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GROUNDWATER LAW AND MANAGEMENT: THE ASIA (IWMI)-KANSAS PROGRAM

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I. INTRODUCTION

Groundwater depletion is a growing problem, not just in the High-Plains and other aquifers of the central and western United States, but also world-wide. Many parts of the globe face serious fresh water shortages, which have resulted from groundwater depletion and water quality problems. Groundwater management as a tool to slow depletion and pollution has been tried in parts of the world, but with questionable success. Various entities are working on the depletion problem. The Consultative Group on International Agricultural Re-

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4. See, e.g., U.N. Administrative Coordinating Committee [ACC], Sub-Comm. on Water Resources, Groundwater Management: The Search for Practical Approaches, 25
search ("CGIAR") is one such entity. Its primary aim is to "achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy, and environment." The CGIAR funds the International Water Management Institute ("IWMI") headquartered in Sri Lanka.

With regional offices and on-going projects in Asia and Africa, IWMI supports the CGIAR mission by focusing on the role of water to improve food security and reduce poverty. In 2006, IWMI began a project within the CGIAR Challenge Program on Water and Food in the Indo-Gangetic and Yellow River Basins, entitled "Groundwater Governance in Asia" ("GGA"). Three groups of Asian fellows were invited to participate in the program: junior fellows with academic backgrounds but little management experience; senior fellows with practical experience in groundwater or river basin management; and media fellows, better known as journalists. The fellows represented the five countries in the two basins—Pakistan, India, Nepal, Bangladesh, and China. While the junior and media fellows worked on field surveys in their respective countries during their research phase, the senior fellows visited a non-Asian country to expose them to "approaches to and practical issues of groundwater management in other countries outside the region." Australia and the United States were the destinations.


10. Email from Karen Villholth, Senior Researcher of IWMI and Director of the Program, to Professor Pock (June 9, 2006) (on file with author) (describing the program). Dr. Villholth's current position is Senior Researcher for the Geological Survey of Denmark and Greenland (GEUS), the website of which is http://www.geus.dk/geuspage-uk.htm.
In late 2006, the University of Kansas ("KU") worked with IWMI in hosting a group of senior fellows from India, China, Bangladesh, and Nepal. The group spent three weeks in Kansas learning different approaches and perspectives on water management and law, with an emphasis on groundwater. The project required each senior fellow to write two papers upon returning home, the first on the travel and project experience, and the second, a research paper, based on the knowledge gained on the study tour and its potential utility in the senior fellow’s respective country. A second group of senior fellows visited South Australia and had a similar experience, hosted by the Centre for Comparative Water Policy and Law at the University of South Australia, Adelaide. In March 2007, most of the senior fellows who had visited Kansas and South Australia joined the junior and media fellows for a summary workshop in Delhi, India.

This Article begins with a description of the Kansas portion of the GGA program. This Article then summarizes the geography, the geology, the demographics, and some of the major water problems South Asia and Kansas faced. The next section presents an overview of water law and policy. This section does not purport to be an in-depth summary or analysis of either Kansas or the Asian countries. Our descriptions of the Asian situations are based primarily on the Asian participants’ lectures and not on our original research. The Asian senior fellows were scientists and administrators, not lawyers or legislators. This Article then describes some projects the countries attempted in order to solve their water problems. Lastly, this Article concludes with some observations about how Kansas and South Asia have grappled with the problem of groundwater depletion and pollution. While the program concentrated primarily on groundwater, the program also covered surface water, because of the recharge of alluvial aquifers by rivers, the hydrological interconnection between groundwater and surface water, and the work of the Asian participants. Experts described river and river basin issues faced by Kansas and the Asian countries, especially China.

11. University of Kansas Law School and the University of Kansas Office of International Programs ("KU") were the University contacts. Dr. Diana Carlin, then Dean of the Graduate School and International Programs, and Professor Peck served as co-directors. Burke Griggs served as project coordinator.
12. Shazr Islam (Bangladesh), Yunpeng Xue (China), John Thomas (India), Sushil Kamra (India), Madhav Shrestha (Nepal), and Pushkar Ghimira (Nepal).
13. See Centre for Comparative Water Policies and Laws, http://www.unisa.edu.au/waterpolicylaw/ (last visited Feb. 2, 2008) for information about the Centre. Professor Jennifer McKay is the Director of the Centre, and she directed the Australian portion of the GGA project. The Centre is located at and is part of the University of South Australia, Adelaide.
14. Larry Cieslik of the U.S. Corps of Engineers in Omaha, Nebraska and David Pope of the Kansas Division of Water Resources in Topeka, Kansas lectured on Missouri
II. THE PROGRAM

In June 2006, IWMI sent an announcement to water professionals in Australia, Spain, Mexico, South Africa, Denmark, the Netherlands, the United States, and the Middle East seeking interest in a program to provide enhanced training to Asian water experts in water management in “developed” countries. The KU Law School received this announcement. Kansas was a logical and favorable location for this program. Kansas has abundant, but diminishing groundwater resources, particularly in south-central and western Kansas. For over sixty years the Division of Water Resources (“DWR”) of the Kansas Department of Agriculture has administered water rights under the Kansas Water Appropriation Act. For over thirty years, Kansas Groundwater Management Districts (“GMD”) have aided DWR in slowing the depletion of Kansas’ aquifers. A team from KU drafted a proposed program schedule. IWMI received positive responses from all of the international recipients of the announcement and chose Australia and the United States. KU served as the American host-spon-
Ultimately, the substantive part of the Kansas program involved many entities and people. While the program sought a balance between water allocation and water quality concerns, water allocation concerns predominated.

The program’s substantive lectures provided information on the water law and policy, groundwater management, hydrology, demographics, geography, and geology of each of the countries represented. Some of these lectures are summarized below. The Kansas lectures included sessions on water allocation law, water pollution law, geology, and socio-economics. The Asian lectures provided com-

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18. Recommendations by both Dr. Villholth and the Asian experts led to changes in KU’s initial program proposal. Dr. Villholth, for example, suggested more information about interstate water issues and from participants outside Kansas, which resulted in adding a water lawyer from Santa Fe, New Mexico, who specializes in interstate water conflicts, and an engineer from the U.S. Corps of Engineers Office in Omaha, Nebraska, who described the interstate issues in the Missouri River Basin. One of the Asian participants suggested information about groundwater remediation, resulting in a trip to the “Water Center” in Wichita, Kansas described below.

19. Lectures provided background information. Field trips provided examples of the problems and attempted solutions in groundwater law and management. Four different units from KU (the School of Law; the Department of Civil, Environmental, and Architectural Engineering; the Department of Economics; and the Kansas Geological Survey); four state government agencies (the Division of Water Resources of the Kansas Department of Agriculture; the Kansas Department of Health and Environment; the Kansas Water Office; and the Kansas Department of Wildlife and Parks); the Governor’s office (Joe Harkins, the Governor’s energy advisor); three legislators (Senators Derek Schmidt and Roger Pine, and Rep. Tom Sloan); an appellate court judge (Hon. G. Joseph Pierron, Jr. of the Kansas Court of Appeals); two federal government agencies (the U.S. Army Corps of Engineers and the U.S. Geological Survey); three other universities (the Agricultural Experiment Station of Kansas State University, Washburn University School of Law, and the Department of Geo-sciences of the University of Missouri, Kansas City); three municipal water suppliers (Wichita Water Utilities, the City of Salina, and Water District No. 1 of Johnson County); three groundwater management districts (Eques Beds Groundwater Management District No. 2; Southwest Kansas Groundwater Management District No. 3; and Big Bend Groundwater Management District No. 5); an irrigating farm (Nicholson Farms, Dodge City, Kansas); an electric power generating company (Sunflower Electric Power Cooperative); an environmental group (the Kansas Chapter of the Sierra Club); and several other interested water professionals (David Warren, Director, Wichita Water Utilities; attorneys Dave Traster of Foulston Siefkin, LLP, Wichita, and Mike Ramsey and Joe Gasper of Hope, Mills, Bolin, Collins & Ramsey, Garden City; engineers Brian Meier of Burns & McDonnell, Wichita, and Bruce Barnes of CDM, Wichita; and hydro-geologist Robert Vincent of Groundwater Associates, Wichita.).

20. Specifically, the sessions included the following presentations: from the KU Law School, John Peck (water allocation law), Robert L. Glicksman (water quality law), and John Head (international law); from the KU School of Civil, Environmental, and Architectural Engineering, Edward Peltier and Dennis Lane (environmental issues in water use and management); from the Department of Economics, College of Liberal Arts and Sciences, Joshua Rosenbloom (Kansas economics and demographics); from the Kansas Geological Survey, Rex Buchanan, Marius Sophocleous, and Don Whittemore (Kansas geology, sustainability, and salinity, respectively); from the Kansas Division of Water Resources, Rich Eubank, Lee Butts, and Will Gilliland (water rights administration) and Dave Pope (interstate water issues); from the Kansas Water Office, Susan...
parable information about each country, but of necessity were more fragmentary and general. The descriptions of the laws and policies of Kansas and of the Asian countries in this Article below mimic the relative size and scope of the lectures—the program provided more detail about Kansas than about each Asian country.

The program included a field trip that took the group across much of the state of Kansas. The group traveled to the Equus Beds GMD No. 2 office in Halstead, to Wichita’s Aquifer Storage and Recovery (“ASR”) project and its Water Center, and to Greensburg and its “Big Well.” In Dodge City, the group heard a lecture on the wastewater reuse project there; in Garden City the group learned about irrigation techniques from the Kansas State University Research Extension Center; visited with a Southwest Kansas GMD No. 3 official; learned about a proposed power plant expansion that would require large quantities of groundwater, and learned about a new bio-energy center project to be developed with the power plant. After a stop at the dry channel of the Arkansas River, the group traveled to

Stover (water planning); from the Kansas Department of Health and Environment, Mike Tate (water quality); from the Kansas Department of Wildlife and Parks, Mike Hayden (water issues in recreation); from the U.S. Geological Survey, Walt Auco (role of USGS); from the U.S. Corps of Engineers, Larry Cieslak (Missouri River Basin); from the Washburn University School of Law, Myrl Duncan (water and land conservation); from the Kansas Chapter of the Sierra Club, Charles Benjamin (water and coal-fired power plants); and John Draper, Esq., of Montgomery & Andrews, P.A., Santa Fe, New Mexico (interstate water litigation).


22. Tim Boese, Manager, and Lee Wheeler.

23. Jerry Blaine, Superintendent of Production and Pumping, conducted the tour of the ASR Project. Kay Johnson, Director, conducted the tour of the Wichita Water Center.

24. Completed in 1888 at a cost of $45,000, this well is 109 feet (33.2 meters) deep and 32 feet (9.6 meters) in diameter, and is laid with limestone blocks. A sign claims that this is the “largest hand dug well in the world.” On May 4, 2007, five months following the field trip, a tornado struck the town causing widespread damage, including damage to the well’s museum and the above-ground well structure. The well itself is being cleaned up.

25. Nicholson Farms is the farm operator on the project. Deketa Sheckman, her brother Chuck Nicholson, and consultant John Zapucnic gave the lecture. Ken Stroble, City Attorney of Dodge City, also participated.

26. Dr. Mahbub Alam, Professor and Irrigation Engineer, Kansas State University.

27. Mark Rude, Executive Director.

28. Kyle Nelson and Clare Gustin, Sunflower Electric Power Cooperative, described these projects.

29. Jim Butler of the KGS led the group over the dry channel at the Larned Research Site. He described the USGS stream gage station and rain gage. He discussed the role of riparian zone vegetation on water discharge, stating that while the
Great Bend to visit with a Big Bend GMD No. 5 official\textsuperscript{30} and to see the Cheyenne Bottoms Wildlife Preserve, which was the subject of the Walnut Creek Intensive Groundwater Use Control Area ("IGUCA") order described below. After a stop at Kanapolis Reservoir (constructed and operated by the U.S. Corps of Engineers) the group went to Salina to visit with officials\textsuperscript{31} about recent water quantity and quality concerns. Finally, the group returned to Lawrence, stopping at Clinton Reservoir, another Corps reservoir which provides part of Lawrence's water supply under contracts with the Kansas Water Office under the Kansas Water Marketing Program. On other days, the group went to Kansas City to visit officials at the treatment plant in Johnson County Water District No. 1,\textsuperscript{32} and to meet with faculty and hear lectures at the Department of Biosciences at the University of Missouri, Kansas City.\textsuperscript{33}

The program's scope extended beyond science and law, by including cultural and social opportunities to learn about American life. The fellows visited shopping centers, stores, and art museums, and attended concerts. They saw a college basketball game and an old-fashioned Christmas parade, were hosted for dinner by Lawrencians in their homes, and ate pizza, barbeque, and steak in restaurants. They were guests at a civic club luncheon, stayed in hotels and motels, and had free time to take walks. They saw the Kansas countryside, watched television, and read American newspapers. They visited with strangers. And Rex Buchanan, Deputy Director of the Kansas Geological Survey, shortened long stretches of Kansas prairie with history lessons and Kansas stories.

III. GEOGRAPHY, GEOLOGY, AND DEMOGRAPHICS

A. INTRODUCTION

Because the boundaries between states result from human history and its accidents, boundaries rarely make geographical sense. This is true in Kansas, whose boundaries were drawn and redrawn

\textsuperscript{30} Sharon Falk, Manager.

\textsuperscript{31} Jason Gage, City Manager; Shawn O'Leary, Director of Public Works; Martha Tasker, Director of Utilities; and Greg Bengtson, City Attorney. Also attending was Duane Schrag, reporter from the Salina Journal newspaper.

\textsuperscript{32} Mike Armstrong, Executive Director, and Tom Schrompp, Director of Production. Also making a presentation was Jeff Henson of Black & Veatch, a consulting engineering firm.

\textsuperscript{33} The group's contacts at UMKC were Dr. Karen Vorst, Dean, UMKC College of Arts & Sciences, and Dr. Syed Hasan, Chair, Department of Geosciences.
during the westward expansion of the United States in the nineteenth century.\textsuperscript{34} This is also true of Pakistan, India, Nepal, and Bangladesh, whose modern boundaries were drawn and redrawn during the partition of British India and its aftermath in the second half of the twentieth century.\textsuperscript{35}

Taken as one geographic whole, however, the subcontinent does make sense. Water surrounds it from the south, from the Arabian Sea in the west to the Bay of Bengal in the east. Mountains surround it nearly everywhere else. The mountains and high plateaus of the Hindu Kush define the subcontinent's boundary in the northwest, separating it from Iran, Afghanistan, and Central Asia. The mountains of Burma (now the Union of Myanmar) define the subcontinent's eastern boundary, separating it from Southeast Asia. Spanning these two ranges is the greatest range of all, the Himalayan Range, which defines the northern border of the subcontinent from Kashmir to Nepal and Bhutan.

The runoff from this ring of mountains forms the Indo-Gangetic Basin, the most populous river basin in the world, reaching from northwest Pakistan to Bangladesh. In the west, the Indus Basin stretches over 1790 miles (2880 kilometers), draining northwest India,

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\textsuperscript{34} The territories of Kansas (1854), Nebraska (1854), and New Mexico (1850, after Utah) originally extended all of the way to the crestline of the Eastern Slope of the Rocky Mountains. Utah Territory (1850) comprised the Western Slope. Colorado Territory, established in 1861, was carved from these four territories. For a one-month period in February of 1861, eastern Colorado was briefly a part of the State of Kansas, which became a state on January 29, 1861, a month before the birth of the Colorado Territory on February 28 of that same year. Fatigued by troublesome miners and Indians, Kansas authorities did not oppose the formation of the Colorado Territory as far east as the 102nd Meridian. THOMAS J. NOEL, PAUL F. MAHONEY & RICHARD E. STEVENS, HISTORICAL ATLAS OF COLORADO, map 14 (Norman ed., 1994). Kansas territorial extent to the Rocky Mountains may explain the appearance of large mountains on the state seal of Kansas.

\textsuperscript{35} British power extended throughout the Indian subcontinent starting in the mid-eighteenth century. What is today Pakistan, India, and Bangladesh were, between the nineteenth century and 1947, parts of the same colonial whole of British India; and Nepal, while nominally independent, was under British dominion during the same period. With partition in 1947, both colonial and post-colonial authorities divided the territories roughly according to religion. The predominantly Muslim areas in the Northwest and the East became West Pakistan and East Pakistan respectively, with plural, but predominantly Hindu, India between them. Within this division, however, lay two more divisions. Partition divided the region of Bengal between predominantly Hindu West Bengal, which became part of India, from predominantly Muslim East Bengal, which became East Pakistan. In the name of Islamic nationhood, Pakistan therefore straddled India, but such nominal unity proved to be untenable almost immediately, due to the profound cultural, ethnic, linguistic, and tribal differences between the two regions. West Pakistan and East Pakistan fought a civil war in 1971, after which East Pakistan became the independent nation of Bangladesh. Nepal is the exception; its boundaries remained unchanged during the period of British decolonization. R.R. Palmer, Joel Colton & Lloyd S. Kramer, A HISTORY OF THE MODERN WORLD 866-68 (Knopf 6th ed. 1983).
\end{small}
eastern Pakistan, Afghanistan, and Tibet, an area of 450,000 square miles (1.17 million square kilometers). The basin receives between 3.9 and 29.5 inches (100 and 750 mm) of precipitation annually. Nearly 350 million South Asians live within the Indus Basin, and between forty-seven and fifty-two percent of them work in farming. The overall agricultural population is between 130 and 140 million people. In the east, the Ganges Basin is slightly smaller and shorter, but the basin drains a wetter and vastly more populous area. The Ganges Basin drains an area of 390,000 square miles (1.01 million square kilometers), spread across China, Nepal, and Bangladesh and runs for 1553 miles (2500 km). Precipitation in the Ganges Basin ranges between 10 inches (250 mm) to as high as 157 inches (4000 mm) annually, visited upon a population in excess of 1.15 billion people. Between sixty-three percent and seventy-nine percent of the workers in the Ganges Basin work in agriculture, for an agricultural population of around 750 million people.36 And where these basins drain to the sea, ancient and ever more populous cities make one last claim upon the water: Karachi, Pakistan, at the mouth of the Indus and Calcutta, India, at the mouths of the Ganges.

1. Nepal

Nepal crowds the geological and climatic variety of much larger countries into a compact land mass. Although best known for Mt. Everest, the High Himalayas are only one of five distinct geographic regions of Nepal. On the southern border Nepal shares with India, the region known as the Terai, the average elevation is less than 650 feet (200 meters) above sea level, and the climate is hot, humid, and tropical. Forty-seven percent of Nepal’s population, roughly eleven million people, live in the Terai. From the Terai northward, Nepal gradually rises, becoming higher, drier, cooler, and more mountainous—from the Siwaliks (foothills), the Middle Mountains, (between 3280 and 8200 feet high (1000 and 2500 meters)), the High Mountains (between 7200 and 13,000 feet high (2200 and 4000 meters)), and finally the High Himalayas (above 13,000 feet high (4000 meters))). Because of the hostile climate of the higher elevations of Nepal, most Nepalese live in the lower areas, especially the Kathmandu Valley, where population density reaches levels as high as 13,300 people per square mile.

Because of its geological diversity and its relatively low latitude, Nepal receives its water from rainfall, snow and glaciers, rivers, and groundwater. The mean annual rainfall in Nepal is about sixty-seven

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inches (1700 mm). More than 6000 rivers flow through the high mountains of Nepal, draining 178 million acre feet (219.6 cubic kilometers) of water into the Ganges River system annually. Nepal’s renewable water potential is 188 million acre feet (231.9 cubic kilometers), 6.4 million acre feet (7.9 cubic kilometers) of which is recharge as groundwater. Overall, groundwater irrigates 580,700 acres (235,000 hectares) of farmland in Nepal—roughly twenty-five percent of all Nepalese farmland. Seventy-five percent of the Nepalese population works in agriculture, and forty percent of the population lives in poverty. Overall, ninety percent of the people in Nepal depend upon groundwater as their major source of drinking water. Groundwater is abundant in the aquifers of the Terai lowlands and in the Kathmandu Valley, but even in the wet Terai, forty-eight percent of the population depends upon groundwater for domestic use. In the populated hill regions, groundwater is less available.

2. India

Embracing the Indus watershed in the west, the Himalayas to the north, and the Ganges watershed in the east, India comprises a total land area of 1.27 million square miles (3.28 million square kilometers). This land supports a population of 1.1 billion people spread out with an average density of 852 people per square mile (329 people per square kilometer). India’s staggering economic growth since the 1970’s has helped to reduce the poverty rate from fifty-five percent in the early 1970’s to under twenty percent in 2006. Over the same period, literacy levels rose from thirty-four percent to sixty-five percent across the country.

Like India itself, its hydrogeology is ancient and enormously varied. Yet for the purposes of this Article that profile can be divided into two principal areas. The first area is the entire Indo-Gangetic Basin. Irrigation of the basin’s surface water is intensive, especially in those states that form India’s northern border, from Pakistan in the East to Bangladesh: Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, and West Bengal. The Indo-Gangetic Basin, for the most part, contains aquifers of high quality and receives substantial recharge from the Himalayan range. Consequently groundwater development, especially within the Eastern Gangetic Basin, has accelerated the problem of geogenic arsenic contamination. And while the coastal areas of the basin are blessed with deep supplies of alluvial aquifers, groundwater development there has led to saltwater intrusion.

The second area, the two-thirds of India beneath and beyond the arc of the Indo-Gangetic Basin, has vastly inferior groundwater supplies. Peninsular India has a semi-arid climate with limited rainfall
for recharge. Peninsular India’s principal aquifers are composed of hard-rock, basaltic formations that have little capacity to store groundwater; and these aquifers vary substantially, even over small distances, making groundwater management both critical and difficult. Consequently, in contrast to the Indo-Gangetic Basin, Peninsular India is a bad place for intensive groundwater irrigation. Yet that has not stopped the concentrated development of groundwater.37

3. Bangladesh

Born in part from a water-related disaster—the Bhola Cyclone of 1970, which killed half a million people—Bangladesh is surrounded by watersheds and inundated with waterways. The Himalayas border Bangladesh on the North, and the Bay of Bengal surrounds it to the South. On the West are the Gangetic plains of West Bengal; the mountainous forests of the Arakan Province of Myanmar and the Tripura and Assam Hills of India define Bangladesh’s eastern border. Within these high geographical boundaries is a low-lying plain of a nation, 55,598 square miles in area (144,000 square kilometers), and one built up largely by the alluvial deposits of its major rivers—the Padma, the Jamuna, the Meghna, and the Karnaphuli. From a hydrogeological standpoint, Bangladesh essentially comprises the lower Eastern Gangetic Basin. Bangladesh’s fertile soils, tropical climate, and high rainfall allow two growing seasons a year.

4. Kansas

Kansas is rather different than South Asia. Kansas has neither mountains nor oceans. Located in the center of the United States and ranked fifteenth of the fifty states in area, Kansas is a state roughly 400 miles (643 km) east to west and 200 miles (322 km) north to south. Kansas’ elevation increases from approximately 800 feet (244 meters) above sea level at its border with Missouri on the east to approximately 4000 feet (1219 meters) at its border with Colorado on the west.

Annual precipitation in Kansas ranges from around forty inches (1016 mm) in southeast Kansas to sixteen inches (406 mm) in far western Kansas. Kansas’ two main river basins, the Kansas and the Arkansas, divide the state roughly in half, north and south, with the northern Kansas River and tributaries flowing eastward into the Mis-

souri River at Kansas City, and in the south the Arkansas River flowing from Colorado into southwest Kansas and exiting Kansas into Oklahoma south of Wichita. The Republican River, a tributary of the Kansas River, originates in Colorado and flows into north-central Kansas from Nebraska. As described below, Kansas has recently been involved in interstate litigation in the United States Supreme Court with Colorado on Arkansas River allocation issues and with Colorado and Nebraska on allocation issues involving the Republican River. Both of those cases have groundwater implications.

One of the largest aquifers in the world, the High Plains Aquifer, lies beneath south-central and western Kansas. This aquifer also underlies portions of Wyoming, Nebraska, Colorado, South Dakota, Oklahoma, New Mexico, and Texas, with Nebraska having the largest share (65%), while Texas (12%) and Kansas (10%) also have large shares.39 Eastern Kansas has little groundwater other than alluvial groundwater.

Kansas is sparsely populated. The 2000 census measured a population of 2,688,418, which ranks thirty-second among the states, or less than the population of sixteen individual Chinese cities, eight Indian cities, and one Bangladesh city.40 The rural parts of the state, primarily in north-central and western Kansas, are becoming even more rural, with population shifting primarily to Johnson County, in the Kansas City metropolitan area. The state’s slow population growth as a whole is found primarily in the Kansas City-to-Topeka corridor in northeast Kansas, the Wichita metropolitan area in south-central Kansas, and the Garden City-Dodge City area in southwest Kansas. With the exception of the agricultural industry, which makes up six percent of Kansas’ gross state product (twice the national average), Kansas’ economic structure resembles the nation’s structure: twenty-seven percent services, sixteen percent government, sixteen percent retail, and twelve percent manufacturing. Thus, it is a misconception to assume that Kansas is only, or even primarily, an agricultural state because of its large size and its sparse population. However, more than eighty percent of the state’s water is used for agriculture.

In short, most of the population and population growth is in eastern Kansas, which has more precipitation and more river flow, but less groundwater. Most of the groundwater resources lie in western Kansas, which, except for the Garden City-Dodge City area, is very

sparsely populated and is becoming even more so. As discussed below, the primary and most obvious difference between the Kansas and Asian situations lies in their dramatically different population densities.

B. THE GLOBAL TRANSFORMATION IN GROUNDWATER: SOUTH ASIA AND KANSAS

I. South Asia

The development of irrigation technology during the second half of the twentieth century has transformed agriculture across South Asia even more dramatically than it has in the United States. Through the 1960's, almost all groundwater irrigation in South Asia consisted of shallow hand-dug wells, requiring people or draught animals to raise the water out of the ground and shunt the water to nearby irrigation ditches. The invention of the tubewell with a motorized pump has allowed far more intensive exploitation of groundwater than was possible with these older wells. Indeed, tubewell irrigation is one of the principal elements of the Green Revolution in South Asia. Along with the development of new rice varieties, groundwater irrigation transformed India and Bangladesh from net rice importers during the 1960's to net rice exporters by the 1990's. Throughout South Asia, groundwater irrigation has performed an important cultural task as well, easing South Asia's sense of food insecurity and giving it no small pride in self-sufficiency.

The growth in South Asian groundwater exploitation dwarfs that of any other region of the globe. In the United States, historians and other experts of irrigation rightly see the development of center-pivot irrigation as one of the transformative events in American agricultural history. Since the invention of the center-pivot in the late 1940's, irrigation in the United States has roughly doubled the use of American groundwater, now spread across nearly 380,000 wells. However impressive this figure might be in isolation, the figure is dwarfed by the Himalayan slope that describes the rise of groundwater use in South Asia. For instance, in India, there were fewer than one million mechanized wells in 1960; forty years later, there were an estimated nineteen million. And in Bangladesh, which used almost no groundwater in 1960, land irrigated by groundwater as a percent of

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41. A “tubewell” is the South Asian English term for a modern, mechanically-bored irrigation well.
42. Shah, supra note 37, at 421.
irrigated area increased from four percent in 1972 to seventy percent in 1999.\textsuperscript{44} As late as 1975, fewer than 6000 groundwater wells existed in Bangladesh; now, there are over 150,000 wells. In 1970, India and Bangladesh pumped a little more than eighty cubic kilometers (64.9 million acre feet) of groundwater annually; by 2010, they are expected to withdraw nearly 330 cubic kilometers (267.5 million acre feet) of groundwater annually.\textsuperscript{45}

The demographic setting of the South Asian subcontinent and the irrigated agriculture that feeds its population are by far the most striking differences between irrigation in South Asia and in the United States. Bangladesh, India, Nepal, and Pakistan together count 1.33 billion people, who populate their lands with a density not seen in the United States, between 167 people per square mile (433 per square kilometer) in Pakistan to 466 per square mile (1207 per square kilometer) in Bangladesh. The populations of the Indo-Gangetic Basin are overwhelmingly rural, ranging from sixty-seven percent in Pakistan to eighty-eight percent in Nepal. And the populations are growing at a consistently slow rate, between one and two percent a year.\textsuperscript{46}

Population growth and the growth of the South Asian economy since the 1970's have put an increasing strain upon South Asia's water supplies. India has sixteen percent of the world's population, but only four percent of the world's fresh water sources. Consequently, India has increased its development of total groundwater resources significantly, from thirty-two percent in 1991 to forty-two percent in 2003. Yet water demand is expected to more than double over the next half-century. This increase has profound consequences for Indian agriculture, because India depends upon irrigation to a greater extent than the United States: of the 400 million acres (162 million hectares) of arable land in India, about 141 million acres (57 million hectares), or thirty-five percent, are irrigated. In contrast, only 57 million acres (23 million hectares) of the United States' total arable acreage of 435 million acres (176 million hectares), or thirteen percent, are irrigated.

The development of tubewell technology and groundwater-dependent agriculture in South Asia has created what Dr. Tushaar Shah of the IWMI has described as the "four stages of groundwater socio-ecology in South Asia."\textsuperscript{47} It is worthwhile to review the four stage socio-

\textsuperscript{44} Shah, supra note 37, at 408.
\textsuperscript{45} Id. 415 fig.6.
\textsuperscript{46} Id.
\textsuperscript{47} Id. at 427-29.
ecology framework in South Asia to determine how well the framework applies to Kansas, a very different setting.

The first stage witnesses the rise in the use of tubewell irrigation in areas of subsistence agriculture, alongside traditional water-lifting devices. In this stage, irrigation protects against the failure of traditional crops and receives government subsidies. This first stage quickly leads to the second stage, the “groundwater based agrarian boom.” Here, tubewell irrigation becomes dominant, making access to it more important, at the expense of traditional water-lifting methods, which sink into decline. Because of the increased productivity by irrigation, the second stage sees a rapid growth in agrarian income and employment.

In the third stage, early symptoms of groundwater over-exploitation emerge. Steady water supplies from irrigation allow further crop diversification, and the groundwater-based economy swells into an economic bubble. Tensions between the boom and its ecological consequences begin to surface, as pumping costs soar, and the burdens of the water market become oppressive. By the third stage, the private and social costs of groundwater use have diverged. Groundwater irrigators emerge as a powerful voting bloc, making it difficult to restrain the overuse of tubewell irrigation. At some point, however, the groundwater-based bubble bursts, which ushers in the fourth stage of agricultural decline and crisis. With groundwater supplies fully exploited, agricultural growth declines. The decline in growth divides farmers: wealthier farmers, who have benefited the most from tubewell irrigation, perceive the groundwater bust long before the poorer farmers do and move away. The poorer farmers are left with shrinking and increasingly contaminated water supplies. The burst of the groundwater bubble has depopulated entire clusters of villages in North Gujarat, Tamil Nadu, and elsewhere in India. In some cases, the situation has become so serious that water must be imported for domestic needs.

2. Kansas

To the extent that Dr. Shah’s groundwater socio-ecology applies to Kansas, it applies in a very different demographic setting. In contrast to South Asia, groundwater development in Kansas has intensified as the population of the state’s western part has declined. Center-pivot irrigation arrived in Kansas in the late 1940’s, and the center-pivot’s continual refinement over the next twenty years transformed agriculture in Kansas and the High Plains just as fundamentally as the Green Revolution transformed agriculture in South Asia. Thanks to
the center pivot, but also thanks to economic studies⁴⁸ and farm subsidies,⁴⁹ applications for new groundwater rights increased to 5730 permits in the 1950’s, 6433 in the 1960’s, and 16,226 in the 1970’s.

Center-pivots have allowed the cultivation of corn, milo, and soybeans, which, unlike the dryland wheat and the canal-irrigated sugar beets that were previously cultivated, are used mostly for animal feed.⁵⁰ Nearly free water, inexpensive diesel and electricity to drive the pumps, subsidized transportation, and a growing demand for beef have together made the High Plains the most concentrated meat producing region in the United States, depleting the Ogallala Aquifer by one million acre feet (1.25 billion cubic meters) a day.⁵¹ Due to increased demand for electricity, power plants may eventually rival the cattle industry as the primary user of groundwater in some areas. Coal-fired energy plants require large intakes of groundwater and have little if any recharge. Ethanol and biodiesel plants are also water-intensive industrial uses, with very little recharge.

IV. PRESSING PROBLEMS WITH GROUNDWATER

The demographic and economic pressures of growth in South Asia pose serious challenges to the proper management of groundwater there: population growth, drought and water scarcity, overexploitation of groundwater, salinity buildup in groundwater, floods, and degradation of water quality in general. Other problems include land degradation and loss of biodiversity, but by far the most important challenge is agrarian poverty.

By comparison, Kansas’ problems are not nearly so dire, but that does not make the solutions any easier. Kansas is blessed with a population that is slowly growing and reasonably prosperous, and the agricultural sector has benefited recently from the global rise in grain prices. Nonetheless, the three main demographic sectors of Kansas water users—irrigators, industries, and municipalities—have their own groundwater problems. The most pressing problem is over-appropriation. Kansas irrigators, who use the lion’s share, over eighty per-


⁴⁹ See, e.g., Jacob J. Burke and Marcus H. Moench, Groundwater and Society: Resources, Tensions & Opportunities 12 (2000) (“The proximate causes of groundwater depletion and pollution . . . are rooted in population growth, economic expansion, the distorting impacts of subsidies and financial incentives, and the spread of energized pumping technologies.”).


cent of Kansas' groundwater, have more groundwater rights than the aquifers can sustain. Over-appropriation has also affected Kansas' industrial sector by making it more difficult for industrial users to obtain water rights changes from agricultural to industrial uses. Finally, the growing urban sectors of Kansas have heightened the challenges of providing a secure and dependable municipal supply of water.

A. Quantity

1. South Asia

Generally speaking, the groundwater supplies of the Indo-Gangetic Basin, Nepal, and Bangladesh are blessed with both high recharge and high saturated thickness. However, the dramatic increase in pumping has stressed groundwater supplies and worsened groundwater quality. According to India's Central Ground Water Board, nearly fourteen percent of the country's groundwater units are either over-exploited (where groundwater withdrawals exceed recharge) or in critical condition (where groundwater development exceeds eighty-five percent of available supplies). This figure is expected to rise to twenty percent by 2017. At the same time, urban exploitation of groundwater continues to intensify as India's population urbanizes, worsening declines in well yields, saline intrusion, and land subsidence. Battles over water supplies in India, and especially in its cities, have become so common that Priya Ranjan Dasmunshi, the Minister of Water Resources, calls himself the "Minister of Water Conflicts."52

Three problems dominate groundwater use in India: depletion due to overdraft; waterlogging and salinization, due mostly to inadequate drainage and insufficient conjunctive use; and pollution from agriculture and industry. The groundwater boom in India has created a short-term rise in agricultural productivity and economic growth, but the poor land-management policies that enabled the boom have caused long-term damage to Indian groundwater supplies. These policies have depleted water tables, especially in urban areas.

Similar problems have arisen in Bangladesh. With no limitations on well spacing and placement, the unplanned drilling of tubewells has impaired active wells. Over-exploitation has permanently depleted static groundwater levels. Overpumping has led to excessive water losses in channels and fields. Poor water distribution systems and poor management have worsened water losses in urban areas.

the water table has sunk, wells and pumps have had to descend farther, increasing pumping and irrigation costs. Unlike India, which has a powerful agrarian lobby, farmers' associations in Bangladesh have failed to obtain the sort of subsidies for irrigation that exist elsewhere in the world. Ultimately, the lowering of the groundwater table has led to the abandonment of wells and to the subsidence of the land itself. In Dhaka, the capital of Bangladesh, groundwater pumping exceeds recharge to such an extent that the static groundwater level has declined by more than three feet (one meter) a year, even with significant recharge.

Nepal is the one country in this group that has not yet over-exploited its groundwater supplies. Nepal's problems lie primarily in the declining quality of its groundwater. Nepalese groundwater is at risk of contamination from three principal sources: sewage (pathogenic bacteria), agriculture (pesticides and nitrates), and industrial effluents. In the Terai, the groundwater is largely alkaline, rich in bicarbonate, calcium, and magnesium. Arsenic contaminates the shallow aquifers, while the deeper aquifers are more alkaline. In the Kathmandu Valley, shallow groundwater supplies are naturally rich in methane, sulphur, and iron, but have become contaminated with industrial and domestic pollutants. The deeper groundwater supplies of both the Kathmandu Valley and the Terai are largely anaerobic, and therefore vulnerable to increased concentrations of iron, manganese, ammonia, and possibly arsenic. Although the shallow aquifers of Nepal enjoy a high rate of recharge due to their permeability, the deep aquifers, like the Ogallala Aquifer in the United States, are ancient (over 200,000 years old) and effectively non-rechargeable.

2. Kansas

a. Agricultural Use: the Problem of Over-Appropriation

For several decades, Kansas irrigators have been pumping groundwater from Kansas aquifers at a higher rate than the aquifers' recharge, especially from the Ogallala, Kansas' largest aquifer but its least rechargeable. Kansas irrigators are not outlaws; on the contrary, ninety-nine percent of them comply with state water usage and water-reporting regulations. Rather, the irrigators are the primary users of groundwater in an administrative system that, for all of its comparative sophistication, has over time granted more water rights than the aquifers can sustain. Kansas groundwater managers and water experts are not blind to the problem. On the contrary, they are

primarily focused on the problem, but, as discussed in Section V below, because water rights are constitutionally protected property rights, the problem of over-appropriation is an exceedingly difficult one to solve. Indeed, as the chief lawyer for DWR Leland A. Rolfs has written, if water rights were not permanent, real property rights, the specific problem of over-appropriation, and of groundwater management in general, would be considerably easier. 54 Most of Kansas is closed to new groundwater appropriations, but the horse is out of the barn.

b. Changes from Agricultural to Industrial Use

Generally, entities seeking water supplies must find and purchase existing water rights because of the difficulty in obtaining new water appropriation permits in Kansas. Current changes related to water appropriation permits involve shifting from irrigation use to industrial or municipal use. A number of cities, for example, have purchased nearby irrigation rights. 55 One potentially large shift from agricultural to industrial use in Kansas involves a proposed new power plant. Sunflower Electric Power Cooperative ("Sunflower") has proposed to expand its current plant in Holcomb by adding three 700 MW units. Although the new power would serve seven states, very little of the power would be used in Kansas. The new units would require large quantities of groundwater, 56 which the plant would have to purchase from irrigators because the area is closed to new water rights. 57 DWR regulations limit changes in water rights to the consumptive use of the transferor, 58 so changes from irrigation use to industrial use should result in no net increase in annual water use.

During the field trip, the Asian group appeared to be more interested in the fact of the open public policy debate and the administrative decisions to be made on this project than in the technical and water requirements of the proposed plants. 59 Prior to Sunflower's

55. Wichita, Kansas, for example, began a program in 1989 to purchase irrigation rights. It publicized a standing offer to pay $400 per acre foot for irrigation rights.
56. Kyle Nelson, Sunflower Elec. Power Coop., Lecture on Water Requirements (Dec. 6, 2006) (stating that over 54,000 acre feet (66.6 million cubic meters) of irrigation rights had been purchased, which, when converted to industrial water would yield approximately 33,000 acre feet (40.7 million cubic meters)).
57. See, e.g., KAN. ADMIN. REGS. § 5-23-4b (2004) (listing 233 townships, an area covering over 8,000 square miles (21,275 sq. km), that are closed to new appropriations).
58. KAN. ADMIN. REGS. §§ 5-5-3, 5-5-9 to -12 (2004).
59. See Xue Yunpeng, Comparison of Water Resources Management of Yellow River Basin in China and Kansas State of USA (Feb. 2007) (on file with authors) ("The ongoing hot debates on the proposed three new 700 megawatt coal fired electric generat-
presentation to the Asian group in Garden City, the city commission of the city of Lawrence, located 360 miles (579 km) northeast of Garden City, had officially announced its opposition to the construction of the plant expansion. After hearing Sunflower’s presentation, the Asian group wanted to hear the counter-arguments to this proposed plant, and a representative of the Kansas Chapter of the Sierra Club provided the counter-arguments. The arguments against the plant expansion have prevailed, at least in the first round, which concerned only the air permit and not water issues. On October 18, 2007, the secretary of the Kansas Department of Health and Environment (“KDHE”) denied the air permit for the new plant stating, “[it] would be irresponsible to ignore emerging information about the contribution of carbon dioxide and other greenhouse gases to climate change and the potential harm to our environment and health if we do nothing.” Sunflower has appealed, and bills are being considered in the Kansas legislature.

ing plants planned for Holcomb, Kansas to be operated by Sunflower Electric Power Corporation provide a wonderful example of how decisions on water rights change permit[s] . . . are made. People who live hundreds or even thousands of kilometers away have joined the hot debates. This democratic decision-making process exhibits the interactive and complex influences of environment and other water issues with the social-economic development and political policy, and provides a useful example on improving water rights transfer management and energy policy in the YRB.”. However, recent news stories from China show that Chinese projects too are being influenced by public opinion, vigorous debate, and public hearings. For an example of objection to a dam project, see Andrew Batson, Dissent Slows China’s Drive for Massive Dam Projects, WALL ST. J., Dec. 19, 2007, at A1 col. 4, available at http://online.wsj.com/article/SB119802214926737977.html. For an example of objection at public hearings to a chemical plant, see Howard W. French, Letter from China, A Harmonious Society: Hearing Different Notes, IST. HERALD TRIB., Jan. 5-6, 2008, at p.2, col. 1, available at http://www.ihl.com/articles/2008/01/04/asia/letter.php.

60. The reasons stated in the Lawrence city commission’s letter to KDHE was that the plant would emit 16.7 million pounds (7.57 million kilograms) of CO₂ per year, that while the energy produced would travel west, the air pollution (particulate matter and mercury) would travel east, and that a combination of wind and other alternative renewable energy sources would create greater positive economic effects in Kansas than would coal plants.

61. At Sunflower’s presentation to the Asian group in Garden City, Sunflower personnel made strong arguments for the plant expansion, stressing the benefits of locating new units adjacent to the existing plant and the positive economic impacts on the region including jobs in both construction and plant operation. Moreover, several cooperating partners could share rail access, unloading facilities, water and wastewater facilities, a waste powder disposal site, and a natural gas pipeline for igniting the fuel.

62. Charles Benjamin stressed the threats of burning coal, claiming that Sunflower’s plant expansion would be the largest new source of greenhouse gases in the United States and would increase Kansas’ power plant mercury emissions by eighty percent, which would affect eastern Kansas due to prevailing wind patterns. He argued that global warming impacts on Kansas are already great and that because Kansas is “near the top in wind resources” Kansas should favor wind energy instead.

63. Scott Rothschild, Coal Plants Denial Stuns State, LAWRENCE J. WORLD, Oct. 19, 2007, at 1, col. 2 (quoting Ron Bremby, Secretary of Kansas Department of Health and Environment). That newspaper account also ran a story “Lawrence Played a Role in
c. Municipal Supply

Three cities in Kansas illustrate the state’s municipal water supply problems. Wichita and Salina have similar water supply departments, both under the umbrella of its municipal government, the former for a relatively large metropolitan area and the latter for a small city. On the other hand, Johnson County Water District No. 1 ("WaterOne") is a “water supply and distribution district,” which is one of the several types of special water districts permitted under Kansas law to carry out specific legislative purposes.64 In terms of population served, Wichita Water Utilities and WaterOne provide water for approximately the same populations, or 360,000 citizens.

Wichita, Kansas’ largest city, is located in south-central Kansas. It obtains its water supply from the Equus Beds Aquifer and from Cheney Reservoir, a federal lake. With the Equus Beds Aquifer water table dropping over the last few decades, Wichita first looked north 115 miles (185 km) to the Kansas River as a possible supply. Wichita then sought to acquire irrigation rights to be changed to municipal use. Instead of these projects, Wichita has now opted to develop the Wichita Aquifer Storage and Recovery ("ASR") Project, described in Section VI, below. Salina, a city of 46,000 residents located in central Kansas, illustrates a different water supply problem. Salina’s municipal water supply comes from both surface and alluvial diversions from the Smoky Hill River. For several decades, the city has depended upon releases from Kanopolis Reservoir, twenty-five miles (forty km) upstream. Salina officials claim that the city has a legal right to water from these releases, despite the lack of a water purchase contract from the state under its water marketing program.65 Serious drought conditions persisted in the six years prior to the Asian group’s visit in December 2006. Further, Kanopolis Reservoir dropped over eight feet (2.4 meters) between January 2005 to November 2006. As a result, the drought substantially strained the municipal water supply system and forced Salina to take emergency action in July 2006. Salina declared a “water watch” when groundwater levels dropped five feet (1.5 meters) below normal, and river flows declined to forty-five cubic feet per second (1.3 cubic meters per second). Salina then issued a “water emergency” when groundwater levels dropped to fifteen feet (4.6 meters) below normal, and river flows declined to fifteen cubic feet per second (0.42 cubic meters per second). Salina also sought and ob-

tained DWR’s help in administering the junior irrigation rights upstream on the Smoky Hill River. The emergency conditions abated later in the summer after DWR’s administration of water rights, city limitations on residential lawn watering, a drop in temperature, and rains. As of December 2006, the drought conditions were still present, but Salina was hit with flooding rains in the Spring of 2007. In May, Salina measured approximately fifteen inches (381 mm) of rain, causing the Corps of Engineers to make releases from Kanopolis Reservoir, which brought the river flow to above 3000 cubic feet per second (85 cubic meters per second).

WaterOne serves a part of Kansas City. WaterOne obtains its water supply from the surface water and the alluvial groundwater of the Kansas River, and from the surface water of the Missouri River. WaterOne’s main supply issue relates to low Missouri River flows and the scouring of the Missouri River channel. The main-stem Missouri River reservoirs in the upper basin states of Montana and the Dakotas, which trap sediments and release cleaner water, together with the channelizing and channel straightening done by the Corps of Engineers, have caused problems for municipal suppliers dependent on river water. WaterOne constructed a new fixed-level intake on the Missouri River in the 1980’s, but low flows in the 1990’s coupled with the channel degradation make water diversion more difficult.

B. Quality

1. South Asia

Perhaps the most significant difference between the groundwater quality of South Asia and Kansas is South Asia’s high levels of geogenic, or naturally occurring, arsenic and other contaminants. The dramatic increases in groundwater withdrawals since the 1970’s have further exacerbated this geogenic problem throughout South Asia. Ninety percent of Nepalese depend on groundwater for drinking water, but arsenic-contaminated areas extend over 11,583 square miles (30,000 square kilometers), putting 550,000 Nepalese at risk. In a 2003 test, the Nepal Department of Water Supply and Sewerage determined that fourteen percent of Nepal’s drinking wells had concentrations over ten micrograms per liter, the safe level for arsenic as set by the World Health Organization, while three percent of Nepal’s

66. There are approximately eighty surface water rights between Salina and Kanopolis Reservoir, including both junior and senior rights to Salina. Jason Gage, Shawn O'Leary & Martha Tasker, Senior Fellows, Remarks on Salina's Municipal Water Supply Problems (Dec. 7, 2006).


68. See discussion infra Part VI.B.3.
drinking wells had concentrations greater than fifty micrograms. In a recent spot survey of 607 Nepalese in the Terai, Nepalese health authorities found between seventy-one percent and ninety-five percent of the samples contained arsenic over the normal limit, and sixty-two percent exceeded the toxic level of 1000 micrograms per liter.

In India, excessive groundwater withdrawals are causing increased arsenic contamination as well. Already high levels of arsenic, fluoride, iron, nitrate, and salt compounds have risen to alarming levels. Increased usage of groundwater has further polluted aquifers with sewer effluent, pesticides and fertilizers, and industrial wastes and solvents. Industrial uses of groundwater have caused heavy metals and other contaminants to pollute groundwater.

Arsenic contamination due to the over-exploitation of groundwater is most chronic in Bangladesh. In many parts of Bangladesh, the arsenic concentration is above fifty parts per billion, and levels of chromium, aluminum, iron, manganese, zinc, nickel, and copper are high as well. Geogenic mineralization, combined with groundwater depletion and industrial pollution, have created alarmingly high concentrated levels of chromium, aluminum, and iron contamination in Dhaka, the capital of Bangladesh. Moreover, these pollution levels are highest at the shallowest levels—precisely where most Bangladeshis obtain their groundwater.

In addition to directly poisonous compounds, South Asia's next most serious problem is salt. Salt contamination continually threatens fresh groundwater supplies, soil fertility, and agricultural productivity. Especially in India, increased pumping of coastal groundwater supplies has led to seawater intruding into previously fresh groundwater supplies. Overall, salt affects approximately 16.6 million acres (6.73 million hectares) of Indian farmland. Native vegetation with deep root systems do not change the salinity of the soil, because native vegetation can access the shallow alluvial groundwater tables, common to South Asia, without causing the salts to migrate within the soil. Irrigated crops, however, tend to increase soil salinity, because irrigation, combined with the shallower root systems of irrigated crops, leach salts from the soil and raise them to the surface. Return flows from continued irrigation then worsen the problem. With the growth of groundwater irrigation in India, management of waterlogged saline soils has become a more pressing need. The biggest challenge to water management is disposing of the return flows from

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irrigated agriculture, what Dr. Kamra referred to as "drainage effluent."

"Upconing" is another problem related to salt water intrusion. Most aquifers in India consist of two zones: an upper zone of fresh water and a lower zone of saline water. Pumping water from the upper zone draws down the water table and creates a cone-shaped volume of saline water that rises closer to the well intake. Left unregulated, the "upconing" of saline water from the lower zone can contaminate the upper zone of fresh water as well as the water drawn upwards from the well. In unconfined coastal aquifers, pumping can also pollute fresh groundwater by drawing saltwater from the sea into the adjacent aquifers.

2. Kansas

Compared with South Asia, Kansas' groundwater is relatively clean and relatively free of high levels of both geogenic and man-made contamination. For a more detailed summary of Kansas' groundwater pollution problems, see Mary F. Fend, Water in Kansas: A Primer 25-27 (1984). For a review of environmental groundwater regulations problems, see Robert L. Glicksman & George C. Coggin, Groundwater Pollution I: The Problem and the Law, 35 Kan. L. Rev. 75, 85-89 (1986). However, the decreasing quality of Kansas' groundwater is a growing concern. Nearly ninety-five percent of the groundwater in eastern and western Kansas is of acceptable quality. However, approximately only fifty percent of the groundwater in Reno, Sedgwick, Butler, and Sumner Counties is acceptable, and less than twenty-five percent of the groundwater in Russell County is acceptable. The sources of groundwater pollution vary. Some of the oldest problems of groundwater contamination in Kansas stem from the long-term consequences of salt mining in Lyon County, near Hutchinson. Other industrial activities remain the most dangerous threat to Kansas' groundwater, especially the oil industry, which has returned to prominence in Kansas with the increased global demand for petroleum products. In addition to the usual hazards associated with oil production, salt water is pumped into wells during secondary recovery and has seriously affected groundwater quality in central and south-central Kansas.

Because Kansas' population is becoming increasingly urban, groundwater pollution in Kansas cities that depend on groundwater has become a particular concern. Kansas is an important aviation center. However, military and civilian aircraft use and production have caused serious groundwater pollution problems in both Salina and Wichita. Salina's water quality issues relate to buildings at a former air force base near Salina releasing industrial water. Ground-
water contamination was first recognized in the mid-1990's, resulting in a dispute among the city, the airport authority, the U.S. Army Corps of Engineers, the KDHE, and the U.S. Environmental Protection Agency ("EPA"). Salina claims that the pollution detrimentally affects the public water supply. However, the Corps, which takes responsibility for old defense facilities, believes the plume would not reach the city's water supply for 75 to 120 years. In contrast, Salina officials believe it will take less than ten years. Salina officials have found it very difficult to reach amicable conclusions with regard to the scope and solutions to the problem.

V. WATER LAW, MANAGEMENT, AND POLICY
A. ASIA
1. India

Water law in India is complex and difficult to synthesize and summarize. There is no comprehensive water law; instead, Indian water law is compiled of an assemblage of colonial-era legislation, provisions in the national constitution, national and state legislation, case law, and custom. Although India shares basic historical, constitutional, and legal similarities with the United States, Indian water law and Indian groundwater management do not focus so solely on water as a private property right as does American law. Rather, Indian groundwater law follows directive principles that stress the duty of the State to secure social and economic justice. Yet two principal common law water doctrines still prevail. For streams, the Riparian Rights Doctrine is still viable, with modifications. For groundwater, the landowner has the right to use underlying groundwater, what Americans call the Absolute Ownership Doctrine, but that doctrine is facing increasing challenge.

72. See Cullet, supra note 71, at 3.
73. Id. at 4.
74. Kansas followed this doctrine prior to enacting the Water Appropriation Act in 1945. See discussion infra Parts V.B.1.
75. See Cullet, supra note 71, at 4. Mr. Thomas stated in his lecture that statutes declaring State sovereignty over all water sources by vesting their ownership in the State, such as land acts and irrigation acts, exclude groundwater by omitting mention of it. In short, state-level land and water legislation do not define rights to groundwater, thereby leaving it in the realm of the common law doctrine. Rights in groundwater are absolute, protected implicitly by irrigation and land laws in the country. Just as the "Rule of Capture" in the United States (Texas, for example) stems from Acton v. Blundell, (1843) 12 M & W 324, 162 E. R. 1223 (Exch.), so too does the common law of
Part IV and Part V of the 1949 Indian Constitution are concerned in part with the sustainable and equitable use of resources for the common good and with the fundamental duties of the state and its citizens in relation to the environment.\textsuperscript{76} These parts contain the directive principles of State policy, while Part IVA concerns the fundamental duties of its citizens. It is the duty of the State to secure a social order for the promotion of the welfare of the people, in which social, economic, and political justice inform the institutions of public life.\textsuperscript{77} In particular, the State has the duty to direct its policy towards securing that the ownership and control of material resources of the community are so distributed as best to serve the common good.\textsuperscript{78} Further, the State must operate the economic system so as not to result in the concentration of wealth and means of production to the common detriment.\textsuperscript{79} Together, the State and the citizens share a fundamental duty to protect and to improve the environment.\textsuperscript{80}

The Indian Constitution vests legislative powers regarding water in both the national Parliament and the states. Under the Constitution, states have powers to legislate on water issues such as water supplies, irrigation, canals, drainage, embankments, water storage, and water power.\textsuperscript{81} Parliament, on the other hand, has the power to legislate for two or more states on matters falling under the state list, if the states so desire, and resolutions are passed to that effect by all legislatures of the requesting states.\textsuperscript{82} The Constitution provides citizens the right of equality before the law and equal protection\textsuperscript{83} of the law as well as the protection of life.\textsuperscript{84} Some view court decisions as implying a fundamental right to water under these Constitutional sections.\textsuperscript{85} Two acts constitute the main statutory law on water in India:

groundwater in India. Landowners generally regard wells as "theirs" and view others as having no rights to restrict or otherwise control their rights to extract water. See also M.S. VANI & ROHIT ASHTHANA, DEVELOPMENT CENTRE FOR ALTERNATIVE POLICIES, NEW DELHI, SUSTAINABLE GROUNDWATER LEGISLATION, http://www.waterandfood.org/gga/Documents_Training\%20Prog/GROUNDWATER\%20LAW.pdf.

\textsuperscript{76} INDIA CONST. arts. 36-151, available at http://indiscode.nic.in/coiweb/coifiles/part.htm (providing access to the 1949 Constitution of India).

\textsuperscript{77} Id. art. 38, § 1.

\textsuperscript{78} Id. art. 39(b).

\textsuperscript{79} Id. art. 39(c).

\textsuperscript{80} Id. arts. 48A, 51A(g).

\textsuperscript{81} See id. arts. 36-51 (providing the Seventh Schedule, List II, No. 17).

\textsuperscript{82} Id. art. 252.

\textsuperscript{83} Id. art. 14.

\textsuperscript{84} Id. art. 21.

the Indian Easements Act and the Transfer of Property Act, both of 1882.86

2. Nepal

Like the other countries of South Asia—and indeed, like Kansas and other states with abundant groundwater—Nepal’s legal and administrative apparatus for dealing with groundwater did not emerge until the development of widespread tubewell irrigation in the 1960’s. The National Code Act of 1963 protected prior users’ rights to surface waters for irrigation use. The Electricity and Related Water Resources Act of 1967 first gave ownership and licensing rights to groundwater. The Water Resources Act of 1992 prioritized the use and exploitation of water, placing drinking water highest, and also developed the concept of a water user group. Alongside these laws came policy advances to exploit groundwater more aggressively. The Agriculture Prospective Plan of 1994 set the goal of constructing 176,000 shallow and 800 deep groundwater wells in twenty years; two years before, the Irrigation Policy of 1992 called for farmers to contribute to the construction and rehabilitation of tubewells.

Although the statutory law on groundwater in Nepal focuses almost entirely on water quantity and apportionment, Nepal has five main groundwater agencies that oversee quantity and quality. Within the Ministry of Water Resources, the Department of Irrigation and the Groundwater Resources Development Board focus on the development of groundwater for irrigation. Within the Ministry of Physical Planning and Works, the Department of Water Supply and Sewerage provides and protects the drinking water supply. Within the Ministry of Industry and Commerce, the Department of Geology and Mines conducts the Nepal Geological Survey and its database. The Ministry of Population and Environment focuses on the protection of groundwater quality. Finally, the Water and Energy Commission Secretariat conducts water resources planning for Nepal.

86. The Indian Easements (The Easement) Act, No. 5 of 1882, § 7(g), available at http://www.bsjain-law.com/BareActs/EaseMentAct.html. The Easement Act recognizes a private right to “all water under the land that does not pass in a defined channel,” describing it as a right “to collect and dispose” of groundwater. Id. The Easement Act also reserves to the State the power to regulate water of rivers and streams. Id. § 2(a). See also The Transfer of Property Act, No. 4 of 1882, § 6. The Transfer of Property Act states that an easement cannot be transferred apart from its dominant heritage—the land that enjoys the easement. Id. There seems to be some question about whether a landowner’s right to groundwater is a property right inherent in the land or if it is an easement. If based on a mere easement, the right in groundwater could not be severed from real property. If based on the notion that the right to groundwater as an inalienable part of the right to land and not an easement, the right could be transferred.
B. Kansas

1. Kansas Law of Water Allocation

Unlike the constitutions of several Western states, the Kansas Constitution contains no provisions on water rights or prior appropriation. Kansas is a prior appropriation state for both groundwater and surface water, having moved in 1945 from the common law Riparian Doctrine for streams and the Absolute Ownership Doctrine for groundwater. In that year, the Kansas legislature adopted the Kansas Water Appropriation Act ("KWA Act"), declaring "all water within the state of Kansas is hereby dedicated to the use of the people of the state." The Kansas legislature named the Chief Engineer of DWR to administer the KWA Act. From June 28, 1945, the effective date of the KWA Act, all uses of water except for domestic use were to be by permit only. Existing uses by riparian landowners and groundwater pumpers were recognized as "vested rights." Rights not being used were simply lost. To perfect water rights, a landowner must first obtain a permit, construct the diversion works, pump water during the perfection period, have DWR officials inspect the works, and finally obtain a certificate from DWR. The certificate states the crucial elements of the perfected water right: the type of use, the place of use, the point of diversion, the priority date, and the official DWR file number of the appropriation or vested right. The water right holder files the certificate in the office of the Register of Deeds. Water rights not used for five years are forfeited as abandoned, unless the holder has "due and sufficient cause" for the non-use. With prior permission of the Chief Engineer, the holders of water rights may change the point of diversion, place of use, and type of use.

87. See, e.g., Colo. Const. art. XVI, § 6 ("The right to divert the unappropriated waters of any natural stream to beneficial uses shall never be denied.").
88. Ownership of land along streams gives the landowner a right to the water in the stream, to be shared with other riparian landowners. Shamieffer v. Council Grove Peerless Mill Co., 18 Kan. 24 (1877).
89. Underground waters are part of the real property, giving the owner the right to take any water from beneath the soil. Kansas ex rel. Peterson v. Kan. State Bd. of Agric., 149 P.2d 604, 609 (1944).
92. The Board of Agriculture became the Department of Agriculture in 1995.
94. The Kansas Supreme Court has upheld the constitutionality of this provision. Williams v. City of Wichita, 374 P.2d 576 (Kan. 1962).
holder may also convey water rights, either with the land or severed from the land.98

The original KWA Act did not define water rights as property rights, although at that time the common law viewed water rights as such.99 The legislature amended the KWA Act in 1957 to provide expressly that a water right is "a real property right appurtenant to and severable from the land on or in connection with which the water is used ...."100

From the lectures and field trips, the Asian group also learned of our methods of data reporting, collection, and storage regarding the more than 47,000 water permits in Kansas; DWR forms; satellite-read meters and email annual use reporting; basin management initiatives; and the WIMUS program for accessing water rights data on the internet. The lectures explained some of the issues regarding the nature of water rights as property rights and the protection of private property against takings by the government without compensation under the Fifth Amendment of the U.S. Constitution.

Increases in applications for new irrigation permits in the 1960's caused concern as state legislators began to realize that water tables were dropping and that the High Plains Aquifer was finite. The legislature enacted the Kansas Groundwater Management District Act ("KGMD Act") in 1972 to begin to manage groundwater.101 The KGMD Act declared dual policies of preserving basic water use and also establishing the right of local water users to "[d]etermine their destiny with respect to the use of groundwater ...."102 The mechanism for the local control was the establishment of GMDs by local land owners and water users.103 Each GMD has a small professional staff and an elected board composed of water users and landowners. The GMDs create a management plan and recommend regulations to the Chief Engineer that, once approved, are unique to that geographical area. The KGMD Act also contains provisions that enable the Chief Engineer to focus regulatory efforts on areas suffering serious ground-

98. KAN. STAT. ANN. § 82a-701(g) (2006).
99. See, e.g., City of Emporia v. Soden, 25 Kan. 588, 37 Am. Rep. 285 (1881) stating that a riparian owner has the right to the undiminished flow of the stream, and that an owner of land owns the groundwater beneath the surface as the owner owns the land itself.
102. Id.
water mining issues by establishing intensive groundwater use control areas ("IGUCAs"). If the Chief Engineer establishes an IGUCA, the KGMD Act gives the Chief Engineer extraordinary powers, including reducing pumping by water users. Five GMDs were established in the 1970's.\textsuperscript{104} The Chief Engineer has established eight IGUCAs.

2. Kansas Law of Water Quality

Water allocation law and administration dominated the program's focus, but the program also touched on water quality issues in lectures, discussion, and field trips. Unlike water allocation law, which is mostly state law with some federal influence, the law of American water quality is largely federal law, with some state influence. The Region VII office of EPA, located in Kansas City, Kansas, is responsible for enforcing these laws. The KDHE has power delegated to it by EPA to enforce many of these regulations as well. EPA and KDHE often work together in enforcing these statutes.

Five federal statutes provide the most powerful environmental regulation of Kansas groundwater. The Solid Waste Disposal Act, better known as the Resource Conservation and Recovery Act ("RCRA"),\textsuperscript{105} regulates solid waste that EPA either lists as hazardous or that exhibits one of the four characteristics of hazardous waste: toxicity, ignitability, corrosivity, or reactivity.\textsuperscript{106} Where RCRA's focus is on prevention, the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA" or "Superfund") usually focuses on the mitigation of already-existing contamination.\textsuperscript{107} The Federal Pesticide, Fungicide, and Rodenticide Act ("FIFRA")\textsuperscript{108}


\textsuperscript{106} 42 U.S.C. §§ 6901-6911. RCRA regulates these materials during their useful life; it regulates the generation and production of these materials; it regulates the transportation of these materials; and finally, it regulates their treatment, storage, or disposal ("TSD"). \textit{Id}. RCRA is most concerned with groundwater quality at the TSD phase, to prevent or minimize the pollution of groundwater supplies by hazardous solid waste in landfills.

\textsuperscript{107} 42 U.S.C. §§ 9601-9675 (2000 & Supp. V 2005). CERCLA assigns potential liability for contamination to all of the potentially responsible parties ("PRPs") who are involved with a contaminated site: the current owners or operators of the site, the owners or operators of the site at the time of disposal, the arrangers of the disposal (including waste generators), and the transporters of the contaminant. 42 U.S.C. § 9607 (a)(1)-(3).

hibits the sale or distribution of any pesticide that has not been regis-
tered with EPA, and EPA may only register a pesticide if it will
perform its intended function without causing unreasonable adverse
effects upon the environment.

The Public Health Service Act, better known as the Safe Drinking
Water Act ("SDWA"), sets drinking water standards. The SDWA
has two programs that are particularly concerned with groundwater.
The first is the underground injection control program, which seeks to
protect underground drinking water sources. The second program
is the sole source aquifer program, which seeks to protect aquifiers
that supply drinking water by prohibiting the federal government
from providing financial assistance to a project that may contaminate
an aquifer through a recharge zone. The most prominent federal
legislation regarding water quality is the Federal Water Pollution
Control Act, better known as the Clean Water Act ("CWA"). The
CWA is concerned primarily with surface waters. Because most of
the water in Kansas is groundwater and not navigable surface water,
the CWA is often of limited applicability in Kansas. The CWA gener-
ally exempts from regulation discharges of groundwater, including
runoff from irrigation (except perhaps groundwater that is hydrologi-
cally connected to surface water). However, the CWA can play a prom-
inent role in Kansas, by protecting wetlands under the Dredge and
Fill Program.

Although DWR is primarily concerned with the regulation of
water withdrawals—by the issuance and supervision of water rights—
it exercises considerable influence in the regulation of water quality
as well. This responsibility is manifested primarily during the pro-
cess of evaluating water rights applications. Here, the Chief Engineer
must consider whether the permit under review would either impair a
use under an existing water right or unreasonably affect the public

110. Under this program, all injection wells require a permit from EPA: Permits are
available if it can be shown that the injection will not endanger drinking water sources.
113. The CWA seeks to improve water quality in the nation’s waters by prohibiting
the discharge of pollutants into the navigable waters of the United States without a
permit that requires compliance with technology-based effluent limitations.
114. Section 404 of the CWA prohibits the discharge of dredged or fill material into
the waters of the United States without a permit from the U.S. Army Corps of Engi-
neers. 33 U.S.C. § 1344. This program applies primarily to the filling of wetlands by
land developers, who are required to mitigate the adverse impacts on wetlands to the
maximum extent possible. The Dredge and Fill Program of the CWA has played a role
in blocking various major construction projects in Kansas, such as the construc-
tion of the K-10 Highway through the Baker Wetlands of Lawrence.
115. What follows depends substantially upon Leeland A. Rolls, A State Agency’s Role
interest. 116 In determining the effect on an existing water right, the Chief Engineer may consider whether the proposed use would cause an "unreasonable deterioration of the water quality at the water user's point of diversion beyond a reasonable economic limit." 117 The Water Appropriation Act also requires the Chief Engineer to consider whether or not the proposed use of water could be reasonably served by lower-quality water, thus preserving water of higher quality for higher uses, such as drinking water. 118

3. Interstate Water Issues

Being inland, Kansas has had no international water issues. Kansas has, however, experienced a long history of interstate water battles, particularly with Colorado, which have led to interstate water compacts and litigation. 119

a. The Arkansas River

Kansas was a party to the seminal interstate water case, Kansas v. Colorado, 120 over the Arkansas River in 1907, in which the United States Supreme Court created the Equitable Apportionment Doctrine. 121 Kansas was unsuccessful in that 1907 case as well as in a

117. § 82a-711(c). Water quality considerations under the public interest element could only be done under the catchall consideration of "all other matters pertaining to such question." § 82-711(b).
118. § 82a-711(a). In addition, a relatively recent section of the Appropriation Act, Kan. Stat. Ann. § 82a-703b (1997), requires that applications for water rights filed between 1984 and 1996 be reviewed in any minimum desirable streamflows ("MDS") the legislature designated in that period. In certain areas, DWR also requires water quality samples to be taken and analyzed prior to permit approval, usually to ensure that the higher saline levels present in lower regions of one aquifer will not migrate upward, or that saline water in one aquifer will not migrate into another aquifer. Similarly, state regulations require check valves on all groundwater diversions works through which chemicals such as insecticides, fertilizers, and herbicides could be injected. DWR also cooperates with KDHE to regulate water quality. Under a Memorandum of Understanding ("MOU") signed in 1984, the agencies share information concerning artificial recharge projects, underground injection of water in secondary and tertiary oil production and salt mining, and the creation of underground natural gas storage. The MOU also enables the agencies to designate a "special groundwater quality area."
119. Several of the Asian participants briefly discussed trans-boundary water disputes: Dr. Kamra and Mr. Thomas discussed water conflicts both between India and Bangladesh, and between states within India. Mr. Islam discussed conflicts between India and Bangladesh. Professor Head attended to several important international water treaties in his lecture.
120. 206 U.S. 46 (1907).
121. Kansas v. Colorado, 206 U.S. 46 (1907). Under the Equitable Apportionment Doctrine, both states enter the Court on equal footing. The Court will not prefer one state's water allocation doctrine over the other. At the time, Kansas was a Riparian Doctrine state and Colorado was a Prior Appropriation Doctrine state. The plaintiff state alleging the harm must prove that the harm it suffers from the defendant's water use outweighs the benefits to the other state obtained by that use. If the plaintiff is
later case, which led Kansas in 1948 to enter into an interstate compact with Colorado to allocate the waters of the Arkansas River. The Arkansas River Compact states that "the waters of the Arkansas river... shall not be materially depleted in usable quantity or availability for use to the water users in Colorado and Kansas under this Compact by such future developments or construction." In 1985, Kansas sued Colorado, claiming a violation of that provision on the basis that Colorado had permitted numerous high capacity irrigation wells to be constructed in the alluvium of the Arkansas River upstream from the Kansas border. The fact that the compact itself did not expressly address groundwater did not keep the Supreme Court from ruling for Kansas on that issue. The Court upheld the special master's decision that Colorado had damaged Kansas by depriving Kansas of approximately 420,000 acre feet (518.06 million cubic meters) of water. Colorado paid Kansas $34,700,000 in 2005. Now, after almost twenty-four years of litigation, that case is nearing completion.

b. The Republican River

In 1942, Kansas signed an interstate water compact with Colorado and Nebraska to allocate the waters of the Republican River. The compact allocated the waters by dividing the basin into small drainage basins, defining the "Virgin Water Supply" in each drainage basin as "the water supply within the Basin undepleted by the activities of man," and allocating to each state a portion of the Virgin Water Supply in each drainage basin.

In contrast to Kansas' history of groundwater regulation and its requirement of prior permitting for groundwater pumping is Nebraska's hybrid Reasonable Use/Correlative Rights Doctrine for groundwater. Under that doctrine, little regulation of groundwater use has been done, and a great irrigation economy has grown in the state of Nebraska. According to Kansas water officials, however, the pumping of alluvial groundwater from the Republican River in Nebraska diminished flows in violation of the Republican River Compact.

unsuccessful in the case, it is not precluded from bringing another suit later if conditions worsen.

123. U.S. CONST., art. I, § 10, cl. 3 (permitting states to enter into compacts, with the approval of Congress).
125. § 82a-520, art. IV (D).
126. § 82a-518.
Kansas brought suit against Nebraska in 1998. Colorado entered the suit. In 2000, the Special Master first ruled that pumping of alluvial groundwater that caused the Republican River flow to diminish could be a violation of the compact, despite no express language in the compact to that effect. In 2003, the three states settled the case, and the Supreme Court approved the settlement. The settlement provided, among other things, that Nebraska would cut down on pumping by its Republican River alluvial groundwater irrigators. Nebraska has placed a moratorium on new pumping, has required metering of wells, has begun to regulate the annual quantity allowed in three Natural Resources Districts, has sought federal money to pay water right holders not to irrigate, and has sought “buy-outs of water rights via Nebraska legislation that would raise money by assessing fees on irrigators . . . .” The districts have set pumping limits. But, several years after the settlement, Nebraska has been unable to comply, and Kansas is considering suing once again, this time on the settlement agreement.

VI. SOLUTIONS/PROJECTS TO ADDRESS WATER PROBLEMS

A. LEGAL/ADMINISTRATIVE/REGULATORY

1. South Asia

Nepal, India, and Bangladesh have begun to take legal, administrative, and regulatory steps to address their groundwater management problems. However, like their western counterparts, many of these steps remain far distant from the goal of sustainable groundwater management. Indeed, the water use laws of South Asia are rarely followed or enforced.


129. In John C. Peck, Water Law: the 2003 Annual Survey of the Law, KAN. BAR ASS'N, 2003, at 321, Peck provides: [A] listing of the subjects contained in the chapter [of the Second Report of the Special Master] titled “The Final Settlement Stipulation” shows the areas of concern: Waiver of Claims for Damages; Treatment of Groundwater Pumping; Mechanisms for Future Compact Administration; Dispute Resolution System; Commitment to Future Joint Efforts; and Non-Severability. The section on Mechanisms for Future Compact Administration contains the following sections: Revised Formulas for Determining Compact Compliance; Use of 5-Year Running Averages; Flexibility of Water Use within each State; Use and Administration of Water above Guide Rock, Nebraska; Information and Data Sharing; Credit for Imported Water; and Water-short Year Administration. Id.

130. Id. at 380.


132. This is an observation by JWM's Mark Giordano, who also states that the "court system is difficult to access and so the laws on the books just don't apply—there
Nepal has established a governmental system for the management of its water supplies, but according to the Nepalese participants in the program, that system would benefit from three additions. First, the system needs a separate regulatory authority to control and monitor groundwater. There are so many governmental institutions involved in the groundwater exploitation problem that no single entity is responsible to control, monitor, and prepare the information required for sound groundwater management. Second, Nepal needs effective legislation on water—legislation concerning water rights, their administration, and groundwater management, and also legislation that establishes legally enforceable national environmental standards. Finally, Nepal needs better land use planning. Without these three reforms, Nepal will not be able to address the challenges it faces in water management. Specifically, these challenges include ensuring a safe drinking water supply by reducing arsenic levels, controlling the use of fertilizers and pesticides, and protecting the aquifer in the Kathmandu Valley from further depletion and pollution. At this time, however, Nepal lacks the economic resources, the necessary political stability, and the political commitment required to reform its management of groundwater.

As a property right, a groundwater right in India can be generally controlled by legislation, in the interest of sustainability and equity. However, this has not been done in India. In 1970 the Central Model Groundwater Bill was introduced, and the bill was revised in 1972, 1996, and again in 2005. A few states have proposed legislation based on the bill. The bill would require registration of all large wells, permits to drill new wells, and regulation to prevent groundwater extraction from exceeding recharge. One reason for the lack of support is that any attempt to enforce a centralized regulatory regime on millions of private well owners may result in unmanageable complexities.

In the last decade, however, India has taken several legal and administrative measures to regulate and monitor its groundwater use. In 1997, the Central Ground Water Authority was organized under the authority of the Environment Act of 1986. The Authority monitors groundwater contamination, regulates agencies involved in the construction of wells, reviews and authorizes groundwater projects, and promotes conservation measures such as rainwater harvesting.

is no recourse if they are violated. This is especially the case in rural areas for irrigation water. As a result, the government's role and options for influencing groundwater management are quite different than in the US. Email from Mark Giordano to John Peck (Jan. 22, 2008, 04:35 CST) (on file with authors).

dian water officials are also preparing a zoning atlas for the appropriate use of water, depending upon the climate and the hydrology of a particular region; a voluntary water use certification program for industries; a plan by which states will regulate the private market in water (worth approximately fifty billion rupees annually); and a plan to use satellite imagery to map groundwater.\textsuperscript{134}

Bangladesh has also developed a national water policy which seeks to achieve the efficient and equitable use of groundwater. First, the policy seeks to develop the knowledge and capability to design future water resource plans that achieve economy, efficiency, gender equity, social justice, and environmental protection. Second, the policy seeks to integrate the management of surface water and groundwater for irrigation. Third, the policy seeks to strengthen the monitoring systems for tracking groundwater recharge, surface and groundwater use, and changes in the quality of both surface and groundwater. Fourth, the policy seeks to encourage future groundwater development for irrigation in both the private and the public sectors. Finally, the government has formed a committee of experts to determine ways to provide subsidies for irrigation development; the committee has already submitted a report to the Ministry of Agriculture.

2. \textit{Kansas}

a. Quantity

(1) GMD's

After the dramatic increase in groundwater extraction in the 1950's and 1960's and the enactment of the Groundwater Management District Act in 1972, people in the affected areas established five GMDs. On the field trip, the GMD managers described the physical and hydrological aspects of the GMDs, explained the issues and chal-

\textsuperscript{134} India has also developed international treaties and agreements concerning groundwater. Bilateral agreements include the following: The Indus Water Treaty 1960, India-Pak., Sept. 19, 1960, available at http://web.worldbank.org/WEBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0,,contentMDK:20320047-pagePK:148736-piPK:583444-theSitePK:223547,00.html (regarding the Indus River); Mahakali Treaty, India---Nepal, June 1997; and Treaty Between the Government of the People's Republic of Bangladesh and the Government of the Republic of India on Sharing of the Ganga/ Ganges Waters at Farakka, Bangl.-India, Dec. 12, 1996, available at http://search.com.bd/articles/Treaty-Between-Bangladesh-India-on-Sharing-Ganges-Ganges-Waters-Farakka.html (regarding the Ganges River). However, with the exception of the Indus Treaty, the other river treaties were executed long after the groundwater boom had occurred in South Asia. India has also entered into an agreement with China to share and develop hydrological information, as well as a cooperation agreement with Bhutan. Outside of Asia, India is a signatory member of the Hague Declaration on the Environment (1989) and participates in international forums such as the World Water Council, the World Water Forum, the Global Water Partnership, and the International Commission on Irrigation and Drainage.
lengths of their respective GMDs, demonstrated how the GMDs collect data, and described some projects and solutions.

Established in 1975, Equus Beds GMD No. 2 ("GMD No. 2") is quite small, about 1373 square miles (3556 square kilometers) and serving more than 560,000 people. GMD No. 2 overlies the Equus Beds Aquifer. There are fifty-five municipal wells (thirty-four percent of the use) in GMD No. 2, which includes the well fields of the city of Wichita, whose boundaries are not within the district. There are 1620 irrigation wells (fifty percent of the use) and 164 industrial wells (fifteen percent of the use) in the district. Annual recharge ranges from three to six inches (76 to 152 mm).

Regulatory measures in GMD No. 2 stress balancing groundwater discharge with recharge, as this is the only GMD that has had safe yield as its primary management policy from the beginning. Its regulations prescribe a two-mile (3.26 km) radius circle test to aid DWR in determining whether to issue a new permit or to approve a change application.\(^{135}\) Under this test, all current permitted withdrawals along with the quantity sought in the application are totaled and compared to the quantity of water being recharged based on an assumed six inches (152 mm) of recharge per year. Recognizing that streams also discharge groundwater, the GMD amended the regulation in 1994 to add the concept of the "baseflow node." Whenever a stream intersects a two-mile radius circle under consideration, the discharge quantity in the circle includes an allocation for discharge points along the stream every 1320 feet (402 m).\(^{136}\) If the totals derived exceed the annual recharge within the circle, the application is denied. GMD No. 2 collects large amounts of data to aid its management efforts—precipitation; groundwater use; groundwater levels (over 550 water level monitoring wells collect 2000-3000 measurements annually); and groundwater quality with a groundwater quality measuring network, including collecting chloride level samples.

The primary current quantity issue in GMD No. 2 is the problem of groundwater mining. Within the GMD are three IGUCAs\(^{137}\) and one "enhanced well spacing area." Data suggests that while the High Plains Aquifer in southwest Kansas is being mined with its safe yield regulation, GMD No. 2 as a whole is not being actively mined. But there are locations within the district where mining is occurring, and there are locations where water levels have increased since 1939.

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\(^{135}\) KAN. ADMIN. REGS. § 5-22-7 (2006).

\(^{136}\) Id. Now Big Bend GMD No. 5 also includes the baseflow node concept.

\(^{137}\) See discussion infra Part VI.A.2.a.(2) (describing Walnut Creek IGUCA in GMD No. 5).
GMD No. 2 has also been involved with the Aquifer Storage and Recovery Project of the city of Wichita.

Organized in 1976, Big Bend GMD No. 5 ("GMD No. 5") is roughly double the size of GMD No. 2, and lies just to the west. GMD No. 5 lies over the Great Bend Prairie Aquifer. Within it are two important wetlands—the Cheyenne Bottoms\textsuperscript{138} and the Quivira National Wildlife Refuge. Most of the groundwater in the western part of this GMD is fresh water. The safe yield policy of GMD No. 5 has become more strict since 1980, when the assumed recharge figure was 9 inches (229 mm); in 1984, that figure was reduced to 4.5 inches (114 mm), and in 1990 to 2.25 inches (57 mm). GMD No. 5 closed several basins to new permits in 1990, and required flow meters in 1992. The entire GMD was closed to new permits in 1998. An inherent conflict in GMD No. 5 is between farmers who want to irrigate and state and national wildlife groups that need water for wildlife.

Starting in 1990, GMD No. 5 started looking at groundwater management by basin. Following DWR's 1992 designation of the Walnut Creek IGUCA, water users in the Rattlesnake River Basin formed a partnership to solve problems in that basin similar to those in the Walnut Creek Basin. These parties, which included the U.S. Fish and Wildlife Service, DWR, GMD No. 5, and the Water Protection Association of Central Kansas (irrigators and other water users), created the Rattlesnake Creek Management Program.\textsuperscript{139} The agreement included strategies such as water banking and various conservation practices.

Besides the basin programs, GMD No. 5 is currently involved in the Water Transition Assistance Program ("WTAP"), the GMD No. 5 Meter Program, the Weather Station Program, and the Water Rights Banking Program. WTAP, one of several such programs, is a voluntary conservation program that purchases water rights with federal money, and then retires them. The Central Kansas Water Bank is the first water bank established under 2001 enabling legislation.\textsuperscript{140} Water rights may be deposited for five years into the bank, which may then lease water under those rights to others. Safe deposit accounts can hold unused water deposited there for future withdrawal. The legislation includes a conservation element by which the account balance must decrease by at least ten percent, as established by the bank. But flexibility in the water right holder's use of the water is gained at the cost of losing some absolute quantity. GMD No. 5 has ten

\textsuperscript{138} See infra Part VI.A.2.a.(2) (discussing the Walnut Creek IGUCA formed to protect the Cheyenne Bottoms).
weather station sites to monitor precipitation, air temperature, wind speed, humidity, solar radiation, and grass referenced evapotranspiration.

Southwest Kansas GMD No. 3 is the largest district of the five GMDs, slightly larger than GMD No. 2 and GMD No. 5 combined. Finney County, located in the north part of GMD No. 3, has the highest use of any county in the state, with nearly 1800 irrigation wells. Pre-1900 irrigation ditch rights from the Arkansas River, the expansion of canal irrigation between 1890 and 1940, and the proliferation of center-pivot irrigation systems in the 1950's through the 1970's have created an irrigation mentality. But over-appropriation has led to serious groundwater depletion. The water table has dropped over ten feet in the last ten years. District-wide, irrigators are annually taking out 2.1 million acre feet (2.59 cubic kilometers), but only 80,000 acre feet (0.099 cubic kilometers) are being recharged. A safe-yield policy in GMD No. 3 would have drastically cut irrigated agriculture. This is why GMD No. 3 chose to adopt a two-mile radius depletion formula rather than a safe-yield formula when its first regulations went into force in 1981. The original formula permitted a forty percent reduction over a twenty-five year time span. Like the water right applicant under the safe-yield formula for the Equus Beds GMD, the applicant in GMD No. 3 would have his application's quantity totaled with all others within the circle, and if the total did not exceed the amount available (based on leaving sixty percent in the aquifer over twenty-five years, considering the thickness of the aquifer and the minimal recharge), the application would be granted.

Impairment complaints have increased recently in GMD No. 3. For claims of direct impairment, the Chief Engineer investigates and takes suitable action if an impairment is found—i.e., shutting down junior rights. The looming issue in GMD No. 3, indeed in the state as a whole, is whether a general impairment complaint can be made, i.e., whether a senior user who is damaged by a general lowering of the water table can successfully claim that impairment was caused by all junior water rights in the region. Kansas has not answered this question, but a case on this issue may be filed. On the conservation front, GMD No. 3 is stressing the Conservation Reserve Enhancement Program (“CREP”), a federal-state funded program under which 100,000 acres (40,469 hectares) of irrigated land would be removed, reducing pumping by 149,600 acre feet (184.5 million cubic meters)

annually. Its claimed benefits include improving Arkansas River flow, thereby enhancing the Cheyenne Bottoms, and reducing energy consumption.

(2) IGUCA's: The Walnut Creek IGUCA\footnote{See supra text accompanying note 104 (explaining IGUCAs).}

The Asian group toured the Cheyenne Bottoms Wildlife Preserve, the subject of an important IGUCA proceeding in 1990 and 1991. In 1949, the Kansas State Fish and Game Commission, now the Kansas Department of Wildlife and Parks ("KDWP"), obtained from DWR two permits totaling 50,000 acre feet (61.68 million cubic meters) per year to divert water from the Arkansas River and from Walnut Creek, one of its tributaries. KDWP wanted the water for recreational use to keep the Cheyenne Bottoms Wetland area full. Located just northeast of Great Bend, this wetland has been described as one of the most important migratory shore bird stopover points in the Northern Hemisphere.\footnote{Dr. Gonzolas Castro, Program Manager of the Western Hemisphere Shorebird Reserve Network, Testimony at the IGUCA hearings (Dec. 5, 1990) (notes on file with authors). Dr. Castro testified on behalf of the Kansas Natural Resource Council and the Kansas Audubon Society. Id. Dr. Castro then explained that shorebirds breed in North America and spend winters in Central and South America. Id. The birds have narrow flyways and need a few key locations to eat because they cannot fly all the way from South America to Alaska without refueling. Id.} From 1949 through the 1970's, irrigators obtained over eight hundred permits to pump groundwater from the Walnut Creek alluvium. A drought in the late 1980's caused the water levels in the wetland to drop. Rather than administering the water rights under the strict prior appropriation system, the Chief Engineer held hearings to consider imposing an IGUCA.\footnote{The hearings, conducted off and on over five months, involved eleven parties with counsel, two parties of which represented collectively all of the irrigators, and produced testimony about water rights impairment, the interconnection between groundwater and surface water, the ecological and recreational importance and use of the wetland, and the economic effect that well pumping curtailments might have on the region.}

The Chief Engineer imposed an IGUCA in a three-county area stretching west from the wetland about seventy miles (113 km). The Order stated that the then current annual pumping in the basin was roughly 44,000 acre feet (54.27 million cubic meters) per year, but that safe yield was only 22,700 acre feet (28 million cubic meters). The aim of the Order, then, was to impose safe yield by halting the issuance of new permits and reducing pumping by existing water right holders. The Order first declared that no more than twelve to fourteen inches (305 to 356 mm) annually were needed for irrigation in this area if proper conservation measures were undertaken. The Order permitted vested rights to continue to be pumped without reduction. To obtain
the almost fifty percent reduction in pumping needed to obtain safe yield, the Order divided the appropriation rights into two groups, "Senior Rights" (October 1, 1965 and earlier) and "Junior Rights" (after October 1, 1965). The Order cut Senior Rights to between twelve and fourteen inches (305 to 356 mm), depending on location in the basin, and Junior rights to between 5.25 and 6.25 inches (133 to 159 mm). The farmer groups appealed the Order, but later settled the matter with DWR and dismissed the appeal. Thus, the constitutional question of whether the statutorily permitted reduction of water pumping constitutes an unlawful taking of property without compensation was never answered.

In an informal session with the Asian group, the Chief Engineer told them that the Walnut Creek IGUCA was the most important decision he had made in his twenty-five-year tenure. He said that the Order established DWR's position on several key points in Kansas water allocation law. First, DWR construes the Appropriation Act as permitting DWR to administer alluvial wells with river rights as long as scientific evidence shows a clear interconnection between the two regimes. Second, DWR may reduce water rights without respecting priority in a pure sense, as expressly permitted in the KGMD Act. Third, DWR can maintain continuing jurisdiction over an IGUCA and over the problems the IGUCA was established to handle.

b. Quality: GMDs and Water Quality

Current water quality issues in GMD No. 2 include unregulated groundwater pits, groundwater pollution from surface contaminants, subsurface minerals such as chlorides, septic waste disposal, oilfield brine, city landfills, and nitrates. The issue regarding unregulated groundwater pits (also known as sand pits) involves untreated urban and rural stormwater runoff that pollutes the pit water and then the Equus Beds groundwater. Possible solutions include discharge prohibitions and discharge treatment. Septic systems deposit nitrates, fecal bacteria, viruses, and cleaning solvents into the aquifer. Unlined waste lagoons and landfills deposit pollutants that eventually reach municipal water wells, causing increased treatment costs and decreased user confidence. In "sensitive groundwater areas," GMD No. 2 is now requiring liners for lagoons. The groundwater in the eastern part of GMD No. 5 contains salt water. It has enacted the Mineral Intrusion Program. In GMD No. 3, CREP may remove 100,000 acres in the Upper Arkansas River Basin from irrigated cultivation, reduc-

146. The western-most rights were allowed more water, because they were in an area of less annual rainfall.
ing pollutant levels in the Arkansas River and the outward migration of river salinity.

B. ENGINEERING/TECHNOLOGY: QUANTITY

1. Conservation

a. South Asia

Generally speaking, groundwater experts throughout South Asia have focused on small projects that village farmers can operate and maintain. Performed thousands of times on a small scale, such projects can yield substantial water savings. A good example of small-scale water engineering is rainwater harvesting. Given the heavy rainfalls that occur throughout India, not to mention those that take place during monsoon season, water experts have sought to increase rooftop rainwater harvesting wherever feasible. Harvesting rainwater is relatively simple. Instead of allowing the rain to flow off of the roof and away, the guttering of a house channels the rainwater into a storage tank. The water passes through filters at either end of the storage tank before being used.147 The Indian government has recognized the need to harvest rainwater by amending its building laws and zoning codes. In at least ten states, providing a method of rooftop rainwater harvesting system has become mandatory; and the Indian government has begun to retrofit such systems on government buildings in Delhi.148 Throughout South Asia, buried pipe irrigation systems have begun to replace earthen open channels, reducing water lost through transportation. Farmers are improving their irrigation channels to reduce water loss in other ways, such as constructing larger, wider earthen channels and using PVC pipes.

In India, other traditional water-conservation techniques have undergone a revival. In Ladakh, small tanks called zings collect glacier water that melts during the day. In Meghalaya, farmers employ an ingenious system of bamboo drip irrigation, which typically transports between eighteen and twenty liters of stream or spring water over several hundred meters. The system then disperses the water through a system of bamboo drip shunts to water plants. In the Thar Desert of Western Rajasthan and in some areas of Gujarat, villagers


148. The states are: Gujarat, Maharashtra, Tamil Nadu, Nagaland, Delhi, Karnataka, Kerala, West Bengal, Madhya Pradesh, and the Union Territory of Daman and Diu.
use a kund, or kundi, to harvest rainwater for drinking. Kunds are essentially a circular underground well with a saucer-shaped catchment that gently slopes toward the center, collecting the rainfall that percolates down. And in Rajasthan, ancient drinking water wells known as baoris, or bers, continue to serve their communities.

Necessity has invented contemporary improvements to traditional rain water harvesting techniques, depending upon the domestic and irrigation needs of the local community. In the high desert regions of Ladakh in Jammu and Kashmir, engineers have devised systems of "artificial glaciers" to capture and preserve water supplies. In the cold desert of Ladakh, the only source of water is from the artificial glaciers, which melt only in late summer. Here, engineers have diverted flow from these glacial streams and channeled the water to a shadowed area of the mountains close to the village of Leh. The water then re-freezes closer to the village, and because this artificial glacier is much smaller, it melts in the spring and irrigates the fields for spring planting. Through the artificial glacier system, water that was previously available only in the late summer is made available in the spring.

b. Kansas

(1) Reuse of Municipal and Industrial Wastewater

The Asian group learned of the Dodge City Wastewater Recycling Project at a farm south of Dodge City, Kansas. Begun in 1987, this cooperative project consists of several partners—the city, a farmer, and a large beef packing plant. The cooperative project utilizes crop and environmental consultants. The project involves moving untreated wastewater from the city and the packing plant to lagoons located eleven miles (17.7 km) south of the city near the farm. There, the wastewater undergoes aerobic and anaerobic treatment, methane gas is collected and burned, and the treated water is pumped to the farmer's land and irrigates fields of corn and alfalfa. The crops recycle the water and the nutrients contained in the water, especially nitrogen. The original forty-year contract between the city and the farmer provided that the city would send all of the wastewater treated in the

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149. See Rainwaterharvesting.org, supra note 147 (describing such techniques as artificial glaciers, nadis (ponds), polymer kundis (tanks), chauka systems (rectangular plots that collect and store rainwater), Jaldhara (farmland set aside for rainwater harvesting), tudums or mongas (mechanism to draw water from tanks for irrigation), networking of farm ponds, and horizontal roughing filters/slow sand filters).

lagoons to the farmer, who would accept all the wastewater sent; that
the farmer would apply the "nutrient enriched" wastewater to fields;
and that the water rights the farmer previously used would be as-
signed to the city. At one time there was more data on this project
than on any other wastewater reuse project in the United States and
possibly the entire world.\textsuperscript{151}

Recent increases in Dodge City's population have increased its
wastewater deliveries. The acreage and number of fields to which
wastewater was being applied has doubled. The city has built new
lagoons, drilled new municipal wells to use the irrigation rights as-
signed the city by the contract, and laid new fresh water pipelines into
the city. Water quality is monitored, and the project has fifty-four
monitoring sites that measure the wastewater's impact on the soil,
down to fifty feet deep (15.2 meters). Excess nitrogen is removed from
the wastewater by the lagoons using sprayers to send nitrogen into
the air, and by the alfalfa itself, which "mines" residual nitrogen in
the soil.

(2) Integrated Use: The Proposed Bio-Energy Center

Sunflower Electric Power Corporation ("Sunflower") has proposed
a bio-energy center as part of its power plant expansion. Sunflower
has formed an alliance with the National Institute for Strategic Tech-
ology Acquisition and Commercialization ("NISTAC") and the Kan-
sas Bioscience Authority ("KBA") to construct an integrated bio-
energy center at the Holcomb plant. The alliance seeks to "integrate
several commercial or near commercial renewable energy technologies
with the existing coal-based power plant."\textsuperscript{152} The center would in-
volve systems relating to "livestock processing, a dairy, anaerobic di-
gestion, an algae reactor, an ethanol plant, and a biodiesel plant all
integrated with one another."\textsuperscript{153} The center would remove carbon di-
oxide from the power plant flue gas. With regard to water, the project
would re-use water and utilize waste streams. For example, in the
livestock processing subsystem, the "wastewater from the processing
plant, when passed through an anaerobic digester, [would] create . . .
methane, reusable water, and a nutrient source for the algae system.
Livestock processors currently purchase carbon dioxide for dry ice re-

\textsuperscript{151} Deketa Sheekman, owner of Nicholson Ventures and Treasurer of BeneTerra
L.L.C., Remarks on Lecture on the Dodge City Wastewater Reuse Project (Dec. 5, 2006).
\textsuperscript{152} Press Release, Sunflower Electric Power Corporation, Sunflower to Develop In-
tegrated Bioenergy Center (Oct. 9, 2006), available at http://www.sunflower.net/News/
2006/NRBioenergyCenter.pdf (stating the Sunflower Electric Power Corporation's in-
tent to develop an Integrated Bioenergy Station).
\textsuperscript{153} Sunflower Integrated Bioenergy Center, Sunflower Electric Power Corp. (Aug.
2006) (handout provided by Sunflower, on file with authors).
frigation which could be supplied from the ethanol plant."\textsuperscript{154} The dairy sub-system would provide manure and wastewater to an anaerobic digester, which would convert them to methane. The wet distillers grain from the ethanol plant and solids from the algae reactor would go to the dairy for cattle feed.\textsuperscript{155} The algae biomass produced in the algae subsystem would be "separated into oil . . . and solids. Those solids can be fed to livestock, burned in the power plant, or used by an ethanol plant."\textsuperscript{156} The project would seek to serve agricultural producers and add value to products raised in western Kansas.

2. \textit{Aquifer Recharge}

a. South Asia

Groundwater depletion in South Asia has created an urgent need for national plans to recharge the aquifers. Indian water authorities have compiled a staggering master plan for artificial recharge: the plan calls for nearly four million artificial recharge structures, mostly in urban areas, which will aim to recharge over 29.1 million acre feet (35.89 cubic kilometers) into areas totaling nearly 123 million acres (50 million hectares). Such a plan is estimated to cost approximately 250 billion rupees (approximately $6.24 billion).

Artificial recharge in India consists of both direct and indirect techniques. Direct recharge techniques fall into two categories, surface spreading and sub-surface techniques. Surface spreading is the simplest method and can usually be achieved without farm machinery: flooding of farm fields; recharging basins using ditches and furrows; and conserving runoff through gully plugs, bench terracing, and percolation tanks. Subsurface techniques include using injection wells, recharge pits and shafts, and dug well recharge. Indirect recharge techniques are typically more technically demanding. They include induced recharge by pumping wells, collector wells, and infiltration galleries; modification of the structure of the aquifer by bore blasting and hydrofracturing; and conservation of groundwater through the use of groundwater dams and fracture sealing and cementation.

b. Kansas: The Wichita Aquifer Storage and Recovery Project

The City of Wichita, with a population of over 350,000, has two primary sources of water: Cheney Reservoir, a Corps of Engineers reservoir located approximately seventeen miles (22.4 km) west of the

\textsuperscript{154} \textit{Id.} at 2.
\textsuperscript{155} \textit{Id.}
\textsuperscript{156} \textit{Id.} at 4.
city; and a well field in the Equus Bed Aquifer, located approximately ten miles (16 km) north of the city. In the late 1990’s, after receiving recommendations from an engineering study of long-range water supply alternatives, the city embarked on the Wichita Aquifer Storage and Recovery Project ("ASR Project"). When all phases are completed, Wichita will be able to divert and recharge 15,000 acre feet (18.50 million cubic meters) of water per year.157

The ASR Project takes water from the surface and alluvial groundwater of the Little Arkansas River during high streamflow events. Pipelines convey this water to recharge pits and injection well locations for recharge back into the Equus Beds Aquifer. Wichita will then be permitted to withdraw this water under complicated formulae found in DWR regulations specifically written for such projects.158 Wichita thus obtains two new water rights that are in addition to their very senior Equus Beds water rights: one is for the diversion of water from the Little Arkansas River and the recharge into the aquifer; the second is for the diversion of this recharged water from the aquifer. In a sense, Wichita is replacing for future use the water it has taken over the past sixty-five to seventy years from the Equus Beds Aquifer. The project aids both Wichita and other holders of water rights in the vicinity. Another advantage of the project, one that helped obtain aid from the Equus Beds GMD and ultimate approval of DWR, was the fact that the injected water will help form a barrier to the migration of a salt water plume located west of the project—a plume that until now has been moving toward the Little Arkansas River.


158. Wichita may have been able to construct this project under then-existing regulations, but officials from DWR, Wichita, and GMD No. 2 wrote new regulations to cover this type of project. See KAN. ADMIN REGS. §§ 5-12-1 to 5-12-4 (2006), which specifically address ASR projects and provides for acquiring water appropriation rights for artificial recharge, determining the volumetric space for the storage space in which the water will be stored, accounting for the water stored and used, and setting hearings to determine whether to approve the ASR application.
3. **Johnson County Water District No. 1: Missouri River Intake**

   WaterOne is devising methods to address the channel degradation. WaterOne’s river intake structure requires 10,000 cfs (283 cubic meters per second) more flow today than it did in 1990 to divert the water. WaterOne is pushing the Corps of Engineers to conduct a regional study on this problem, but in the meantime is using a new “low water pumping facility” with submersible pumps. WaterOne has also constructed a new system of horizontal collector wells to take alluvial groundwater. These wells consist of caissons that at given depths have wells projecting out horizontally in a radial pattern and that induce surface water infiltration.\(^{159}\)

C. **Water Quality**

1. **South Asia**

   The problem of geogenic arsenic and other contaminants of groundwater in South Asia has generated a variety of technical responses. The primary goal is to prevent the problem of contamination from worsening. Where the problem is already severe, as in Bangladesh, authorities have devised a simple yet effective system for protecting the rural users of those wells. Safe wells are painted green, while contaminated wells are painted red. Further, newer filters can remove enough arsenic to make the water usable. Trenches and drainage pipes within and at the edges of irrigated fields carry away the drainage effluent before it reaches the groundwater table.

   Groundwater engineers in India have devised three solutions to the problem of upconing. Each method reduces the upward pressure that the saline upcone exerts upon the upper zone of fresh water. The first method uses a multi-strainer well: multiple, vertical wells are attached to a single pump to disperse the pump’s power and keep it from pumping deep into the interface between the upper and lower zones. The second method uses radial collector wells: a shallow, hub well is dug, and then horizontal collector wells are dug outward from the main well, as spokes from the hub well. A single pump then pulls the freshwater in the upper zone through the radial collector wells. By dispersing the collection of the fresh water in the upper zone across a much wider area, radial collector wells diffuse the pumping pressure that would otherwise cause upconing. The third method uses a scavenger well: a shallower well pumps out fresh water, while a deeper

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well pumps out saline water from the upper zone, relieving the upcoming pressure. The saline water collects in small basins or percolation tanks, from where it passes through sand and gravel filters and returns underground. Where the filtering is sufficient to remove or significantly reduce the salinity of the water, recharge can take place into the cavity of the fresh water well; where filtering is insufficient, the water returns to the lower zone through shafts that extend below the interface between the fresh and saline zones.

Given the high water tables and shallow aquifers in most of South Asia, and the widespread existence of saline deposits in the lower regions of those aquifers, there is a constant requirement to withdraw fresh groundwater at a sustainable rate while avoiding upcoming. Groundwater engineers have combined the respective technologies of wells and recharging mechanisms to produce what are called “skimming structures”: wells that both withdraw water from the upper, freshwater part of the aquifer, and recharge the aquifer safely. The Indian provinces of Andhra Pradesh and Tamil Nadu border the Bay of Bengal and contain shallow freshwater aquifers underlaid by thick, saline clay formations. Skimming wells are of particular necessity in such areas, to prevent the salinization of the upper zones of the aquifer. In semi-arid regions such as Karnal (Haryana), skimming structures employing scavenger wells have protected fresh groundwater supplies from further upcoming. In wetter areas such as Junagadh, in Gujarat, skimming structures take the form of pumps combined with groundwater recharge ponds, from which water is piped into a sand filter before returning to the well.

Reclaiming alkaline soils is an important part of soil and groundwater management in South Asia, especially near the Bay of Bengal. The process begins with berms to surround parcels of land, store rainwater, and distribute irrigation water uniformly. Then, the soil is sampled to determine how much gypsum is required. Farmers then spread gypsum by hand to the upper four inches (10 cm) of soil. After the application of gypsum, the bermed fields are next flooded with water for at least one week prior to the transplanting of rice, and salt-tolerant varieties of rice are used. This simple, inexpensive method has reclaimed 3.2 million acres (1.3 million hectares) in Haryana, Punjab, and Uttar Pradesh—nearly one-third of all alkaline-affected soils in India.

2. Kansas: Contamination Remediation, The Wichita Water Center

In 1991, Kansas authorities discovered an area of downtown Wichita consisting of 3850 acres (1558 hectares) to be contaminated with tetrachloroethene, trichloroethene, dichloroethene, vinyl chloride,
and additional contaminants. This historic industrial site was at first the subject of litigation and more recently created the incentive for the Gilbert-Mosely Project, which consists of both a treatment system and an education building. Using a hydraulic-venturi air stripper treatment system, thirteen wells, and over five miles of pipeline, the system cleans large volumes of contaminated groundwater.\(^{160}\) The system has been continuously operated since 2002.\(^{161}\) The Kansas Water Appropriation Act requires DWR issuance of a permit for any diversion of water, except for domestic use.\(^{162}\) The diversion of polluted groundwater for remediation and return thus requires a permit. DWR regulations list “contamination remediation” as a beneficial use of water.\(^{163}\) DWR regulations define contamination remediation as “the diversion of water by a state agency, or under a written agreement or order of an appropriate state agency, for the purpose of improving the water quality.”\(^{164}\) Wichita obtained a term permit\(^{165}\) from DWR for this project in 2000, which allows an annual diversion of 1,862.97 acre feet (2.3 million cubic meters) of water at 1155 gallons per minute (4.37 cubic meters per minute). After cleanup in the system, the water is discharged into the Arkansas River.

**VII. CONCLUSION**

The IWMI-Kansas program provided enhanced training of Asian senior fellows in groundwater management in the United States. Perhaps more importantly, the program provided an opportunity for both sides to learn about legal, administrative, and technical innovations. Kansas and South Asia share similar problems of groundwater depletion and water quality. But what can either side really learn from the other?

At first, it seems too hopeful a question. Above the ground, the contexts of groundwater management in South Asia and Kansas appear to be too different to be useful. Compared to South Asia, Kansas is sparsely populated; it is cold in the winter, dry, and wealthy; and it

\(^{160}\) City of Wichita, Water Center Main, http://www.wichitagov.org/CityOffices/Environmental/WATERCenter/ (last visited Feb. 9, 2008).

\(^{161}\) See id. ("The Gilbert & Mosely Project is considered to be one of the most innovative public-private partnerships ever created to solve the complex environmental problem of groundwater contamination," says Mayor Carlos Mayans. "The project has earned the City of Wichita national recognition of its development to avoid Superfund intervention and the impacts upon public health, environmental risks and the local economy.").


\(^{164}\) Id. § 5-1-1(t).

\(^{165}\) Term permit No. 20009098-00.
is blessed with relatively clean groundwater and a highly developed groundwater management regime. Compared to Kansas, South Asia is densely populated; it is hot, wet, and poor; and it is plagued by groundwater contamination and the lack of a workable groundwater regime. Viewed from this superficial perspective, Kansas appears to be in a more desirable position, and thus, presumably, a model to be imitated.

But beneath the ground, the place that really matters when it comes to groundwater, South Asia and Kansas are all too similar. Both areas are contaminating their groundwater, and with the exception of Nepal, both areas are running out of groundwater. These troubling common characteristics raise a series of concerns about the relationship between a legal system for groundwater management and its effectiveness.

The legal regime that governs groundwater in Kansas is comprehensive and workable. As this Article has shown, Kansas groundwater law rests upon well-defined statutes, regulations, and practices, in force and actively administered since 1945, and is continually evolving as groundwater depletion problems have emerged and grown more serious. Kansas' recognition of water rights and its system of water permitting, as set forth in the 1945 KWA, evolved to incorporate groundwater management in local districts and to empower the Chief Engineer to designate IGUCAs that can force reductions in water rights. In addition, the legislature has established flex accounts and water banking, and the KWA Act permits the Chief Engineer to require certain water right holders to adopt conservation plans. The state helps EPA enforce federal environmental laws on water quality.

Kansas' legal system and its innovations have succeeded in reducing groundwater pollution and the rate of depletion in some areas, but they have not succeeded enough. The KWA expressly defines water rights as property rights. The public interest and the Public Trust Doctrine matter in American water law, and while they are sometimes seen as concepts on par with private property rights under the Prior Appropriation Act, often they matter mostly as checks upon

166. See, e.g., United Plainsmen Ass'n v. N.D. State Water Conservation Comm'n, 247 N.W.2d 457 (N.D. 1976) (expressing the view that a statute that states that all waters of the state belong to the public expresses the Public Trust Doctrine, thereby requiring an analysis of water supply needs, both present and future, before water is allocated and allocated by the state).

167. See, e.g., Nat'l Audubon Soc'y v. Superior Court of Alpine County, 658 P.2d 709 (Cal. 1983) (holding that the Public Trust Doctrine and the Water Appropriation Doctrine must be accommodated, the state has continuing supervisory control over navigable waters, the state may grant usufructuary licenses for water use, the state has an affirmative duty to consider the public trust in planning and allocation, and the state has the power to reconsider allocation decisions).
private property rights in water. In Kansas, the KWA Act's declaration that "all water . . . is hereby dedicated to the use of the people of the state," and the concomitant adoption of the Prior Appropriation Doctrine and of an administrative regime to govern groundwater, memorably precipitated a judicial claim of communism. Nearly fifty years later, where sound groundwater management would seem to require the reduction of pumping under water rights, or the securing of enough money to purchase and retire them, groundwater management has proven difficult, no matter how ostensibly sophisticated the legal regime.

By contrast, water law in South Asia is less comprehensive and advanced. India, Nepal, and Bangladesh have much less law and structure in their groundwater management and pollution control, and what law that exists is seldom enforced. Unlike Kansas, which stresses that water rights are constitutionally protected property rights, the Indian Constitution appears to stress the duty of the State to secure social and economic justice, to ensure that the ownership and control of water serves the common good, and to ensure that the economic system does not result in the concentration of wealth and means for production to the common detriment. Within this difference lies an enormous opportunity for groundwater management, at least in India. Given such a sweeping constitutional mandate to manage water for the common good, Indian law appears to endow the Indian State with great powers to manage groundwater. Yet without the economic resources and the political will to establish an administrative structure to exercise those management powers, such constitutional mandates are not as useful as they might be.

One obvious challenge for India, China, and Bangladesh, even if they sought to require permits, is the sheer number of people and tubewells involved. Although the regulation of eight hundred irrigation wells by the Kansas Chief Engineer in the 1991 Walnut Creek IGUCA Order may sound impressive to a Kansas water lawyer, a

168. See, e.g., United Plainsmen Ass'n, 247 N.W.2d at 457. In 1990, the Kansas Supreme Court refused to apply the public trust doctrine in the context of the rights of the public to use a non-navigable stream running through private property. Kansas ex rel Meek v. Hays, 785 P.2d 1356 (Kan. 1990).
170. "Not to be outdone by the legislature in the confiscation of private property, the Supreme Court of Kansas upholds the constitutionality of the 1945 Water Appropriation Act . . . by decreeing an established property right . . . to be nonexistent . . . If such arbitrary exercise of the police power of the state withstands the federal constitutional test of due process . . . all private property within Kansas may be communized without cost to the state." Williams v. City of Wichita, 374 P.2d 578, 586 (Kan. 1962) (Schroeder, J., dissenting).
171. See supra note 132.
172. INDIA CONST. arts. 38-39. See also supra text accompanying notes 77-80.
South Asian visitor would deadpan in response that there would be ten times that number of tubewells in a comparable area in South Asia. Due to the vast numbers involved, it may be impractical to require existing tubewell irrigators in South Asia to obtain permits. Even a concept such as an IGUCA, or the retroactive curtailing of pumping, would pose huge management problems in a system where wells are not registered.

Legally speaking then, Kansas and South Asia may be very different sides of the same groundwater management coin. The Kansas side illustrates the fact that, no matter how sophisticated an administrative system, such a system is only as effective as its fundamental legal principles allow. India illustrates the other side: Without a workable administrative system to manage groundwater, fundamental legal principles that could protect groundwater are rendered less meaningful. And yet, from these very different original legal positions regarding groundwater, both South Asia and Kansas have made substantial progress towards each other. In Kansas, the statutes that enabled the Chief Engineer to curtail water rights in the name of aquifer health have survived scrutiny so far. And in India, some states have begun to require permitting. Where pragmatism has prevailed over ideology, groundwater management has made progress.

Innovations in engineering and technology are perhaps more easily transferable between Kansas and South Asia, because these advances are less embedded in law. Both the Asians and the Kansans described interesting innovations, ranging from the most mundane to the highly technical. Aquifer storage and recovery projects exist in both India and Kansas, and India has a national master plan to recharge aquifers. Kansas has the large-scale Wichita ASR Project; but it also contains a less formal system of water storage and aquifer recharge in the form of numerous farm ponds and watershed district lakes. Sensibly, India has focused on small projects that village farmers can operate and maintain, and Bangladeshi water monitors have devised perhaps the simplest system of all, painting safe wells green and arsenic-laden wells red. Other advances in South Asian groundwater engineering remain ahead of their American counterparts. India has devised highly complex pumps and other “skimming structures” to mitigate the problem of upconing, and India has led the

173. This was the reaction to Professor Peck’s description of the IGUCA at a session of the 3rd World Water Forum in Kyoto in March 2003—800 irrigation wells, with eleven lawyers, taking two years to obtain the chief engineer’s decision. Someone remarked that if this had been in India, a comparable area would have had 8,000 tubewells, only one lawyer, if any, and a twenty year period to obtain a decision.
way in rainwater harvesting, something just now being proposed more in the United States due to climate change.\textsuperscript{174}

Both in South Asia and in Kansas, groundwater experts recognize the urgent need to confront the facts and the consequences of depletion and contamination. This shared recognition—above and beyond the countless differences between Kansas and South Asia—was perhaps the most important aspect of the IWMI program. This recognition necessarily places pragmatism at the center of any useful discussion of how South Asian and American groundwater experts can assist each other.\textsuperscript{175} Advances in engineering and technology can be readily shared, because the truths of science are independent of historical, political, legal, and cultural contexts. Advances in the law and the policies of effective groundwater management, on the other hand, may prove more difficult to transfer from Kansas to South Asia or vice versa, precisely because of the law’s entanglement with these contexts. Yet ultimately, there remains the need for the law to align with hydrological reality; and for that to occur, leaders in water policy should consider implementing the goal of sustainability in their reforms.


\textsuperscript{175} In September 2007, the Government of India Planning Commission published the Report of the Expert Group on “Ground Water Management and Ownership.” \textit{See Government of India Planning Commission, Report of the Expert Group on “Ground Water Management and Ownership”} (2007), http://planningcommission.nic.in/reports/genrep/rep_grndwat.pdf [hereinafter Planning Commission]. Dr. Tushaar Shah was a member of the expert group. \textit{See supra} note 2 The report analyzes the Indian situation and compares it to international experiences in groundwater management from the Western United States, Oman, Spain, and Mexico. The report proposes no basic change in the legal regime relating to ownership and use of water rights. It concludes that “there is need to rely less on control mechanism and more on decentralization and cooperative action.” Planning Commission, \textit{supra}, at 41. It further concludes that “[t]he balance between individuals’ rights and Government’s obligation . . . can be achieved by adopting for all groundwater management units a sustainable-yield management goal, which means that average withdrawals should not exceed long-term recharge.” \textit{Id.} at 47. The report has been criticized. See T.N. Narasimhan, \textit{Groundwater Management and Ownership, ECON. & POL. Wkly.}, Feb. 16, 2008.