Columbia Water Center: A Decade of Cutting Edge Research

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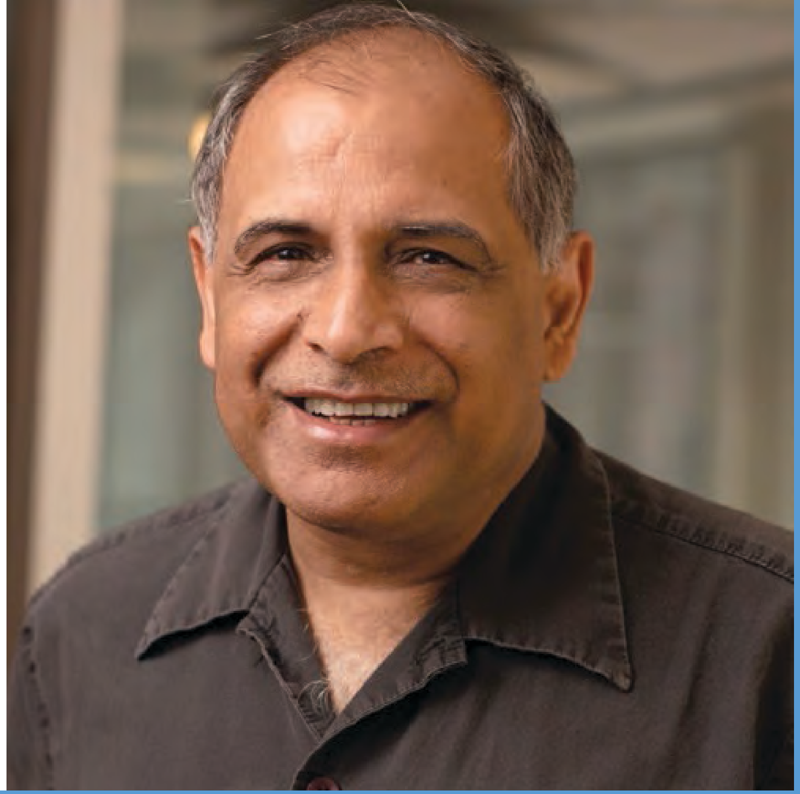
THE EARTH INSTITUTE
COLUMBIA UNIVERSITY

A Letter from the Director of the Columbia Water Center Upmanu Lall



When the Columbia Water Center was conceived in early 2007, we never imagined that the journey over the next 10 years would be as intense, exciting and impactful as it has turned out to be. The initial mission at launch was to study, assess, understand and improve global water sustainability. It was one of the first academic efforts at a Global Water Initiative. An initial project focused on a range of different questions in Brazil, China, India and Mali, supported by the PepsiCo Foundation, thanks to efforts by Jeffrey Sachs, the former Director of the Earth Institute, led to the launch of the Center in 2008. The engagement in the field in Brazil, India and Mali, with farmers, water and electric utility managers, ministers, governors, and policy makers allowed us to learn in depth about the issues, and also test innovations in technology and policy tailored to each setting, ranging from how to address groundwater depletion in India through policy reform as well as precision irrigation, and monsoon prediction; to the use of water infrastructure to improve farm incomes in Mali; to climate forecast informed reliable water contracts for multiple sectors of use as a method for reservoir operation and water allocation in Brazil; as well as a diagnoses of why rural drinking water programs often fail, and a successful pilot of a social and engineering approach to develop sustainable water sources. A large number of Columbia faculty, students and researchers, and external partners collaborated leading to a very enriching experience.

Around the same time, Columbia students worked with Universities in Tigray, Ethiopia and the UN Millennium Village in Koraro, Ethiopia to design and implement a modern "qanat" – a subterranean aquifer recharge and conveyance system that provided water for irrigation and drinking to the village of 10000, and enabled them to weather droughts and increase the number of crops they could produce.

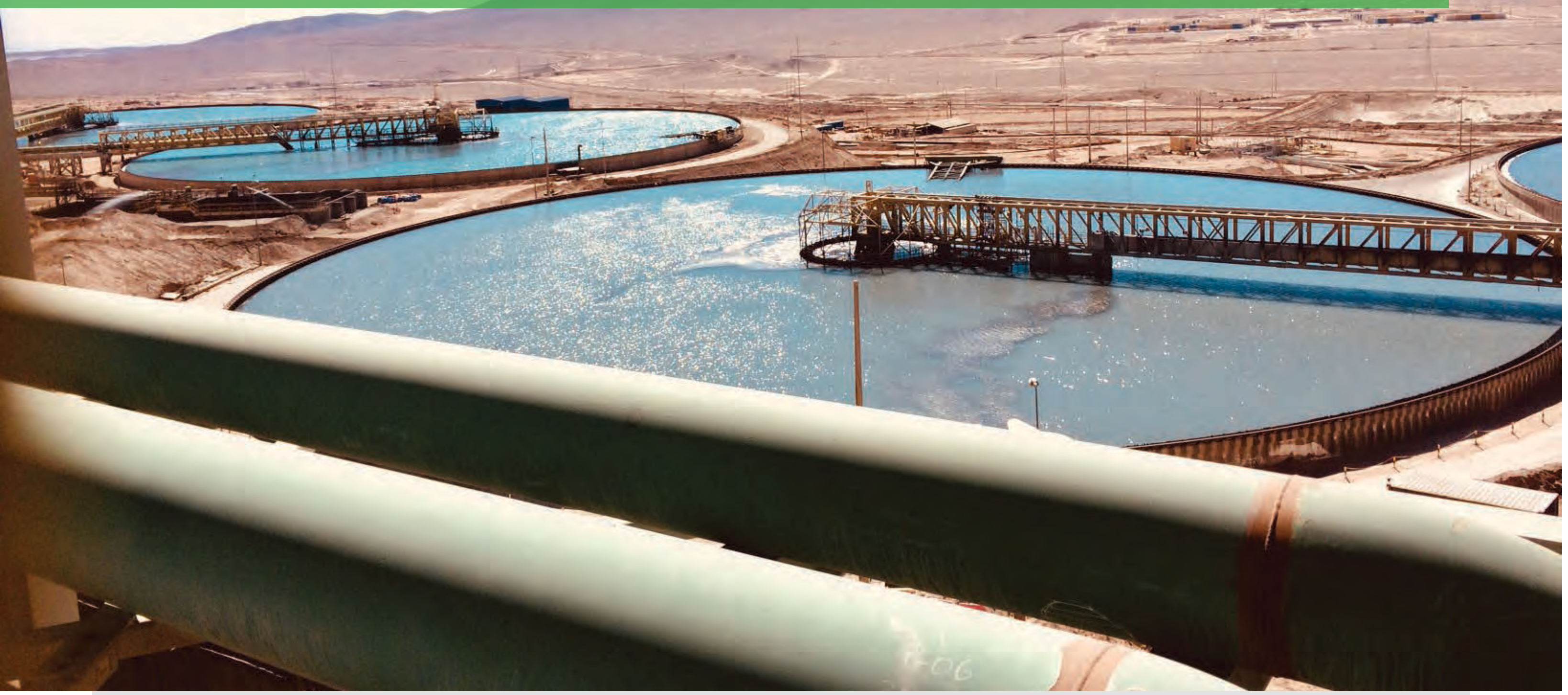
These early experiences led to a series of projects with state governments in India, the World Bank, the Inter-American development bank and other organizations that provided rich experiences to Columbia students and researchers. They also opened us up to questions as to the state of water in the USA and this led to the birth of the America's Water Initiative, which has been supported by the NSF. This has led us to an exciting discovery of the state of water, climate induced risks, the water-energy-food nexus, the state of drinking water and clean water, and to new initiatives towards solutions for water infrastructure that assure affordable human and ecological health.

The various dimensions of water risk, their quantification and mitigation, to achieve systems resilience emerged as a common thread across geography, governance, demographics and types of water challenges. Water risks derived from climate extremes have been a common thread in the inquiry. How these can be quantified in a changing climate and demographics, and mitigated has been a cross cutting theme at the Center. The climate risk framing leads to a fundamental inquiry into how floods and droughts are manifest in specific regions, including land-atmosphere feedbacks and compound risks or spatial risk concentration across space due to the organization, persistence and recurrence of atmospheric moisture transport and precipitation. Once one understands these patterns, the question of supply chain or portfolio risk impacts emerges quite naturally. These considerations have influenced research on floods and droughts, using contemporary as well as paleoclimatic data and applications to populations, food, mining and renewable energy. A focus on financial instruments for risk mitigation in addition to investment analyses in structural measures considering sequential decisions on investments under deepening uncertainty has opened a new line of scientific inquiry. The mining sector has been of particular interest in this regard and was the target of a significant collaborative project supported by the Norges Bank, which has also led to a new theme on sustainable mining at the Center and in Fu Foundation School of Engineering and Applied Science.

We begin the second decade with our cross hairs on America's Water Infrastructure. America was once the standard bearer for water and wastewater services. Today, the state of the infrastructure and the emerging risks posed to society due to its failure are mounting. Most dams are now beyond their design life, and the state of maintenance is not clear. Groundwater depletion is rampant. Thus, storage to buffer drought is a serious concern. Likewise drinking water quality and wastewater services are deteriorating as aging pipes and sewers fail. While these are financial challenges, they also provide an opportunity to rethink our infrastructure. Advances in sensors, and miniaturized treatment systems suggest that decentralized networks with recovery and reuse may be a useful strategy, instead of focusing solely on improving treatment techniques for centralized systems. We plan to work with partners to shape the future of America's Water as a global example for climate resilience, and assured and affordable water supply.

I personally have learned more in these 10 years than perhaps in the previous 30, thanks to an engaging group of faculty, student and postdoctoral researchers, and external collaborators who have managed to enlighten me to a vast array of literature. For this I am very grateful. We have also had an amazing staff who seem to make things happen and create opportunities where there are none evident. I salute all of them and look forward to what these groups can accomplish in learning while doing, and helping create a better world for all of us.

Our mission is to creatively tackle water challenges of a rapidly changing world where water and climate interact with food, energy, ecosystems and urbanization.



Founded in January 2008, the Columbia Water Center (CWC) is committed to understanding and addressing both the role and scarcity of fresh water in the 21st century. The CWC was established for the purpose of studying the diminishing levels of fresh water and creating innovative sustainable and global solutions. CWC combines multidisciplinary academic research with solutions-based fieldwork to develop and test creative responses to water challenges around the world.

Dr. Upmanu Lall is the founder and director of the Columbia Water Center. Lall has broad interests in hydrology, climate dynamics, water resource systems analysis, risk management and sustainability. He is motivated by challenging questions at the intersection of these fields, especially where they have relevance to societal outcomes or to the advancement of science towards innovative application. A number of faculty and researchers from across Columbia University contribute to the Columbia Water Center.

As populations grow and affluence increases, the demand for food and water is on the rise across the world. At the same time, climate variability and change make it difficult to provide water where and when it is needed, and add to the exposure of vulnerable populations to floods. Floods destroy communities in one part of the world, while in another people trek miles every day just to get enough water to survive. Given its pervasiveness and the need for local action, water scarcity is becoming one of the most difficult challenges we need to address in the 21st century.

The Columbia Water Center is researching innovative solutions to these problems—recognizing the public and private sector roles and opportunities, and the unique water, climate and socio-economic settings around the world. Our work stresses analytics at multiple scales, from technologies at the farm level, to new systems-level thinking in the design of urban smart water grids, reservoir and groundwater operations, ecosystems restoration, water-informed agriculture and food procurement and national and regional water policy. Sophisticated water demand/supply and flood forecasts using climate information and their integration with financial risk management instruments are central to our work.

"Working at the Columbia Water Center while doing my PhD at Columbia University was an invaluable experience and training opportunity. I was surrounded by passionate researchers with innovative ideas, and had all the freedom, encouragement, and resources to follow my heart and pursue my research goals. From basic climate science to applied research on water resources, the team at the Columbia Water Center is at the forefront of world-class research focused on Earth's most pressing environmental issues."
-Christina Karamperidou, PhD, Assistant Professor, Department of Atmospheric Sciences, University of Hawaii at Manoa

RESILIENCE: PREDICT & MANAGE CLIMATE, WATER, ENERGY, FOOD FUTURES

"The Columbia Water Center does excellent work, exploring imaginative and flexible solutions to critical problems of water resource management, in ecologically and often culturally challenging environments. Dr. Lall and his team achieve this with creativity and a wide technical scope, matched by notable efficiency and practicality. In our experience on several projects with them in Ethiopia they have been as effective at conserving administrative resources as in conserving precious water."

-Christina Eisenbeis and Ralph Martin,
The Ceil & Michael Pulitzer Foundation

Global Water Sustainability

"The Columbia Water Center was one of the original core partners of the PepsiCo Foundation's Water Portfolio a decade ago, which I was fortunate to co-create. At the time, it was the largest grant by the Foundation to a single grantee, which brought interest in the collaboration from many stakeholders, both internal and external. Dr. Lall and the team at the CWC did not disappoint! The partnership not only provided over four million people with access to safe water, but proved innovative models of predictive water allocation, and demonstrated the impact that can result when world-class academic rigor, private sector support, and an enabling policy framework by government work together in unison."

-Dan Bena, Former Head of Sustainable Development,
PepsiCo Global Operations
Professor (Hon) and Trustee, Glasgow Caledonian University
Founder, danbena.com

In 2008, the PepsiCo Foundation awarded a $6 million grant to the Earth Institute at Columbia University, establishing the Columbia Water Center, with Dr. Lall as its director. PepsiCo is a global food and beverage company dependent on water intensive agricultural activities. Developing a water stewardship program was fundamental for sustaining the company operations, supply chain and communities where they operate. CWC developed innovative and holistic strategies to connect people with water by looking at policies, operational structure and in the field practices.

By implementing newly developed software based technologies to improve water management, CWC was able to impact more than 4.3 million people in Brazil, India, Mali and China, and ultimately easing the demands on resources.

Water, Food, Energy Nexus
Punjab, India

The Problem:

Punjab, the "breadbasket" of India, was historically considered to be one of the most fertile areas on Earth, producing wheat, cotton, sugarcane and vegetables. In the 1970s, however, the Indian government's "Green Revolution" sought to combat famine and poverty in the region by increasing yields in Punjab. New policies and agricultural techniques were undertaken to accomplish these goals, but over time they began to have unintended ecological and social consequences.

Since then, wheat and rice production has grown increasingly important, as Punjab became a government mandated rice district and a primary source for government grain reserves. Covering only 1.5 percent of India's land, today the state produces nearly 20 percent of the nation's wheat and 12 percent of its rice.

The ubiquitous practice of annual rice/wheat cropping comes with a huge cost, however, consuming enormous resources, from fertilizers to maintain high yields to enormous amounts of electricity to pump declining groundwater from ever-greater depths. Rice in particular is a very water intensive crop requiring seasonal flood irrigation of fields. As farmers drill deeper and deeper they tap older and older aquifers that will take many years to recharge.

The Solution:

The Columbia Water Center, in collaboration with Centers for International Projects Trust (CIPT) and Punjab Agricultural University (PAU), did field research in Central Punjab to study, test and implement practical, rapidly scalable solutions to Punjab's groundwater depletion crisis. In the first phase, through a structured field test the research team attempted to identify one or more technologies or practices that save water in rice cultivation. In the second phase, the project team developed and pursued a strategy to rapidly recruit farmers to scale up the application of the tensiometer, the most successful of the approaches tested in the first phase.

In addition, the team worked with corporate food producers such as Del Monte/FieldFresh to study the potential to promote more diverse and water-efficient cropping patterns among farmers through contract farming. Such contracts are designed to grow farmer income without increasing crop risk, while providing corporate partners with higher value crops such as vegetables and corn.

Our strategy Included:

Of the approaches tested in the first phase of the project, the tensiometer, a tool used to measure the moisture content of the soil, quickly emerged as the most successful and was an easily adopted approach to save water in rice cropping. By taking the guesswork out of irrigation, the device allows farmers to water only when needed, thus saving water and promoting better crop health. Dr. Kukal a PAU scientist, developed a simple, affordable tensiometer that cost only $7. By calibrating the tensiometer for a specific crop (in this case rice) they were able to produce a device that was not only substantially less expensive than the conventional alternatives but also easy for farmers to use.

In 2011 the CWC/PAU recruited 4,500 farmers to participate in the next phase of the tensiometer trial. The demonstrated effectiveness of this simple, affordable technology has facilitated rapid adoption in a short amount of time and we continue to promote its dissemination.

Water Management and Decision Support System in Pernambuco, Brazil

The Problem:

Pernambuco, a semi-arid state, and the seventh-most populous state in Brazil, relies solely on rainfall and surface water for survival. This leaves the region particularly vulnerable to droughts. The development of Pernambuco's society and economy requires increasing the efficiency of water allocation, and reducing costs of water supply.

The Project:

The Columbia Water Center, in collaboration with the Inter-American Development Bank, Arizona State University, RTI, the Water and Climate Agency of Pernambuco, and the Pernambuco Department of Water and Energy Resources, has developed an integrated water resource decision system. The system uses rainfall forecasts to understand future water supply and to reduce the cost of water in the state. A continuing drought since 2011 makes this development critical and timely.

This decision-support system has three components:

1. Seasonal rainfall predictions are generated by a Columbia Water Center model. The model relies on predictors such as ENSO and the Tropical Atlantic Variability to make the forecasts.
2. Streamflow forecasts are calculated across each watershed, with the rainfall forecasts as an input, using the Hydro-BID tool developed by RTI, with support from the Inter-American Development Bank.
3. A reservoir optimization model, developed by the Columbia Water Center, predicts water availability based on streamflow forecasts. The model helps determine the cost of water supply in the future, to better manage supply and to ensure access to water.

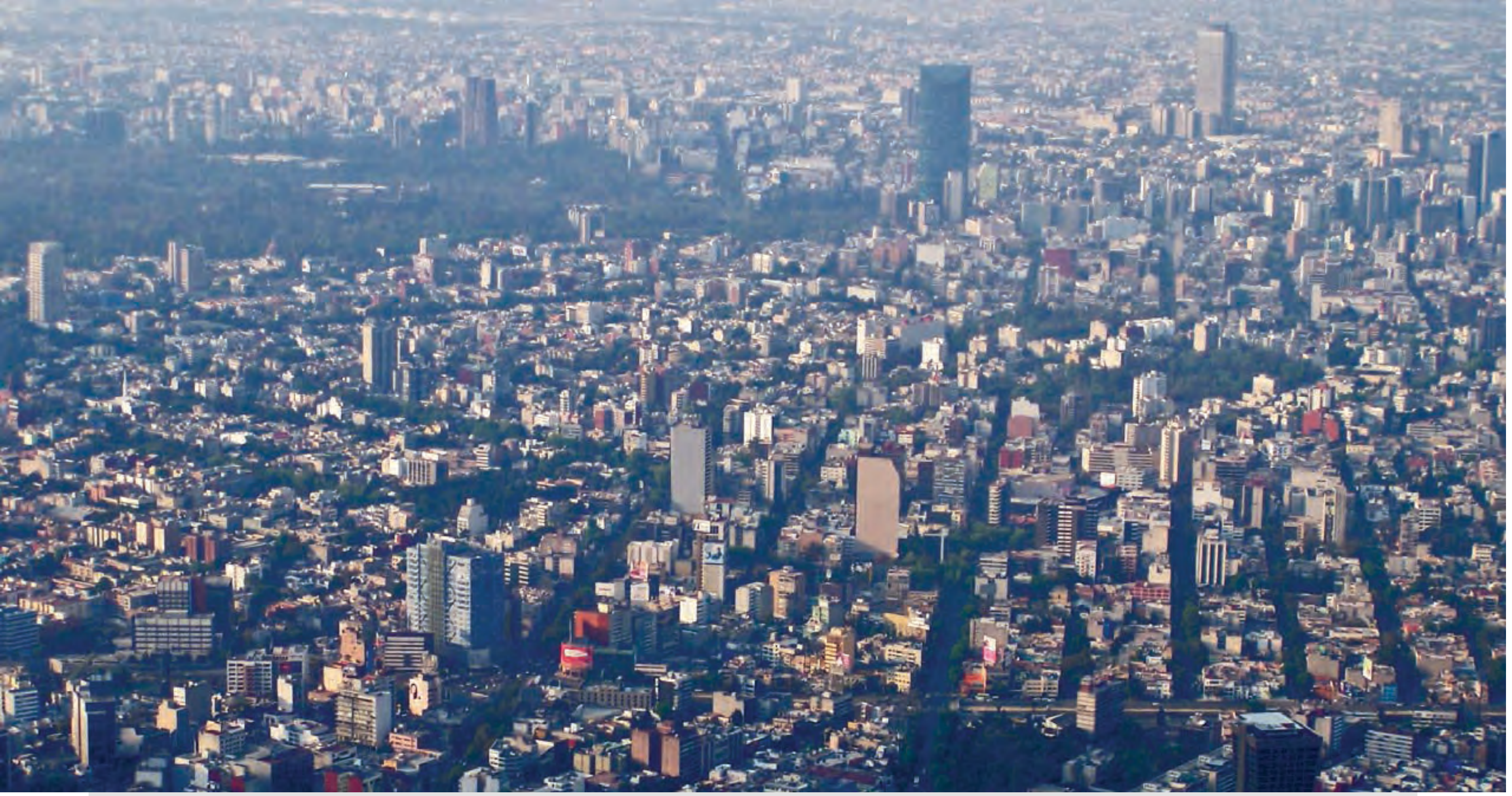
Results:

The forecasting system:

- Reduces costs. By informing decisions on where to source a city's water supply, the forecasting system minimizes costs from local reservoirs, imported water, and failure to provide water.
- Identifies vulnerable areas and improves water supply reliability for all users.
- Evaluates how future infrastructure projects will impact water supply and prices. In Pernambuco, the system calculates that a pipeline from Rio Sao Francisco would aid in reducing prices and water shortages.
- Incorporates economic trends, climate projections, and other variables to guide short-term strategy.
- Integrates with a long term strategy where relief and response measures are tied to development goals.

Future Developments:

With the initial goals of the project successfully completed, the Columbia Water Center hopes to expand the forecasting systems to other Latin American countries. This will require increasing the complexity of the model to account for groundwater supply as well as water demand from agriculture, hydropower, and mining.



Assessment of Decentralized Water Systems in Residential Buildings in Mexico City

The Problem:

Mexico City faces severe water challenges. The city has a population of 20.1 million with 9 million facing water issues ranging from unreliable water supply, flood risk, poor water quality and land subsidence due to aquifer over extraction. Mexico City needs innovative solutions for their vast water issues. With 2.5 million residential buildings and a dynamic construction sector, rainwater harvesting is a key solution to solving many of these water related problems. The market for rainwater solutions is still practically untouched, and to our knowledge, the potential impacts to aquifer restoration are not yet fully quantified.

Rotoplas is the most widely recognized water solutions brand in Mexico, and already offers a rainwater harvesting product targeted to rural communities. To expand Rotoplas' current product portfolio in its Integrated Solutions branch, the Columbia Water Center assessed the design characteristics of rainwater harvesting (RWH) systems for densely populated areas such as Mexico City, and developed a design tool that enables flexibility based on local rainfall patterns, building type and intended use.

Project Objective:

To create an interactive design tool to select the optimum RWH system configuration for single family, multi- family, and commercial buildings in Mexico City. The tool was developed in the open-source platform RShiny, and assesses the technical performance, water saving potential and economic efficiency (net present value, payback time, and internal rate of return) of RWH systems in different building configurations, demand scenarios, and end uses (potable or non-potable) in the 16 boroughs of Mexico City. The application takes into account precipitation patterns and rainfall intensity by borough, capital and maintenance costs, existing incentives, and the local water tariff structure to make a recommendation of the best system configuration applicable to each case. The tool can also be used for any location if local data is provided.

GLOBALIZATION, CLIMATE & FLOOD RISK MITIGATION

"The CWC has helped define the frontier of water resources engineering for climate extremes in a changing world. They have paved the way for new methods that can reconcile the statistical characterization of extreme events often favored by engineers with innovations in climate science needed to understand the causes of those extremes, and how they might change in the future. My time working on these topics as a postdoctoral fellow at the CWC launched my academic career, and it is thanks to the innovative and inspirational environment that has been carefully cultivated by Dr. Lall. His integrity, dedication, and work ethic provide all young faculty that pass through the CWC with a model to which they can aspire in their future careers."

-Scott Steinschneider, PhD, Assistant Professor, Department of Biological and Environmental Engineering, Cornell University

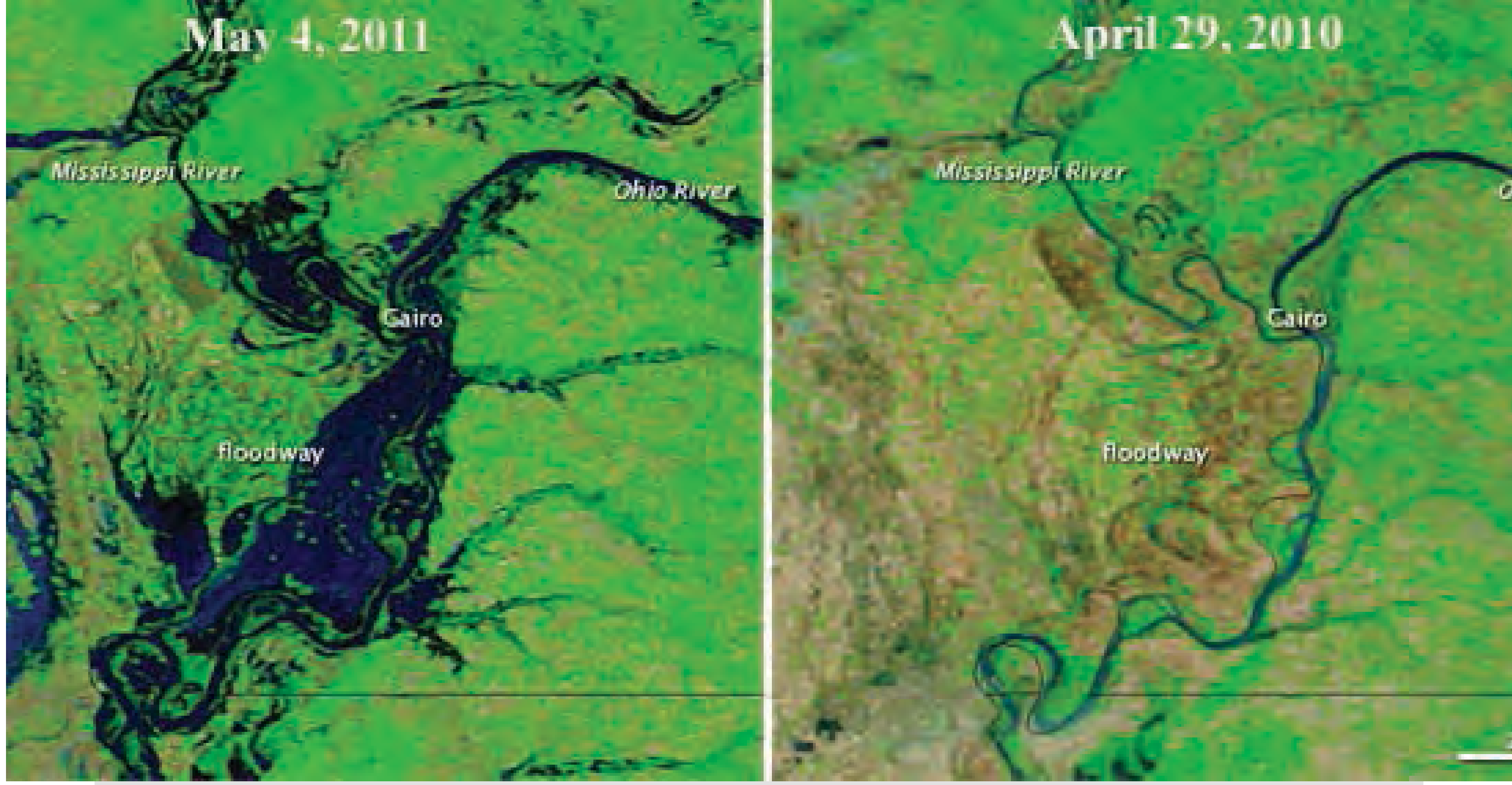


Photo Credit: NASA Earth Observatory Images

Adaptation to Climate Variability and Hydrologic Extremes: Predictive models for extreme floods linking statistical theory and climate models

With climate change altering extreme rain and snow showers in many regions, how will the frequency and intensity of floods change in the coming century? The Columbia Water Center, in conjunction with UMass Amherst, NCAR and the U.S. Military Academy, is developing a robust methodology for estimating future flood hazards in the Ohio River Basin. Based on historical observations and climate projections, our model will help the Department of Defense recognize and manage climate threats to its installations in the area, and provide infrastructure design guidance.

Background and Challenges:

Engineers currently design hydrologic structures based solely on past records of rainfall and flooding. These backward-looking estimations, however, may be ill-suited for future risks, given the changing climate. At the same time, many future hydroclimatic projections based on global climate models are not yet accurate enough to be used to estimate future hydrologic hazards and risks in specific geographic areas. This dilemma led to three key research questions:

1. What basis should engineers use to design water-related infrastructure?
2. Can we combine climate model projections with theory and historical data to better estimate the future distribution of hydrometerological extremes?
3. How do engineering design methods need to change to address the evolving nature of hydrologic extremes?

Findings:

- Flood hazards will increase across the Ohio River Basin in the coming decades.
- Our methodology of combining historical data with future projections produced more accurate predictions of extreme precipitation events than global climate models alone.
- Small errors in global climate models—such as a jet stream deviating by a few degrees—can dramatically alter projected storm tracks. As such, water scientists need to be careful in using global climate models to predict regional hydrological conditions. These findings highlight the need for a more robust way of evaluating climate models before they're applied in hydrology.

"Prof. Lall and the Columbia Water Center, possess deep domain expertise in global water risk management topics - whether the risk is due to floods or drought. When we worked on a Climate Informed Flood Risk Initiative, Prof. Lall was able to quickly pull together a multi-disciplinary research team across various institutes to contribute to various aspects of the project. In a very short time, the team was able to deliver cutting edge and impactful research insights."

-Vijay Manghnani, AIG

Delivering Data and Analysis to Inform Flood Response in Southeast Asia

The Problem:

Natural disasters can cause a national government to scramble to gather its resources and establish an effective response with sufficient relief. This is cially true in Southeast Asia, wherein natural disasters—including monsoons, earthquakes, tropical cyclones, and typhoons—occur more frequently than in many parts of the world. In such emergencies, it is critical for governments to make quick decisions, which requires a rapid assessment of flood impacts and response costs on a national scale. However, developing nations rarely have access to adequate data, analytical techniques, and/or computing power to inform these decisions.

Our Solution:

The Columbia Water Center and Columbia's International Research Institute for Climate and Society developed a platform that captures flood severity and duration in near real-time, both during and after a disaster. The model relies on existing public datasets, including satellite data, population distribution,

and geographical elevation to inform disaster response. In addition to compiling and analyzing data, our system delivers recommendations based on a decision-making framework developed in consultation with the World Bank and the country governments. The platform was initially targeted to lower-income countries in Southeast Asia, including Myanmar, Cambodia, and Laos, but is easily adaptable for other countries.

Our strategy included:

- Using Google Earth Engine to rapidly display processed flood images from the Sentinel-1 satellite and other remote sensing products. We've linked these flood maps to a rapid estimation of the people, agricultural areas, and infrastructure affected. (In addition to Google Earth, publicly owned tools are also being investigated as engines for rapid data delivery and analysis.)
- Developed and integrated economic loss estimation tools to convert flooded area estimates into potential loss estimates. These identify the hardest-hit areas to inform relief actions, and help nations plan ahead financially.
- Cataloging storm and rainfall types that have the potential to cause catastrophic flooding in each region. The analysis includes factors such as potential dependence on El Niño or other climate states, to aid with risk estimation and climate adaptation planning activities. We've integrated these analyses into the platform for visualization and scenario analysis.

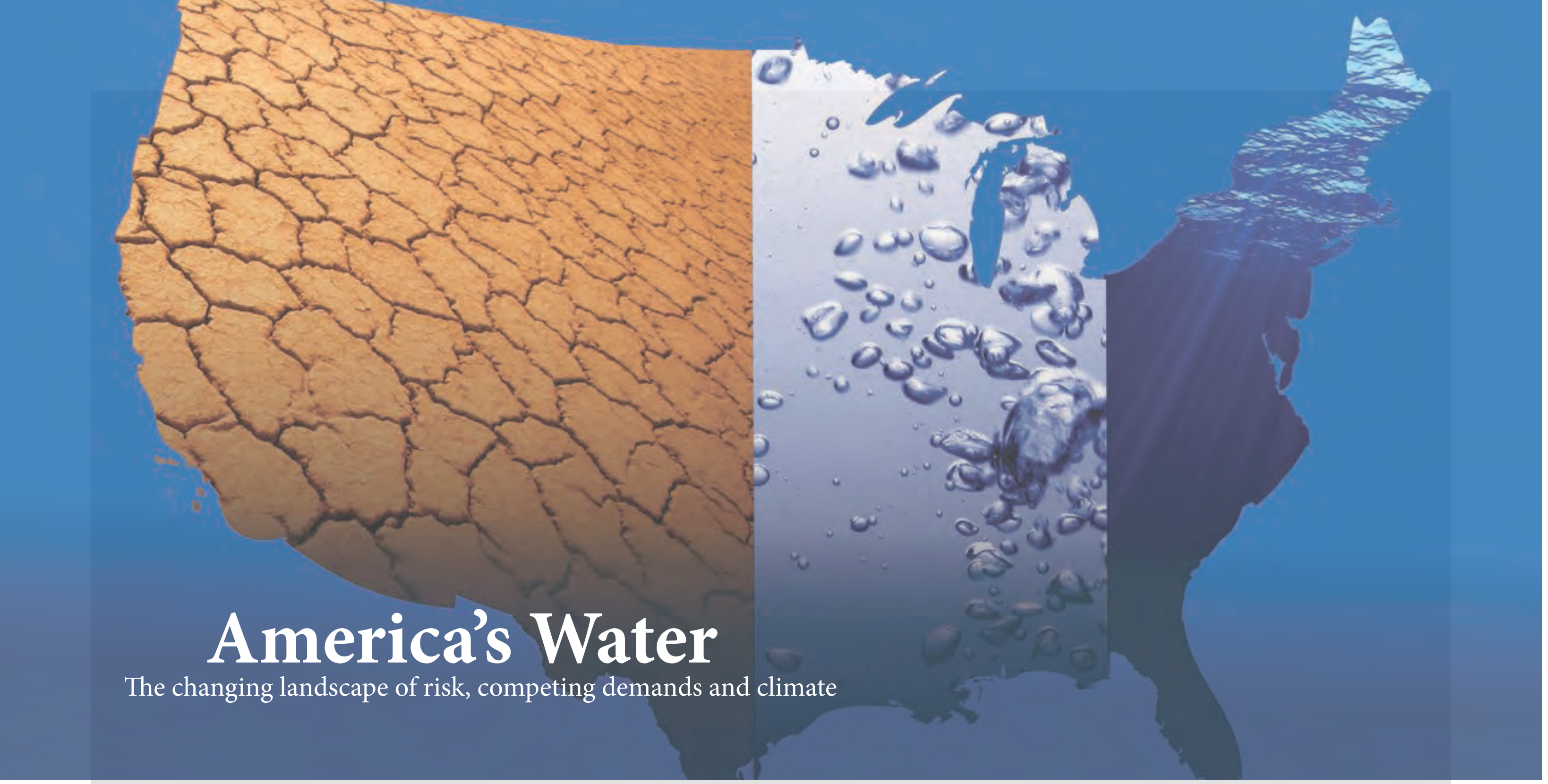
Steps To Success:

We have developed a working platform and successfully tested it on the severe flooding in Bangladesh and Thailand in 2016 and 2017. The system can produce results and recommendations in as little as half an hour. For the next stage of the project, we aim to give the platform a simpler interface that can automatically process the images. With this new interface, government officials will be able to rapidly see which areas need assistance and how much the response will cost, all with just the click of a button.

WATER INFRASTRUCTURE FOR THE 21ST CENTURY

"One of our avenues of interest at the CWC was aimed at envisioning the future of water in the US and ensuring that water infrastructure was adequate to meet the needs of current and future demands for water to support economic activities. Our work found that the state of dams in the US ranges broadly in terms of safety, maintenance, operation efficiency, and plans for future use. Our findings were presented at a congressional subcommittee hearing on the future of federal water infrastructure management and development. There is still plenty of research that is needed regarding dams and surface water storage and this was just an initial step in providing information that will help plan for the future of dams in the US."

-Michelle Ho, Former CWC Researcher



America’s Water

The changing landscape of risk, competing demands and climate

Envisioning the Future of Water in the United States

From the Oroville dam crisis to the lead contamination in Flint, MI, and California’s drought, today’s water problems are widespread and complex. That’s why the Columbia Water Center’s signature initiative, the America’s Water project, takes a comprehensive look at the past, present, and future of this precious resource. We are collecting data on water availability and usage patterns, flooding and drought history, infrastructure vulnerabilities and more for every county in the nation. This high-resolution data is being combined into an interactive tool to help water managers and private citizens make smarter decisions on how to sustainably use their region’s water. The project will identify at-risk areas, discover water use inefficiencies, and expose infrastructure needs to protect against droughts and floods.

A National Focus:

Water is at the base of every economic activity in the world. We need it to live, grow food, and produce energy. Yet despite the fact that water security in the United States is increasingly under threat--from aging infrastructure, over-extraction, floods, pollution, and more--our country lacks national-level policy and strategic planning to manage this crucial resource. Because water is seen as a state and local issue, safety monitoring and efficiency standards are inconsistent and responsibility is fragmented. By building a transparent and fact-based resource, America’s Water and its academic, public, and corporate partners hope to kick off a comprehensive vision for the future of water in the U.S. We need a plan for how to use the nation’s water, so that we can adapt to a warming future.

Demonstrating Research-Based Solutions:

With help from a major award from the National Science Foundation in 2014, America’s Water is already seeing results. Our research has revealed that America’s drought risk is higher than previously thought. Our sea level and precipitation models are helping in the restoration of the Everglades. By reconstructing the history of the Missouri River Basin, we’re providing decision-making tools to manage the river and make the region more resilient to droughts and floods. And we’ve developed a water management plan for the Delaware River Basin to support trout fisheries without undercutting supplies to New York City and New Jersey. By some estimates, the plan has resulted in economic gains of $163 million annually from boating and fishing income, and a 200 percent increase in fish habitat.

The America’s Water project has three key objectives:

1. Assessing the State of America’s Water Use
   Evaluate how variations in climate, energy development and national/global economics over the last century influenced changes in water use and its valuation across the U.S.
2. Envisioning the Future of America’s Water Use Develop interactive models for envisioning the future evolution of water supply and demand.
3. Creating an Open-Source Cyberinfrastructure Provide access to a large number of diverse data sets, and analyze the implications of different water policies or technologies

Media and Outreach:

In concert with our work to assess and envision the past, present and future of America’s water use, the team is creating modules and curricula for communication, visualization, education, and outreach. Our goal is to make national water issues more transparent and understandable to diverse audiences, including primary school teachers, researchers, and the next generation of water managers. The CWC team frequently connects with the public about our work through events, webinars, social media, blog posts, and peer reviewed journal articles.

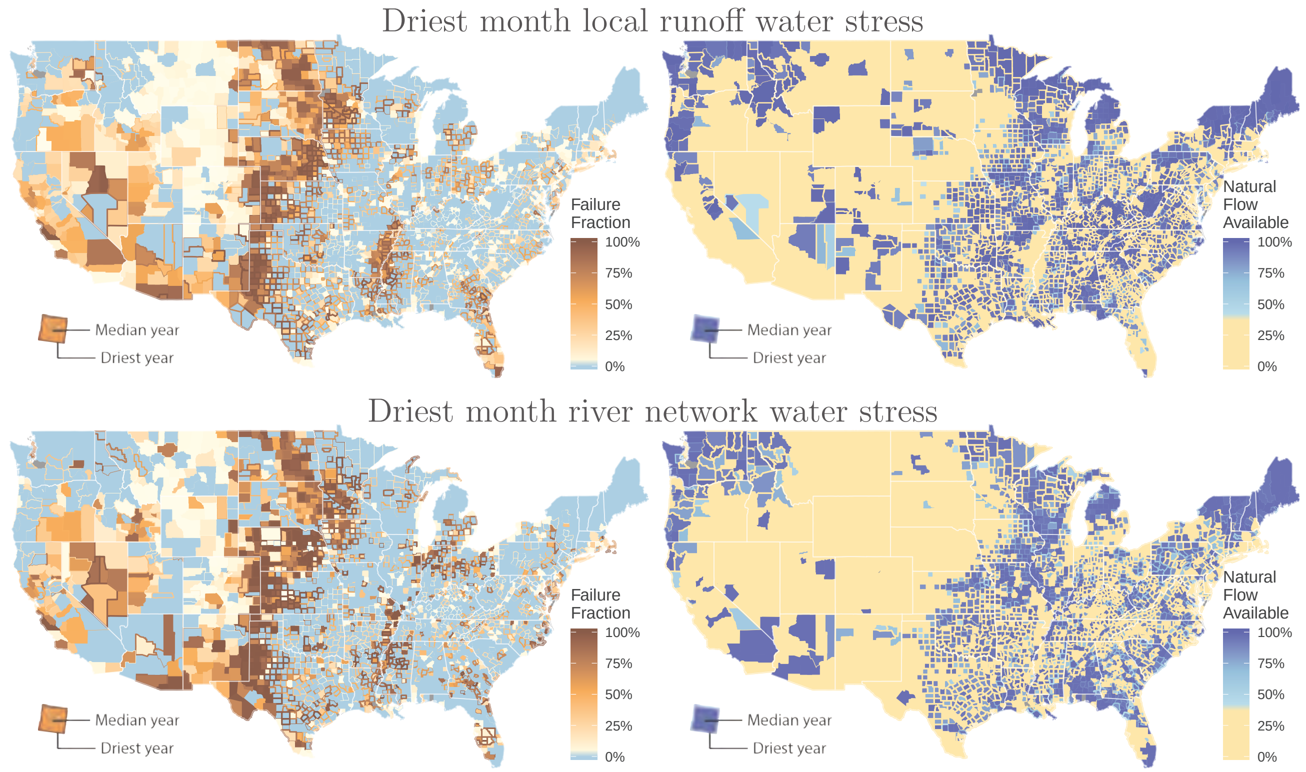


Figure Above: Water stress in the driest month, according to county-average runo (Top) or surface water network availability (Bottom)

AWASH: America's Water Analysis, Synthesis and Heuristics

Rivers and aquifers don't confine themselves to municipal or even state boundaries, yet in many situations limited county-level data guides many of the decisions regarding how we use water. The America's Water Analysis, Synthesis, and Heuristics (AWASH) model is stitching together local data into a map of the sources of and stresses on water across the entire nation. It gives the big picture at a high resolution, to identify risks, opportunities, and solutions for balancing water use by agriculture, energy, industry, and cities. The model promotes sustainable economic development by analyzing threats to water security and simulating what future water supplies might look like in a world subject to more extreme climate.

Simulating the Future:

America's Water, the signature project of the Columbia Water Center, is documenting the nation's water supply and demand, to help municipalities and businesses make sustainable choices about how to use this precious resource. The AWASH model plays a crucial role in the project, making it possible to ask and answer questions about the past, present, and future of water in America.

AWASH uses historical climate data to better understand future risks. It has the power to quantify the role of our current water infrastructure, and predict the regional effects of building a hydroelectric dam or other power plants. It can show where crops could be grown to limit irrigation without sacrificing productivity, and evaluate how a long-term drought in one state could affect water resources elsewhere.

A Flood of Data:

Political issues can make it challenging to obtain data on water supply and consumption, but the Columbia Water Center is working hard to compile data from multiple federal agencies, states, and private businesses into one comprehensive model of America's water. The data covers a vast array of factors, including:

- Water supply from lakes, rivers, aquifers, and precipitation
- Industrial and agricultural patterns of water consumption
- Land area used by 10 major crops, as well as yield
- Prices of crops, energy, and water
- A 500-year history of drought and streamflow
- Groundwater levels
- Dams taller than 15 meters
- Maps of the electric grid and electricity demand
- Estimates of water, energy, and food production and consumption at the county level

What's Next:

In the coming months and years, we'd like to use AWASH to explore a broad array of questions. Can today's dams protect us from water shortages? What are the water risks associated with the growth of renewable energy? How will dietary trends impact water security? The questions we can analyze with this powerful tool are nearly endless.

We would also like to transform AWASH into an educational resource. With a simplified interface, elementary to graduate school students could interact with AWASH to better understand humanity's complex relationship with water. The model would illustrate how their actions—such as choosing some foods over others, installing solar panels or limiting time in the shower—may have environmental, financial and political implications across the country.

MINING, CLIMATE, WATER & FINANCIAL RISKS

Mining and Water Risk: Diagnosis, Benchmarking and Quantitative Analysis of Financial Impacts

Mining companies face many water-related challenges, including water scarcity, pollution discharge, water rights issues, and climate variability. If not properly addressed, these challenges can lead to environmental problems, social conflicts, and/or financial threats to the company. The Columbia Water Center recently completed a three-year project sponsored by Norges Bank Investment Management to develop a modeling platform to quantitatively assess mining-related water and environmental risks and their financial implications. In the coming years, we hope to continue improving it.

Project Outputs

The new modeling platform provides investors access to a targeted analysis of water-related mining risk that includes:

- Relevant climate and physical data
- Analysis of the gaps in governance, monitoring, reporting, and verification
- Remediation and mitigation options
- Financial implications of particular risks at the asset and portfolio levels, especially from a climate perspective
- Causal connections between risk factors and financial performance

- Assessment of initiatives involving local communities to avoid conflict related to water resources
- Financial modeling tools for real option analysis to account for risks related to water, climate, commodity prices, and other quantifiable factors.

Types of Risks Included in the Model:

- Tailings dam failures
- Accidents and spills
- Biases in reporting of environmental liabilities and remediation costs
- Extreme climate events and their clustering in time and space
- Water requirements, mining activities and community needs
- Conflicts with local communities
- Potential changes in governance such as rights and regulations
- Cumulative effects of mining on water and financial requirements of remediation

Future Directions

Environmental Impact Assessments are expensive and not always useful. Because they're only done very early in the life of a project, they consistently underestimate the potential impacts. This can harm companies, investors, and local communities.

With better monitoring and modeling, the Columbia Water Center aims to develop a system that can continuously assess a mine's impacts. This modeling platform would take into account the climate variability of a region over hundreds of years, for instance, and calculate the cumulative effects of an area's pollution legacy. Combined with on-the-ground data, it could be used to create a flexible framework that adapts throughout the life of a mine, to help decision-makers assess potential problems and determine the best solutions.

A Risk-Based Water Valuation for Mining Companies

The Problem:

Water is a critical resource for mining operations. Yet, often the risks associated with its temporal and spatial variability and the shared nature of water are not adequately incorporated in decision processes. There are many recent examples of significant revenue losses associated with production disruption, project delays, and asset stranding related to environmental and social externalities such as drought, floods, water pollution, and the ensuing competition for water. Inadequate preparation for such events may result in reputational impacts, decline in share value, lost opportunities (e.g. expansions, new projects in a region), difficulty to access capital, and loss of license to operate. These are financially material risks.

The Solution:

The mining industry has increasingly focused on water conservation, recovery and reuse, and desalination, as a part of mine valuation and design. Water monitoring, data collection, and disclosure have increased as part of environmental stewardship efforts directed at water footprint and water balance analyses. Several guidelines, metrics, and indicators have been developed to support such effort. However, water related risks, beyond the costs for infrastructure, treatment, and distribution, need to be better understood and priced for project valuation and development. The "water risk" metrics being used reflect a desire to see sustainable water use practices, but typically do not price risk nor consider uncertainty. To address the long term risks associated with water, companies and investors need to consider risk exposure pathways related to water scarcity, flooding, water pollution, infrastructure failure and their impacts on asset operations, ecosystems, society, and reputation.

Our Strategy Included:

Columbia Water Center researchers present a framework that contributes to water risk valuation by mapping water-related risk pathways, including uncertainties and probabilities, into ranges of net present value (NPV) outcomes to the decision maker. This approach leverages internal and external data to "internalize externalities" in the valuation process, reflecting how impacts to the community and the environment, and from climate variability can translate into direct and indirect costs for the company and its investors. We exemplify the application of this framework in the hypothetical analysis of a groundwater source. We emphasize that it is important to understand not just the expected value impacts on a NPV of the mine, but to also identify the relative likelihood of different types of impacts, to help policy and investment decisions.

Thank You to Our Donors

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