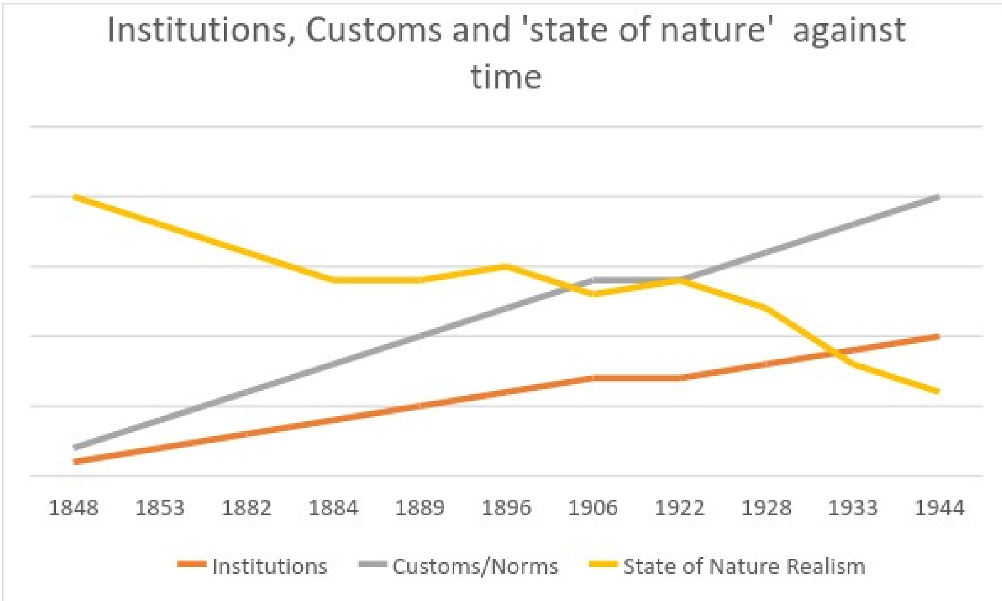
The analytical framework presented here, though developed for the purpose of this chapter, is not contrived. The UN highlights that:

> Legal agreements on water sharing have been negotiated and maintained even as conflicts have persisted over other issues. Cambodia, Laos, Thailand, and Vietnam have been able to cooperate since 1957 within the framework of the Mekong River Commission, and they had technical exchanges throughout the Vietnam War. Since 1955 Israel and Jordan have held regular talks on the sharing of the Jordan River, even as they were until recently in a legal state of war. The Indus River Commission survived two wars between India and Pakistan…. These cases reflect two important elements of international water resources cooperation: the need for **an institution to effectively develop a process of engagement over**

367 Charles Covell, *Hobbes, Realism, and the Tradition of International Law* (Houndsmills, Basingstoke, Hampshire: Palgrave Macmillan, 2004), *eBook Collection,* EBSCO*host,* accessed February 25, 2016.
368 Ibid.

time *(author's emphasis)*; and well-funded third-party support trusted by all factions.[369]

Figure 14.1.
Chart Conveying Hypothesis



Source: Compiled by author.

Note: The figure visualizes the analytical framework described above—it conveys that as cooperation and institutions increase, the state of nature is altered and persists at less pernicious levels.

Antecedents to the 1944 Treaty

This section discusses the historical developments and contexts leading to the ratification of the 1944 Treaty, and their implications within our analytical framework. As discussed previously, the 1944 Treaty is the result of decades of institution- and custom-building juxtaposed against an incipient international order that approximated a "state of nature."

1848

On February 2, 1848, the Treaty of Guadalupe Hidalgo was signed marking the end of the Mexican-American War. As a product of its resounding defeat in the war, Mexico ceded 525,000 square miles (1.3 million square kilometers) to the U.S. That parcel of ceded territory made up parts of modern-day Arizona California, Colorado, Nevada, New Mexico, Utah, and Wyoming. Mexico also gave up all claims to Texas and recognized the Rio Grande as America's southern boundary in exchange for $15 million.[370]

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[369] United Nations, "Transboundary Waters," 2016, http://www.un.org/waterforlifedecade/transboundary_waters.shtml.
[370] History.com, "Treaty of Guadalupe Hidalgo," 2016, http://www.history.com/topics/treaty-of-guadalupe-hidalgo.

The Treaty of Guadalupe Hidalgo continues to be a sore spot for many Mexicans. Americans too were uncomfortable with the war. The Massachusetts legislature of the day considered it "a war of conquest" and "a crime."[371]

1853

On December 30, 1853, James Gadsden was granted full powers to affect the "Gadsden Purchase," which became necessary to facilitate the construction of the Southern Pacific Railroad. Under the 1848 Treaty, the Southern U.S. border was defined by the line of the Gila River and the Rio Grande. Plans for the Southern Pacific Railroad, key to developing the newly acquired territory (under the 1848 Treaty), would take the project south of the Gila River. Gadsden was able to purchase an additional 30,000 square miles (77,000 square kilometers) in what is today Southern New Mexico and Arizona.[372] (See Figure 15.2 for territorial acquisitions and dates.)

The resulting Treaty Relative to Boundary Line, Transit of Persons, Etc., Across the Isthmus of Tehuantepec (1853 Treaty) is considered by some to be the most direct precursor to the 1944 Treaty. Article 1 of the 1853 Treaty establishes:

> For the performance of this portion of the Treaty, each of the two Governments shall establish one Commissioner to the end that, by **common consent** *(author's emphasis)*, the two thus nominated having met in the City of El Paso del Norte, three months after the ratification of this Treaty may proceed to survey and mark out upon the land the dividing line stipulated by this article […][373]

Two things stand out from this excerpt from Article 1: 1) Commissioners would have to be equipped with certain technical expertise given the nature of their first task; 2) "common consent" is introduced and is today an important feature of public international law.

On the issue of common consent, however, most would argue that this arrangement was made between two nations at distinct points in their national trajectories, and quite possibly with different notions about how much of their respective inputs would go into the "common consent."[374]

Article VII of the 1853 Treaty colorfully encourages the peaceful resolution of any disputes between Mexico and the U.S., using war only as a last resort. The actual text reads: "Should

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371 Historytoday.com, "The Gadsden Purchase," 2016, http://www.historytoday.com/richard-cavendish/gadsden-purchase.

372 Ibid.

373 International Boundary and Water Commission (IBWC), "Treaties between the U.S. and Mexico," 2016, http://www.ibwc.state.gov/Treaties_Minutes/treaties.html.

374 We do not wish to naively suggest that initial relations were founded entirely on goodwill and in the interest of comity. Our argument, however, is that despite its foundations, cooperative bilateral relations were conditioned by the early engagements.

there be any further period (which God forbid) occur any disagreements between the two Nations…"[375]

Figure 15.2.
U.S. Territorial Acquisitions

Source: U.S. Department of the Interior, "U.S. Territorial Acquisitions," National Atlas of the United States, 2006, accessed February 25, 2016, https://commons.wikimedia.org/wiki/File:U.S._Territorial_Acquisitions.png.

1882

The July 29, 1882, Convention Providing for an International Boundary Survey to Relocate the Existing Frontier Line Between the Two Countries West of the Rio Grande (1882 Treaty) was concluded in an effort to restore, replace, and erect new monuments west of the Rio Grande so as to preclude any ambiguities and disputes. As was the case in the 1853 Treaty, Article II of the 1882 Convention allowed each country to commission a survey party that would be headed by an "Engineer in Chief."

Article II of the 1882 Convention goes on to state: "The two parties so appointed shall meet at El Paso del Norte, or at any other convenient place to be agreed upon, within six months from the

[375] IBWC, "Treaties between the U.S. and Mexico."

exchange of the ratifications hereof, and shall form, when combined, an '**International Boundary Commission'**" *(author's emphasis)*.[376]

In describing the work of each section of the Commission, Article V of the 1882 Convention states: "On commencing operations, each section shall report to its government the plan of operations upon which they shall have jointly agreed; and they shall from time to time submit reports of the progress made by them in the said operations; and finally they shall present a full report, accompanied by the necessary drawings, signed by the Engineer in Chief and the two associate engineers on each side, as the official record of the International Boundary Commission."[377]

Indeed, the procedure just described, and its underlying rationale, are the precursors to the minute process of the 1944 Treaty.

1884

On November 12, 1884, another convention was concluded. According to the 1848 and 1853 treaties "certain parts of the dividing line between the two countries follow the middle of the channel of the Rio Grande and the Rio Colorado. The 1884 Convention Touching the International Boundary Line Where it Follows the Bed of the Rio Colorado addressed what would happen to that dividing line as the river channels were altered either by forces of nature or by man-made activities. Article I of the 1884 Convention establishes that, "the dividing line shall forever be that described in the aforesaid Treaty and follow the center of the **normal** *(author's emphasis to show norms and customs)* channel of the rivers named…"[378] Article II makes much the same provisions for manmade changes.

1889

Article 1 of the March 1, 1889, Treaty Concerning the Water Boundary establishes that "**All** *(author's emphasis)* differences of questions that may arise on that portion of the frontier between the United States of America and the United States of Mexico where the Rio Grande and the Colorado rivers form the boundary line…shall be submitted for examination and decision to an International Boundary Commission."[379] Articles II and III establish that each section should be headed by a commissioner, without specifying that they be engineers, to be supported by consulting engineers. The aforementioned articles also specify where and how meetings of the International Boundary Commission can take place. Interestingly, Article VII gives the International Boundary Commission (IBC) the power "to call for papers and information… relating to any boundary question."[380]

Article VIII goes on to state that "If both Commissioners shall agree to a decision, their judgment shall be considered binding upon both Governments, unless one of them shall

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376 Ibid.
377 Ibid.
378 History.com, "Treaty of Guadalupe Hidalgo."
379 IBWC, "Treaties between the U.S. and Mexico."
380 Ibid.

disapprove it within one month reckoned from the day on which it shall have been pronounced. In the latter case, both Governments shall take cognizance of the matter, and shall decide it amicably."[381]

Much of the institutional framework laid out from 1853 to this Treaty of 1889 can be found, in some measure, in the 1944 Treaty.

1906

The Convention on the Equitable Distribution of the Waters of the Rio Grande of May 21, 1906, though economical in text, is worthy of special attention. The Convention was the first attempt to divide the waters forming the international boundary. As Stephen Mumme points out, issues relating to the right of navigation were treated in the 1848 Treaty, but an apparent lack of foresight prevented the parties from conceiving water as a divisible and finite resource.[382] That lack of foresight is probably fortuitous for bilateral water relations between the U.S. and Mexico. Mumme proceeds to explain that at the time (late 19th and early 20th centuries) upstream diversions began affecting downstream communities' access to water, "international law was in its infancy, [and] nationalist attitudes provided few incentives for incorporating equitable considerations in diplomatic approaches."[383]

As such, we argue that had the two parties attempted to resolve the division of water prior to the institutional history and norms outlined above (1853-1906), it is likely that the matter would have been concluded in a less cooperative and amicable manner; that is, in a manner overwhelmingly consistent with what Thomas Hobbes would expect to see in an anarchic international system not dissimilar to his notion of a "state of nature."

However, by 1906 the two parties had become used to the notion of "common consent" as introduced in the 1853 Treaty; and had grown used to the operationalization of that common consent through the ad hoc International Boundary Commission of 1882 and the standing IBC created in 1889. So even as U.S. Attorney General Judson Harmon argued that based on the existing treaties, the U.S. had no obligation whatsoever to negotiate with Mexico on water (part of the more general Harmon Doctrine),[384] reminiscent of the tone of international relations of the late 19th and early 20th centuries, our argument is that the 1906 Treaty is a manifestation of a separate reality created by half a century of post-conflict bilateral cooperation that encouraged the considerations for the sake of comity that Harmon described as totally discretionary.[385]

In 1896, the year of U.S. Attorney General Judson Harmon's opinion, the IBC issued a report attributing water scarcity in Ciudad Juárez to upstream diversions in the U.S. The report called for the construction of an international dam just upstream of El Paso to secure to each nation its

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[381] Ibid.
[382] Stephen Mumme, *From Equitable Utilization to Sustainable Development: Advancing Equity In U.S.-Mexico Border Water Management* (Colorado State University, 2008).
[383] Ibid.
[384] Ibid.
[385] Norris Hundley (1966), quoted in Stephen Mumme, *From Equitable Utilization To Sustainable Development*, 23-24.

"legal and equitable rights" with the impounded waters to be divided equally between the two countries.[386] Interests of the Rio Grande Dam and Irrigation Company would delay construction, however, and result in the dam being built at Elephant Butte in New Mexico from 1907 to 1916. Instead of the 50-50 split originally proposed by the IBC, the 1906 Convention allocated 60,000 acre-feet to Mexico annually. This volume was based on the "maximum known uses of Mexican settlers in the Valle de Juárez."[387] Despite the eventual outcome, the spirit of the rationale used in dividing the water is at worst a compromise between the prevailing spirit of cooperation in the post-1953 institutions and the state of nature realism of a weak international regime[388]; or at best, 60,000 acre-feet a year based on the "maximum known uses of Mexican settlers" was a bona fide attempt to give to the less-developed Mexico less water with no regard for the Harmon Doctrine. Whatever the case might be, state of nature realism did not prevail. Again, our argument is that the sovereigns' conscience was influenced by the post Mexican-American war building of institutions and norms.

We would trivialize our argument if we were to ignore the importance of geography as a push factor to the bilateral cooperation on international waterways between Mexico and the U.S.

As a result of the proximity of El Paso and Ciudad Juárez, Mexico's Consul General, José Zayas Guarneros, wrote to his Foreign Minister in 1894 expressing concern that in the absence of a remedy to the problem of water being deviated upstream in Colorado and New Mexico, both the Mexican Ciudad Juárez and El Paso in the U.S. would be decimated. In reality, and an important catalyst to the politics of the international border, any action in prejudice of Ciudad Juárez would also affect El Paso.[389] Notwithstanding the foregoing, the possible correlation between geographic proximity of large population centers along the international border and the decades of cooperation previously outlined is irrelevant for the purposes of this paper. Indeed, even if geography is correlated to, or even causes, cooperation, it cannot be varied to suit our purposes. The incremental institution-building and the creation of norms and customs remain our central focus.

A final observation is that the Supreme Court, in *Kansas v. Colorado* in 1907, found "that disputes between states of the United States over shared water resources were to be resolved in such a way as to achieve an equitable apportionment of those resources."[390] The Court held that "disputes between U.S. states were governed by principles of international law, among others, and—contrary to Colorado's position of absolute territorial sovereignty—found that facts might exist that would justify its interposition."[391] It is not known to what extent this litigation may have influenced the U.S. government's position in the dispute with Mexico, or vice versa, but the

[386] Ibid.

[387] Neill Reynolds (1906), quoted in Stephen Mumme, *From Equitable Utilization To Sustainable Development*, 58.

[388] The U.S. may have been uncertain as to the direction of international law, and was therefore keen to establish in the Convention (Article V) that no legal precedent was set, and that Mexico waived all claims for damages resulting from upstream diversions.

[389] Stephen McCaffrey. *The Harmon Doctrine One Hundred Years Later: Buried, Not Praised*, 1996, http://lawschool.unm.edu/nrj/volumes/36/4/13_mccaffrey_harmon.pdf.

[390] Kansas v. Colorado 1907, 206. Ibid, 579.

[391] Kansas v. Colorado 1907, 143 and 147. Ibid.

end result in both cases was an effort to apportion the waters in an equitable manner.[392] This section suggests that the years immediately leading up to 1906 represent a point of inflection in the way North American neighbors would share waterways for non-navigational uses.

1909

So while no legal precedent denouncing the Harmon Doctrine was set in the 1906 Convention, the prevailing custom of the early 20th century was that neighboring countries and states would act in the spirit of comity. Interestingly, the unbridled use of the Harmon Doctrine would be inconvenient to the U.S. along its northern border with Canada vis-a-vis the Milk river which runs from Alberta to Montana. Stephen Mumme observes that "While the 1909 Treaty[393] partially incorporated Harmon's perspective in upholding each nation's right to control [and] divert tributary waters of boundary rivers and streams, it qualified this right by providing that any diversions in one country that injured a party or parties in the other country entitled the injured party the same right to sue as if the injury had occurred in the country in which the diversion was made."[394]

The 1909 Treaty divides the waters of the Milk and St. Mary's rivers equally between the U.S. and Canada. It may appear, therefore, that Mexico might have gotten a "raw deal" in the 1906 Treaty. However, it is worth noting that "Navigation treaties between the United States and Canada (represented by Great Britain) have existed since the birth of the United States."[395] This is to say that the two countries had years of prior institution- and confidence-building under their belts. The fact that the U.S. and Canada shared a colonial history, while Mexico's history was significantly different, may also offer an explanation for differences in the interpretation of "equity" as in the 1906 Convention versus the 1909 Treaty. Though beyond the scope of this report, there are remarkable parallels between U.S.-Mexico, and U.S.-Canada relations if we were to compare the respective treaties, customs, and norms using our analytical framework.

1922 and 1928

With the signing of the Colorado River Compact in 1922, the interstate development of water[396] in the U.S. took primacy over international commitments to comity. Article 1 of the Compact states:

> The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System; to establish the relative importance of different beneficial uses of water, to promote interstate comity; to remove causes of present and future controversies; and to secure the

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[392] Ibid.
[393] The 1909 Treaty Between the United States and Great Britain Relating to Boundary Waters, and Questions Arising Between the United States and Canada. This treaty also created an International Joint Commission.
[394] Mumme, *From Equitable Utilization To Sustainable Development*.
[395] Daniel Dewitt, "Great Words Needed for the Great Lakes: Reasons to Rewrite the Boundary Waters Treaty of 1909," Indiana University School of Law, 1994, http://ilj.law.indiana.edu/articles/69/69_1_Dewitt.pdf.
[396] The signatories of the 1922 Compact were: Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming

> expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two Basins, and an apportionment of the use of part of the water of the Colorado River System is made to each of them with the provision that further equitable apportionments may be made.[397]

At that juncture (1922), Mexico was still reeling from its defining revolution and little to no consideration was given to its needs relating to the downstream flows of the Colorado River system. At the end of the revolution, Mexico started developing the Rio Conchos and other tributaries of the Rio Grande. This set off alarms in the U.S., so in 1928 when Mexico approached the U.S. to form an International Water Commission, both parties had an interest in forming such an entity.[398] Although the IWC was largely a failure, its creation was catalyzed by the need to address water sharing, an issue that had previously been outside the scope of the IBC and dealt with partially in the 1906 Convention.

1933

On February 1, 1933, the two governments signed the Treaty for the Rectification of the Rio Grande (1933 Treaty), where they agreed to jointly construct, operate, and maintain, through the IBC, the Rio Grande Rectification Project.

The 1944 Treaty

According to Stephen Mumme, "[it] is well known, the 1944 Treaty negotiation entailed Mexican concessions on the Rio Grande in exchange for U.S. concessions on the Colorado river."[399] By this time, rapid developments along the Colorado and on the Mexican side of the lower Rio Grande were sufficient to worry both parties. "In answering these questions the federal governments of both countries effectively abandoned any lingering inclination to claim absolute territorial sovereignty and proceeded pragmatically, acknowledging the reality of reciprocal sovereignty and informed by the growing **international practice** *(author's emphasis)* of settling water disputes on the basis of equitable apportionment."[400]

The abovementioned "international practice" is without doubt the work that had led to the 1906 Convention. We find parallel reasoning in a letter from Chas D. Walcott, Director of the U.S. Geological Survey, to the Secretary of the Interior:

> The public discussion of this matter has tended to the view that in the interests of international comity the question should not be decided upon its purely legal aspects, more particularly in view of the plans considered by the International

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397 U.S. Bureau of Reclamation (USBR), "Colorado River Compact, 1922," 2016, https://www.usbr.gov/lc/region/pao/pdfiles/crcompct.pdf.
398 Mumme, *From Equitable Utilization To Sustainable Development*.
399 Ibid.
400 Jerome Lipper (1967), "Equitable Utilization," quoted in Stephen Mumme, *From Equitable Utilization To Sustainable Development*, 26-27.

> (Water) Boundary Commission .... The effort of this commission has been to devise some means of obtaining a supply of water for the Mexican lands without unduly depriving lands within the limits of the United States.[401]

The Treaty for the Utilization of the Colorado and Tijuana Rivers and of the Rio Grande (1944 Treaty) brought Mexico and the U.S. together on the issue of non-navigational uses of the waters of the Rio Grande (Rio Bravo) from Fort Quitman to the Gulf of Mexico as well as the Colorado further west. The 1906 Convention would continue to guarantee the delivery of at most 60,000 acre feet annually at “the head works of the Acequia Madre, known as the Old Mexican Canal, (that) now exist above the city of Juárez, Mexico.”[402]

Article II of the 1944 Treaty provides for the creation of the International Boundary and Water Commission (IBWC), building on the International Boundary Commission created in the 1889 Treaty, which itself built on and expanded the mandate of the *ad hoc* Commission provided for in the 1882 Treaty; and the International Water Commission (IWC)[403] created in 1928 as a first attempt to resolve controversy between Fort Quitman and the Gulf of Mexico. Article II also reintroduces the idea of the Engineer Commissioner first seen in the 1853 Treaty but not specified in the 1889 Treaty.[404] Article III specifies the order of preference given to distinct uses, while Article IV speaks to the allocation of water, points which we will develop later.[405]

Overview of the Minute Process

An important caveat to the study of any instrument of public international law is that “public international law is built on the foundation of state consent.”[406] This characteristic of international law necessarily requires the “common consent” referred to in the 1853 Treaty, and the cooperation between states exhibited in the events leading up to 1944. It goes without saying that a relatively robust international law regime is mutually exclusive to Hobbes’ “state of nature.”

Article 39 of the Vienna Convention on the Law of Treaties establishes: “A treaty may be amended by agreement between the parties.” The rules laid down in Part II apply to such an agreement except in so far as the treaty may otherwise provide. Very few treaties, if any, give broad interpretive powers to a body created by the treaty itself as is the case of the IBWC via the minute process to the 1944 Treaty.

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[401] Letter from Chas D. Walcott (1905),quoted in Stephen McCaffrey, *The Harmon Doctrine One Hundred Years Later: Buried, Not Praised*.

[402] IBWC, “Treaties between the U.S. and Mexico.”

[403] The IWC failed and discontinued its work in 1930. It would appear that new nationalist tendencies in post-revolution Mexico and the Great Depression may have played a role in undermining past willingness to compromise.

[404] We are of the view that calls for non-engineer commissioners make assumptions about the academic formation of the engineers that fall outside objective analysis.

[405] IBWC, “Treaties between the U.S. and Mexico.”

[406] Andrew Guzman, “The Consent Problem in International Law,” *Virginia Journal of International Law* 52(4) (2012): 747-790.

Described simply, the minute process outlines the steps to be taken by the IBWC's U.S. and Mexican sections to record decisions taken by the Commission subject to approval from the Department of State and the Mexican Foreign Ministry. Article 25 explains that, procedurally, minutes are produced in both English and Spanish, signed by both Commissioners, and forwarded to the respective governments within three days of being signed. In the absence of explicit rejection or acquiescence, a minute to which a government does not offer a response to the Commission within 30 days shall be deemed approved, unless explicit governmental approval is a requirement of the Treaty.[407]

As Sally Spener described in an interview conducted on November 10, 2015, "the minute process starts when an issue is identified by the commission itself or a stakeholder who comes to the commission with a concern and then the IBWC gets together to act."[408]

Allie Umoff explains that "The Minute process has proven useful in situations where the Treaty, as originally written, was silent or vague. The Minute process also gives the Treaty the adaptability it needs, enabling the IBWC to secure long-term compliance through short-term flexibility."[409]

The above features of the minute process are essential to the ensuing discussion over the role of the minute process in the implementation of the 1944 Treaty by the IBWC.

Table 15.1.
Overview of Minutes Adjusting Allocation Schedules in Times of Emergency

Minute #	Date approved	Summary
318	2010	Adjustment of delivery schedules for water allotted to Mexico for the years 2010 through 2013 as a result of infrastructure damage in irrigation district 014, Rio Colorado, caused by the April 2010 earthquake in the Mexicali valley, Baja California.
310	2003	Emergency delivery of Colorado River water for use in Tijuana, Baja California, due to drought and poor infrastructure.
293	1995	Emergency cooperative measures to supply municipal needs of Mexican communities located along the Rio Grande downstream of Amistad dam as a result of drought.
240	1972	Emergency deliveries of Colorado River waters for use in Tijuana as a result of drought.

Source: IBWC, "Minutes between the United States and Mexican Sections of the IBWC," http://www.ibwc.state.gov/Treaties_Minutes/Minutes.html..

Table 15.1 shows that the minute process has allowed for adjustment in allocation schedules in response to myriad shocks such as earthquake damage to infrastructure and drought. It is important to note that minutes related to allocations tend to include the clause "pursuant to

[407] IBWC, "Treaties Between the U.S. and Mexico."

[408] Sally Spener, International Boundary and Water Commission, telephone interview on the Minute Process, by Podie Chitan, 2015.

[409] Allie Umoff, "An Analysis of The 1944 U.S.-Mexico Water Treaty: Its Past, Present, And Future," *Environs: Environmental Law and Policy Journal* 32(1) (2008): 69-98.

instructions of their respective governments to negotiate an agreement, subject to the approval of the two governments…"

The IBWC

Article II of the 1944 Treaty establishes that "The application of the present Treaty, the regulation and exercise of the rights and obligations which the two Governments assume thereunder, and the settlement of all disputes to which its observance and exercise may give rise are hereby entrusted to the **International Boundary and Water Commission** *(author's emphasis)*, which shall function in conformity with the powers and limitations set forth in this Treaty."[410] "The effectiveness of the 1944 Treaty has been repeatedly questioned; it suffers heightened criticism with each drought and with each water delivery deadline that goes unmet."[411] In Texas, farmers have voiced support for scrapping the Treaty altogether. The IBWC has been called a "dinosaur"[412] and a "toothless wonder."[413]

Minute 318

Steven Ingram argues that "the IBWC's critical flaw is that its functions are tied to the outdated 1944 Treaty between the United States and Mexico."[414] We would argue that the minute process, being an integral part of the 1944 Treaty, allows for incremental and pragmatic cooperation between Mexico and the U.S. on issues such as drought, climate change adaptation and/or mitigation, environmental and ecological uses of water, and others. The minute process also allows new customs and norms to be set based on the interpretation that the IBWC gives to the Treaty vis-a-vis the exigencies of the 21st century, and the IBWC's willingness to engage civil society in its deliberations. In short, the minute process, even though focused on seemingly innocuous technical minutes, could serve to strengthen the institutions of bilateral cooperation on water in much the same way as cooperation on border issues from 1853 to 1906 did.

While any changes to the current allocation regime would require the approval of both countries' senates,[415] matters relating to conservation, and response to drought and shortages due to natural disasters are well within the purview of the minute process. For example, section G of Minute 308 does not read like the work of an "institutional dinosaur":

> G.1. Measures of Cooperation on Drought Management—Mexico's National Water Commission will present to the International Boundary and Water Commission a progress report on its studies concerning drought management planning to support the Commission as a forum under which the proper authorities in each country may coordinate their respective drought management plans.

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410 IBWC, "Treaties Between the U.S. and Mexico."

411 Stephen Ingram, "In A Twenty-First Century Minute," *Natural Resources Journal* 44 (Winter 2004): 163-211, http://lawschool.unm.edu/nrj/volumes/44/1/06_ingram_minute.pdf.

412 Mumme, quoted in Ibid., 210.

413 Lindell, B1, quoted in Ibid., 184.

414 Ingram, "In A Twenty-First Century Minute."

415 Umoff, "An Analysis of The 1944 U.S.-Mexico Water Treaty."

> G.2. Sustainable Management of the Basin—The Commission took note of the desire of both Governments to convene a bi-national summit meeting of experts and water users from each country for the purpose of providing the proper authorities and stakeholders information concerning sustainable management of the Rio Grande Basin. Taking the recommendations of the summit into account, the two Governments will consider a binational sustainable management plan for the basin.
>
> G.3. International Advisory Council—The Commission, subject to the provision of financial and personnel resources to each Section by the respective governments as a step to strengthen the Commission's role in the area of sustainable management of the basin and drought management planning, will establish a forum for the exchange of information and advice to the Commission from government and non-government organizations in their respective countries.[416]

Similarly, minute 318 provides for the adjustment of delivery schedules to Mexico for the years 2010 to 2013 in response to infrastructure damage in Irrigation District 014 caused by the April 2010 earthquake. Minute 319 speaks to cooperative measures on the Colorado River that can benefit both countries. The most recent minute, Minute 320, regarding a General Framework for Binational Cooperation on Transboundary Issues in the Tijuana Basin, calls for "an inclusive process to obtain recommendations from stakeholder groups on transboundary issues in the Tijuana River Basin."[417]

As discussed in the concluding remarks on a "New 21st Century Minute," these consultations with stakeholders are a feature of the 2015 Sustainable Development Goals and the OECD Best Practices on Water. The consultations also provide the Engineer-Commissioners with distinct points of view and therefore provide a solution to Ingram's reference to the fact that the Engineer Commissioner has resulted in very few of the 320 minutes approved to date to create any policy. Specifically, Ingram points out that "throughout the 1900s and early years of the 21st century, the IBWC issued Minutes that were technical documents, focusing on allocation formulae, moving due dates, and changing scheduled amounts due…"[418] Additionally Annelia Tinklenberg argues that much of the problem is that the 1944 Water Treaty does not define how the IBWC should interact with stakeholders and other border agencies or how it should release information to the public.[419,420]

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[416] IBWC, "Treaties Between the U.S. and Mexico."
[417] Ibid.
[418] Ingram, "In A Twenty-First Century Minute."
[419] Annelia Tinklenberg, "Will The Minute System Work To Modernize The International Boundary And Water Commission?" Master's Thesis, The University of New Mexico, 2007.
[420] United Nations, 2016. Goal 6 b of the Sustainable Development Goals calls for Support and strengthen the participation of local communities in improving water and sanitation management.

The 1997 UN Convention

In his paper "In a 21st Century Minute," Steven Ingram argues that the IBWC is forced to operate within the constraints of the 1944 Treaty. He advocates for a "21st Century Minute, or Policy Minute" that will quickly bind the IBWC to "modern international principles of watercourse law as articulated in the U.N. Convention on the Law of Non-Navigational Uses of International Watercourses of 1997" (1997 Convention).[421]

To date, there are only 36 states party to the 1997 Convention.[422] Ingram relays the curious account of Mexico proposing the initial text for what was later adopted as the 1997 Convention, with the co-sponsorship of the U.S. The Convention was since adopted in the UN General Assembly and has gathered the requisite ratifications to enter into force without either the U.S. or Mexico being among the original ratifications nor the later accessions. Ratification in both countries would require congressional approval.

Nonetheless, the 1997 Convention could be adopted as a framework for action in the policy minute that Ingram recommends. That international law that could and should inform the U.S.' legislative process was articulated by the courts in what has been dubbed as the "Principle of Contemporaneity."[423] Essentially, the courts have shown an increasing willingness to be guided by international law when deciding on matters that are not clearly defined by U.S. domestic law. If the IBWC were to issue such a policy minute, it would be forced to have difficult conversations with legislators over issues such as the "equitable and reasonable utilization and participation" in the international watercourses in question as stipulated by Article 5.1 of the 1997 Convention.[424,425] A new set of norms and customs would be established and as we have argued to this point, history has shown that the institutions will quickly follow the prevailing practice.

Article 6 of the 1997 Convention helps make our case for the incorporation of the Convention's principles in a policy minute. In defining factors relevant to determining what is considered equitable and reasonable utilization, Article 6 highlights factors such as:

> 1. Utilization of an international watercourse in an equitable and reasonable manner within the meaning of article 5 requires taking into account all relevant factors and circumstances, including:

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421 Ingram, "In A Twenty-First Century Minute."

422 United Nations, "UNTC," 2016, https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-12&chapter=27&lang=en).

423 Ingram, "In A Twenty-First Century Minute."

424 United Nations, "Convention on the Law of the Non-navigational Uses of International Watercourses," 2016, http://legal.un.org/ilc/texts/instruments/english/conventions/8_3_1997.pdf .

425 Article 5.1 of the 1997 Convention on Watercourses: "Watercourse States shall in their respective territories utilize an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be used and developed by watercourse States with a view to attaining optimal and sustainable utilization thereof and benefits therefrom, taking into account the interests of the watercourse States concerned, consistent with adequate protection of the watercourse."

a) Geographic, hydrographic, hydrological, climatic, ecological and other factors of a natural character;
b) The social and economic needs of the watercourse States concerned;
c) The population dependent on the watercourse in each watercourse State;
d) The effects of the use or uses of the watercourses in one watercourse State on other watercourse States;
e) Existing and potential uses of the watercourse;
f) Conservation, protection, development and economy of use of the water resources of the watercourse and the costs of measures taken to that effect;
g) The availability of alternatives, of comparable value, to a particular planned or existing use.

2015 UN Sustainable Development Goals

In addition to the 1997 Convention, the Sustainable Development Goals adopted on September 25, 2015, provide another policy framework, complementary to the 1997 Convention, for the IBWC's operations which too can be implemented via a policy minute. The incorporation of Goal 6 in a policy minute would help set the way for the future of the IBWC and the 1944 Treaty.

- Target 6.1: By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

- Target 6.5: By 2030, implement integrated water resources management at all levels, including through **transboundary cooperation** *(author's emphasis)* as appropriate.

- Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes.[426]

The Texas Commission on Environmental Quality's Position

The progress being made toward a 21st Century Minute, like the progress made toward the equitable distribution of the waters of the Rio Grande and the Colorado River in its time, is hindered by "state of nature" tendencies occasioned by the relative weakness of international law. So while custom and institutional history would dictate that the Harmon Doctrine, or similar notions, have no place in a civilized 21st century, we continue to witness battles between the Texas Commission on Environmental Quality (TCEQ) and the IBWC over the interpretation of the 1906 Convention and the 1944 Treaty as it relates to the division of water between Acequia Madre and Fort Quitman.

The TCEQ asserted that "Many government entities and water right holders firmly believe, and the evidence points to the fact that the waters of the Rio Grande below El Paso are allocated entirely to the United States under the 1906 Convention with Mexico. The IBWC has historically allocated 50 percent of this water to Mexico when it reaches Fort Quitman, Texas. Fort Quitman

[426] United Nations, "Sustainable Development Goals," 2016, http://www.un.org/sustainabledevelopment/sustainable-development-goals/.

is where the 1944 Treaty on the Rio Grande begins. We believe this water belongs entirely to the United States. Allocating the water to Mexico deprives our Texas users of their water supplies."[427] Needless to say, the TCEQ does not have a comparable history of bilateral cooperation with Mexico as does the IBWC.

Drought

Another set of issues, as observed by Tinklenberg, is that while "the 1944 Water Treaty does stipulate rationing rules for drought conditions, it does not include a definition of what drought conditions are nor does it give authority to the IBWC to decide when those conditions have been met."[428] The term "extraordinary drought" in the 1944 Treaty is severely inadequate to assist the IBWC to determine drought conditions. Tinklenberg further states that "The lack of groundwater, ecological needs, and defined drought management in the 1944 Water Treaty reveals the next criticism: an outdated mandate."[429] To that outdated mandate we may wish to add the issue of climate change.

On the treatment of drought Ingram notes that under the 1944 Treaty:

> Mexico must deliver 350,000 acre-feet of water to the United States from the Rio Grande annually. The United States is required to deliver 1.5 million acre-feet of water from the Colorado River to Mexico every year. If Mexico, because of extraordinary drought, is deficient in its delivery to the United States of the one-third portion, after the run of a designated five-year cycle, it must make up any deficiency in the five-year cycle that immediately follows. In the event of such deficiency Mexico would have to pay "double" for a five-year period: the dent from the previous five-year cycle and "the allotment for the next five-year period." This assumes that any drought or other "extraordinary" circumstance would self-correct and make up for losses in neat five-year increments. Unfortunately, the Treaty never defined the term "extraordinary."[430]

Conclusion: A New 21st Century Minute

Just as the incipient institutions and treaty bodies of the mid-19th to mid-20th centuries faced constraints in the form of the Harmon Doctrine and other survival of the fittest paradigms, a 21st Century Minute as has been called for by Steven Ingram[431] will be challenged by "states of nature" attitudes that see bilateral water sharing through the lens of game theory. Globalization has increased the contacts between citizens of different states; so much so that sympathy for a neighbor in distress is natural. The 320 minutes issued to date have set the stage for a deeper and

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427 TCEQ, "Rio Grande International Water Accounting - Fort Quitman, Texas," 2016, http://www.tceq.state.tx.us/border/international-water.html/.

428 Stephen Mumme and Nicolas Pineda (2001), quoted in Annelia Tinklenberg, "Will The Minute System Work to Modernize the International Boundary and Water Commission?"

429 Tinklenberg, "Will The Minute System Work to Modernize the International Boundary and Water Commission?"

385 Ingram, "In A Twenty-First Century Minute."

431 Ibid.

more proactive cooperation between Mexico and the U.S. It would be irrational to view drought, natural disaster, or any other contributor to water shortages in one country as issues that can be confined to borders drawn for reasons as fickle as the passing of a railroad.

The New 21st Century Minute would establish a modern framework for the Colorado, Rio Grande/Rio Bravo, and Tijuana River basins, based on international best practices as articulated in the 1997 Convention, the Sustainable Development Goals, and the OECD Principles on Water.[432] The work of the IBWC would then be scrutinized based on this framework. At the very least, stakeholders will have benchmark information regarding the performance of the 1944 Treaty in relation to today's exigencies. Where shortcomings are highlighted, the strong democracies of both Mexico and the U.S. will act responsibly in the face of "state of nature" inclinations to egoism.

It is clear that the 1944 Treaty reflects past realities and concerns. According to Stephen Mumme, "Treaties…are the political documents that reflect the diplomatic possibilities of the past as reinforced by their cumulative record of institutional practices in their service, and, as such, are often difficult to change…[and] it is highly unlikely that the present binding treaties will be reopened for revision given the enormity of the political stakes."[433]

Our analytical framework suggests that if a policy minute is not forthcoming, the IBWC may fall into a lull that would preclude the type of cooperation that the functionalists see as key to progress. In other words, inasmuch as the IBWC becomes stagnant, we run the risk of unlearning decades of cooperative behavior. The minute process provides an avenue for the IBWC to make progress in areas where the 1944 Treaty is silent. This progress, though it may seem nominal, is absolutely key to the bigger picture of the continued relevance of the 1944 Treaty and the IBWC.

Recent minutes suggest that the Treaty is highly receptive to political will. Where the two governments so instruct, the Treaty is far from a "dinosaur." Allocation schedules can be shifted to accommodate crises. What is true, however, is that anything beyond a postponement or advance of due allocations would run contrary to the soul of the Treaty. Much, however, can be done through the minute process, to ensure that the risks associated with drought and other climatic events are not as acute as they could be in the absence of cooperation. In addition to the management side of things, a policy minute could serve as an aspirational framework, highlighting the Treaty's shortcomings *vis-a-vis* the 1997 Convention, the Sustainable Development Goals, and OECD water principles.

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[432] OECD 2016, Principle 10 calls for the promoting of stakeholder engagement for informed and outcome-oriented contributions to water policy design and implementation.

[433] Mumme (1999), quoted in Stephen Ingram., "In A Twenty-First Century Minute."

Chapter 16. The Rio Grande Compact of 1938: Legal and Environmental Challenges of the 21st Century

by Podie Chitan

Introduction: The Unique Legal Character of the Rio Grande

The Rio Grande is both an interstate and international river. Drought conditions, together with the increased demand for Rio Grande water, have put a strain on the river's supply. Adding to the strain are issues of evaporation losses and sedimentation that have implications under the legal framework governing the Rio Grande. This strain has been the catalyst for political and legal action among the states party to the Rio Grande Compact of 1938. Groundwater pumping and unauthorized diversions challenge the effectiveness of the complex scheduling and accounting system of the Compact. A clear understanding of the intent and purpose of the Rio Grande Compact is vital to the continuation to the interstate comity intended by the Compact.

The Rio Grande begins its long journey in Colorado and flows southward for more than 400 miles across New Mexico. After leaving New Mexico, it turns eastward and forms the boundary between Texas and the Republic of Mexico for about 1,250 miles to its mouth. The total length of the river is about 1,800 miles.[434]

The 1938 Compact governs the river in its character as an interstate stream up to Fort Quitman. A portion of the Rio Grande that forms the international boundary, that is from the head of the Mexican Canal down to Fort Quitman, Texas, is governed by the 1906 Convention between the U.S. and Mexico for the Equitable Distribution of the Waters of the Rio Grande (1906 Convention). The 1944 Treaty between the U.S. and Mexico governs the Rio Grande where it forms the international boundary below Fort Quitman up to the mouth of the river in the Gulf of Mexico.[435] The 1938 Rio Grande Compact is the focus of this chapter.

History

The preamble to the operational clauses of the Rio Grande Compact of 1938 adequately address the reason for its ratification by the states of Colorado, New Mexico, and Texas. The preamble states: "…desiring to remove all causes of present and future controversy among these States and between citizens of one of these States and citizens of another State with respect to the use of the waters of the Rio Grande above Fort Quitman, Texas, and being moved by considerations of

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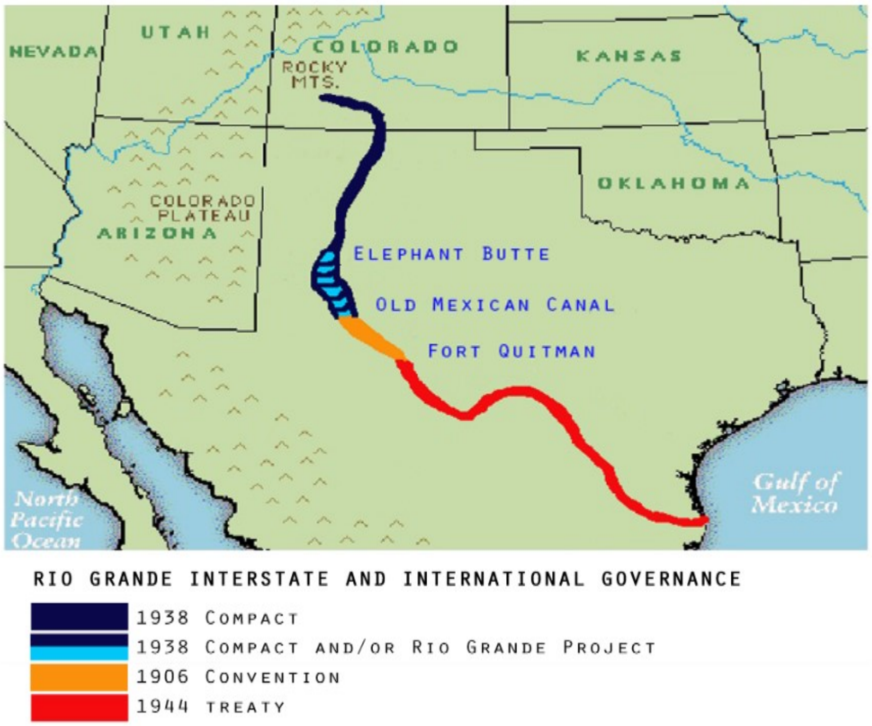
[434] Raymond Hill, *Development of The Rio Grande Compact of 1938* (The University of New Mexico School of Law, 2016), http://lawschool.unm.edu/nrj/volumes/14/2/01_hill_development.pdf.

[435] Article XIV of the Compact precludes the use of increases of decreases in Mexican water delivery under the 1944 Treaty as reason to modify Compact delivery schedules.

interstate comity, and for the purpose of effecting an equitable apportionment of such waters, have resolved to conclude a Compact for the attainment of these purposes."[436]

Figure 16.1.
Rio Grande Governance Map



Source: Created by author in Illustrator.

Note: The serrated line below Elephant Butte reservoir represents the river segment related to the question of whether New Mexico's compact obligations end with water delivery at San Marcial. This matter is discussed below.

Douglas R. Littlefield argues that post-1938 interstate water conflicts are the result of the lack of understanding of the history of the 1938 Compact.[437] According to Littlefield, for many it is an "enduring mystery" as to why the Compact provides water deliveries to New Mexico at the Colorado-New Mexico state line, measured at or near Lobatos, while New Mexico's water delivery to Texas is made at San Marcial, just above the Elephant Butte Reservoir, some 105 miles from the Texas state line. This detail continues to be relevant in the interpretation of the respective states' obligations under the Compact, most evidently in the legal proceedings before the U.S. Supreme Court since January 8, 2013, on the issue of whether New Mexico is in violation of the Rio Grande Compact and the Rio Grande Project Act, which apportion water to

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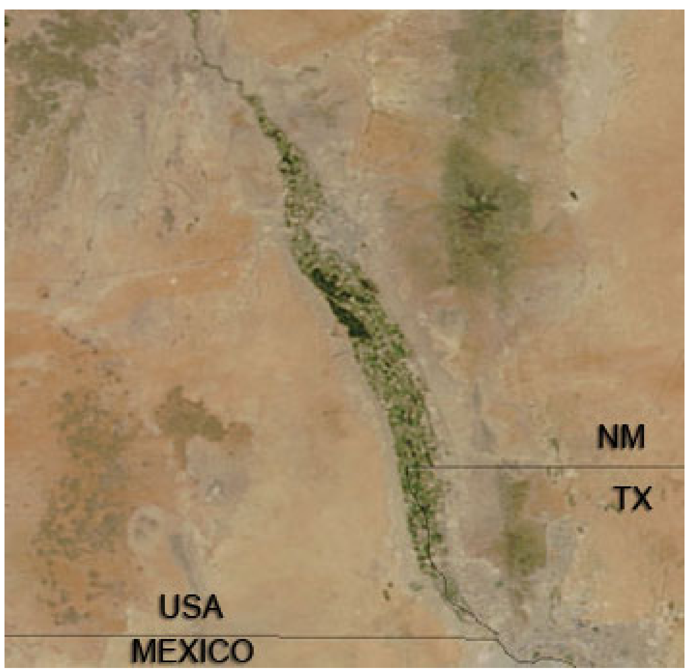
[436] New Mexico Water Resources Research Institute, "Rio Grande Compact," accessed March 27, 2016, http://www.wrri.nmsu.edu/wrdis/compacts/Rio-Grande-Compact.pdf.
[437] Douglas Littlefield, "The History of The Rio Grande Compact of 1938," WRRI Conference Proceedings, 1999, http://www.wrri.nmsu.edu/publish/watcon/proc44/littlefield.pdf.

Rio Grande Project beneficiaries. Littlefield rebuts arguments suggesting that Texas' negotiators were "taken" in the build-up to the 1938 signing.

Littlefield, a historian, argues that the seemingly glaring oversight to guaranteeing that Rio Grande water would get to Texas in the agreed amount is a misunderstanding of the spirit of the Compact. According to Littlefield, the Compact is silent on water delivery to the New Mexico-Texas border because this, in fact, was provided for in 1905 "when Federal lawmakers authorized the construction of the Rio Grande Project in southern New Mexico and western Texas by the U.S. Reclamation Service (today, the Bureau of Reclamation).[438] Based on studies conducted, the Reclamation Service determined that the water of the Rio Grande Project would be apportioned in such a way as to supply sufficient water for irrigating 88,000 acres of arid lands in southern New Mexico and 67,000 acres in western Texas.

The Rio Grande Project was constructed by the Reclamation Service and water stored behind the Elephant Butte structure would serve New Mexico and Texas in corresponding amounts as determined by the Service's previously mentioned studies, and would also guarantee 60,000 acre-feet of water to satisfy Mexico's demands, in anticipation of a treaty being agreed with Mexico for the latter point. That Treaty was indeed signed in the form of the 1906 Convention.

Figure 16.2.
NASA Image Showing the Impact of the Rio Grande Project



Source: National Park Service, "Making The Desert Bloom," The Rio Grande Project, accessed March 27, 2016, https://www.nps.gov/nr/twhp/wwwlps/lessons/141RioGrande/141RioGrande.htm.

[438] Ibid.

Figure 16.2 provides a visualization of the impact of the Rio Grande Project in southern New Mexico and West Texas. The heart of the Rio Grande Project is the Elephant Butte and Caballo dams, whose features are described in Part I of this report.

Relevant to this paper is the fact that although the Rio Grande Compact does not explicitly provide for the delivery of water to the Texas state line, such a provision may have been deemed redundant by the Compact negotiators, as Littlefield argues, since the Rio Grande Project preceded the Compact by over three decades. If this is the case, then it may be interpreted that the Compact subsumes the Rio Grande Project and that a violation of the terms of the latter would naturally hinder the intent and purpose of the former.

Making a case for the spirit (intent and purpose) of the Compact, Littlefield recounts the initial reticence of the Texas legislature to ratify the Compact in 1938 over concerns that Texas' water delivery would paradoxically be made in New Mexico territory. Those concerns were removed when the then Texas Compact Commissioner, Frank Clayton, explained that:

The negotiators of the new Rio Grande Compact (1938)[439] had recognized an existing apportionment of the river's waters between New Mexico and Texas below Elephant Butte Dam through the allocations made by the Bureau of Reclamation and the operation of the Rio Grande Project…. [T]he question of the division of the water released from Elephant Butte reservoir is taken care of by contracts between the [irrigation] districts under the Rio Grande Project and the Bureau of Reclamation.[440]

The Compact

This section will highlight those features of the 1938 Compact most relevant to the present discussion.

- Article Ib provides for the creation of the Compact Commission, on which each of the contracting parties is to have a representative (Commissioner).

- Article Ip defines actual spill as all the water spilled or released as a flood control measure (in excess of credit water[441]) in excess of current demand on project storage which does not become usable water by storage in another reservoir.

- Article Iq defines a hypothetical spill as that which would have occurred if 790,000 acre feet had been released from project storage at rates proportional to the actual release in every year from the starting date to the end of that year.

- Article VI provides that in a year of actual spill no annual credits nor annual debits shall be computed for that year. Furthermore, Article VI states that "In any year in which there is actual spill of usable water, or at the time of hypothetical spill thereof, all accrued

439 The 1938 Compact was preceded by one in 1928.
440 Littlefield, "The History of The Rio Grande Compact of 1938."
441 Annual credits are the amounts by which actual deliveries in any calendar year exceed scheduled deliveries; annual debits are the amounts by which actual amounts fall short of scheduled deliveries.

debits of Colorado, or New Mexico, or both, at the beginning of the year shall be cancelled."[442]

- The compact provides delivery schedules at given gaging stations, and establishes that intermediate quantities shall be computed by proportional parts.

- The Resolution Adopted by the Rio Grande Commission in 1948 defines evaporation losses as to be applied in Article VI of the Compact as:
  - Evaporation losses for which accrued credits shall be reduced shall be taken as the difference between the gross evaporation from the water surface of Elephant Butte Reservoir and rainfall on the same surface.
  - Evaporation losses for which accrued debits shall be reduced shall be taken as the net loss by evaporation as defined in the first paragraph.

Controversies and Challenges to the Compact

Overview

The rationale behind the seemingly perennial interstate conflict between the states of the Rio Grande is probably best captured by the following excerpt from President Theodore Roosevelt's first State of the Union Address on December 3, 1901:

In the arid region, it is water, not land, which measures production. The western half of the United States would sustain a population greater than that of our whole country today if the waters that now run to waste were saved and used for irrigation.[443]

The sustainability of economic endeavors in arid New Mexico, Texas, and Mexico are undeniably hinged on the availability of water. Analyzing the president's discourse, it is evident that in 1901 the challenge was to capture floodwaters that would ordinarily go to waste. Upstream development in Colorado only affected downstream users because water capture was not efficient. The president thus explicitly references the role of government, not private entities, in constructing and maintaining reservoirs.[444]

As an aside, and in keeping with observations in this report's Reservoir Impact Assessments, President Roosevelt, in his wisdom, made the following statement in his State of the Union:

It would be unwise to begin by doing too much, for a great deal will doubtless be learned, both as to what can and what cannot be safely attempted, by the early efforts, which must of necessity be partly experimental in character.[445]

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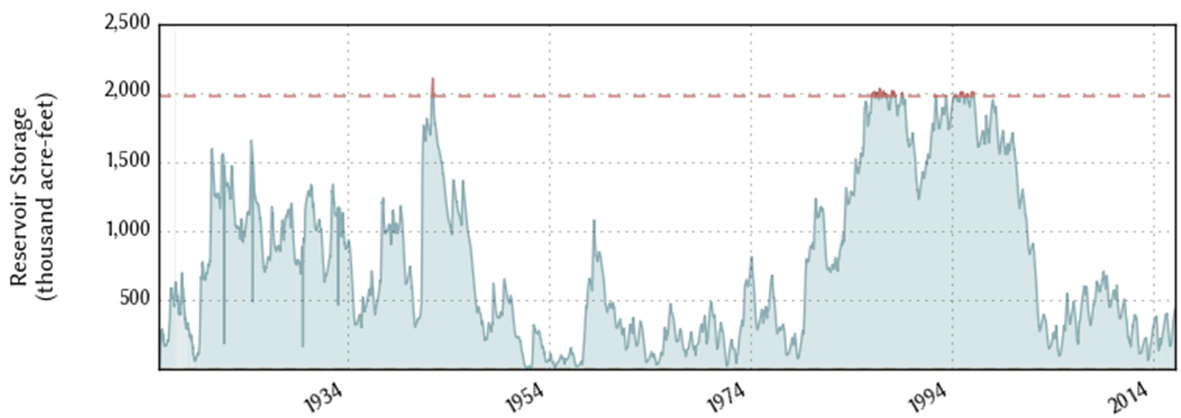
[442] Rio Grande Compact, 2016.
[443] The American Presidency Project, "Theodore Roosevelt: First Annual Message," December 3, 1901, http://www.presidency.ucsb.edu/ws/?pid=29542.
[444] The President argued that their (reservoir) construction has been conclusively shown to be an undertaking too vast for private effort. Also, as Littlefield (1999) explains, rivalry between the companies proposing dams at Elephant Butte and El Paso were motivated by business interests.
[445] Ibid.

Current Drought

Today, however, despite the ability of the Elephant Butte and Caballo dams to store approximately 2.3 million acre feet of water, drought conditions have put the spotlight on grey areas in the Compact and the 1948 Compact Commission Resolution and have exacerbated interstate tensions.

Notably, the Compact contains provisions for "appropriate adjustments" to be made in water delivery schedules to account for a) any change in location of gaging stations; b) changes in the runoff above inflow index gaging stations; and c) any trans-mountain diversions into the drainage basin of the Rio Grande.

Figure 16.3.
Elephant Butte Reservoir Storage since Closure



Source: Water Data for Texas, "Elephant Butte Lake," http://www.waterdatafortexas.org/reservoirs/individual/elephant-butte.

Figure 16.3 captures both the variability in water storage as well as the marked decline in storage levels in the Elephant Butte dam since 2004. The graphic is supported by the following observations:

- These conditions (average or above average precipitation from 1965 to 1998) gave way by 1999-2000 to conditions that were warmer and drier than at any period in the 20th century or the preceding 1,200-plus years.[446]
- Since 2001, a great part of the Southwest U.S. has experienced drought, with particularly widespread and severe drying in 2002, 2003, 2007, 2009, 2011, and 2012. During these

[446] Glen M. MacDonald, David W. Stahle, Jose Villanueva Diaz, Nicholas Beer, Simon J. Busby, Julian Cerano-Paredes, Julie E. Cole, Edward R. Cook, Georgina Endfield, Genaro Gutierrez-Garcia, Beth Hall, Victor Magan, David M. Meko, Matias Méndez-Pérez, David J. Sauchyn, Emma Watson, and Connie A. Woodhouse, "Climate Warming and 21st Century Drought in Southwestern North America," *EOS Transactions* 8(9) (2008): 82-83.

extremes, precipitation across the region averaged 22 to 25 percent below the average for all of the 20th century.[447]

The decrease in water supply is made worse by the increase in demand, and Census Bureau statistics show that some downstream communities are growing by as much as 45 percent. The gap between supply and demand will grow even if there are no increases in average annual precipitation. The growing imbalance between supply and demand will likely lead to a greater reliance on non-renewable groundwater resources. Increased reliance on groundwater resources will lead to greater losses from the river into the groundwater system.[448]

This confluence of increased demand and decreased supply has lead the U.S. Bureau of Reclamation to consider as real the possibility of 30 percent less water as the new hydrological normal.

Sedimentation and Evaporation Losses

In addition to drought conditions, the Compact delivery schedules are affected by difficult to measure variability in surface water evaporation, and reduced reservoir capacity caused by sedimentation.

Estimates of evaporation losses, based on different modelling approaches, have ranged from 230,000 to 350,000 acre-feet per year in the Rio Grande basin.[449] Scientists readily admit that direct measurement of evaporation from water surface is very difficult. The process of evaporation is a complex phenomenon, which is a function of solar radiation, temperature, wind speed, vapor pressure deficit, atmospheric pressure and the surrounding environment.[450]

The 2007 sedimentation assessment by the U.S. Bureau of Reclamation reports that sediment has claimed 600,000 acre-feet (23.16 percent) of the Elephant Butte Reservoir 2.6-million-acre-foot capacity.[451] Caballo Reservoir lost 6.3 percent.[452]

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[447] Glen M. MacDonald, "Water, Climate Change, and Sustainability in the Southwest," Proceedings of the National Academy of Sciences of the United States of America, 107(50) (2010): 21256-21262.

[448] Dagmar Llewellyn and S. Vaddy, "West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment," Upper Colorado Region, U.S. Bureau of Reclamation, 2013, http://www.usbr.gov/watersmart/wcra/docs/urgia/URGIAMainReport.pdf

[449] S. Hansen and J. Gould (1998), and B. Wilson (1997). Cited in William E. Eichinger et al. "Lake Evaporation Estimation in Arid Environments," IIHR Technical Report No. 430, 2003, http://www.iihr.uiowa.edu/wp-content/uploads/2013/06/IIHR430.pdf .

[450] Ali Abbasi and Nick van de Giesen, "Evaporation Modeling in Lakes in Arid and Semi-Arid Regions," *Geophysical Research Abstracts vol. 14, EGU2012-933*, 2012, http://meetingorganizer.copernicus.org/EGU2012/EGU2012-933.pdf.

[451] Matt Weiser, "Sedimentation is A Building Problem in The West's Reservoirs," April 20, 2011, https://www.hcn.org/issues/43.6/muddy-waters-silt-and-the-slow-demise-of-glen-canyon-dam/sedimentation-a-building-problem-in-the-wests-reservoirs.

[452] Ibid.

The Accounting System

The above-mentioned difficulties in estimating sedimentation and evaporation losses undoubtedly compound Rio Grande Compact accounting. In the 2013 annual Report of the Rio Grande Commission to the governors of Colorado, New Mexico, and Texas, in the section on Compact accounting, the following opening paragraph highlights the challenge facing Compact administration:

> The Engineer Advisers reviewed the streamflow and reservoir storage records and other pertinent data for the Upper Rio Grande Basin during calendar year 2013 **and are again unable to reach a consensus on the 2013 accounting** *[author's own emphasis]*. The lack of consensus arises from a disagreement that began in 2011 amongst the Texas Engineer Adviser and New Mexico and Colorado Engineer Advisers on the release of water by Reclamation from Elephant Butte Reservoir in late summer 2011. As a result, the Engineer Advisers have not reached consensus on how to finalize the 2011, 2012, and 2013 Rio Grande Compact Delivery Tables for Colorado and New Mexico and the Release and Spill from Project Storage Table.[453]

In addition to the challenge of accurately measuring system losses due to evaporation, sedimentation, and as we will see below, diversions and ground water pumping, concern has been raised by the New Mexico Engineer adviser that there is double accounting of evaporation on New Mexico credit water stored in Elephant Butte Reservoir when Article IV and Article VI of the Compact are applied.

Groundwater Pumping and Diversions

In the 2013 case of *Texas v. New Mexico and Colorado*, still before the U.S. Supreme Court, the Texas Commission on Environmental Quality, on behalf of the State of Texas, contends that as a result of ground water pumping (an resource that falls under a separate legal regime from surface water) and unauthorized surface diversions between Elephant Butte and the Texas State line since 1938, Texas does not receive its share of water allocations as provided for in the Compact and in accordance with federal law for the Rio Grande Project. Texas asserts that New Mexico is in violation of its Compact obligations, and issues between sovereign states that can only be resolved by the U.S. Supreme Court.[454]

New Mexico counters that it does in fact deliver the mandated volumes of water to the Elephant Butte reservoir as provided for in the Compact. It argues that any diversions or groundwater pumping below Elephant Butte and above Texas state lines are a violation of the Rio Grande Project and not the 1938 Compact. If the latter were to prove true, the matter would need to be raised by the El Paso County Water Improvement District in its capacity as project beneficiary,

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[453] Rio Grande Compact Commission, "Report of the Rio Grande Compact Commission to the Governors of Colorado, New Mexico and Texas," 2013, http://www.ebid-nm.org/legalUpdates/legalUpdates/2013_RGCC_Report_Final.pdf.

[454] Under the U.S. Constitution, the Supreme Court has original and exclusive jurisdiction over controversies between two or more states.

and would therefore not be a matter for the Supreme Court. As discussed previously, while the Compact provides for the delivery of water at San Marcial, New Mexico (just above the Elephant Butte Reservoir), some 105 miles north of Texas State lines, the terms of the Rio Grande Project guarantees the delivery of water to Texas.

In determining whether the Compact was violated, the Supreme Court would have to interpret the rationale of the Compact negotiators when they decided to deliver Texas' water in New Mexico territory. New Mexico argues that Texas' claim is not based on the express terms of the Compact, while Texas argues that the 1905 Rio Grande Project and the obligations thereunder are an integral part of the spirit in which the Compact was accorded. Irrespective of the legal interpretation on which this matter hinges, the Honorable Pat Gordon, Texas' Rio Grande Compact Commissioner, estimates that 2,500 wells have been drilled below Elephant Butte since the compact was signed.[455]

Conclusion

The spirit of the 1938 Rio Grande Compact is to divide the waters of the Rio Grande in a manner that would preclude the types of conflicts that brought the states of Colorado, New Mexico, and Texas to the negotiating table in the first half of the 20th Century.

Today, drought conditions have exacerbated underlying tensions that are given life by Compact ambiguities and actions perceived to run contrary to the spirit of comity that must prevail for the effective management of a waterway as unique as the Rio Grande (interstate and international).

Compounding the drought conditions is a complicated accounting system that naturally suffers from the difficulty of dealing with sedimentation and evaporation losses. The difficulty of measuring evaporation losses is an ambiguity which may enter the ongoing Compact/Rio Grande Project dispute.

There appears to be sufficient historical evidence to suggest that obligations under the Rio Grande Compact were not intended to end with New Mexico's delivery of water at San Marcial, 105 miles north of the Texas state line. While this point is the subject of ongoing debate, the account of former Commissioner Frank Clayton appears to sufficiently establish that the Rio Grande Project was viewed as an integral part to the intent and purpose of the Rio Grande Compact.

[455] Michael Haederle, "Texas, New Mexico Tangle Over Water," *Los Angeles Times,* January 25, 2013, http://www.acmwater.com/assets/Texas-New-Mexico-tangle-over-water.pdf.

Chapter 17. The Energy-Water Nexus in the Paso del Norte Region

by Faith Martinez Smith

Introduction

The purpose of this chapter is to address the energy-water nexus in the Paso del Norte (PdN) segment of the Rio Grande. The study seeks to determine the types of energy consumed and produced, the water available, the uses of ground and surface water, and the future of water for energy production. Using the Energy Information Agency's online database, the energy production within the PdN was determined to primarily be for electricity generation. Most forms of electricity generation require water to generate power. Additionally, electricity is used to heat, treat, and pump water for various end uses. The interconnectedness of water and energy production is termed the *water-energy nexus.* The PdN Region has a robust mixture of electricity generation as well as various end uses for both electricity and water produced in the region.

Water Availability in the Paso del Norte

The PdN region uses both groundwater and surface water, and is primarily reliant upon surface water. The region begins at the Elephant Butte Reservoir in Sierra County, New Mexico, and continues along the Rio Grande's pathway southeast towards El Paso. The Rio Grande then begins to form the border between the United States and Mexico. The Rio Grande begins as a stream in the San Juan Mountains of southern Colorado, continuing south through the PdN Region and eventually flowing into the Gulf of Mexico. Along this pathway the Rio Grande meets Fort Quitman, ending the PdN Region. A significant portion of the PdN includes the north eastern portion of the Mexican state of Chihuahua. The energy-water connection in the PdN, due to limited supply and heavy demand, is complex.[456,457,458]

The PdN includes both urban and rural population centers, severe climatic differences, and numerous economic activities as well as the use of both surface water via the Rio Grande and groundwater resources. The watershed of the Rio Grande is large, covering 336,000 square miles, with half of the drainage basin being arid or semiarid, which limits the contribution of runoff water to the flow of the Rio Grande.[459]

Surface water in the PdN is supplied by the Rio Grande drainage basin, which is over-allocated and relied upon for a variety of uses. This includes potable use in health care, education, construction, public administration, food services, and other service industries in addition to

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[456] National Water and Climate Center, "Basin Wide Reservoir Summary," as of January 31, 2014, http://www.wcc.nrcs.usda.gov/ftpref/data/water/basin_reports/new_mexico/wy2014/barenm12.txt.
[457] Natural Resources Conservation Service, "Water Supply Products," accessed March 2016. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/snow/waterproducts/?cid=nrcs144p2_068877.
[458] Natural Resources Conservation Service, "Water Supply Products."
[459] National Water and Climate Center, "Basin Wide Reservoir Summary."

irrigation, and power plant cooling.[460,461] Groundwater within the region exists, but is often brackish, containing a high concentration of total dissolved solids or brine. Groundwater is used in southern New Mexico along the Rio Grande for irrigation of pecan groves.[462,463,464] Groundwater for the groves is pumped near the Rio Grande, impacting the water table, and according to the Texas Water Development Board, reducing the flow received by Texas from New Mexico. During drought years the United States proportionally reduces the 60,000 acre-feet water delivery to Mexico required by the 1906 Convention for regular years.

Energy Production in the Paso del Norte

Power plants in the PdN are primarily located along the Rio Grande for their proximity to accessible surface water for cooling. Renewable energy, including hydropower and solar, depend on water, elevation changes, and sunlight.[465] Fuel types within the U.S. typically vary between coal, natural gas, uranium or nuclear, renewables, and petroleum. Within this region, several of those fuel types are utilized in various power plant types. This region uses geothermal power, natural gas, hydropower, solar, wind, and coal. Within the portion of the PdN in the United States, hydroelectric, solar, natural gas, geothermal, and wind are the fuel sources, while the Mexican portion of the PdN primarily uses coal-fired generation. Summer capacity tends to be the maximum capacity that a power plant can produce, due to the increased demand required in the PdN region for air conditioning purposes. Variations between capacity are directly related to fuel source, and hydrocarbons are a much more energy-dense resource when compared to the sun, wind, or water resources.

Hydropower

The PdN begins in New Mexico at the Elephant Butte Reservoir, which was created for the primary purpose of irrigation for the surrounding region's valleys, Rincon, Mesilla, and El Paso.[466] When Elephant Dam was built (1908-1916), demand for electricity was relatively low and hydropower turbines were not included in the dam.[467] However, increased demand for energy eventually took hold, and hydropower generation was incorporated in 1940 after the

460 U.S. Bureau of Labor Statistics, "Occupational Employment and Wages in El Paso, Southwest Information Office: U.S. Bureau of Labor Statistics," May 2014, http://www.bls.gov/regions/southwest/news-release/occupationalemploymentandwages_elpaso.htm.

461 New Mexico Department of Workforce Solutions, "Quarterly Census of Employment and Wages Program & Local Area Unemployment Statistics Program in Conjunction with U.S. Bureau of Labor Statistics," accessed March 16, 2016, http://bber.unm.edu/visualizations/CountyProfile/Sierra County.html.

462 U.S. Geological Survey, "WaterWatch -- Streamflow Conditions," http://waterwatch.usgs.gov/?m=real.

463 Texas Water Development Board, "Texas versus New Mexico Water Lawsuit Should Move Forward U.S. Solicitor General Says Texas Has Adequately Pleaded Case for Injury," 2013, https://www.twdb.texas.gov/newsmedia/press_releases/2013/12/texas-v-newmexico.asp.

464 Michael Porter, Office of the State Engineer, New Mexico, "Declared Underground Water Basins," 2005, http://www.ose.state.nm.us/Maps/PDF/Decl_gw_basins_PLSS_Lines.pdf.

465 U.S. Energy Information Administration (EIA), "Independent Statistics and Analysis," http://www.eia.gov/state/maps.cfm.

466 National Park Service, "Elephant Butte Dam and Spillway---Bureau of Reclamation Historic Dams, Irrigation Projects, and Powerplants--Managing Water in the West," 2016, http://www.nps.gov/nr/travel/ReclamationDams IrrigationProjectsAndPowerplants/Elephant_Butte_Dam_and_Spillway.html.

467 Ibid.

completion of the Caballo Reservoir downstream from Elephant Butte.[468,469] The tandem operation of these reservoirs is important. Hydropower is produced year-round at Elephant Butte, while irrigation water is released from Caballo Dam only during the growing season. Hydropower was and is important for a region relying primarily on agriculture. Elephant Butte Reservoir's summer capacity is 27.9 megawatts (MW). For perspective, there are 1,000 watts in a kilowatt; a traditional light bulb uses about 100 watts, while 1 megawatt can power about 1,000 homes. Capacity is the maximum that a generator or turbine can produce under strenuous conditions. Summer capacity is used in arid, dry, and hot climates to estimate the most extreme environmental conditions under which a generator is able to operate at full capacity.

Solar

Along the Rio Grande in New Mexico, solar energy generation using photovoltaic panels has become fairly popular for municipal use, educational institutions, and industrial users. The City of Truth or Consequences, the village of Hatch, and SunE near Las Cruces have all installed photovoltaic cells to capture sunlight and convert it to electricity. According to the EIA, the City of Truth or Consequences' solar power plant produces 1.9 MW, Hatch Solar Energy Center produces 5 MW, and SunE produces 13.6 MW during summer capacity.[470] Siemens Government Technology also generates electricity using solar, but is privately consumed. El Paso also has a solar power plant, Newman Solar, which generates 10.3 MW.[471]

Wind

Wind is popular in West Texas, but most power generated is sent to other major population centers such as Dallas, Houston, or Austin. Horizon City Wind, near El Paso, is a part of the PdN, and it produces wind power through a traditional wind turbine, which generates electricity by spinning a turbine, blades in this case. Summer capacity for Horizon City Wind is 1.3MW.[472]

Fossil Fuels

Electricity production in the Texas part of the PdN is not as diverse as in the New Mexican portion of the PdN region. However, El Paso and Ciudad Juárez produce significantly more electricity, primarily due to demand to meet urban and industrial needs. The primary fuel choice for these cities is natural gas, which is used in natural gas combined cycle plants, natural gas steam turbines, and natural gas combustion turbines. In many cases, city centers or businesses that require some sort of back-up generation have options onsite, for example Providence Memorial Hospital in El Paso. The hospital requires a back-up for safety precautions if the grid is down or unable to meet demand, so a natural gas internal combustion engine is used as its generating source, allowing the hospital to have power at any time regardless of the outside resources. Additionally, Phelps Dodge Refining in El Paso is included in a list of available back-

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468 Ibid.

469 U.S. Geological Survey, "USGS 08361000 Rio Grande Below Elephant Butte Dam, Nm," http://waterdata.usgs.gov/nm/nwis/inventory/?site_no=08361000.

470 EIA, "Independent Statistics and Analysis."

471 Ibid.

472 Ibid.

up resources for the potential of using the generation in emergency or assisted situations, such as helping back up the grid, and the plant can sell excess power generated to the grid operators.

The following is a list of fossil fuel power plants, all using natural gas, in the U.S. part of the PdN, including their summer capacity:

- Newman (760.9 MW);
- Rio Grande (324.2 MW);
- Providence Memorial Hospital (4.2 MW);
- Phelps Dodge Refining (14.8 MW);
- Copper (62 MW); and
- Montana Power Station (200 MW).

Mexico's energy production is primarily owned and operated by the federal government, including electricity generation under the Federal Electricity Commission (CFE).[473] The CFE's North Region in Mexico encompasses the entire portion of the border Texas shares with Mexico, including the PdN.[474] This region contains 17 percent of the nation's generating capacity, or 6,835 MW.[475,476] Within the region, the following states are included: Chihuahua, Coahuila, Durango, Nuevo Leon, and Tamaulipas.[477] The PdN is entirely within the state of Chihuahua, with a population of nearly 3.3 million, and five major cities. Juárez is the largest of the cities, with a population approaching 1.3 million.[478] The state currently only represents 10 percent of the economic activity of Mexico, primarily from assembly plants, while timber production, mining, and livestock ranching used to be "staples of the economy."[479] While economic activity is relatively low, Chihuahua is the richest state in Mexico due to its livestock (beef), and mining, as the second-largest silver producer in Mexico.[480] Outside of the major cities, population is sparse, resulting in numerous types of generation, including traditional power plants, diesel generators, and geothermal.

Cooling Technologies for Power Plants and the Energy-Water Nexus

The majority of the power plants in or near the PdN region use water for cooling purposes. However, some of these plants do not require water for cooling purposes. The PdN region relies heavily on surface water, even when available water is low. The region is well aware of water

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473 Comision Federal de Electricidad (CFE), Mexico, "Informe Annua 2014," 2014, http://www.cfe.gob.mx/inversionistas/Style%20Library/assets/pdf/InformeAnual.pdf.
474 Power-technology.com, "Samalayuca II CCGT Plant, Chihuahua, Mexico," http://www.power-technology.com/projects/samalayuca/.
475 CFE, "Combined Cycle Power Plant Norte III," http://www.cfe.gob.mx/Licitaciones/Licitaciones/Documents/NorteIIIIN1003.pdf.
476 CFE y La Electricidad En México, "Consulta Tu Recibo," 2015, http://www.cfe.gob.mx/ConoceCFE/1_AcercadeCFE/CFE_y_la_electricidad_en_Mexico/Paginas/CFEylaelectricidadMexico.aspx.
477 Tony Burton, "Map of Mexico and Mexico's States," March 2, 2009, http://www.mexconnect.com/articles/3437-map-of-mexico-and-mexico-s-states.
478 History.com, "Chihuahua," January 1, 2009, http://www.history.com/topics/mexico/chihuahua.
479 Ibid.
480 Ibid.

concerns, as demand from numerous users including “municipalities, irrigation, mining, industrial, and other users” exists.[481,482]

The major cities in the PdN of Las Cruces, El Paso, and Ciudad Juárez receive top priority for water use, closely followed by thermoelectric power plants that require water to produce electricity. Thermoelectric power plants generate excessive amounts of heat when producing steam to generate electricity. Some plants do not use water to create steam for generation; instead the fuel source is burned to generate electricity directly through the turbine. With many of these power plants, water is required in different quantities, and in many cases can either be consumed or simply withdrawn and discharged back into the system with minimal losses. There are three main types of water or non-water use cooling options: once-through, recirculating, or dry cooling.

Once-through cooling uses local water sources to absorb heat from the steam in condensers by withdrawing the water, using the water for cooling, and then discharging the water into the local system.[483] Once-through systems consume little water, but they withdraw significant amounts of water. When the water is released to the local system it can be harmful due to its high temperature. These systems are not used frequently, but still exist. The second system for cooling is a recirculating system or a closed-loop system where the water is reused in a secondary cycle or through cooling towers. In a closed-loop system, the amount of water withdrawn tends to be less than in the case of once-through systems. However, these systems consume more water than once-through systems, as water is consumed or evaporated in the process and is replaced with additional water withdrawals.[484] Lastly, dry-cooling systems are used to help reduce water consumption, where air is used instead of water to cool the steam system. Dry-cooling systems can be used in combination with different types of natural gas and solar thermal power plants. However, dry-cooling is not an option for coal-fired or nuclear generation, but it is common for combustion turbines as it is a non-steam system.[485]

Within the PdN region, all cooling types are utilized depending on available water resources and water rights. The majority of the natural gas-fired power plants in the U.S. are combined-cycle plants, and within the PdN only three natural gas generators are not combined-cycle plants. Combined-cycle plants are much more energy efficient, meaning they are able to generate more electricity than just burning the fuel as they capture the waste heat from the initial combustion to then generate steam to turn an additional turbine. These power plants require significantly less water than traditional steam turbine plants since they recirculate the water in the secondary process. Natural gas steam generation systems require more water than the combined-cycle systems, while combustion turbines require no water for electricity production.

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481 USGS, “USGS Reservoir Storage Summary 2015,” 2015, http://md.water.usgs.gov/waterdata/.
482 Constance L. Danner, Daene C. McKinney, Rebecca L. Teasley, and Samuel Sandoval-Solis “Documentation and Testing of the WEAP Model for the Rio Grande/Bravo Basin,” The University of Texas at Austin, 2006, https://www.crwr.utexas.edu/reports/pdf/2006/rtp06-08.pdf.
483 Union of Concerned Scientists, “How It Works: Water for Power Plant Cooling,” 2015, http://www.ucsusa.org/clean_energy/our-energy-choices/energy-and-water-use/water-energy-electricity-cooling-power-plant.html.
484 Ibid.
485 Ibid.

Desalination

Desalination is the most unique project the region has taken on, as a partnership between Fort Bliss and El Paso Water Utilities to create and operate the Kay Bailey Hutchinson (KBH) Desalination Plant. It is the largest inland desalination plant in the world, and is unique in that it treats brackish groundwater as opposed to ocean water, common to plants near coastal areas.[486] This desalination plant relies on local electricity to produce fresh water, and it is very energy intensive to do so. Because of the increased energy required to process the water, additional costs are added for the users.

The KBH plant is capable of producing 27.5 million gallons of water each day, significantly impacting the region's water supply.[487] Desalination strips the water of total dissolved solids, the majority of which are salts, making the water safe for consumption, but the process produces solid waste which adds another layer to the complexity of using the resource. Brackish groundwater is also an exhaustible resource, which should also be taken into consideration if the region is heavily encouraged to shift to utilizing this resource.[488] However, the precise volume of brackish groundwater is unknown.[489]

Because of the increased energy required to process desalinated water, additional costs are added for the consumers. The high cost of desalination makes the desalination plant almost uneconomical to run and local citizens would rather change their water consumption behavior to avoid the increase in water prices. Other desalination plants in the world are coupled with an onsite power plant, which helps reduce costs and provides additional revenue stream options for the company—selling electricity, water, or a combination of the two to maximize profit.

Energy Consumption and Water Consumption

Water resources are closely tied to energy production, in this case, specifically thermoelectric power plants, which require water to operate. Because they are directly connected, cost is considered when building or choosing to operate certain types of power plants. Additional costs should also be considered for municipalities and irrigators as water becomes more scarce. This is because water for use in municipalities requires electricity for pumping and treatment to become potable water. Irrigation also requires electricity, typically for pumping or other on-site operations, but is usually not directly tied with water or typical power plant operations. However, diesel or natural gas generators are used for most on-site applications.

Irrigation districts in both the U.S. and Mexico are second on the list of priorities for water. These stakeholders already have claim to the water resources, and in some cases have water rights equal to or higher than cities. While it is not directly input in many directives, industrial users also have claim to the water resources, and also have water rights. The water rights are

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[486] El Paso Water Utilities, "Public Service Board, Water Rates," 2016, http://www.epwu.org/service/water_rates.html.
[487] Ibid.
[488] Neena Satija, "Brackish Water Abounds, but Using It Isn't Simple," *The Texas Tribune,* January 8, 2014, https://www.texastribune.org/2014/01/08/plenty-brackish-water-underground-still-elusive/.
[489] Ibid.

generally many-years-old claims for the right to use the water resources. For this region, there are several options for water resources, including, but not limited to surface water, wastewater, treated wastewater, desalination systems, rainwater harvesting and pumping of various grades of ground water. Surface water requires the water rights to obtain the water rightfully, while groundwater typically only requires permitting for pumping.[490]

Even with water rights in place, various stakeholders may be willing to pay more for their share of water. However, policy changes for pricing structures of water may need to occur before certain users are willing to participate in conservation or reduction of uses. Other options such as subsidies may need to be considered for irrigators, or municipalities to improve their technologies or to reduce consumption of water and energy resources.

The Texas Water Development Board and the TCEQ monitor and determine the use of water resources in Texas. In Mexico, the waters are managed by the government as well. Water management and conservation has been at the forefront of the locals' minds for decades. The expected decrease in water resources has led them to explore additional options, such as switching power plant options to reduce or eliminate water needed for cooling, using groundwater resources, and opening a desalination plant near El Paso. While groundwater seems to be a logical option, it does have flaws as it is generally connected to surface water, and can impact the level of surface water if wells or pumping occurs near the riverways. This is an issue currently being argued between the State of New Mexico and the State of Texas, as Texas claims it is unable to provide the allocated water resources as part of the Treaty to Mexico due to over-pumping of groundwater resources near Las Cruces, New Mexico, along the Rio Grande.[491, 492] This issue only adds to the complexity of water concerns in the region.

Conclusion

The PdN region understands the importance of conservation and has already taken significant steps to reduce water consumption. Some of the reduced consumption is due to drought, but some may be due to the inability to obtain water rights. Examples of this include the power plants that have chosen to use closed-loop cooling or dry cooling options, irrigators who have updated their irrigation technology, the desalination plant to increase water supply in El Paso, and the use of renewables when generating electricity such as wind and solar.

As the future of water within the PdN remains contentious, it is necessary to use planning methods focused on the energy-water nexus. So far, most stakeholders may ignore the energy-water nexus in their planning and management. The PdN produces energy from a variety of resources, primarily natural gas. The process requires water and the nexus between energy and water requires increased attention.

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490 Samuel Sandoval Solis, "Water Planning and Management for Large Scale River Basins Case of Study: The Rio Grande/Rio Bravo Transboundary Basin," Ph.D. Dissertation (The University of Texas at Austin, 2011).

491 Texas Water Development Board, "Texas versus New Mexico Water Lawsuit."

492 Tiffany Dowell, "Texas v. New Mexico: Review of New Mexico's Motion to Dismiss—Texas Agriculture Law," June 16, 2014, http://agrilife.org/texasaglaw/2014/06/16/texas-v-new-mexico-review-of-new-mexicos-motion-to-dismiss/.

Chapter 18. Survey of Paso del Norte Water Stakeholders

by Deirdre Appel

Introduction

At the request of the Paso del Norte Water Task Force, the PRP conducted a survey on water scarcity in the region. We received input from a range of stakeholders and believe this input is critical to prepare for a Rio Grande/Bravo future with less surface water. Survey results were presented at the May 2016 Task Force workshop on response strategies to water scarcity in the river segment from Elephant Butte Reservoir to Fort Quitman, including parts of New Mexico, Texas, and Chihuahua. Workshop participants received a brochure summarizing the information listed below.

Purpose

There are several reasons why it is timely to prepare for a future with less river water.

- The Paso del Norte is in the midst of a multi-year drought. Elephant Butte Reservoir stands at 14.5 percent of storage volume (July 4, 2016). Changing El Niño patterns suggest that the region has entered a period with increased threat of persistent droughts.

- The U.S. Bureau of Reclamation and other experts predict that climate change may cause a loss of 30 percent of river water by 2040, compared to the 1990 norm. Increased evapotranspiration and reduced snowpack are the likely causes of the decreases in available surface water.

- According to sediment surveys by the Bureau of Reclamation, Elephant Butte Reservoir loses 2.5 percent of its storage volume each decade. In 2016, 100 years after closure, the reservoir has lost 25 percent of its storage volume.

- With important economic sectors, such as agriculture and energy, and a growing population dependent on water, current and future water availability is an important aspect of safeguarding the livelihoods of the region's people and maintaining good relations among riparian neighbors. Equally important: reduced stream flow will increase environmental damage.

Methodology

The Paso del Norte Water Task Force sought to gather feedback on current methods of water management from stakeholders in the Paso del Norte region, which include irrigation districts, water utilities, water governance institutions, water planning agencies, and other water stakeholders/NGOs. The purpose of the survey was to document how PdN stakeholders:

1) Address changing hydrologic conditions,

2) Plan to operate under a scenario of future water shortage, and
3) Envision a sustainable water future for the PdN segment of the Rio Grande/Bravo.

Our research utilized a qualitative survey method to explore the issue and gather input from the range of stakeholders. The sample of survey participants were recruited using recommendations from the steering committee of the PdN Water Task force, supplemented by desk research and expert input. This group of individuals received an email invitation to participate in the survey on January 28, 2016, with a follow-up reminder email on February 3, 2016. We estimate the initial total sample size to be 54. Of those, 31 respondents began the survey and 22 respondents completed the survey.

The survey began with nine questions for all participants on perceptions on the severity of the drought, measures used to cope with drought, and suggested measures to help cope with a reduced Rio Grande/Bravo flow. The participants were then asked to identify which organization they most closely identify with: irrigation districts, water utilities, water governance institutions, water planning agencies, or other water stakeholders/NGOs. Based on this selection, the participants then addressed eight questions relevant to their stakeholder group. At the conclusion of the survey, all participants were provided the full questionnaire. The list of survey questions along with a list of organizations of the survey respondents can be found at the end of this chapter.

Ensuring Privacy and Confidentiality

Prior to participation in the survey, participants were made aware that responses gathered from their participation in the survey would be kept confidential and anonymous. To ensure privacy of the collected data, the survey team created a collaborative electronic workspace and shared folder to which only team members had access.

Limitations of the Methodology

The survey was limited by the number of responses received. As previously stated, the sample size of respondents was 22 participants. The analysis of responses from each organizational subgroup is numerically limited even more. While a smaller sample size is less relevant for qualitative research and prohibits the Task Force from drawing general conclusions on the matter or extrapolating individual responses, the information provided by the participants should serve as insight into the matter. Issues discussed or brought up in the survey should be further explored and should not serve as a consensus of that affiliated group.

Results

Questions Asked of All Participants

At the onset of the survey, all participants were asked a series of eight questions. In regards to the participant's perception of the severity of the 2015 drought, almost half of the participants (45 percent) described it as a severe drought while the other half (41 percent) described it as a moderate drought. Two participants selected abnormally dry. One participant perceived it as an exceptional drought.

Participants were then asked how this drought affected their organization. Answers to this question can be grouped into three categories:

1) *Not Severely Affected/Did Not Affect:* A large portion of the participants (7) believed that their organization was not directly affected by the Paso del Norte drought last year.
2) *Planning Difficulties/Changes in Planning:* This category has a range of responses but the common thread is the drought's impact on water plans, particularly water restrictions. Respondents noted the need to impose restrictions on use of surface water in northern Chihuahua, southern New Mexico, the City of El Paso, and West Texas, and restrictions of everyday use such as swimming pools or car washing. These restrictions in turn affect revenues. More preventative impacts were noted such as advancing water supply projects to provide drought proof supply. One participant from the IBWC noted that the drought resulted in a reduced delivery of flows under the 1906 Convention with Mexico. It also hurt their ability to implement native riparian environmental enhancement within the project areas. Another IBWC participant mentioned that because the drought varied across the Rio Grande basin, impact varied by region as well. The IBWC, however, was directly involved in planning and executing various studies, designs, and maintenance projections that involved the drought. For a water resource planning consultant, the 2015 drought made water planning particularly difficult as many communities the organization works with had to truck water in for the first time in a long time. With the increased water needs around the El Paso area and a shortage of surface water supply, an Integrated Water Management Plan needs to be developed using innovative ideas to prepare for future water demands.
3) *Impacts on Farming:* In addition to imposed restrictions, respondents noted the consequences droughts have upon the agriculture community. During the drought, certain producers were only allowed to plant 15 percent of their available land. Another respondent noted that the rural sector in particular is greatly affected as it causes crop failures and economic stresses. City residents, on the other hand, do not experience this stress. Yet the urban population is especially vulnerable because they do not expect supply constraints in the short term but rather continuous availability.

Table 18.1.
Perceived Severity of Drought

Answer	Responses	Percentage
Abnormally dry	2	9%
Moderate dry	9	41%
Severe drought	10	45%
Exceptional drought	1	5%
Total	*22*	*100%*

Participants were asked to rate the level of importance of each of the following coping mechanisms. The rating scale is from 0 to 10 (10 being most important, 0 if not applicable) Results are displayed in Table 18.2.

Table 18.2.
Perceived Importance of Drought Coping Mechanisms

#	Coping Measure	Level of Importance	Total Responses
1	Greater emphasis on water conservation	7.73	22
2	Increased groundwater pumping	4.9	21
3	Letting fields lie fallow	4.45	20
4	Change to more efficient irrigation technologies	5.10	20
5	Putting distribution channels underground	3.70	20
6	Repair leaking pipes	5.19	21
7	Municipal watering restrictions	5.29	21
8	Other*	8.80	5

*Includes education, groundwater management, wastewater recycling, reuse of treated wastewater, and new homes with xeriscaped front yards.

Participants were then asked whether they plan to adopt additional measures to cope with drought conditions if the drought continues: 59 percent of respondents (13) indicated they would while 41 percent of the respondents (9) indicated they would not. Of those who plan to adopt measures, these measures fall into the four categories below.

1) *Research:* Research should be conducted on the impacts of climate change, the growing and competing demands of water, the effect of decreasing groundwater levels, and on the coordination of reservoir water releases to minimize losses.
2) *Water Use and Water Rights:* To cope with less water in the future, participants noted the need for reallocation of water and changes in the management to improve water use efficiency.
3) *Water Supply Projects:* Such projects could be the collection and use of rainwater, advanced design of water supply projects, and investigation into market-based solutions to encourage more efficient water supply.
4) *Conservation/Community Projects:* Several respondents noted the need for more conservation practices governed locally, or through the regional water group. They also indicated the need for the use of reclaimed water, waterless urinals, participation in a nation-wide discussion on water situation.

In addition to inquiry of action to be taken under the agency's jurisdiction, the survey asked what action the respondent would like to see taken to improve the economic, social, and environmental sustainability in respect to water resources in the entire PdN region. Participants would like to see the following actions taken:

1) *Conservation:* The need for public education on conservation methods or increased water conservation in general was a common theme in these respondents. One respondent noted that conservation is especially necessary for agricultural uses while another noted the need for the continued expansion of the use of reclaimed water, 360 recycling for waste water, water conservation through further limitations.
2) *Regional Cooperation:* Two respondents noted a need for a regional approach to preserving the water available from the Rio Grande. Another noted the need for a rapid

resolution of treaty disputes and a reexamination of water rights as they are being used inefficiently. According to another respondent, regional cooperation is not enough. The region and the state need to move towards a "conjunctive" use mind set. Stakeholders should recognize that surface and groundwater are all part of the same hydrologic cycle and they should be considered as one source when planning for a growing population with drought like conditions.

3) *Funding:* The lack of funding is a common challenge for respondents. They would like to see an awareness of the need for additional supplies and the cost of these supplies.
4) *Infrastructural Support:* One respondent noted they would like to see piped municipal drinking water provided to Juárez while another mentioned the need for a greater emphasis in urban planning to include more green space design and reduce outward expansion.
5) *Research/Knowledge Sharing:* Respondents would like to see research conducted on the impact of subsidized surface water use on water transfers as well as the sharing of knowledge, strategies, and technologies in the use of water for human consumption, water reuse, salvage industrial uses, and agricultural uses. Emphasis should be placed on the expansion of environmental science concepts in school to promote awareness of the environment for future leaders. Additionally, water availability should be taken into account in new initiatives or endeavors in a stronger way.

The participants outlined the following obstacles to implementing the measures described previously in the survey to cope with continued drought.

1) *Lack of Incentives and Funding:* A large share of respondents noted the financial burden on individual organizations to take on conservation practices. Additionally, there is a lack of funding to create change and a lack of incentives to promote change.
2) *Institutions/Legal Framework:* Such institutional constraints include the water rights system and the lack of remedial action. One respondent noted that the rules and regulations that currently oversee the permitting of surface water and groundwater are operated by two very different agencies. Each agency has their own set of guidelines which rule surface and groundwater very differently. Changing policy to make this a more uniformed system will continue to be a challenge but is necessary.
3) *Culture/Education Surrounding the Issue:* Respondents noted a public apathy and lack of knowledge held by government officials not directly involved in water management. There exists, for some, a culture of failing to perceive lack of water as a problem or failing to engage *effectively* at the regional level.

As previously mentioned, the next section of the survey was determined by each respondent's organizational identification. The breakdown of the participants based on organizations is found in Table 18.3.

Table 18.3.
Breakdown of Survey Participants Based on Organization Type

#	Organization Type	Responses	Percent
1	Irrigation District	1	5%
2	City or County Water Utility	3	14%
3	Water Governance Agency (involved in water allocation)	6	27%
4	Water Planning Agency	5	23%
5	NGO/Other	7	32%
	Total	*22*	*100%*

Questions for Irrigation Districts

The PdN has four irrigation districts. Unfortunately, only one took part in the survey. Irrigation districts face reductions in river water allocation during droughts. The district reported that they were allocated 10,000 acre-feet during a non-drought growing season and only 5,600 acre-feet during the most serious drought year. This has serious implications for the farmers as districts must change their water allocations.

Farmers use a range of techniques for irrigation. Respondents noted sprinklers and drip irrigation, laser leveling techniques, and concrete lined ditches. To encourage water conservation, irrigation districts use public awareness campaigns, naming and shaming private measures, and charges to the farmer for the amount of water used. Despite these measures, there is a consensus that farmers face great difficulties in coping with drought. To do so, they will try crop switching, minimize crop switching and system losses, and achieve greater overall efficiency. The greatest barriers for using water more efficiently are inability to change farmer practices, outdated infrastructure, ineffective enforcement of water use, and high cost of conservation methods.

Questions for City and County Water Utilities

All utilities foresee an increase in demand for drinking water in their respective service area by 2040. According to El Paso Water Utilities, monthly water loss ranges from 8-15 percent. This is due to poor infrastructure, such as leaking distribution systems or pipes. Two out of these three respondents use purple pipe water (partially treated water) or non-potable water for non-drinking purposes.

Respondents were asked to specify the percentage of water they receive from each of the following sources: river water, fresh groundwater, desalinated groundwater, and other. El Paso Water Utilities specified they received 50 percent river, 46 percent groundwater, 3 percent desalinated groundwater, and 1 percent reclaimed water while Junta Municipal de Agua y Saneamiento Ciudad Juárez noted they receive 100 percent from river water. The third respondent did not specify a breakdown.

Questions for Water Governance Agencies

Water governance agencies play a critical role in allocating water to different user groups. In order to change allocation rules, water governance agencies noted they either have monthly meetings with water users or, in the case of Texas users, making request to the TCEQ to change water allocations.

When asked how their agencies address the connection between surface and groundwater (conjunctive use), the agencies noted difficulty because the matter is not properly defined or addressed by the legal system. Regardless, they do study and determine the impacts to find out how to address it.

For example, current Texas water law does not license or regulate groundwater extraction. Groundwater is treated as a privately owned resource, that of the surface property owner, thus making it difficult to protect and regulate. "In Texas, these are regulated differently. While recognizing that there are connections, in one case (surface water), it is the state that grants the rights to use water, and in the case of groundwater, the landowner has full use of water. It makes no sense but that's the law. It could create a groundwater conservation district (GWCD), but it is doubtful it was created."

The survey asked water governance agencies what changes to the Rio Grande Compact are needed to cope with increased water scarcity. One respondent believes changes to the Compact will be difficult due to interstate political relations. The focus should be on greater enforcement of the Compact. One respondent noted that with a very probable reduction in surface water supply, the induced recharge to aquifers will diminish surface water even further. This must be addressed first before any changes to the compact can occur. Another indicated honest implementation by the states is needed, not changes. While another recommends a joint study and use of scientific and technical measures as opposed to legal. Based on the responses by Water Governance Agencies, it appears changes to the Rio Grande Compact should be secondary to other action.

A similar question was posed to the agencies in respect to the binational 1906 Convention and 1944 Water Treaty. A respondent noted political pressure on Mexico to compel is needed to better cope with increased water scarcity. One respondent worries that any changes made to the treaties will "only open Pandora's Box." Another questions how Mexico would be interested to renegotiate the 1906 Convention as it allocates Rio Grande surface water to Mexico even in times of drought. Alternatively, another respondent believes these changes should be discussed domestically and followed by a binational forum.

Of those water governance agencies asked, three believed these changes to the 1906 Convention and 1944 Water Treaty can be achieved using the IBWC minute process. One indicated they do not know.

Two governance agencies are involved in inter-basin transfers for supplemental water supplies and two are not. There transfers are expected to occur in the future when the El Paso dam is completed or if market based solutions are factored in.

In closing, water governance agencies indicated they did not need new rules to cope with a potential 30 percent reduction in surface water supply. The current rules offer adequate flexibility and there is no need for more rules; instead, “we need local action.”

Questions for Water Planning Agencies

There were not enough responses from the “Water Planning Agency” category to conduct a qualitative analysis. The following questions were addressed:

What is your timeline for planning ahead?
The Texas water planning process is on a five-year term. Every five years we update the Regional and State Water Plans to keep the information as current and accurate as possible.

Do you consider reduction of groundwater supplies in your plans, if so how?
Groundwater Conservation Districts through the joint-planning process must agree on a “desired future condition” for each aquifer within their Groundwater Management Area. In the development of these values, each District is able to consider how they want their aquifer to look 50 years from now and how best to reach those goals. Groundwater modeling scenarios guide the group in making sure they do not over-pump (deplete) their aquifer supplies. Most districts consider maintaining a sustainable supply for future generations as top priority.

Do you consider the impact of climate change? If so, how?
New to the 2016 regional water plans, coordinated by the Texas Water Development Board, was chapter 7. This chapter is dedicated to drought and water management in times of drought. Each region was able to discuss among the water planning group the impacts drought has on their specific region. Climate change can be discussed within this chapter.

Do you factor in reservoir sedimentation? If so, how?
The regional plans do factor in reservoir sedimentation. For each strategy (project) that is developed to meet growing demands, along with the project the Plan must discuss all types of impacts that are associated with the strategy. Although, my office does not specialize on the surface water side of things, we team with an engineering firm that can bring their expertise on this topic.

What changes in land use do you expect in your planning between now and 2040?
More dry farming.

What population changes do you expect in your planning area between now and 2040?
Population is projected to continue to grow between now and 2070, which is the planning horizon that we plan for.

Questions for Non-Governmental Organizations and Other Agencies

The concerns ranged from environmental flows to upland watersheds and from research to cost. There was no general consensus over concerns regarding water. Yet when asked how their organization sees the water future for the Paso del Norte all believe work must be done to deal with the pessimistic future of increased demand and decreased supply. NGOs were then asked what is necessary from a range of different stakeholders to cope with water scarcity in the future. Their responses are compiled in Table 18.4 below.

All the NGOs that participated in the survey are involved in environmental restoration aside from one. Actions for environmental restoration include the improvement of upland watersheds, restoration of riparian wetlands, rangeland restoration, and cooperative governance. When asked what incentives are needed to support such environmental restoration initiatives, respondents noted funding, investment, training, and viable alternatives to conservation. While NGOs have recognized the issue of water scarcity in the region, their effectiveness is limited in the following ways: remote location and fragmented governance, lack of incentives for water conservation, lack of good institutional planning, lack of resources, and the Texas and New Mexico Compact suit.

Table 18.4.
Summary: Needed Measures for Coping with Water Scarcity

Irrigation Districts	City and County Water Utilities	Water Governance Agencies	Water Planning Agencies
Investment in efficient irrigation technologies	Improve handling leaks and efficient management of groundwater sources	Less politics and more actions/investments	Hire personnel more qualified/trained on the importance of the resource
Incentivize water conservation	Incentivize water conservation	n/a	Include climate change in long-term plans
Reduce transmission losses	Encourage conservation	Encourage conservation	Encourage conservation
Fallow leasing program	System efficiencies	Explore water rights for the river	Explore water rights for the river
Maintenance of infrastructure and water conservation	Water conservation and ordinances	Water conservation	Strategic planning for future use associated with anticipated growth

Survey Respondents and Questionnaire

Survey Respondents

- Center for Environmental Resource Management (CERM)
- The University of Texas at El Paso (UTEP)
- Universidad Autónoma de Ciudad Juárez
- Texas A&M University El Paso
- El Paso County Tornillo Water Improvement District
- Retired from DOI, Bureau of Reclamation
- Texas Commission on Environmental Quality
- Junta municipal de agua y saneamiento Ciudad Juárez
- New Mexico State University
- Rio Grande Restoration
- Presidio County Underground Water Conservation District
- El Paso Water Utilities

- Bureau of Land Management
- Bureau of Reclamation
- HCCRD#1 (Irrigation district)
- International Boundary and Water Commission (IBWC)
- U.S. Section, International Boundary and Water Commission
- LBG-Guyton Associates

Survey Questionnaire

Questions for all participants

1. In your view, how severe is the current drought in the Paso del Norte?
   a. Abnormally dry
   b. Moderate drought
   c. Severe drought
   d. Exceptional drought
   e. Extreme drought
2. How has the current drought affected your organization/your part of the Paso del Norte? (*Max 10 lines)*
3. Please indicate and rate the measures you currently use to cope with drought conditions in the column below. Please rate on a scale from 0 to 10 (10 being the most important, 0 if not applicable).
   a. Greater emphasis on water conservation
   b. Increased groundwater pumping
   c. Rainwater collection and use
   d. Change to more efficient irrigation technology
   e. Desalination
   f. Reallocation of agricultural water to urban supply
   g. Lawn watering restrictions
   h. Other (Please specify)
4. Does your organization plan to adopt additional measures to cope with drought conditions if the drought continues? If so, what are they? *(Max 10 lines)*
5. Thinking about the *Paso del Norte region as a whole,* what actions would you like to see taken to improve the economic, social and environmental sustainability of the region? (*Max 10 lines)*
6. What obstacles do you see to implementing the measures you describe in Question 5?

Additional questions for irrigation districts

1. How much river water are you allocated during a non-drought growing season?
2. How much river water were you allocated during the most serious drought year? Specify the year.
3. How did you change your river water allocations to farmers during the current drought?
4. What irrigation techniques do your farmers use? (give percentages for methods used)
5. How do you encourage water conservation?

6. How do your farmers cope with drought?
7. What is the greatest barrier for using water more efficiently?
    a. Inability to change farmer practices
    b. Outdated infrastructure
    c. Water theft
    d. Ineffective water use enforcement
    e. Other (specify)
8. How do you reach decisions on changing water allocation rules?

Additional questions for city and county water utilities

1. How much water do you receive each year?
2. Specify the percentage of water you receive from each source:
    a. River water
    b. Fresh groundwater
    c. Desalinized groundwater
3. By how much were your water allocations reduced during the most serious year of the current drought? (Specify the year)
4. How much drinking water do you lose to leaking distribution systems?
5. What is the current per household water use?
6. How has water use per household changed over time?
7. Do you use purple (partially treated) water for non-drinking purposes? If yes, please specify its purposes.
8. What is your prediction of future drinking water demand in your service area in 2040?

Additional questions for water governance agencies

1. What are your operating rules for dealing with drought conditions?
2. What is your procedure for changing water allocations?
3. Do you currently have contingency plans for dealing with increased water scarcity?
4. How do you address connections between surface and groundwater use (conjunctive use)?
5. If you or your agency is involved in inter-state water sharing, what changes to the Rio Grande Compact might be needed to cope with increased water scarcity?
6. If you or your agency is involved in transboundary water sharing:
    a. What changes to the 1906 Convention and the 1944 Treaty between Mexico and the United States of America might be needed to cope with increased water scarcity?
    b. Can these changes be achieved by using the IBWC minute process?
7. Is your agency involved in interbasin transfers for supplemental water supplies?
8. Do you expect such transfers to occur in the future (when)?
9. What new rules might your agency need to deal with a potential 30 percent reduction in surface water supply?

Additional questions for water planning agencies

1. What is your time horizon for planning ahead?
2. Do you consider reductions of available groundwater supplies in your plans? If so, how?
3. Do you consider the impact of climate change? If so, how?
4. Do you factor in reservoir sedimentation? If so, how?
5. What changes in land use do you expect in your planning area between now and 2040?
6. What population changes do you expect in your planning area between now and 2040?

Additional questions for NGOs/Others

1. What aspect(s) regarding water is your organization most concerned with?
2. How do you see the water future of the PdN?
3. What do you recommend to the groups/agencies listed below?
    a. Irrigation district managers
    b. City and county water utilities
    c. Water governance agencies
    d. Water planning agencies
4. Are you involved with environmental restoration? If so, please specify.
5. In your view, what incentives are needed for water owners, managers and users to support environmental restoration?
6. What enhances and/or limits your organization's effectiveness in addressing water issues in the PdN?

PART IV.
EUPHRATES-TIGRIS AND PASO DEL NORTE WORKSHOPS

Chapter 19. Euphrates-Tigris Workshop

by Aysegül Kibaroğlu, Haytham Oueidat, and Jurgen Schmandt

Aysegül Kibaroğlu convened a workshop at The Ohio State University entitled "The Evolution of Transboundary Water Politics in Turkey, Iran, Iraq and Syria" as part of the Hydropolitics Seminar Series on Water Scarcity and Water Security, co-sponsored by the Middle East Studies Center, Mershon Center for International Security Studies and Global Water Initiative.

The two-day workshop, held April 21-22, 2016, provided a platform to reconvene the Euphrates-Tigris Initiative for Cooperation with a purpose to uncover the intersections between technical and traditional knowledge bases, and address the misunderstandings that arise due to conflicting epistemic perspectives. Current issues, such as the impending evacuation around the Tigris due to issues with the Mosul dam, make this workshop particularly salient. Participants came from the Euphrates-Tigris riparian nations (Syria and Turkey) and the United States, and three members of the LBJ School PRP attended the event. The workshop agenda and summary are found below.

Agenda

Thursday, April 21 - Keynote Address

Aysegül Kibaroğlu, "The Evolution of Transboundary Water Politics in Turkey, Iran, Iraq and Syria"

Friday, April 22 - Euphrates-Tigris Water Issues

9-9:15 a.m. - Welcome Remarks

- William Brustein, Vice Provost for Global Strategies and International Affairs, The Ohio State University

9:15-9:45 a.m. - Origin, Mission, and Activities of Euphrates-Tigris Initiative for Cooperation (ETIC)

- Faisal Rifai, Executive Director of the Euphrates-Tigris Initiative for Cooperation (ETIC), retired Professor of Water Resource Management from Aleppo University

9:45 a.m. - Collaborative Planning and Knowledge Development 2008-2011

- Eblal Zakzok, Assistant Professor of Water Resource Management, The Ohio State University
- Faisal Rifai, Executive Director of the Euphrates-Tigris Initiative for Cooperation (ETIC), retired Professor of Water Resource Management from Aleppo University

10:30 a.m. - Comparative Transboundary Issues: Rio Grande and Euphrates Rivers

- Jurgen Schmandt, Professor Emeritus, Lyndon B. Johnson School of Public Affairs, University of Texas-Austin

1-2 p.m. - Concurrent Sessions

1. Geographical Information Systems (GIS) as useful tools in water resources management: how to continue GIS projects with war on the ground, political tensions, humanitarian crises? (Eblal Zakzok)
2. Capacity building in transboundary water management: Regional and local perspectives (Faisal Rifai)
3. Urgent water issues in the ET basin: Case of Mosul Dam (Haytham Oueidat, LBJ School, UT-Austin)

2-3:15 p.m. - Report from Concurrent Sessions

- Whole group discussion

3:15-3:30 p.m. - Concluding Remarks

- Alam Payind, Director of the Middle East Studies Center

Summary

The Euphrates Tigris workshop addressed current situation in the region, which faces major challenges. The riparian nations of Turkey, Syria, Iraq, and Iran have sought to maximize their benefit from the water sources within their borders, often causing issues for their neighbors. The Euphrates Tigris Initiative for Cooperation (ETIC) was formed to address these challenges through cross-border cooperation, and the improvement of information and knowledge sharing. Board members and participants of this organization spoke at the workshop, along with other experts, to share knowledge regarding public policy, political science, civil engineering, technology for gathering and processing current data, and environmental sustainability. Conversations were lively due to the diverse priorities of each professional discipline, and the diverse cultural perspectives. A desire for sustainable water usage and peaceful cross-border relations unified the group.

The challenges are formidable. Concurrent development projects in each of the countries, and multiplying forms of water resource extraction and usage have increased demand and created competition for water resources between these countries. Dams were originally installed for flood control, but quickly they became means for industry, irrigation and power generation. Currently, water resources from reservoirs are allocated for drinking and domestic use, as well. As time passes dependence on artificial sources becomes more entrenched, making water development a path of “no return.” At the same time, means for usage reduction, and more effective management are improving. Major issues include:

- Periods of tension over water rights, sometimes verging on the brink of war.
- Implementation of water management systems and issues with decaying dams negatively impacting local communities.
- Increasing war and terrorism due to the formation and entry of jihadist groups, and misguided interference of world powers in the region.

Since the U.S. invasion of Iraq, the increase in the number and intensity of conflicts, and the continued involvement of outside powers, and especially the involvement of the so-called "Islamic State," have made it increasingly difficult for researchers, government officials, and technical professionals to continue their work. As the civil wars and the factional cross-boundaries conflicts have steadily increased, cross-boundary cooperation has become correspondingly more difficult, especially since the civil war began in Syria in 2011. At the same time, outside powers depict crises that may be manageable from the perspective of locals on the ground. The U.S. government reported that the Mosul Dam, for example, was on the verge of rupture, but according to Oueidat, these claims are overblown. It is true the design of the dam is inherently flawed, utilizing a gypsum foundation, but regular maintenance of the dam could forestall any ruptures for many years.

The keynote lecture of the workshop, presented by Professor Kibaroglu, focused on how the current situation of water competition in the region evolved over time. The competition started in the 1960s, as Syria and Turkey built dams to protect against floods and provide for droughts. These quickly became irrigation projects, and hydroelectric power plants were built. Demands increased further as these became primary sources of drinking water. The draw on the water is made more severe by the natural evaporation which occurs as the two rivers cross arid planes in Iraq and Syria, while the development of dams exacerbated the loss of water. While the countries had similar objectives of security, water supply and sanitation, food, and energy (hydropower), they conducted their reforms nationalistically, consolidating resources for their own populations.

The nationalistic direction described above took the form of Ba'athist party centrism in the Syrian and Iraqi Ba'athist regimes, in addition to Turkish development projects focusing on its southeast region. This led to a period of aggression, but eventually all sides sought to negotiate water resource management agreements. The organization Euphrates Tigris Initiative for Cooperation emerged from the corresponding dialogue amongst academics and lower level government professionals desiring pragmatic solutions to bypass political obstacles. The organization's goal was, and continues to be, to seek collaborative solutions to the problems faced by each country. ETIC facilitated cooperation, under the auspices of the USAID, UNEP, the Indian Government, the Swedish Government, U.S. universities, such as Kent State, and other supporters. ETIC has served its mission of knowledge sharing, exchange of information, and supporting data collection and analysis across borders by hosting stakeholder meetings and training workshops.

Major activities of the Euphrates Tigris Initiative for Cooperation (ETIC):

- ETIC Stakeholder Workshop, World Water Congress, Nov. 2005, New Delhi;
- Dam Safety Training Program for Water Managers, February 2006, Istanbul;
- ETIC Stakeholder Meeting, 4th World Water Forum, March 2006, Mexico City;
- Stakeholder Meeting, World Water Week, Middle East Seminar, August 2006, Stockholm;
- Modeling training workshop, Sandia National Labs, Nov. 2006, Amman;
- CSD-15 Partnership Fair, United Nations, May 2007, New York;
- Project Development, Workshops on ET Region, University of Tokyo, March 2005, March 2006 and Nov. 2006, Tokyo;

- Participation in the Joint Seminar with Nile Basin Initiative, FAO, Gov. of Italy, July 2007, Como;
- ETIC Stakeholders Workshop and Conference, Bahcesehir University, Istanbul, 11-17 September 2007;
- Workshop on Knowledge Technology, Gaziantep, Turkey, 13-15 March 2009;
- Training Workshop on Global Geographic Information System, Aleppo, Syria, 2010; and
- Conference of ETIC and the German National Committee of the international Hydrological Program (IHP) of UNESCO and the Hydrology and Water Resources Program (HWRP) of WMO Okan University, Istanbul October 18-21, 2011.

Since 2011, and the events of the uprisings across the Arab world, along with intensified conflict in Iraq, riparian nation cooperative activities have slowed down in the region. The ETIC Board met in Istanbul in 2012, the last meeting to take place in one of the riparian nation states.

The Euphrates Tigris riparian nations are not alone in most of the issues they are facing, however. A global view on river basins water issues provided by Professor Schmandt aided the discussion of universal properties of this critical source of fresh water for many of the world's largest population centers. Rivers are distant sources of water, originating from mountain snow, or tropical rainfall. Their journey downstream creates fertile soil but also entails loss of water to evaporation through what are often arid climates. This is certainly true in the Euphrates Tigris region. Worldwide, dams, reservoirs, canals, distribution channels, modern forms of agriculture which require intensive irrigation, and growing basin populations , are putting immense pressure on these water resources. Massive rivers, such as the Rio Grande, actually dry to a trickle in some seasons. Clearly these factors make cross-border cooperation, not only more necessary, but more fraught with conflict based on competing interests.

Conclusion

The evolution of water resource management and associated national and foreign policies in Turkey, Syria, Iraq and Iran, the riparian nations of the Euphrates and Tigris rivers, has been both predictable and volatile since the 1960s. Development of the economy, of the social benefits of becoming a "developed country," and of the natural assets of the terrain of each country drove each country to invest heavily in water management projects. Turkey's Güneydoğu Anadolu Projesi, or "GAP" project, is perhaps the most well-known of these projects. Since the inception of such projects local and global perspectives on water management have become more inclusive of environmental, social, and political demands. ETIC was formed in response to these needs.

The water development projects began with modest goals of preventing floods and droughts, but quickly became more ambitious. As the scope of the water resource uses increased, the number and significance of the issues also increased. For example, the issue of natural evaporation over the arid plains has existed for centuries, but accelerated evaporation from large reservoirs has made the issue of water loss much more severe. This is made more complex by the dependence the reservoirs have created in regard to drinking water, irrigation and hydropower. There are a host of complex issues created by the new technologies that effect people, wildlife, and the environment.

In addition to the intrinsic challenges of water management and cross-border negotiation of water usage, local academics and professionals capable of addressing these challenges are increasingly fleeing from the region with the increasing number of conflicts, terrorist groups occupying the region, and persecution from local groups, governments or foreign occupiers. The work of ETIC continues, but much of the work must now operate remotely. Universities and other organizations in the business of knowledge production and knowledge sharing may continue to host these activities. There is hope that with the Internet and satellite technology that the regional knowledge will continue to be developed and exchanged amongst the riparians.

Chapter 20. Paso del Norte Workshop

by Sara Eatman, Marimar Miguel, and Jurgen Schmandt

The Paso del Norte workshop was held on May 27, 2016, in El Paso, Texas, with participants from the U.S. and Mexico. This chapter contains the workshop agenda, bulleted summaries of the presentations and sessions, and a table showing the results of a vote by attendees on the priorities for water planning.

Agenda

Paso del Norte Water Task Force Workshop
"Preparing for Less Water in the Paso del Norte"
University of Texas at El Paso

Morning session: Chair Jose Garcia

8:30 Opening Statements

- Welcome by IBWC/CILA Commissioners Ed Drusina and Roberto Salmon: On behalf of the PdN Water Task Force, IBWC/CILA are pleased to work with PdN stakeholders to develop a vision for a regional water future
- Goals for today: Review and discussion of expert views and stakeholder input on PdN water future, Oscar Ibañez, Water Task Force Steering Committee
- Goals for 2016/17: Use PdN Water Taskforce for developing binational strategy to cope with water scarcity, Jose Garcia, Water Task Force Steering Committee

9:00 Short expert reports on need for planning ahead NOW
9:00 Projected 2030 population growth in the PdN, Ed Archuleta, UTEP
9:15 PdN/Mexico 2030 surface water supply and demand, Oscar Ibañez, UACJ
9:30 PdN/Texas 2030 surface water supply and demand, William Hargrove, UTEP
9:45 PdN/New Mexico 2030 surface water supply and demand, Philip King, NMSU
10:00 How climate change/variation reduce surface water supply, David Dubois, NMSU
10:15 Coffee Break
10:45 The economic impact of climate change on the PdN, Brian Hurd, NMSU
11:00 How reservoir sedimentation reduces Elephant Butte storage volume, Bert Cortez, U.S. Bureau of Reclamation
11:15 Q and A session
11:30 PdN Stakeholder survey, Jurgen Schmandt, HARC and UT Austin
11:45 Comments by Diana Natalicio, President of UTEP
12:00 Lunch, Remarks: Lic. Antonio Andreu, Presidente de Junta Municipal de Agua y Saneamiento Juárez (JMAS)

Afternoon session: Chair René Franco

13:30 PdN Water Task Force Draft Action Plan, Jurgen Schmandt, HARC and UT Austin

13:45 Discussion: Comments on proposed Action Plan
14:45 Main points raised by stakeholders, Sara Eatman and Mariam Miguel, UT Austin
15:00 How our PdN regions will work together—Oscar Ibañez, Ari Michelsen, José Garcia
15:30 Closing remarks, CILA and IBWC Commissioners, René Franco
16:00 Meeting adjourns

Summaries

Morning session: Chair Jose Garcia

Opening Statements: IBWC/CILA Commissioners Ed Drusina and Roberto Salmon. On behalf of the PDNWTF, IBWC/CILA are pleased to work with PdN stakeholders to develop a vision for a regional water future.

Ed Drusina, USA:

- The Colorado Basin system has been in a 15-year drought. The Bureau of Reclamation has been monitoring water from U.S. to Mexico Colorado basin: 10 percent chance of Lake Mead hitting lowest mark ever this year, and the chance increases to 64 percent in 2020.
- The 2011 drought on the Rio Grande resulted in only 6 percent water allocation, which is the lowest allocation recorded.
- Reviving the Paso del Norte Water Taskforce is an important step, since drought is a regional issue that requires cross-border cooperation. "Political lines are just that when it comes to natural resources."

Roberto Salmon, Mexico:

- The Paso del Norte region, on both sides of the border, has more similarities than differences. We are distant from state and national capitols and so the region is dependent on cooperative efforts like the Task Force and the IBWC/CILA to ensure water issues are addressed. Sustainable water management requires binational effort.

Goals for Today: Review and Discussion of Expert Views and Stakeholder Input on PdN Water Future

Oscar Ibañez, Water Task Force Steering Committee:

- Today we will select priorities for the work of the Taskforce.
- Preparation of the PDNWTF workshop:
  - Talks began last fall and a number of people helped with the preparation.
  - Dr. Jurgen Schmandt has been overseeing a research group at UT Austin, which developed and circulated a survey of regional stakeholders, asking about goals and interests in the region concerning drought and water scarcity.

- The PdN has a unique set of issues, so water management requires local input and informal engagement, like that of the Paso del Norte Task Force, to develop appropriate solutions.
- Stakeholder input is critically important.

Goals for 2016/2017: Use PDN Water Taskforce for developing binational strategy to cope with water scarcity

Jose Garcia, Water Task Force Steering Committee:

- As a region we have one river, two countries, three states, and various political jurisdictions that deal with water management and distribution, which can make this process very difficult. However, water management can be an opportunity for a region-building exercise, bringing together all of these entities and working toward a common goal of sustainable water supplies across the Paso del Norte.
- The Taskforce includes policy-makers, water managers, and many of the decision makers. If these people can speak together about the issues facing the Paso del Norte, they're more likely to be heard at higher levels of government.
- The role of the Paso del Norte Task Force is to convene and facilitate the exchange of views, understanding similarities and differences, and trying to find a single voice. The goal is to understand concerns, goals, and suggest next steps.

Population Projections for 2030

Ed Archuleta, UTEP - El Paso segment of the PdN:

- El Paso has created a 50-year water plan for the city. It is being implemented successfully with assistance from the state of Texas. Population projections were developed by the state demographer.
- NAFTA in 1994 led to more coordination across the border, through the EPA and now through other channels.
- El Paso has been involved in county and state regional water planning, which has allowed for sharing of expertise and resources for gathering population data and projecting growth of the population and water demands.
- El Paso drives the regional water demands as the largest city by far in the Texas portion of the Rio Grande PdN sub-basin, although there has been some growth in Presidio and Marfa. In recent years, birth rates have exceeded death rates. We expect an increase in migration into the region due to economic development projects underway.
- El Paso City has a population of 700,000 plus, and grows by 10-12,000 per year.
- Bottom line: No economic development or growth can happen without water. Networking, communication, will help us work on things we agree on and define next steps forward.

Eng. Vicente Lopez, IMIP - Juárez Municipality:

- Ciudad Juárez saw a reduction in population due to security issues in 2008, but in 2015 and 2016 has seen record employment numbers. The 2015 population for Ciudad Juárez is 1,382,753, it was 789,522 in 1995, and it is projected to be 1,616,344 in 2030.
- As a result of security problems, demographic shifts in the population, and changes in industrial employment, there have been many re-adjustments in the projections of population in recent years. In 1995 NAFTA promised a lot of jobs, but some of the industries that moved in have created fewer jobs than expected, and the economic landscape is constantly changing.
- The city has been growing, but the aging population and predominantly working-class population make it difficult to manage infrastructure with the limited resources available.
- The city has been working to encourage centralized development, because low population density presents a challenge to city utilities.
- The rural population is decreasing, but the region is still working to find a balance between urban and rural water users. Agricultural water efficiency requires improved technology, including application and metering.
- The hope is that the PdN Water Taskforce will work towards sustainable solutions to secure water for the next generation. "We hope that the Taskforce is able to stay together and achieve the goals that are set forth at the end of this meeting."

2030 projected water supply and demand in the PDN segment of the Rio Grande/Bravo

William Hargrove, UTEP:

- The water resources that need to be considered in this area are both surface water and groundwater.
  - The main aquifer is the Hueco Bolson.
- Water scarcity issues are a result of growing competition for water in the basin, the changing and uncertain climate, prolonged drought and extreme events
- Bureau of Reclamation has developed climate projections for the southwestern USA
  - Temperature increase of 5-7 degrees F over this century
  - Precipitation increase in the northwestern basin, and north central, and a decrease in the southwest and south central
  - Decrease in April 1 snowpack
- Climate projections for the Rio Grande basin are particularly severe
  - Upward trend in average temperature since the 70s
  - Annual snowpack is less than 50 percent of normal, which has been a trend for about 10 years.
  - Higher demands, particularly agricultural, both from increased evapotranspiration and the longer growing season.
  - The state-wide reservoir storage in New Mexico is predicted to drop 55 percent by 2100
- Elephant Butte has not been full for years, and may not fill regularly in the future, it's management is based on the assumption that the climate of the 1990s was typical, when in fact that was an unusually wet period. So, we would like to think that the last few years were an anomaly, but actually, the high supply years were the anomaly.
- The riverbed in the Paso del Norte runs dry 9-10 months of the year.

- The growing season has been impacted: 100-year average of the date of the last frost was March 23, whereas the last 10-year average is March 1. The growing season is getting longer, which causes greater evapotranspiration. Region E (the Texas Regional Water Planning group that contains El Paso and six other west Texas counties) projects water demand in 2020 will be 73 percent for irrigation, and 21 percent municipal/industrial.
- Texas, since groundwater use isn't regulated, allows farmers to grow things like pecan trees that require massive amounts of water even in years of drought, effectively "borrowing from" the aquifer.
- We at UTEP have been talking to stakeholders, including large and small farmers in the Rio Grande basin in Nnew Mexico, Texas, and Chihuahua, Industrial water users, government entities, etc., and for all of these stakeholders, the chief concern was the prolonged drought and how to respond.
- Key questions to keep in mind:
  - Can we manage across boundaries and jurisdictions?
  - Can we cooperate across sectors instead of compete?
  - Can we come up with a win/win situation?

Update on Water in New Mexico's Lower Rio Grande

Philip King, NMSU:

- There are opportunities to influence policy in several arenas.
- The 1938 Rio Grande Compact describes a simple system for water delivery from Colorado to the NM state line according to gauge data. NM makes its deliveries to TX determined by gaged values and delivers at Elephant Butte, even though the end users are Mexico, New Mexico, and Texas ("Compact Texans").
- Working with Elephant Butte Irrigation District, I report decline in total irrigated acreage but increase in water use due to more water-intensive crops.
- Releases from Caballo are directly related to available diversions to the downstream irrigation districts: the data show increased groundwater withdrawals in low precipitation years. The drought of the 50s depleted groundwater and increased the depth to water over that period. We have maintained high agricultural production through drought by borrowing from groundwater supplies. Water supplies currently are similar to drought of record, but the increased temperatures mean that this drought is significantly more severe.
- "Compact Texans" are impacted more severely by drought simply because they're downstream. The Compact referred to a relatively wet time as the standard expected. Equity depends on going between wet and dry years, which are imbalanced because of the datum selected. An increasingly arid climate was not contemplated in design of project, or the obligations outlined in the Compact.
- As we look toward solutions, it's important to understand that most of the irrigation "conservation" doesn't actually reduce groundwater depletions. Efficiency of on-farm irrigation reduces groundwater recharge; so reduced irrigation negatively impacts groundwater levels. Although we talk about shifting to lower water demand crops, selection follows market crop prices and will not follow water use for the sake of conservation.

- Other solutions that have been discussed include brackish water desalination, which is expensive but reliable, storm water capture, which is difficult in a region with highly variable precipitation (would require significant flood and storage infrastructure), and conservation or rain capture, which may be useful but aren't significant enough in volume to make a dent in the overall needs.
- A "Depletion Reduction Offset Program" (DROP) would allow agricultural users to voluntarily fallow land to allow for another use (M&I).
- Is water available? Yes. Is cheap water available? Sort of, but you get what you pay for (reliability). Is cheap and reliable water available? Nope.

PdN/Mexico 2030 Water Supply and Demand

Oscar Ibañez, UAC – Mexico:

- Cuidad Juárez population hasn't grown as much as was expected for 2020 (2.5 million) and projections have been adjusted down. Employment and migration have impacted growth, and now the expectation is 1.8 million in 2030. That's a significant decrease and is good news with regard to demand. However, the rate of growth has surpassed what was expected.
- Irrigation water is limited specifically to water from the 1906 Convention, however demand for municipal/urban water is the largest group (surpasses irrigation). 149 cubic meters/year per-capita use. Needs to be reduced.
- Under the 1906 Convention, 74 million cubic meters per year are delivered through the Compact and there are normal variations, but the change in storage regimes have decreased the delivery volumes. The delivery period requires when the water can be used, which often forces lower efficiency. They could supplement urban use with the water guaranteed by the convention.
- Right now the city is reusing water which decreases return flows, which has been impacting District 009. District 009 was more efficient in the last year than it had ever been, which involves using treated water from the city.
- The 2000 Paso del Norte plan intended to reduce irrigated acreage. Reduction has fluctuated. They have been using groundwater at a rate almost twice of a reliable extraction volume. Estimated that between 1-1.5 meters of abatement of the aquifer occurs annually – which is a significant depletion.
- The need that we see for balancing supply and demand has changed with changing demand projections. However, there are challenges and conflicts between agriculture and urban use. We can maintain agricultural production in the Juárez area but it requires improvements in technology and management.
- Trying to find the right balance between demand supply presents us with a challenge. Originally, we thought the demand was going to increase and would cause for more expensive projects (e.g. if we try to recapture the water). We face potential conflicts between agricultural and urban use – we can have productivity, but we would need accord and availability of water that would provide a more sustainable environment. It needs cooperation and MONEY.

How climate change and variation are reducing surface water supply

David Dubois, NMSU:

- Looking at the changing climate in New Mexico: periodic droughts with increasing intensity since the 1980s. Temperature increase that peaked in 2012 with about 2.8 degrees F higher average temp (worst in 121 years), decreased snowpack, increased demands, seasonality changes (earlier runoff and more rain instead of snow), increased surface runoff; 2012 was third-driest year in records.
- Dust storms in the four-corners area then blow over to the mountains in southern Colorado and change the albedo on snowpack, so that it heats faster—forces land management decisions outside of our planning area that directly impact snowpack and water supplies.
- A range of different climate factors will continue to stress the water resources in the region, both in direct ways (like precipitation and use in the basin) as well as indirect ways, like the impact of dust storms.
- Management strategies should address these regional and intra-regional issues.
- Good recent data source: USBR, 2016 Secure Water Act Report to Congress

The economic impact of climate change on the PDN

Brian Hurd, NMSU:

In addition to climate and demographic factors, one must look at the economic value of water.

- Using a model developed by Julie Coonrod (UNM) looked at the economic impacts of streamflow variations. The dollar amount ranged from $30 million/year to $100 million/year depending on the climate scenario. How can we adjust, since water is only going to become more scarce?
- Various mechanisms for appropriating water:
  - Prior appropriation method, the current standard, respects the current water rights but it imposes a constraint that lays the burden of the drought on particular users and user types.
  - An economic model (i.e., water pricing) will distribute the impacts over all of the users based on the value of water, and encourage the highest value use of water.
  - Proportional adjustment, either for all users or categorize users and assign portions of the drought burden (i.e., limit agricultural use in drought).
- Return flow availability is going to be another complicated issue as we move toward efficiency and reuse, and therefore reduce return flows which downstream users (and aquifer recharge) may depend on.
- Another issue will be how groundwater management has shifted from a supplemental supply during drought to more of a permanent supply.
- How should we manage groundwater?
  - The aquifer is our bank in times of shortage, but has been over-extended in the northern part of the state and will become a permanent feature rather than a supplement.
  - How do we think about the sustainability?
  - We need to take the present value of water and think of what it will mean in the future to deal with increased scarcity.

How reservoir sedimentation reduces Elephant Butte storage volume

Bert Cortez, U.S. Bureau of Reclamation:

- Elephant Butte / Caballo
  - The Bureau authorized the Rio Grande project in 1905, and it was completed in 1916.
  - Current storage is about 2 million acre-feet.
  - Elephant Butte Reservoir is turning 100 years old this year.
  - Elephant Butte was initially authorized for irrigation, then in 1920 a special act authorized the sale of water for municipal, industrial, and miscellaneous uses.
  - Caballo Reservoir was supposed to be for flood control, but was increased for storage and power generation.
- The 1906 Convention states that 60,000 acre-feet be delivered to Mexico at the Acequia Grande.
- The Rio Grande Compact treats everything downstream of Elephant Butte as "Texas."
- The rate of sedimentation has decreased slightly, possibly due to upstream reservoir construction. However, we can still assume about 6500 AF/year of storage capacity will be lost, 0.68 percent per year, 25 percent by now. Estimate from 2007: the reservoir will be at half initial capacity in 2164 (1.02 million AF). Half-life of reservoir is 157 years.
- How should we respond to lower inflows and lower storage? Reclamation started as a way to settle the western states but it has become a water management agency since then. Promotion of conservation and active management in response to drought are central to the current mission of the Bureau.
- Today, BOR is a modern water management agency with a strategic plan outlining numerous programs, initiatives, and activities that will help the western states, Native American tribes, and others to meet new demands.

Remarks by UTEP's President
Diana Natalicio, UTEP

The importance of interdisciplinary research is central to the mission of the University and to solving problems. UTEP serves an area that has been historically underserved and undereducated, and provides opportunities for people in the area on both sides of the border to create opportunities to move into professional careers. The University has tried to foster work on water and natural resources, and look at the way that political boundaries impact the management of shared resources, called Connectography. Some of the ongoing work at UTEP includes engineering research of nanotechnology in water treatment and Dr. Hargrove's work on sustainable water resources for irrigated agriculture in arid regions.

Eng. Manuel Herrera, on behalf of Lic. Antonio Andreau, Presidente de Junta Municipal de Agua y Saneamiento Juárez (JMAS)

Presented a ConAgua study which estimates 12.6 percent losses through water spills. Stated that we suffered from watershed loss. We fell into 60 percent to micro mediation.

- One of the priorities is to reduce the estimated 12 percent losses, and to be more efficient delivering water in the residential sector.
- In green areas, we use a purple-pipe system (recycled non-potable water).

- Aquifers are being overdrawn, and we are trying to approximate this with aquifer models. We have seen the aquifer behavior patterns, and have tried to model the rates of recharge and withdrawals.
- What are we doing?
- In Mexico, we recharged in 2014 and 2015. Applied rigid rules for reuse in drinking water.
- We've been working with legislators to create incentives to work for reuse and recharge of aquifer water by treatment.
- We need to recharge our own aquifers.

Results of PdN Stakeholder Survey

Jurgen Schmandt, Sara Eatman, Marimar Miguel, University of Texas at Austin:

- The increasing need for preparing for increased regional drought has been demonstrated by all of today's speakers. Drought, sedimentation of reservoirs, and aquifer over-use need to be addressed together. All impact the Rio Grande Basin and the Paso del Norte area.
- As a part of a larger effort, a group of graduate students at the University of Texas at Austin's LBJ School of Public Affairs conducted a survey of stakeholders in the Paso del Norte to address current concerns and response to drought.
    - The survey was provided to stakeholders in New Mexico, Texas, and Mexico in both English and Spanish. A brochure on results was distributed today, Paso del Norte Water Task Force, *2016 Stakeholder Survey: Preparing for Increasing Water Scarcity.*
    - Results are also summarized here.
    - Participants included Irrigation Districts, City and County Water Utilities, Water Governance Agencies, Water Planning Agencies, and NGOs; 53 surveys were distributed; useable responses were received from 22 participants.
    - Participants were asked about how entities cope with drought and plan for action.
    - Shortcomings: few responses were received from irrigation districts and Mexico.
- Stakeholders propose four overall priorities for action:
    - Conserve water
    - Cooperate rather than take legal action
    - Conduct research on impacts of climate change and groundwater depletion
    - Obtain funding for infrastructure improvements
- Priorities for irrigations districts:
    - Crop switching
    - Use sprinklers and drip irrigation
    - Line ditches/put them underground
    - Minimize system losses
    - Encourage water conservation
- Priorities for water governance agencies:
    - Change water laws to conjunctive management of surface and groundwater
    - No new rules are needed to cope with 30 percent reduction in surface water supply
    - Instead, we need action

- Priorities for city and county water utilities
    - Plan for increased demand of drinking water due to population growth
    - Repair water leaks
    - Use purple pipe water for non-drinking purposes
- Priorities for NGOs
    - Funding, investment, training for environmental restoration and water conservation
    - Focus on practical steps, not political disputes
- The PdN survey is part of a larger ongoing effort to understand how 10 different river basins around the world are coping with increasing water scarcity (see http://harcresearch.org/work/SERIDAS).
- The project proposes a new definition for sustainable water supply and demand in a river basin in arid or semi-arid areas:
    - Nature's water supply, averaged over the period of the most severe drought experienced in the historical record, delivers a dependable yield sufficient to meet human and ecological needs in the basin.
    - To prepare for increased water scarcity from either natural or human causes, water managers and stakeholders proactively search for ways to use water more efficiently.
    - Whenever observed or projected changes in the natural system or human actions modify river flow, the dependable yield is recalculated, and water managers, after consultation with stakeholders, adjust existing rules for water allocation and water use to match the new level of dependable yield.
    - PdN water managers are invited to look at the applicability of the definition for their region.
- The Paso del Norte Taskforce is an example of stakeholder involvement in regional water planning and sustainable drought response. It provides an opportunity to gather practitioners, water planning professionals and academics to guide water policy.

Using technical information and survey results for developing a water action plan for the PDN: Summary of main points

Chair René Franco and Lorenzo Arriaga:

Potential solutions and avenues for collaboration in Paso del Norte were listed and grouped in categories in an interactive discussion. Several categories of potential solutions were listed on posters and each attendee was given six stickers to indicate which category or specific items represented the highest priorities.

The solutions proposed are listed below, followed by a table showing the results of priority voting.

- Engage other sectors in management and conservation of water resources
    - Chamber of Commerce and the business sector
- Environmental management
    - Watershed improvements (invasive plant species removal, storm water management)
- Define the demand of growth and the source of growth; having detailed demographic projections, industrial and agricultural demand data help to meet demands

- Evaluate the potential for regional-scale infrastructure (Texas, New Mexico, and Chihuahua)
    - Desalination plant proposal to serve the whole region
    - Watershed management, like Arundo donax eradication
- Irrigation management at all three levels: river, canals and then farms—opportunity for conservation
    - Farm-level conservation (crop selection, laser leveling, narrow border flood, drip, etc.)
    - Irrigation district conservation (delivery channel improvements, operational efficiency, loss prevention, metering)
- Research
    - Interdisciplinary approaches including academia, stakeholders, community
    - Economic incentives, financial and price incentives
    - Environmental science, climate and natural systems
    - Treatment technology, water supply
    - Revisit the 1906 Convention to be sure it's adapting to changed conditions
- Better stakeholder engagement
    - Encourage collaboration through role-playing activities, "table-top exercises" where participants work through issues as a different party (e.g. irrigation district manager versus regulator)
    - Annual conference to give ideas for water management, share thoughts, provide forums for engagement
    - Supreme Court case may be impeding the communication with the irrigation districts, keeping them from participating
- Green infrastructure
    - Rainwater harvesting (single property-scale)
    - Potable/non-potable reuse
    - Greywater
    - Storm water capture and management

Table 20.1.
Results of Voting on Priorities

STRATEGY		VOTES	PERCENT
Reuse		**11**	**5.2%**
	Potable	9	
	Non-potable	2	
Economic Incentives		**18**	**8.6%**
	Price Incentives	3	
	Financing	7	
Education		**22**	**10.5%**
	General public	9	
	Schools	3	
	Political	9	

Environment		**16**	**7.6%**
	Watershed & Water Quality	16	
Legal/Regulatory		**15**	**7.1%**
	Environmental Protections	5	
	Diversion/Pumping limits	6	
	Enforcement of (existing) Laws	4	
Engagement		**24**	**11.4%**
	More stakeholders	15	
	More involvement	2	
	Table-top exercises	2	
	Surface Water – Groundwater coordination	1	
	Forums	4	
Governance		**28**	**13.3%**
	Inter-sector	2	
	Cross-border (state and national)	23	
	Change in laws	3	
Green Infrastructure		**20**	**9.5%**
	Rainwater harvesting	5	
	Greywater	0	
	Storm water capture	4	
Technologies		**29**	**13.8%**
	Desalination	16	
	Research & development	13	
Conservation		**27**	**12.9%**
	Municipal	2	
	On-farm	9	
	Irrigation district	12	
	River management	4	

CONCLUSION

Chapter 21. Defining Sustainability of Engineered Rivers in Arid Lands

by Aysegül Kibaroğlu, Jurgen Schmandt, and George Ward

Two months before the end of the academic year, we asked our PRP team to reflect on whether our work helps to answer the question that we had started with: What is needed to make Euphrates-Tigris and Rio Grande/Bravo, and engineered rivers in arid lands generally, more sustainable? We searched for definitions of sustainability of water resources in general, and of engineered rivers in arid lands specifically. Policy reports and research studies guided our quest. Our conclusion: Helpful, but a more detailed definition, including numbers, is needed to guide policymakers and stakeholders. Here is a short summary of how we proceeded, followed by our new definition.

Initially, sustainability of water resources was not at the center of the sustainability debate, which began in earnest with *The Limits to Growth* (1972) and *Our Common Future (*1987). This changed since the beginning of this century. Chapter 18 of Agenda 21 of the U.N. Conference on Environment and Development calls for integrated, watershed-based management with priority given to "the satisfaction of basic [human] needs and the safeguarding of ecosystems."[493] The 2030 Agenda for Sustainable Development (Rio+20) contains 17 Sustainable Development Goals (SDGs), including a dedicated goal for water and sanitation (SDG 6) that calls for "availability and sustainable management of water and sanitation for all."[494] In April 2016 the U.N. Secretary-General and the President of the World Bank appointed ten heads of state and government and two special advisors to the High-Level Panel on Water. The group is charged with mobilizing action to accelerate the implementation of SDG 6.[495] Previously, in 2015, a group of 15 countries from all parts of the world launched the Global High Level Panel on Water and Peace at a ministerial gathering in Geneva. The mandate of this panel is to propose global architecture to transform water from a source of potential crisis to an instrument of cooperation and peace.[496]

In 1998, the American Society of Civil Engineers published a report entitled *Sustainability Criteria for Water Resource Systems.*[497] Their definition of a sustainable water resource was further refined by ASCE committee member D. P. Loucks in a UNESCO Hydrology Series publication, published in 1999 and also titled *Sustainability Criteria for Water Resource*

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493 U.N. Conference on Environment and Development, *Agenda 21,* Chapter 18: "Protection of the Quality and Supply of Freshwater Resources," 1992.

494 United Nations, "Transforming our world: the 2030 Agenda for Sustainable Development," 2015, https://sustainabledevelopment.un.org/post2015/transformingourworld.

495 U.N. News Center, "UN and World Bank chiefs announce members of joint high-level panel on water," April 21, 2016, http://www.un.org/apps/news/story.asp?NewsID=53747#.VyBQOJMrIgo.

496 Geneva Water Hub, "Global High-Level Panel on Water and Peace Launch," 2015, https://www.geneva waterhub.org/news/global-high-level-panel-water-and-peace-launch.

497 American Society of Civil Engineers, *Sustainability Criteria for Water Resource Systems* (Reston, Virginia, 1998).

Systems: "Sustainable water resource systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity."[498] In 2015 ASCE concluded that its suggested definition had not had the desired impact: "Somewhat surprisingly, given the urgent stressors associated with rising global temperatures and competitive demands on water, definitions of sustainability [of water resources] have not been particularly evident in the intervening years." [499] Brian Richter proposed specific sustainability principles based on the water management approach by the Australian Murray-Darling basin authority. The principles are: build a shared vision for your watershed; set limits on consumptive water use; allocate a specific volume to each user, then monitor; invest in water conservation; enable trading of water entitlements; subsidize reductions in consumption; learn from mistakes or better ideas; and adjust as you go.[500]

These are excellent principles. We add this recommendation: Use the calculated yield of river water under normal and historical drought conditions as the critical starting point for moving reservoir management towards river sustainability. Let us explain by using the example of the Amistad-Falcón reservoirs in the Rio Grande/Bravo basin.

The fundamental problem for engineered basins in arid regions is the time variability in the natural water supply, i.e. the river flow. Reservoirs for storage of water are essential in engineered basins because of their capability to retain water during surfeit periods for distribution during drought. Design and operation of heavily engineered water systems require a long period of record (POR) of river flow, either from historical measurements or from long-term simulations, to meet minimal needs during periods of low river flow or drought. Mathematically, these are periods of negative trends in the measure of water availability. Drought for a reservoir is defined by a period of declining trend in stored water, called a drawdown period. The *dependable yield* of a reservoir is the constant volume of withdrawn water, *met without failure*, during the POR.[501] This occurs during severe drought, specifically, the "drought of record," also called the "critical drawdown period."

An example determination of dependable yield for the reservoirs in the Lower Rio Grande is shown in Figure 21.1. The first two estimates of the constant withdrawal clearly bound the dependable yield, since the reservoirs meet 200 and 250 million cubic meters per month during the time period considered. Yet the latter withdrawal was no longer possible during the drought of record in the mid-1950s. Additional approximations within these bounds converge to 229.6 million cubic meters per as the dependable yield during the critical drawdown period. While dependable yield is a theoretical construct, it is the single most important management indicator for assessing reservoir performance, and is often used as a basis for allocation of water from a

498 D.P. Loucks and J.S. Gladwell, eds., *Sustainability Criteria for Water Resources Systems* (UNESCO International Hydrology Series, Cambridge University Press, New York, 1999), 131.

499 George F. McMahon, Helene Hilger, and Cristiane Queiroz Surbeck, "Special Issue on Sustainability," Journal of Water Resources Planning and Management, 141(12) (2015), http://ascelibrary.org/doi/full/10.1061/%28ASCE%29WR.1943-5452.0000608.

500 B. Richter, *Chasing Water: A Guide for Moving from Scarcity to Sustainability* (Island Press, Washington, D.C., 2014), 140.

501 R. Linsley and J. Franzini, *Water-resources engineering* (McGraw-Hill Book Co., New York, 1964); T. McMahon and R. Mein, *River and reservoir yield* (Water Resources Pubs., Littleton, Colorado, 1986); and R. Wurbs, *Modeling and analysis of reservoir system operations* (Prentice Hall, Upper Saddle River, NJ, 1996).

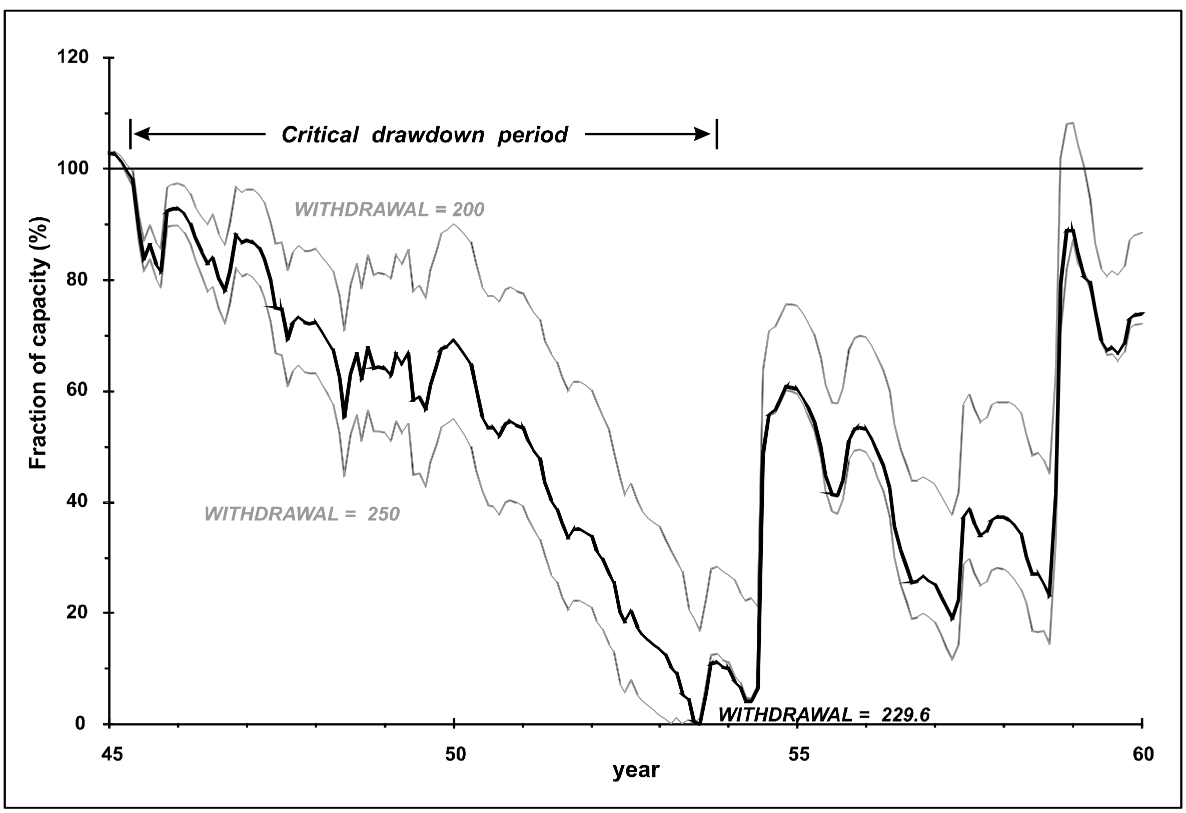
reservoir system. We argue that it needs to be carefully monitored and recalculated whenever natural or social conditions in the basin reduce water supply or increase water use. Climate change and population growth are change factors that need special attention. Based on the concept of dependable yield we propose this definition for sustainability of engineered rivers in arid lands:

A reservoir-dominated river in arid lands is *sustainable* when these conditions are met:

1. Nature's water supply, averaged over the period of the most severe drought experienced in the historical record, delivers a *dependable yield* sufficient to meet human and ecological needs in the basin.
2. To prepare for increased water scarcity from either natural or human causes, water managers and stakeholders proactively search for ways to use water *more efficiently*.
3. Whenever observed or projected changes in the natural system or human actions modify river flow, the dependable yield is recalculated, and water managers, after consultation with stakeholders, *adjust existing rules* for water allocation and water use to match the new level of dependable yield.
4. An *ecologically prudent level of in-stream flow* is maintained or restored.

Figure 20.1.
Dependable Yield Calculation (229.6 Million Cubic Meters per Month) for Combined Contents of Amistad and Falcón Reservoirs on Rio Grande, in Tandem Operation

Constant withdrawals in million cubic meters per month, 1945-1960



Source: Designed by author George Ward.

Following weeks of reflection and debate our team added three sobering comments on obstacles that at this time stand in the way to reaching sustainability of engineered rivers in arid lands.

Management practices: The revised definition of sustainability of water resources given above can guide a rational and quantitative approach to sustainable management of a water resource, especially that of an engineered river in an arid region. However, each of our four criteria calls for a departure from the usual management practices of most river basins. Their application requires a willingness of the prevailing management culture to consider changes in their traditional operational practices. We invite river management agencies, as well as water stakeholders, to adjust their views and procedures so that maintaining, or moving towards, sustainability becomes the principal goal for river management.

Conjunctive management: Sustainable water management requires integrative consideration of connections between river water and groundwater. Existing law in some rivers, for example the Texas part of the Rio Grande basin, makes this goal difficult to reach. We urge movement towards conjunctive management of water resources.

Water conflicts: Where water becomes the core of, the trigger to, and a weapon in active conflict, the goal of sustainable water supply and demand is unattainable. Sustainability of water resources requires stability, cooperation, and peace. The sub-state level conflicts and illegal control of water resources and water infrastructure in the Euphrates-Tigris deprive people of access to sufficient clean water, energy, and food resources in Syria and Iraq. The lack of water undermines the search for sustainable development and causes agricultural, economic, and political decline. Hence, we argue that the prerequisites for establishing or restoring sustainability in a river basin include stability as well as participatory, transparent, inclusive, and accountable governance structures.

Only when these issues are addressed can river managers and stakeholders cope with the looming problems of water scarcity, climate change and variation, reservoir sedimentation, population growth, economic losses, food security, and ecological damage.