> *In contemporary armed conflicts, water resources and installations are being increasingly attacked and used as weapons of war. Moreover, water scarcity is exacerbated in a world with a growing population facing human-induced climate change. Despite these problems, humanity will have to find ways to produce 50 percent more food and double its energy production by the middle of the century.*[1]

Issue. Water-related issues increase the vulnerability of water-poor and water-starved societies and have been causal factors leading to crisis, unrest, instability, and violence.[2] Predicting where the next conflict will occur, and pursuing proactive solutions that are well "left of the bang," requires a detailed understanding of the leading indicators of conflict; supported by high-fidelity, timely, tailored, data-driven insight and analysis. The universal need for water, an enduring basic human need,[3] is a constant that is correlated to socioeconomic, political, religious, and geographic boundary variables associated with conflict. Therefore, water-related variables serve as the vanguard to conflict and water-related data must be proactively collected, assessed, and analyzed to understand the scope, scale, and severity of a potential crisis.

Objective. Predict where global water insecurity is developing, supply the information necessary to effectively get "left of the bang," and mitigate or prevent crisis from occurring through proactive and sustainable solutions.

To support this objective, a comprehensive understanding of the total volume and quality of available water resources, as well as how these resources are being distributed, or exploited, is critical to supporting sound strategic and tactical DOTMLPF-P functional solutions analysis.[4] This requires high-fidelity, timely, and tailored water resource information.

Solution. Power 7 research and development (R&D) efforts seek to maximize the potential of our proprietary Transformational Groundwater Exploration (TGE) and ECHO-Global Precipitation Modeling (ECHO-GPM), to expedite and automate the assessment of groundwater resource potential. Applying AI and ML to TGE and ECHO-GPM (TGE/ECHO), Power 7 will expeditiously and more precisely identify favorable variables for groundwater exploration and development. Already merging traditional Earth Science tradecraft algorithms and state-of-the-art technologies used in natural resource exploration, TGE/ECHO R&D will create a functional AI/ML platform capable of identifying, developing, and managing (in real time) previously undiscovered groundwater resources.

[1] Turk, Danilo, Strategic Foresight Group and Geneva Water Hub, "A Matter of Survival – Report of the Global High-Level Panel on Water and Peace," Blue Peace Initiative.
[2] See enclosure case studies.
[3] Maslow's Hierarchy of Needs theory states the basic human needs are food, water, warmth, and rest.
[4] Defense Acquisitions, Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy, AcqNotes.

Power 7 TGE/ECHO-GPM Platform. Power 7 will automate the analysis of data, research, cohort activities, and the growing "internet of things," to facilitate the integration of layered-data and inform users of variables impacting surface and groundwater resources. The platform will be used to predict future water-related issues, manage existing water resources, and enable the development of additional water resources. In addition, the platform will support multi-variable analysis to assess the interrelatedness of specific activities, programs, and policies on socio-economic and geopolitical stability.

The goals of Power 7 TGE/ECHO R&D are:

- Automate the holistic assessment of total water budget[5] capacity
- Enable water resource identification, mapping, development and management
- Develop artificial intelligence (AI) and iterative machine learning (ML) to enable predictive analytics and modeling
- Integrate traditional tradecraft algorithms, cutting edge technologies, time-sensitive big data sources, AI, and ML, on a cloud-based computing platform
- Create a paradigm shift in the methods used in identification, calculation, and assessment of unique and / or interrelated water resources
- Display outputs in a 3-dimensional, user-defined, multi-data fusion format that enables holistic and integrated analysis of inter-related variables and data sources
- Cloud-based, multi-data fusion, anonymous sharing portal, multi-tenant, and multi-modal system
- Information technology (IT) and intellectual property (IP) protection via proactive cyber-security[6]

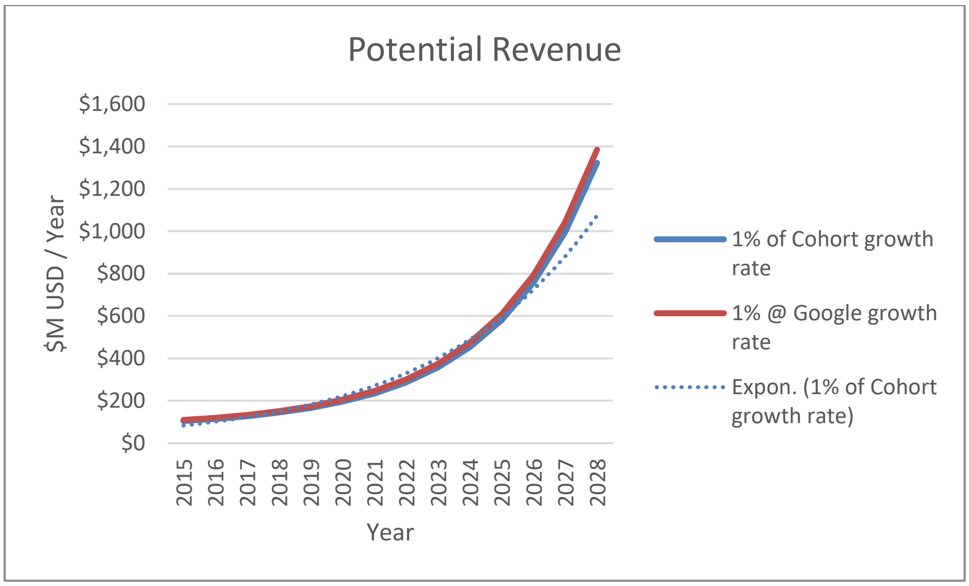
Market. Research has highlighted a growing interest and investment in AI/ML in support of content delivery networks (CDN), enterprise solutions, and cloud-based services at the C-suite level of leadership. AI expected to be in the top 5 investment priorities for more than 30% of Chief Information Officers (CIO). Investment in AI was between $8B and $12B in 2016. ML is attracting nearly 60% of the total investment in AI.

Power 7 seeks to enter the market by creating an application program interface (API) that provides cloud-based services in support of the delivery, optimization, and securing of content and business applications over the internet. The API will be accessed via a website service provider (eg. **Google**, Yahoo, AOL, and Microsoft). The API will require support from cloud-based computing technologies (eg. Amazon, Akami, IBM, Enki Consulting, Rackspace, Verizon, **Google**, Linode, Microsft, and Salesforce; in order of market share).

[5] National Aeronautics and Space Administration, www.nasa.org "NASA Balances Water Budget with New Estimates of Liquid Assets", 7 July 2015.
[6] Handshake agreement with IT company, Authentic8, to support platform IT security.

Revenue Potential. Applying a "Freemium" software as a service (SaaS) business model, Power 7 anticipates generating revenue primarily through subscription-based user fees. Determining the potential revenue, Power 7 analyzed the revenue associated with capturing a market share equivalent of 1% of Google Network Members' website business[7] and compared it to an equivalent share of the average revenue of viable cohorts.[8] The market demand for these services is expected to generate $151M of revenue in 2018, with a 4.7% annual growth rate.[9]

Given the myriad applications of this program, and the international customers Power 7 anticipates being consumers of our services, we assess these numbers to be a conservative estimate of the venture's valuation. Future revenue growth will be enhanced by the cross-selling of the application to diversified users and will add to the revenue generation and growth potential.



[10]

Anticipated revenue as a percentage of the average revenue of assessed cohorts

[7] Google Network Members' website revenue represents an average of 22.3% of its total revenue from 2013-2015.
[8] Evaluation of Amazon, Akami, and IBM 10-K SEC filings
[9] Annual revenue is based on capturing 1% of the average annual revenue of applicable lines of business within identified cohorts. Annual growth rate is pegged to Google Partner Member revenue growth.
[10] Calculations based upon published financial reports (10-K), 2015.

Background. Approximately 1.1 billion people, half of the developing world's population, lack access to clean and reliable water sources. Approximately 1.6 million people die each year from diseases attributable to a lack of access to clean water; 90% of these fatalities are in children under the age of 5.[11] Crop production relies on ample supplies of readily available irrigation water. The demand for agriculture-related water supplies accounts for 70% of the total global water demand, and roughly 80% of the total water demand in the United States (over 90% in many Western States).[12] Growing global populations, and rising standards of living, increase pressure on food production.[13] Reliable, economical, and environmentally friendly water production is a requirement for national security and public health. Typical "solutions" are capital-intensive, commonly unaffordable to developing nations, and environmentally invasive: desalination plants, dams, reservoirs, pipelines and aqueduct systems.

In areas of the world where water scarcity and water insecurity are present, tensions build over the allocation and use of precious water resources. We share and trade water directly and indirectly, through hydrologic units and through global trade; virtually importing water through the products traded. Climate change and the increasing demand for water by multi-national corporations (MNC) play a role in globalizing water issues.[14] The World Water Development Report, drafted by the United Nations, stated the "water crisis is essentially a crisis of governance and societies are facing a number of social, economic and political challenges on how to govern water more effectively."[15]

Recognizing the nexus between water and peace, the UN Member States created the Global High-Level Panel on Water and Peace, on 16 November 2015.[16] The panel identified the need for stronger and more coherent global cooperation on water. In addition, the panel studied the role of water in armed conflicts in which water resources and installations are increasingly becoming targets of attack – or used as weapons of war. The recommendations of the panel included the creation of a "Blue Peace Framework" that would facilitate the financing of water-related projects.[17]

Since the late-1980's, the Pacific Institute has tracked and categorized events related to water and conflict, in an effort to understand the connections between water resources, water systems, and international security and conflict.[18] Since 2011, more than 125 incidents around the world have been tied directly to water. Broadly categorizing the types of conflict, it becomes clear many of the causal factors are inter-related and the importance of water to life means that providing for water needs will never be free of politics. However, broadly speaking, water-related issues can be captured in the following bins:

- Control of Water Resources (state and non-state actors)

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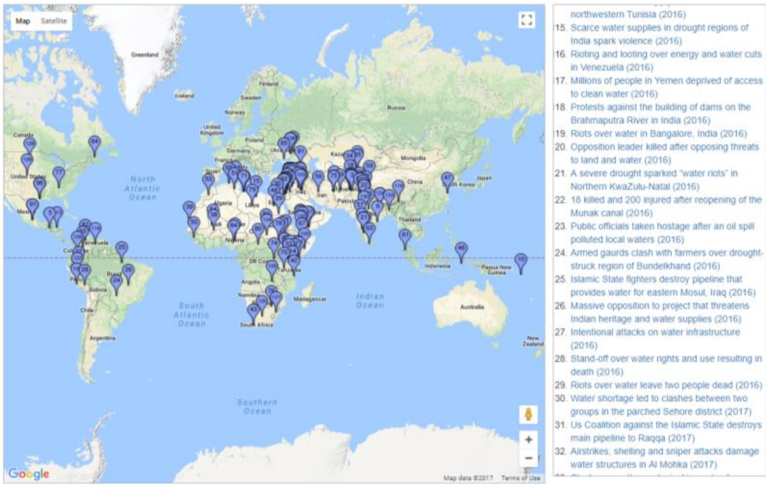
[11] World Health Organization data; http://www.who.int/water_sanitation_health/mdg1/en/
[12] https://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx
[13] http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf
[14] Cooley, H. (et al), "Global Water Governance In the Twenty-First Century", Chapter 1 (v.8)
[15] UN 2003b, 370
[16] Turk, Danilo, Strategic Foresight Group and Geneva Water Hub, "A Matter of Survival – Report of the Global High-Level Panel on Water and Peace," Blue Peace Initiative.
[17] Turk, Danilo, Strategic Foresight Group and Geneva Water Hub, "A Matter of Survival – Report of the Global High-Level Panel on Water and Peace," Blue Peace Initiative, page 68.
[18] http://worldwater.org/water-conflict/

- Military Tool (state actors)
- Political Tool (state and non-state actors)
- Terrorism (non-state actors)
- Military Target (state actors)
- Development Disputes (state and non-state actors)



[19]

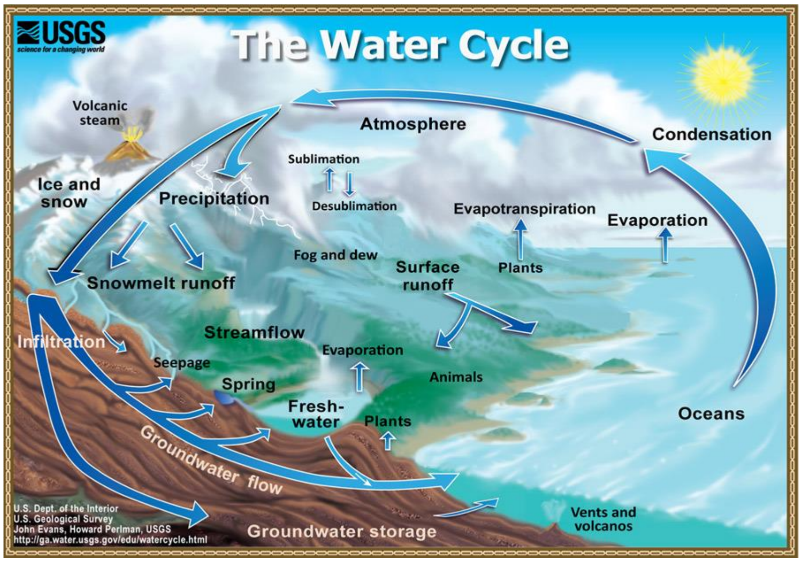
Pacific Institute: Water Conflict Chronology Map

From a national security perspective, accurately assessing the domestic and international potential of surface water and groundwater in a given location, state, country, or region – as well as the variables impacting water quantity, quality, and use – are critically important for shaping water policy, regulations, and intervention strategies. Water-related issues serve as leading indicators of unrest, volatility, and conflict. Implementing appropriate, sustainable and resilient solutions, in advance of conflict, can positively influence events and outcomes while avoiding the costs of conflict resolution.

To inform strategic and tactical decision-making processes around water security issues, it is important to understand the current condition of all surface and groundwater supplies and systems. As well, we must comprehensively understand the uncertainties impacting the viability, security, and sustainability of those water supplies. Without this understanding, the implementation of resilient and sustainable solutions is unlikely. One variable that has been consistently misunderstood and overlooked is the presence and value of renewable groundwater resources.

Power 7 TGE/ECHO-GPM will provide a holistic and integrated view of water-related and interrelated variables, linked to real-time and near-real-time data inputs, to inform, enable, and empower the analysis and decision-making process.

[19] Pacific Institute, Water Conflict Chronology Map, http://www2.worldwater.org/conflict/map/



USGS: The Water Cycle[20]

Identifying, developing and managing renewable groundwater resources leverages the existence of the naturally occurring hydrologic cycle (above). As surface waters become increasingly stressed, however, the world is under increasing pressure to better understand the recharge, transmission and discharge of groundwater. Surface water, such as rivers and lakes, is well understood because it is visible and readily measurable. Groundwater, on the other hand, is relatively invisible and difficult to quantify. Although much is known about shallow groundwater flow through rocks with primary porosity and permeability, little is known about fresh groundwater flow at depth. An example of our incomplete understanding of deep groundwater flow is seen in the abundance of unstudied submarine groundwater springs that emerge on continental shelves around the world. Although a few of these springs (called submarine groundwater discharge vents, or SGD) have been well-studied, the vast majority are known only via local fishing lore. Key questions our efforts will answer are: (1) How does this SGD get to continental shelves; (2) What underground geological processes control their flow paths; and (3) What is the magnitude and distribution of this resource?

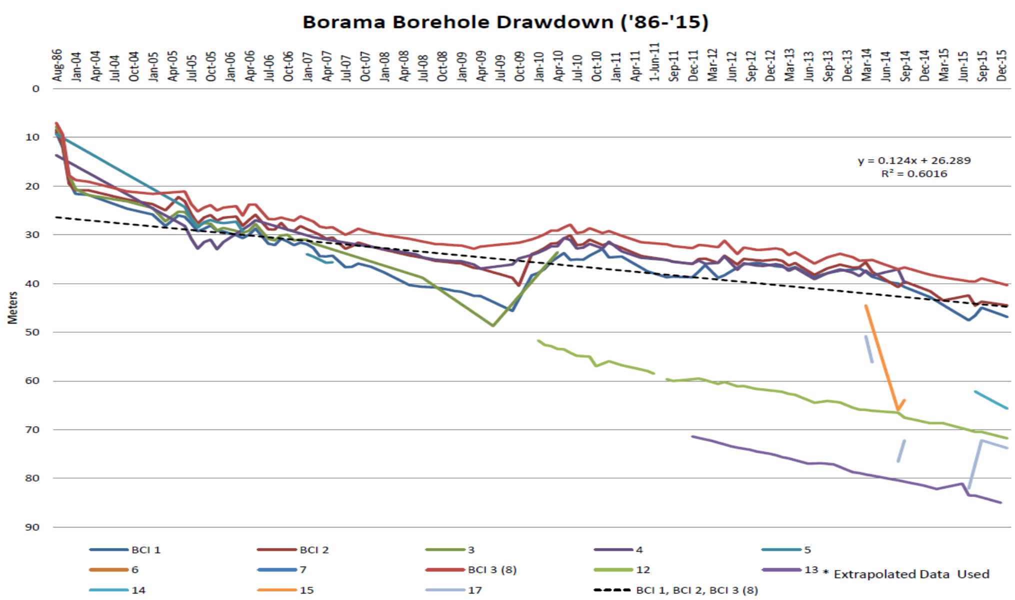
Research and exploration over the past three decades demonstrates that there are substantial amounts of fresh groundwater moving via fracture networks, possessing what is called "secondary porosity and permeability". We at P7 recognize that these fracture networks store vast amounts of fresh groundwater and transmits this water much faster than through rocks with only primary porosity and permeability. Some researchers refer to these fracture networks as "fast paths" for fluid flow. This is a phenomenon that is well-understood by the petroleum industry when extracting oil and gas via hydrofracturing (aka fracking) methods.

Since the quantity of water contained in these natural fracture networks is largely unobserved and uncalculated, there are large errors in assessing the total quantity of water in the water cycle.[21] By

[20] USGS, Summary of the Water Cycle
[21] https://water.usgs.gov/edu/watercycle.html

accessing fracture networks that meet specific criteria, through field mapping, subsurface geophysics and the creation of a network of precisely-located deep groundwater wells, untold quantities of previously undiscovered and unaccounted-for water resources can be made available to meet the growing demand for this precious resource. Importantly, because these “megawatershed” resources are recharged by precipitation events, properly managed wells provide a renewable groundwater resource that will continue to provide consistent water volumes.

Commercially proven renewable, megawatershed groundwater wells have been in continuous operation for over 30 years in locations that were previously assessed to be devoid of groundwater resources. For example, in Borama, Somaliland, three wells were developed by BCI Geonetics, in 1986, that still provide nearly 1 million gallons of water per day (MGPD) to the local municipality. [22] Well data, maintained and current as of 2015, show the stark contrast in performance between renewable groundwater wells and traditional shallow groundwater boreholes. While traditional borehole water levels steadily decline, the BCI Geonetics wells exhibit characteristics of seasonal recharge of water volumes. Water quality and well yields have remained consistent over the reporting period. The source of water for these wells was determined to be from the Ethiopia Mountains, more than 100 miles from the wellhead. Robert Bisson, founder of BCI Geonetics, is a key adviser to the P7 science team.

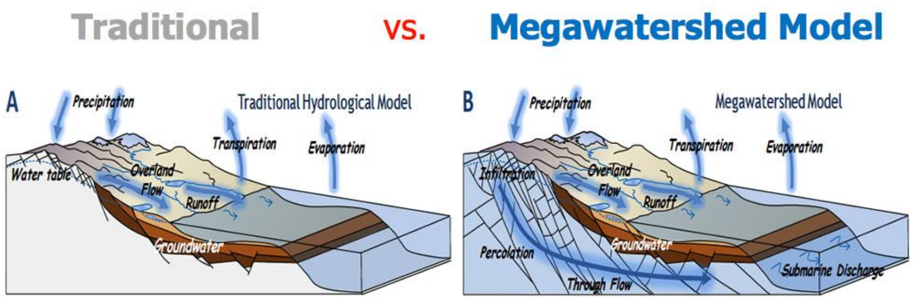


Borama, Somaliland Well Data[23]

Paradigm Shift. For more than 40 years, Mr. Robert Bisson successfully located renewable groundwater resources for municipal and industrial water applications through his innovative exploration and development techniques.[24] Renewable groundwater resources are found in deep bedrock fractures, created by the movement of tectonic plates. The existence of these fractures is widely known to the geoscience community. However, the importance of these fractures, and their role in the transmission and storage of

[22] Bisson, R. BCI Geonetics USAID funded project in support of groundwater exploration and development, 1986.
[23] Somalia Water and Land Information Management (SWALIM) Data & Documents Repository,
[24] Bisson and Lehr, Modern Groundwater Exploration; 2004

groundwater, is not widely known or appreciated. These deep bedrock fractures can transmit water over long distances (hundreds to thousands of kilometers) and over large geographic areas (including across international boundaries)[25]. Importantly, these interconnected fracture fast paths contain distinctly separate groundwater resources, relative to traditional aquifers, and are renewed through the natural water cycle.[26] This concept represents a paradigm-shifting approach to groundwater exploration and development.



Bisson: Megawatershed Model[27]

Water is a non-compressible solvent, and it seeks the lowest possible elevation level. Each time a precipitation event occurs, water flows downhill until it is captured (lakes, dams, reservoirs, catchments) or until it flows into the ocean. Along the way, some of this water is absorbed by vegetation or evaporates back into the atmosphere. Most readily familiar surface flows are rivers and storm water runoff. However, a significant percentage of precipitation flows into geologic fracture systems, "recharging" them with fresh water. Gravity forces fresh water flows through these fast path systems and, in many cases, discharges the water into the ocean via submarine groundwater discharge[28], where it is "lost" to the ocean.

Because these deep fracture systems are not considered in traditional water balance calculations, current water models may significantly underestimate the volume of available fresh groundwater. Precipitation volumes in recharge areas, feeding the deep fractured aquifers, are therefore underestimated.[29] The accepted water balance equation is:

Precipitation = Runoff + (Evaporation + Plant Transpiration) + Soil Storage

Bisson's approach effectively re-calculates the water balance equation, accounting for the "through flow" that occurs within fracture networks, to account for these persistently available and previously undiscovered water resources:

Precipitation = Runoff + **Through Flow** + (Evaporation + Plant Transpiration) + Soil Storage

[25] Transboundary Waters statistics from UN Water.org
[26] USGS publications; "Dynamic Tectonics"; http://pubs.usgs.gov/gip/dynamic/tectonic.html
[27] Askary, H, "A Revolutionary Development Plan For The Middle East", Solidarity & Progress, 5 December 2012;
[28] USGS publications, "Example case study of Submarine Groundwater Discharge"; http://water.usgs.gov/ogw/seawat/langevin.gw200341.pdf
[29] http://cals.arizona.edu/watershedsteward/resources/module/Intro/intro_page8.htm

Over the past two years, Tim Bechtel, Robert Walter and their student Jake Longenecker, and an international collaborative group of hydrogeology experts including members from the Power 7 Team,[30] developed a method for correlating spring hydrographs with newly available, high-resolution, satellite-based Global Precipitation Measurement (GPM) data to rapidly and remotely locate recharge areas.[31] Called ECHO-GPM, the group's peer-reviewed and published discovery is a major step towards better management of groundwater resources. More importantly, ECHO-GPM algorithms can isolate the sources of precipitation and empirically link it to the discharge point.

A hydrograph is a plot of the variation of water discharge with respect to time at a specific point, typically expressed in cubic- meters (m^3) or cubic-feet (ft^3) per second (cms or cfs).[32] While a hydrograph is able to track variations in flow rates, it does little to identify sources of water contributing to the flow. Comparing and correlating time-stamped GPM data with specific hydrograph results, using terrestrial rain gage data and hydrographs from springs with known catchments in Europe and North America, the team developed a novel algorithm that instantaneously assesses millions of global precipitation data points and compares and correlates precipitation events with peak hydrograph flow for a spring or well. Through these "big data" time-series analyses, Longenecker, et al. 2017, verified the occurrence of remote recharge of the groundwater flow via paths crossing multiple tectonic provinces. In one location, the observed groundwater output was five-to-seven times the expected rate, based on its known topographic watershed modeling. ECHO-GPM, highlights the shortfalls of, and divergence from, traditional watershed evaluation and modeling techniques. Furthermore, the verification of groundwater flow across multiple rock types (some previously considered to be hydrogeologic barriers) provides independent verification of Bisson's assertions that fast path fracture networks can transmit groundwater over great distances. These findings represent a significant opportunity for renewable groundwater identification, mapping, development, and management.

Dr. Robert Walter[33], Power 7 co-founder and Chief Science Officer (CSO), has leveraged the lessons learned from Bisson's prior art, his own academic research, and the collective experience of the Power 7 Science Team over the past 10 to 15 years with advances in natural resource exploration technologies, to develop a scientific groundwater exploration process that we term "Transformational Groundwater Exploration" or TGE. The Power 7 TGE technology enables high-probability renewable groundwater exploration and development, utilizing satellite imagery, published research, archived data, geophysical exploration technologies, and precision drilling techniques.

For 30 years, Dr. Timothy Bechtel[34] (Power 7 Chief Geophysicist) has been identifying, developing, and refining land, marine, and borehole geophysics, and remote sensing methods for groundwater exploration and subsurface flow characterization. While many of the individual methods are widely available (e.g. Very Low Frequency (VLF) and electromagnetics and electrical resistivity tomography (ERT)), Power 7

[30] Longenecker, Bechtel, Chen, Goldsheider, Liesch, Walter, "Correlating Global Precipitation Measurement Saltellite Data With Kast Spring Hydrographs For Rapid Catchment Delineation", Geophysical Research Letters, Volume 44, Issue 10, 29 May 2017.

[31] NASA GPM Program, https://www.nasa.gov/mission_pages/GPM/main/index.html

[32] NOAA definition, http://www.nws.noaa.gov/os/hod/SHManual/SHMan017_hydrograph.htm

[33] Walter, R.C., Biography; Associate Professor, Geosciences, Franklin & Marshall College

[34] https://www.fandm.edu/timothy-bechtel

has developed special field procedures and data processing – typically doing joint inversion / interpretation with multiple physically-independent geophysical methods, using additional constraints from satellite or aerial remote sensing data. Dr. Bechtel has worked and published on neural network (AI) approaches for interpreting geophysical data,[35] and Power 7 is developing these methods for joint analysis of large data sets which incorporate results of previous similar exploration programs interpretation (i.e. AI and ML). An example is the ECHO-GPM algorithm which combines precipitation-time-series data for millions of global pixels with ground-based well hydrographs, spring hydrographs, or river discharge records to delineate recharge areas. This requires automated discharge event recognition using AI (beyond normal base flow separation), and intelligent screening of the massive global precipitation data sets for small fast-moving storms that can provide highly detailed recharge mapping. Power 7 is also working on innovative web-based methods to create a global catalogue of unmapped SGD resources using the massive online databases represented by social media platforms.

Summary. Develop a TGE/ECHO AI/ML platform that will successfully identify favorable variables for groundwater exploration and development, while facilitating the holistic DOTMLPF process of analyzing domestic and international water resources. Create a broadly accessible platform with a tiered-permissions, subscription-based, software as a services (SAAS) business model. Through this platform, Power 7 Corporation provides services that empower end users to make strategic and tactical decisions about the use of available water resources. When combined with functional data overlays, customers will be able to assess, analyze, and address multi-variable water-related issues.

Power 7 is seeking equity investors who see the intrinsic value of the platform and, through their network, can help the company execute our go-to-market strategy.

Contact. Further information on Power 7 Corporation is available on our website: www.power7water.com. Questions or requests for additional information should be directed to Kevin Mulligan, via email kmulligan@thepower7.com or phone (917) 242-7374.

[35] Windsor, C., L. Capineri, and T. D. Bechtel. "Buried object classification using holographic radar." Insight-Non-Destructive Testing and Condition Monitoring 54, no. 6 (2012): 331-339.

APPENDICES

Power 7 Corporation

In December of 2015, Power 7 Corporation was created by Kevin Mulligan and Dr. Robert Walter to further advance the renewable groundwater exploration science, TGE, and apply it to markets in need of water resources. Renewable groundwater exploration and development, via the TGE process, occurs with a level of precision and accuracy that minimizes environmental impacts and maximizes success rates. Feasibility studies map macro-level indicators and provide valuable information to decision makers. Detailed exploration processes provide increasingly precise information to enable high confidence development planning operations. Developed production wells are delivered with an analysis of sustainable yield per well, based on the unique characteristics of local hydrogeologic variables.

With a relatively short time-to-market, developed wells provide more expeditious and enduring solutions to local and regional water issues. Accurate modeling of precipitation and groundwater recharge rates enables sustainable long-term operations.

TGE wells provide an economical, enduring, and environmentally friendly solution to water supply issues in water-poor and water-starved markets. The commercially proven track record of successful projects, in some of the most austere and challenging locations, shows their incredible potential and enduring benefit. The relatively low capital and operational expenses associated with Power 7 development operations and expeditious time-to-market, combined with environmentally friendly and sustainable production practices, enables fiscally constrained markets to rapidly recover exploration and development costs. The intrinsic social enterprise value of renewable groundwater resource development is undeniable. Providing sustainable water resources to water-poor and water-starved markets satisfies a critical requirement for stability and economic growth. Developing renewable groundwater resources enables access to safe, reliable, and economically viable water supplies that decrease the vulnerability of water-poor and water-starved markets to unrest and instability.

Transformational Groundwater Exploration (TGE):

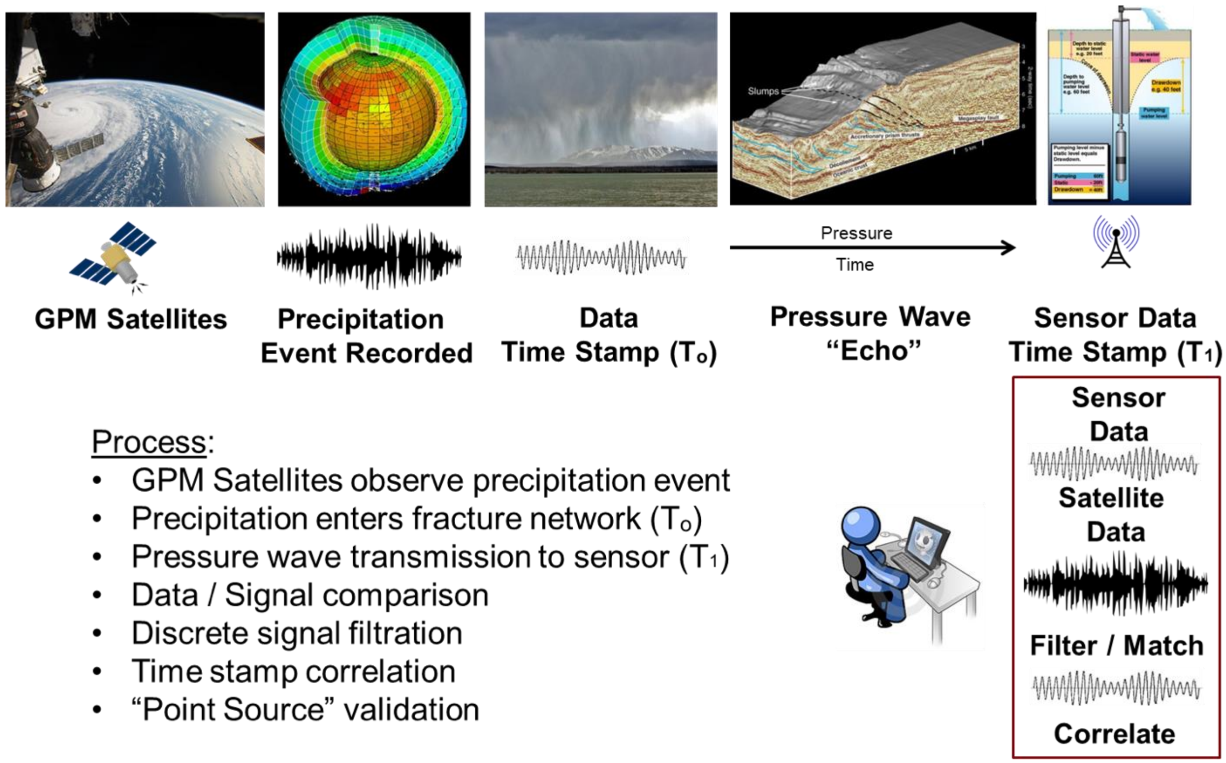
Comparison of Power 7 TGE to Alternative Solutions

Variables (Pro - ✓/ Con - ×)	Power 7 TGE	Reverse Osmosis (RO)	Reservoir / Dam Catchment	Reuse / Recycle	Aquifer / Well
Low Capital Investment Cost	✓	×	×	×	✓
Low Operational Expenses	✓	×	×	×	✓
Low Maintenance Expenses	✓	×	×	×	✓
Variable Costs / Consumables					
• Low Energy / Carbon Footprint	✓	×	×	×	✓
• Low Maintenance Costs	✓	×	×	×	✓
• No Recurring Chemical Costs	✓	×	×	×	✓
• No Recurring Filtration Costs	✓	×	✓	×	✓
• No Brine Water Discharge	✓	×	✓	✓	✓
• No Solid Waste Disposal Costs	✓	×	✓	×	✓
Risk to Resources / Operations					
• No Bacteria Blooming	✓	✓	×	×	×
• Contamination Resistant	✓	✓	×	×	×
• Protected from Evaporation	✓	×	×	✓	×
• Small Environmental Impacts	✓	×	×	×	×
• No Seasonal Disruptions	✓	×	×	✓	×
Renewable Resource	✓	✓	×	×	×

An evaluation of the capital and operating expenses associated with these projects is also noteworthy. Relative to alternative solutions, the capital and operating expenses to access and operate these resources are relatively low.

- Cost recovery is possible over the enduring life cycle of properly managed wells
- Potential profit margins enhanced via the sale of water resources to third parties
- Wells developed as close as possible to the end user, thereby minimizing the costs of conveyance infrastructure and the energy required for pumping and delivery processes
- Water remains underground until needed; limiting exposure to contaminants and bacterial blooming
- Environmental impacts of the small well sites (similar in size to a natural gas well) are minimal; in comparison to dams, reservoirs, and pipelines
- No waste products; unlike desalination and wastewater recycling processes
- Development of multiple wells distributes operational risk across a region; ensuring the single point failure of a single well does not negate the entire system
- Sustainability of the water resource is verified by the successful track record of multiple projects that have continued delivering water at predicted volumes for more than 30 years

ECHO-GPM:

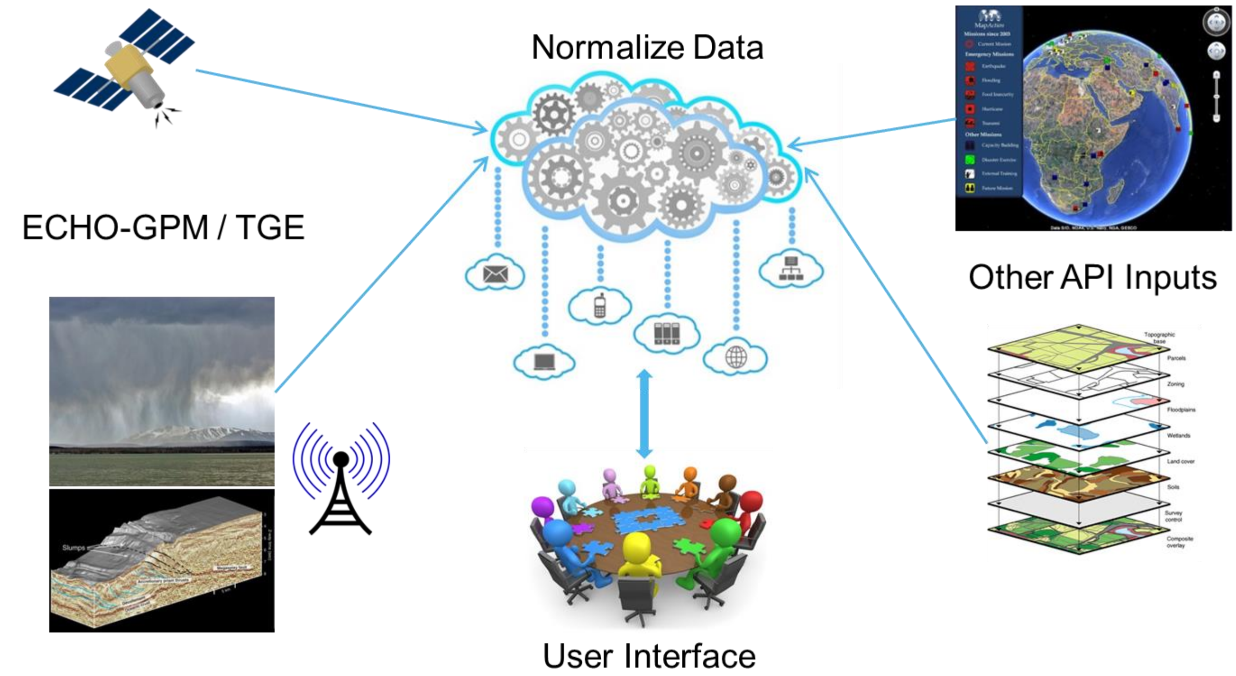


ECHO-GPM accesses real-time Global Precipitation Modeling (GPM) data and compares it to sensor data from the discharge points. The algorithm matches sensor data with satellite data and correlates the time difference between the two outputs. The resulting information correlates the signal and time information to determine the precipitation event responsible for the signal change in the water column. Further monitoring of flow rate and temperature deviations aids in calculating groundwater transmission timelines.

As a result, any water source with a hydrograph can be analyzed and compared to continually-updated GPM data. This data informs the water resource manager of the source of recharge to the system and the flow rate that can be expected.

ECHO-GPM represents the first step in the AI/ML development effort and highlights the potential value of the concept among likely users in the broader water market.

TGE/ECHO AI/ML Concept:



Data is pulled from multiple sources that are normalized and optimized. AI/ML provides automated calculation of TGE/ECHO variables to expedite resource location and development. Filtered outputs and layered data are displayed on a user interface that assist strategic and tactical decision making. Tiered permissions, via a subscription-based business model, provide customizable service offerings that meet the customers' specific information needs.

Areas of analysis include, but are not limited to:

Total water budget
Water scarcity
Water quality
Water-Energy-Food nexus
Cross-functional project planning
International strategy and policy development
National Security Strategy (NSS) development
Ecosystem analysis/management
Climate change
Globalization and "virtual water" flows
Global water governance (UN)
Water-related risk mitigation
Domestic infrastructure planning
National Military Strategy (NMS) development

USE CASES: (sectors exposed to substantial water risk)

1. **Department of Defense**
2. **Department of State**
3. **Department of Interior:** Department responsible for the protection and management of the Nation's natural resources and cultural heritage.
4. **US Department of Agriculture:** Department responsible for promoting, protecting and advancing agriculture and forestry, and soil and water resources
5. **US Environmental Protection Agency:** Responsible for protecting human health and the environment
6. **Commercial Agriculture:** Engaging in large-scale Agriculture activities that contribute to the management and cultivation of land, and the production of commercially traded commodities
7. **Bottled Beverage Industry:** Engaging in the collection and treatment of water for the expressed purpose of commercial production of containerized beverages
8. **Energy / Mining:** Engaging in the extraction of natural resources and commodities from the environment for industrial and commercial purposes
9. **Municipalities:** Agencies and enterprises responsible for the management of facilities and systems that provide critical infrastructure support for municipal users

CASE STUDY #1

IRAN: Water-Related Indicators of Future Unrest, Famine, and Migration

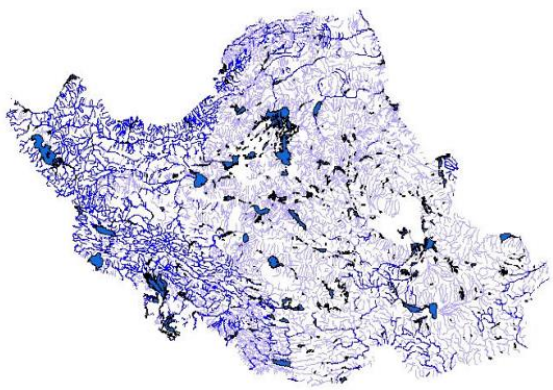
In some parts of the world, particularly the Middle East, life without access to sufficient quantities of fresh water is becoming more than a theoretically disturbing possibility. As climate change, mass migration, environmental degradation, drought and political instability - among other issues - make the use and management of diminishing water resources an increasing challenge, Iranian water issues are alarming.[36] Water shortage and the increased demand associated with uncontrolled development, intensive agriculture, mass tourism, over-population, and over-consumption have created a complexity of interrelated problems affecting social, economic, and natural stability in Iran.[37]

> **Our main problem that threatens us, that is more dangerous than Israel, America, or political fighting, is the issue of living in Iran… groundwater has decreased and a negative water balance is widespread, and no one is thinking about this.[38]**

Introduction and Geography

Covering an area of 1.65M square-kilometers, Iran is the 17th largest country in the world, neighboring the Caspian Sea, Turkmenistan, Azerbaijan and Armenia in the north; Afghanistan and Pakistan in the east; Turkey and Iraq in the West; and the Persian Gulf and Sea of Oman along to the south. Including its Persian Gulf neighbors, Iran has 15 neighbors; seven of which share borders with Iran. With an estimated population of 71.4-million people, Iran is the most populous country in the region and the 16th-most populous in the world.[39] With population centers focused in areas of the north, north-west, and south-west, where natural water supplies are more prevalent, vast land areas are vacant of habitants. However, over-population in Iranian cities has put these areas under critical water conditions.[40]

[36] Al Jazeera, “Iran’s Water Crisis”; People and Power, 13 November 2016.
[37] Khani, Khalil, “How Serious is Water Crisis in Iran?”, 15 April 2017.
[38] Karami, A.; Interview with Issa Kalantari, former Minister of Agriculture under Ayatollah Rafsanjani, Ghanoon newspaper, 9 July 2013.
[39] Larijani, Kaveh Madani, “Iran’s Water Crisis; Inducers, Challenges, and Counter-Measures,” ERSA 45th Congress of the European Regional Science Association, August 2005.
[40] Larijani, K.; August 2005.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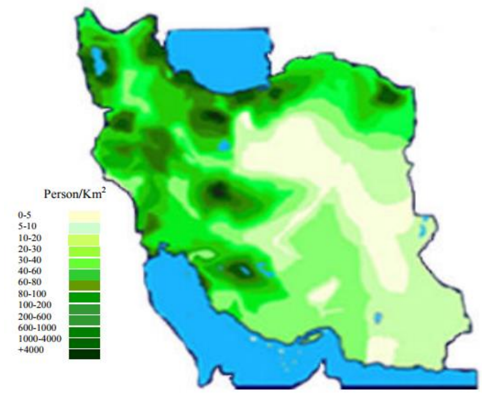

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Iran has a mean annual precipitation (MAP) of only about 250 mm, which is about one third of the global average. Nearly 70% of this slight precipitation is being lost due to evaporation. About 65% of the country is considered as arid and 20% is semi-arid. Also, water resources distribution in the country and temporal distribution of precipitation during the year is heterogeneous and uneven. Water scarcity in Iran is combined with inefficient water use where domestic use of water is 70% higher than the global average. The total renewable freshwater of the country and the total recycled water from consumption are respectively estimated at 130 and 29 bcm annually. The annual renewable water per capita in Iran is estimated to be less than 1,700 m^3, well below the global level 7,000 m^3 and slightly above the Middle-East and North Africa MENA level 1,300 m^3.[43]

> **If this situation is not reformed, in 30 years Iran will be a ghost town. Even if there is precipitation in the desert, there will be no yield, because the area for groundwater will be dried and water will remain at ground level and evaporate.[44]**

Water Crisis

Since the 1979 Islamic revolution, Iran has remained largely outside of the influence of Western-directed development. Some of the identified causal factors of Iran's water crisis include the doubling of Iran's population in less than two decades, inefficient agricultural sector management, years of war with Iraq, and the impact sanctions.[45] Stark examples of the Iranian water crisis can be seen across the country. Lake Urmia, one of the world's largest saltwater lakes, is down to 10-percent of its former size. Iconic

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[41] GIS View of Water Networks in Iran (Motiee, 2003).

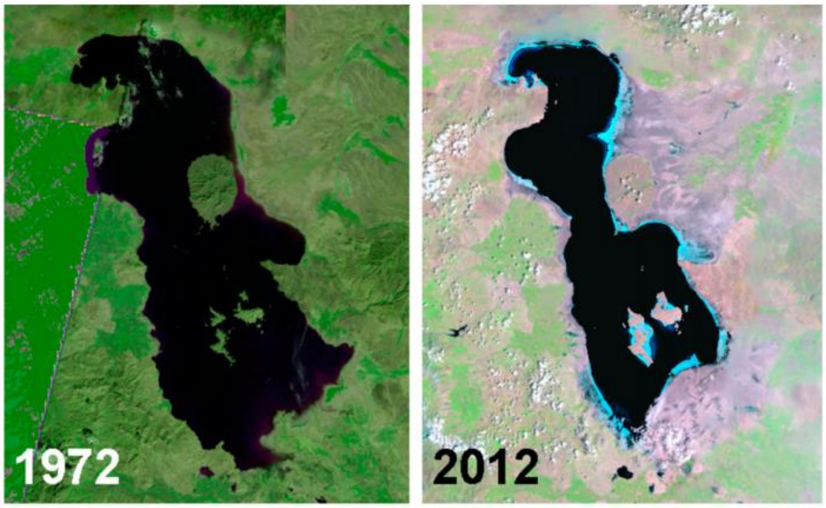
[42] Distribution Map of Population in Iran (1996), www.eri.u-tokyo.ac.jp/KABE-LAB/Bam-Hossein?seisVul.thm

[43] Khani, Khalil, "How Serious is Water Crisis in Iran?", 15 April 2017.

[44] Karami, A.; Interview with Issa Kalantari, former Minister of Agriculture under Ayatollah Rafsanjani, Ghanoon newspaper, 9 July 2013.

[45] Al Jazeera, "Iran's Water Crisis"; People and Power, 13 November 2016.

landmarks, like the Isfahan's famous Zayandeh Rud, the river that gave birth to the ancient city, have dried up. As towns run out of water, massive sink holes are appearing. The public outcry about the water crisis has become a front page topic in the media and on social media. Iranian expats, approximately 4-5 million around the world, have taken notice.[46]



[47]

Lake Urmia over the past decade

There is growing concern over food self-sufficiency and food availability. The linkages of water are complex and must be understood to address this crisis.[48]An existential threat in years to come, Iran needs to rethink its attitude towards water.[49]

Water shortage in Iran has been considered as one of the limiting factors for sustainable development. It is predicted that Iran is among the countries which will face an absolute water scarcity by 2025. The principal role of water in agriculture, industry and people's lives, will this variable a primary driver of political and social, problems. In the Middle East, with a history of water-based political conflicts, scientists have warned about intense water scarcity and desertification in future. Even per capita water availability will fall by 50 percent by 2050. Therefore, understanding Iran's water crisis, both its intensity and causes, is needed in order to confront or to mitigate its effects (12).[50]

[46] Al Jazeera, "Iran's Water Crisis"; People and Power, 13 November 2016.
[47] Madani, K, et al; "Iran's Socio-economic Drought: Challenges of a Water-Bankrupt Nation", Iranian Studies, 7 December 2016.
[48] Al Jazeera, "Iran's Water Crisis"; People and Power, 13 November 2016.
[49] Al Jazeera, "Iran's Water Crisis"; People and Power, 13 November 2016.
[50] Khani, Khalil, "How Serious is Water Crisis in Iran?", 15 April 2017.

Transboundary Water Conflict

The Central Intelligence Agency (CIA) notes the transboundary surface water friction between Iran and Afghanistan over the damming of Helmand River tributaries during drought. However, much of the CIA assessment of transnational issues focuses on territorial disputes within the Persian Gulf.[51] Prior to the Taliban regime in Afghanistan there was an agreed flow of 27 m^3/s (850 million m^3/year) of the Helmand River entering the Islamic Republic of Iran. However during the Taliban regime in Afghanistan (1995–2001), this agreement ceased completely and this caused an economic and environmental disaster in the provinces of Sistan and Baluchistan bordering Afghanistan and Pakistan (Bybordi, 2002). The Helmand River is the longest river in Afghanistan. It stretches 1,150 km from the Hindu Kush mountains about 80 km west of Kabul and crosses southwest through the desert to the Seistan marshes and the Hamun-i-Helmand lake region around Zabol on the Afghan-Iranian border.[52]

Violence associated with transboundary water issues have been on the rise in recent years (2010-present): and it is believed these occurrences will increase in number and intensity over the coming decades if water grievances are not addressed:

- **Water disputes between Iran and Afghanistan escalate (2010-2013)**: Disputes over water between Iran and Afghanistan are escalating. One Afghan newspaper, Weesa, has suggested that Iran blocked the transport of fuel oil to Afghanistan in 2010 as a means to put more pressure on the country over water. An Iranian editorial calls for bolder action by the Foreign Ministry and states that any aid to Afghanistan should be linked to "Iran's rights to water."
- In 2011, Mullah Dadullah, a Taliban commander captured in southwestern Afghanistan by Afghan authorities, claims to have been trained in Iran to sabotage projects in Afghanistan, including being offered $50,000 to destroy the Kamal Khan Dam, a claim Iran has denied.
- Shakila Hakimi, a member of the Nimroz provincial council, accuses Iran in 2012 of conducting an insurgency in order to prevent construction of the Kamal Khan Dam.
- **Iranian border guards open fire on Afghan villagers accessing river water (2015):** A dispute over the allocation and rights to water from the Hari Rud River between Afghanistan and Iran leads to at least ten deaths when Iranian border guards allegedly open fire on Afghan villagers trying to collect river water. The river provides water for agricultural production in Herat province, Afghanistan, and to the downstream Iranian city of Mashhad, Iran's second largest city.
- **Iran faces transboundary quarrels with Turkey, Afghanistan and the Kurdish people which add to Iran's significant domestic water security challenges.[53]**
    - Risk of reduced flow from the Euphrates and Tigris River systems
    - Turkish dam projects could drastically reduce downstream water supplies
    - Iran threatens to inhibit river flows if Kurds push for independence
- **Why Turkish Dams Could Push the Region Toward New Conflict (2017):** Turkey plans to construct 22 new dams in the South Anatolia region has sparked concern of Iranian authorities.

[51] CIA Factbook, www.cia.gov/library/publications/the-world-factbook/geos/ir.html
[52] www.fao.org/nr.water/aquastat/coutnries_regions/IRN/
[53] Future Directions International, "Iranian Response to Growing Water Scarcity Provides a Chance for Regional Leadership", 20 September 2017.

Construction will lead to the drying up of two major water sources for Iran. **"About 90 percent of the recruits of [Daesh] were from among the unemployed residents of these dried out and desert areas."**[54]

Domestic Water Conflict

The Director of the environment committee at the Energy Ministry, Mohammad Ali Hamedi, stated that 200 of the 600 plains in Iran are in "critical condition" in terms of water scarcity. "There have been fierce conflicts over water at times especially at the time of drought in Iran in the past; however, the conflicts may re-escalate once the water crisis worsen." [55] Hamedi stated that water is a national resource and the government has the right to transfer water resources from one city to another. This policy is only fueling the internal conflicts in Iran:

- **Protests to protect shrinking Lake Urmia lead to violence (2010-2011):** Security forces flown to the region to restore peace over Lake Urmia water issues. Attempt to address water loss in the lake has led to a proposal of an ambitious water-transfer project from the Caspian Sea. The project risks causing further ecological damage to both sea and lake, and fails to address the root cause of water loss in the area.[56]
    - **Level of Urmia Lake is 20 centimeters lower than the target set for the end of the water year.** Based on the plan, the level should have been 40 centimeters higher than three years ago**. (28 September 2017)**[57]
- **Farmers clash with police over water diversions (2013):** Hundreds of farmers in the town of Varzaneh, in Iran's Esfahan province, clash with police during a protest against the government's **decision to divert water from the area to another province**. Iranian media say farmers smash a pipeline carrying water from Zayandeh Rood river to neighboring Yazd province in an effort to **prevent the water transfer**. Dozens are reported injured and more arrested.
- *"It sounds more logical to displace the population but it is not possible…we should accelerate development in other areas with richer water resources so that the population opt for moving there."*[58]
- *"Combating drought is impossible and Iran must learn instead to adapt to its effects."*[59]

Water Crisis Impact on Agriculture/Economy

Drought has placed extreme strain on water resources, drinking water supply systems, livestock, and agriculture. The impacts of drought are skewed, having the greatest impact on rural and poor populations. In over 70% of the rural areas, the flow of water has been moderately or severely disrupted. With roughly

[54] Sputnik News, "Why Turkish Dams Could Push the Region Toward New Conflict", 26 July 2017.
[55] Tehran Times, "Iran: Water Scarcity May Lead to Conflict Between People in the Country", 20 August 2017.
[56] Water Politics, "Iran's Water Crisis", 27 February 2014 www.waterpolitics.com/2014/02/27/irans-water-crisis
[57] The Iran Project, "Iran's Urmia Lake Restoration Target Elusive", 28 September 2017
[58] Tehran Times, "Iran: Water Scarcity May Lead to Conflict Between People in the Country", 20 August 2017.
[59] Fianancial Tribune, "Iran: Must Adapt to Drought" quote by Masoud Goudarzi, head of the Drought and Climate Change Workgroup at the Agricultural Research, Education and Extension Organization, 20 August 2017.

50% of the country's population affected, nearly 80% of the drinking-water wells suffered from low water yield, a drop in water table, saltwater intrusion, or completely dry holes.[60]

Table 1 Brief Overview of Water Cycle in Iran *Source:* (Ardakanian, 2003)

	BCM (Billion Cubic Meters)
Internal Surface Water Resources	92
Transboundary Surface Water Resources	13
Total Surface Water Resources	105
Infiltration from Surface Water	13
Total Available Surface Water Resources	92
Direct Infiltration from Rainfall	25
Total Infiltration (Including Direct Infiltration from Rainfall)	38
Available Fresh Water Resources	130
Return Water from Consumption	29
Total Available Water Resources	***159***

[61]

One-third of Iran's economy relies on agriculture. However, even with land and labor being readily available for agriculture, food production and exports have been limited by a lack of water resources. 92.8% of the total water demand is attributed to agriculture. Iran's fresh water supplies are now under unsustainable strain. Ninety percent of the country is arid or semi-arid, and an estimated two-thirds of its rainfall evaporates before it can replenish rivers. Analysis reveals seven of the country's 32 provinces are classified as experiencing a "water shortage," while 13 provinces face a "critical water situation." None of the provinces, including the Caspian Sea region, can be categorized as having sufficient water basins.[62]

As a result, Iran provides more than half of its water needs by drawing from underground aquifers, but public usage is rapidly draining the subterranean reservoirs. At current rates of overuse, twelve of Iran's thirty-one provinces will exhaust their groundwater reserves within the next 50 years. Iran's water problems now risk undermining the national economy.

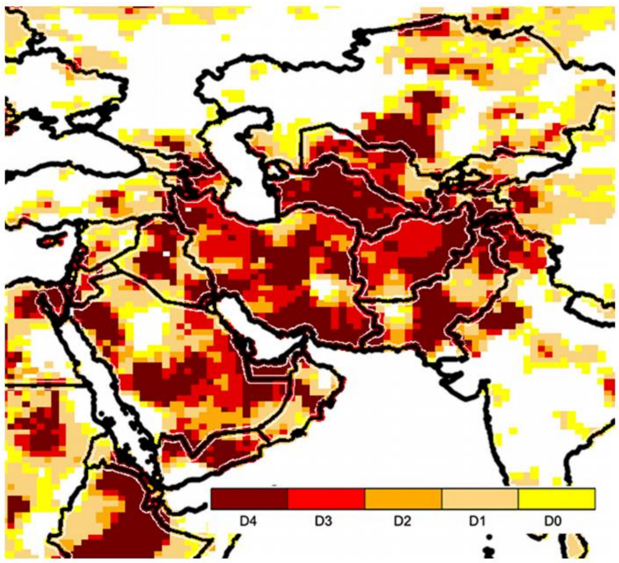
> **Deserts in Iran are spreading, and I am warning you that South Alborz and East Zagros will be uninhabitable and people will have to migrate. But where? Easily I can say that of the 75 million people in Iran, 45 million will have uncertain circumstances. If we start this very day to address this, it will take 12 to 15 years to balance.[63]**

The agricultural sector produces 10 percent of Iran's GDP and employs a quarter of the labor force. It also supports national food security, a top priority since the 1979 revolution. Tehran subsidizes producers and consumers alike in a dual strategy to promote self-sufficiency in staple crops by bolstering both supply and demand. Yet Iran's food security is now imperiled because agriculture accounts for more than 92 percent of the country's water use, but only produces about 66 percent of the food supplies for its 79 million people. Tehran has to import the rest. The intensifying "water stress" threatens to further sap

[60] Larijani, K.; August 2005.
[61] Larijani, K.; August 2005.
[62] Khani, Khalil, "How Serious is Water Crisis in Iran?", 15 April 2017.
[63] Karami, A.; Interview with Issa Kalantari, former Minister of Agriculture under Ayatollah Rafsanjani, Ghanoon newspaper, 9 July 2013.

agricultural output, increase import bills and aggravate fiscal burdens. Some areas, such as the central Kashan plain, have been rendered unfit for farming because of soil salinity, as groundwater overdrafts sink water tables. Pistachios, Iran's second largest export after crude oil, are vanishing. [64]

The economic impacts of rising inflation have further aggravated the internal struggle for scarce water resources. The rate of inflation is on the rise, with the food and beverage price inflation index at 19.9%. The Central Bank has a target rate of 10% and is trying to lower the baseline interest rate, now at 18%. The Central Bank has postponed a decision to end the current dual exchange rate regime of the market rate and preferential official rate for essential imports until the end of February 2018.[65]



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Spatial Patterns of Drought in mid-2000

(D0: Abnormally dry; D1: Moderate drought; D2 Severe drought; D3: Extreme drought; D4 Exceptional Drought)

In 2017, remote sensing images indicate a delayed start to the growing season, due to a late onset of rains in the north-west and central-west parts of the country; potentially impacting yields. Favorable weather conditions prevailed across the rest of the country, with above-average temperatures towards the end of the growing season accelerating crop development in central and northern Iran. The 2017 harvest is expected to be about 15% above the 5-year average. Government subsidies are expected to support the purchase of 11 tons of domestic wheat production at guaranteed prices. With wheat and barley as the main cash crops, wheat represents 70% of the aggregate cereal production. Bulk wheat production relies on rainfall, with only 1/3 of the crop being supported by irrigation. However, reports indicate the government plans to improve irrigation by introducing irrigation systems to 450,000 hectares of farmland.

[64] Khani, Khalil, "How Serious is Water Crisis in Iran?", 15 April 2017.

[65] www.fao.org/giews/countrybrief/country.jsp?code=IRN&lang=en

[66] Madani, K, et al; "Iran's Socio-economic Drought: Challenges of a Water-Bankrupt Nation", Iranian Studies, 7 December 2016.

2017 cereal imports are expected to increase by 9% over the previous year's number, but 12% below the 5-year average. Exchange rate concessions from the government are made for essential imports. [67]

The increasing trend of importing food allows the Iranians to address their water crisis via the virtual importation of water; water used to produce the goods and services that are consumed come from ther countries that produce and export them to Iran. "Providing food security does not necessarily mean producing it domestically but importing and extraterritorial farming are also two practical solutions," Hamedi stated.[68] If this policy continues, Iran exposes itself to the volatility of the international commodities markets and will become more dependent on foreign trade to support its population; similar to the Hashemite Kingdom of Jordan.

Government Water Crisis Management / Policies

Contributing to the stress is the systemic mismanagement of water resources. In 1990 and 1999, Iran faced water shortages so severe that the government accepted foreign aid for the first time since the 1979 Islamic revolution. Due to gross mismanagement and its ruinous impact on the country, Iran faces the worst water future of any industrialized nation.[69] Many academics and other experts state that mismanagement of water resources is a major contributor to the water crisis; compounding the impacts of drought.[70]

> **Analyses of the Iranian security threat often miss a central piece of the puzzle: Iran's government is not very good at many of the basic tasks of governing. The mullahs and their allies have built an unsustainable system…Tehran's quest for regional hegemony isn't just driven by abstract ambition, historical nostalgia, and religious zeal. It's also driven by the realization that Iran must expand in order to acquire the resources it needs to stay afloat.[71]**

An open letter from an organization dedicated to treating the water crisis in Iran criticized Iranian President Rouhani for his mishandling of the crisis. Signed by 110 experts, researchers and scientists in the field of water security, the letter stated Iran is facing an "unprecedented water crisis" and that "in the near future, competing for limited water resources will expand, and conflicts over shares will spread across the country."[72]

Diminishment of the annual renewable water availability, assessed by International Hydrological Standards, show that Iran will be facing water scarcity (less than 1000 m^3/day/capita) by 2025.[73] Water quality and wastewater treatment issues have impacted sanitation practices, especially in urban areas. Excessive groundwater extraction beyond sustainable levels cause saline or polluted water to contaminate

[67] www.fao.org/giews/countrybrief/country.jsp?code=IRN&lang=en
[68] Tehran Times, "Iran: Water Scarcity May Lead to Conflict Between People in the Country", 20 August 2017.
[69] Washington Post, "Iran's Water Challenge" 31 May 2017.
[70] Larijani, K.; August 2005. (Foltz, 2002).
[71] Khani, Khalil, "How Serious is Water Crisis in Iran?", 15 April 2017.
[72] Iranian News Update, "Water Crisis In Iran May Lead to Future Conflict", 18 July 2017.
[73] Larijani, K.; August 2005.

existing reservoirs. These extractions, causing land subsidence at a rate of 1.5 meters per year, are threatening to permanently destroy existing aquifers. [74]

Water Crisis Population Migration

It is assessed that as the trend of population migration into urban areas continues, water demand will shift from agriculture to municipal users. This will increase tensions on sectors within the Iranian water market.[75] Over the last three decades, tremendous efforts have been made to supply water, primarily an extensive program of development with dam building at the forefront. However, the process of such massive dam construction was given to IRGC, which have been performed without fundamental consideration toward the environment and ecosystems' welfare. A water official at the Iranian Energy Minister stated that 295 cities, including six major cities, are facing drought as the water crisis spreads across the country.[76]

> **50 million Iranians will have to emigrate over the next 20 years in order to survive, creating another wave of refugees.[77]**

Natural Disaster / Resilience

Further exacerbating the Iranian water crisis and governance challenges is Mother Nature. As one of the 10 disaster-prone countries in the world, Iran has experienced annual natural disasters that have cost more than 1-trillion Rials ($1.2B USD). Nearly 70% of the costs were related to drought and flooding. The fragile status of Iran's water resources degrades the country's ability to respond to natural disasters and could be the catalyst for a large-scale humanitarian crisis.

Disaster	Date	No. of Affected People
Drought	2000	37,000,000
Drought	July 2001	25,000,000
Flood	August 2001	1,200,000
Flood	July 1980	950,000
Drought	1964	625,000
Flood	February 1993	484,728
Flood	August 2002	200,000

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[74] Larijani, K.; August 2005.
[75] Larijani, K.; August 2005.
[76] Iranian News Update, "Water Crisis in Iran May Lead to Future Conflict", 18 July 2017.
[77] Iranian News Update, "Water Crisis in Iran May Lead to Future Conflict", 18 July 2017. Statement by former Minister of Agriculture, Issa Klanter, in 2015.
[78] Larijani, K; Iran's Severest Floods and Droughts (1964-2002) from EM-DAT 2005 (www.em-dat.net)

Future trends

If the current trends continue in Iran, in fewer than 50-years we can expect to see one of the largest humanitarian crises in human history. For a country ruled by a mistrusted regime, largely isolated from international aid and assistance, addressing this crisis will pose unprecedented challenges to both Iran and the global community. A crisis of this magnitude, with 10-times more refugees seeking asylum than the current Syrian conflict, will have a destabilizing effect on the regional and an already stressed global geopolitical environment. Recent trends away from globalization and towards populism, and nationalism will be accelerated and magnified by a crisis of this magnitude.[79] As the international community attempts to address the crisis, concerns about cultural identity, economic opportunity, and terrorism will create significant challenges to any humanitarian relief effort.

A water crisis will create a surge in Iranian migration to surrounding countries like Iraq, Syria, Lebanon, Gulf States, or even Yemen. As the regional power with aspirations for religious hegemony, Saudi Arabia will view the migration of Shia Muslims as a threat to their national security. The Australian Strategic Policy Institute claims that over the next few decades the “Great Game” that will emerge in the Middle East will involve a Sunni pitch for hegemony, and the non-Sunni attempts to resist. Sectarian violence in Bahrain (2011), Syria’s civil war, and the ongoing conflict in Yemen will pale in comparison to the violence this migration will cause. For Saudi Arabia to realize its plan for the Middle East, they will need to play an integral role in either preventing or responding to a humanitarian crisis on their doorstep.

A water crisis-induced mass migration from Iran will amplify the existing “brain drain” issue Iran is already facing. Between 150,000 to 180,000 highly-skilled Iranians are leaving the country each year. A majority of the country’s doctoral students studying in the US are reported as staying in country after their studies. The water crisis will encourage, or force, more Iranians to go abroad and add to the diaspora. However, the opportunities for these less educated and lower-skilled refugees will be limited by observed populist and nationalist trends. The potential for instability and violence in internationally mandated safe havens has the potential of further eroding already damaged relationships, treaties, and agreements that will complicate the geopolitical environment.

For those Iranians who remain behind, the water crisis will highlight the government’s mismanagement of water and the corruption of its institutions. As citizens continue to migrate from rural environments to urban areas, pressure on the struggling Iranian infrastructure systems will continue to build and contribute to internal tensions. Sanitation-related issues will result in the spread of disease, adding to the severity of the humanitarian crisis. As well, the rural poor will be further isolated from aid and support. The resulting tension has the potential of escalating incidents of water-related domestic violence and garnering an oppressive response from a regime seeking maintain control and power.[80]

The sustainability of the Iranian agricultural economy will be put at risk, as manpower abandons the fields and the traditional farmer culture collapses. The long-term macro-economic impacts on Iran will be significant, as they seek to satisfy their food demands through the increased importation of commodities.

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[79] Ulansky, Witenberg, “Is Nationalism on the Rise Globally?”, Huffington Post

[80] Future Directions International, “How an Iranian Water Crisis Could Intensify Regional Geopolitics, the Country’s Brain Drain and the Deep State”, 31 May 2017.

However, foreign exchange rates, inflation, and a depressed economy will require significant subsidies and enduring foreign aid to be applied.

Recommendation

Having a thorough understanding of the Iranian water crisis and the true water balance of the region is strategically important for the United States to inform and guide our national security and national military strategies. In order to get "left of the bang," a comprehensive understanding of the total volume and quality of available water resources, as well as how these resources are being distributed, or exploited, is critical to supporting sound strategic and tactical DOTMLPF-P functional solutions analysis.

- Monitor and assess Iranian water crisis to determine the probability of system collapse
- Use of water resource development assistance, via United Nations (UN) members, as a diplomatic and economic tool to inspire compliance with UN sanctions
- Assess the Saudi Arabian and neighboring GCC States response to mass migration of Iranian refugees
- Assess the regional and global response to mass migration of Iranian refugees
- Analyze regional and global economic impacts and costs associated with a mass migration of Iranian refugees
- Assess potential policy change requirements to support an effective response to an Iranian water crisis / humanitarian crisis, as part of the strategic and tactical contingency planning process
- Assess the role water-related variables have on current and future Iranian military activity and its impact on current doctrine
- Determine the viability of developing water resources in neighboring countries that directly or indirectly compete with Iran for water supplies and contribute to transboundary water conflict and regional tension
- Assess likely responses of the regime and IRGC in the face of humanitarian crisis
- Identify and prioritize specific areas within Iran that are most likely to be forced to migrate
- Monitor indications of water-related system failures and preposition forces accordingly
- Identify and prepare future safe haven locations for humanitarian assistance / disaster relief
- Identify and prepare forward operating bases in support of Iran population migration support activities
- Identify locations inside of Iran that are suitable for future renewable groundwater development

Supporting these actions requires the kind of high-fidelity, timely, and tailored water resource information the TGE / ECHO-GPM AI/ML platform is focused on providing. Integrating the platform with relevant planning tools will enhance the value and accuracy of the strategic and tactical planning processes.

CASE STUDY #2

JORDAN: Tipping Point - Water Crisis as the Catalyst for Violence and Instability

"Water is an existential threat to Jordan."[81]

One of the driest countries, Jordan is the third-most water insecure country in the world.[82] Jordan faces a perfect storm of pressures. Refugee water demands compound long-standing supply-side challenges, unsustainable management, and aging infrastructure. As a result, there are rising tensions over insufficient water supplies and water scarcity issues are threating the health and stability of one of the Arab world's most durable states. Addressing these issues requires a multi-faceted and integrated response by the government of Jordan, donors, and Non-government organizations (NGO), with an eye on long-term sustainability.[83]

"I have nothing to lose. If I don't drink water, I will die."[84]

Introduction

Precipitation over Jordan is highly variable in space and time from 6,000 to 11,500 million m³/year.[85] The rainy season stretches from October/November to April/May, with 80% of precipitation occurring in the period from December to March and practically zero outside the rainy season.[86] The northwest of Jordan is semi-arid, receiving 200–600 mm/year of precipitation. Much of the eastern and southern part of the country, constituting about 80%–90% of Jordan's surface area, is classified as arid and receives only 50–100 mm or less of precipitation each year.[87] Groundwater availability is assumed to be equal to the "safe yield" from renewable groundwater resources, which is approximately 277×10^6 m³/year.[88] Jordan's renewable surface water resources was estimated in the period 1996–2005 at 373×10^6 m³/year by taking the sum of treaty allocations (220×10^6 m³/year) and flow from wadis in the Jordan River Valley (153×10^6 m³/year) in the year 2000.[89] Total renewable water resources (surface and groundwater) are therefore estimated at 650×10^6m³/year. This is slightly higher than the sum of developed surface water resources, flow secured by the peace treaty with Israel, and safe yield from groundwater as reported for the year 2007 in Jordan's national water strategy, namely 620×10^6m³/year.[90] Due to Jordan's high dependency on water from upstream and neighboring countries, total blue water availability in Jordan is not purely natural runoff. Rather, it is actual inflow into Jordan from upstream countries (natural inflow minus what

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[81] Marwan Al Muasher, former Deputy Prime Minister of Jordan, Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.
[82] Columbia University, Earth Institute, "Water Shortages in Jordan," 20 June 2012.
[83] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.
[84] Mercy Corps interview with the leader of Al Sabt during armed protest of field operations.
[85] Mohsen, M.S., "Water Strategies and Potential of Desalination in Jordan," Desalination 2007, 203, 27-46.
[86] Toernros, T.; Menzel, L.; "Addressing Drought Conditions Under Current and Future Climates in the Jordan River Region." Hydrol. Earth System Science, 2014, 18, 305-318.
[87] Mohsen, M.S., "Water Strategies and Potential of Desalination in Jordan," Desalination 2007, 203, 27-46.
[88] Hadadin, N.; et al; "Water Shortage in Jordan – Sustainable Solutions," Desalination 2010, 250, 197-202.
[89] Hadadin, N.; et al; "Water Shortage in Jordan – Sustainable Solutions," Desalination 2010, 250, 197-202.
[90] Ministry of Water and Irrigation (MWI), Water for Life: Jordan's Water Strategy 2008-2022; Ministry of Water and Irrigation, Amman, Jordan, 2009.

has been consumed through upstream WFs) plus naturally generated runoff from precipitation over Jordan.

When comparing the blue water footprint (WF) to blue water availability, it is determined that Jordan is severely water scarce (water scarcity ratio >0.40), and that groundwater is overexploited (water scarcity ratio >1). The groundwater scarcity index indicates that the blue ground-WF in Jordan is nearly double the groundwater availability. Other quantitative estimates of the country-average ratio of groundwater withdrawal over safe yield range from 1.6 to 1.9. Although other studies have also described water scarcity in Jordan as severe, these estimates are even more alarming, since they have assessed water consumption (excluding return flows) rather than withdrawals.[91]

Despite fears of water-related violence, Israel has maintained basic cooperation with Jordan and the Palestinians over their shared water, even after the second intifada began in September 2000. Under the umbrella of the UN Truce Supervision Organization, low-level cooperation extends back to the 1950's, even though the countries were at war. This built sufficient trust to formalize an agreement between Israel and Jordan, in 1994, and the establishment of a Joint Water Committee to resolve disagreements over allocations. This agreement has assisted in maintain a shared water environment, even in the face of conflict between Israel and the Palestinians. This link of water cooperation to politics represents a highly complex process that is influenced by domestic and international considerations. Further, it highlights the importance of water as a diplomatic tool.[92]

> *Thriving, rather than merely surviving, will require new appreciation of the cost of water, improved technologies, and effective local and regional governance to enforce sustainable water use.*[93]

Water Demand and Refugee Support

A supply of 80-liters per capita per day (ppd) is required to meet a Jordanian's needs.[94] Over-exploitation of groundwater resources was pursued by the government to meet the increased demand presented by the refugee population. The rate of extraction from the Azraq Aquifer, in northeastern Jordan, is approximately twice the sustainable level.[95] However, with groundwater resources depleted, water supplies have dropped to below 30-liters ppd. Sanitation levels have declined, incidents of disease are on the rise, and subsistence crops are failing. Adding to the stress is the cultural disparity between Jordanians, experienced with water rationing since the 1980's, and Syrian refugees who lack the basic habits of water management. This has fostered a growing resentment towards refugees and the "culture of hospitality" among Jordanians is wearing thin. In April, 2013, a poll indicated that 71% of Jordanians want the government to close the border.[96] In some cases, tensions have already resulted in violence.[97]

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91 Schyns, J.F.; et al; "Mitigating the Risk of Extreme Water Scarcity and Dependency: The Case of Jordan, 2015.
92 Jagerskog, A. "State of the World 2005: Redefining Global Security", p. 86.
93 www.jo.usembassy.gov "Water Security and the US Jordanian Partnership"
94 World Health Organization, www.who.int/water_sanitation_health/publications.
95 Columbia University, Earth Institute, "Water Shortages in Jordan," 20 June 2012.
96 Khaled Niemat, "Majority of Jordanians call for end to Syrian refugee influx," Jordanian Times, 15 April 2013.
97 Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.

Water shortage causes riots in Jordan (2013): The Syrian civil war and the displacement of **refugees into Jordan contribute to a growing water supply crisis**. In summer 2013, **riots associated with water shortages** are reported by the director of water utilities in Jordan's Mafraq governorate.

"Mafraq was on fire. People burned tires in the street and closed the roads. **There was tension over water in the past, but the Syria crisis has made it much worse.**"

"People screamed, 'You're government! You're shit! You need to provide water to us!' It was a disaster."[98]

Hundreds of Jordanians blocked the roads in Mafraq and Karak, warning Amman of a popular uprising if the taps continued to run dry. King Abdullah II personally intervened.[99]

Foreign Aid and Assistance

Foreign aid has increased in response to the Syrian crisis and to assist in supporting the large refugee population, now over 600,000 people, who have sought out the Jordanian safe haven. Adding to this number are hundreds of thousands of non-refugee Syrians, bringing the total estimate of displaced Syrians to approximately 1.4M. The refugee numbers are equivalent to approximately 10% to 25% of Jordan's pre-conflict population, with refugees being largely confined to the northern region of the country. In addition, Jordan has more than 2.17M Palestinian refugees and 63,000 Iraqi refugees as a result of regional conflicts.[100] Each person is an additional water user and has foiled Jordan's carefully-laid plans to manage its water. The water costs for supporting Syrian refugees is approximately $848M per year.[101] Estimating a consistent population growth to 7.8M Jordanians by 2022, the population approached 8M by 2013. Some Jordanians are resentful of the foreign aid, perceiving it as unfairly tilted towards Syrians. In Mafraq, the issue is the most intense, with an NGO buying private water at higher-than-market price and distorting the local water market.[102] While foreign aid has been helpful, with $920M being contributed in 2013 (10% of which was for water, sanitation and hygiene [WASH]), it has not been applied to upgrading and maintaining existing infrastructure. From 2013-2016, an estimated $750M was needed for WASH needs alone.

The US Government has established a 60-year partnership with Jordan and is investing more in the water sector than any other sector. These projects are focused on reducing water losses, improving institutions and policies, and encouraging best business practices in water utilities.[103] Water infrastructure projects supported by Mercy Corps, USAID, UNICEF, and UNHCR include:[104]

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[98] Ali Abu Sumaga, Director of the Mafraq Water Directory
[99] Amos, D; Bulos, N. " In a Rough Neighborhood, Jordan Clings to Its Stability," NPR 1 July 2013.
[100] www.cia.gov/library/publications/the-world-factbook/geos/jo.html
[101] The Arab Weekly, 19 March 2017.
[102] Mercy Corps, Mapping of Host Community-Refugee Tensions in Mafraq and Ramtha, May 2013.
[103] www.USAID.gov/jordan/water-and-wastewater-infrastructure
[104] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.

- Upgrading the Mafraq Wastewater Treatment Plant $56.3M
- Water and Wastewater Infrastructure Project
- Zaatari Refugee Camp: 2 new wells and pump stations to serve a refugee population of 120,000 at a cost of $450K.
- Tabaqet Fahel Well Project: Renovation and expansion of well for an additional capacity of providing 63,000 people with 80 liters ppd at a cost of $250K.
- Zabdah Reservoir: Renovation providing 27,000 people with 80 liters ppd at a cost of $530K.
- Abu Al Basal Pipeline: 2.5km of pipes to address emergency shortages and refugee-affected area at a cost of $70K.
- Spare parts: to enable maintenance at a cost of $400K

Socioeconomic Impacts

The population boom has strained schools, hospitals, mosques, and housing. Multiple Syrian families pack into single-family homes, some living on rooftops and renting chicken coops. The majority of refugees are living in the cities, not in camps, causing added strain on urban systems. As well, water shortages are linked to an increase in domestic disputes; adversely impacting socially-isolated women and children. Water trucks provide private well water, at a price, and is influenced by social standing and biased towards servicing men who are allowed to engage in manual labor. It is assessed that 89% of women, 28% of teenage girls, and 39% of boys and girls under the age of 12 fear harassment on their way to and from public bathrooms.[105] The glutted labor market has resulted in downward pressure on wages, made worse by rising rent prices. The youth movement, Hiraq "Nashama al-Mafraq" was started by Jordanians protesting the eviction of Jordanians by landlords seeking rent from Syrians. The government stepped in and promised state-funded housing for evicted Jordanians, but ill feelings linger. Therefore, water issues are simply one of many challenges facing the Kingdom. Regionally, the Syrian conflict is posing similar challenges for Lebanon, Iraq, and Turkey.[106]

Approximately 27% of the Kingdom's population is assessed to be hydro-insecure. This insecurity is accompanied by one or more issues such as poverty, war and conflict, low women's development, and environmental degradation. This is supported by the labor force participation rate of 36.4% and a poverty rate of 31.9%. Female farmers make up only 10% of the total agricultural farming population but are responsible for 60% of the work.[107]

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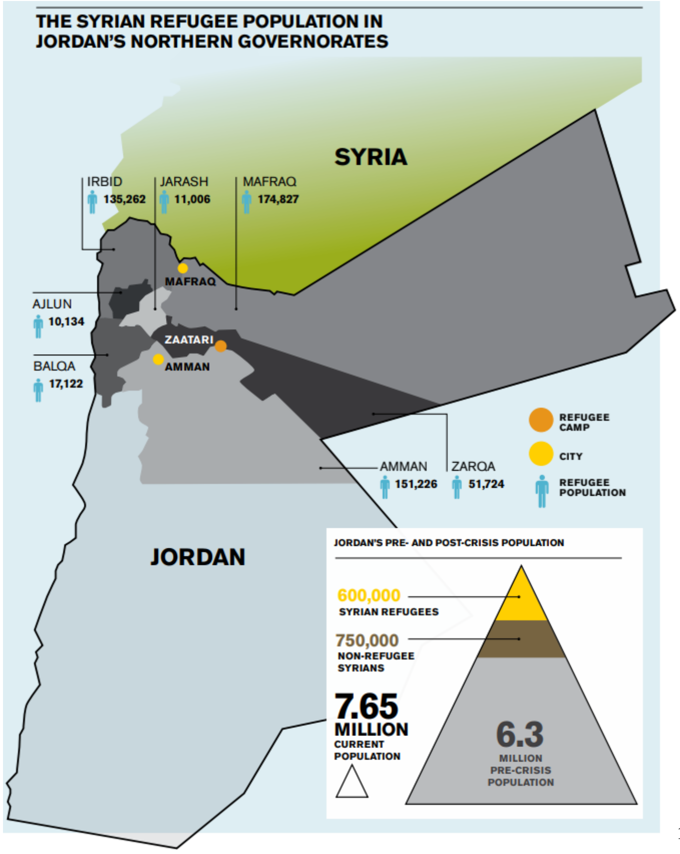
[105] UNHCR (2013), p.107

[106] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.

[107] Namrouqa, H.; "1.7 Million People in Jordan are Water Vulnerable – Report", Jordan Times, 21 March 2015.



108

Aging Infrastructure

The water supply system is losing much of its water due to aging infrastructure, with volumes that could support an estimated 2.6M people being lost through leaks in the system. As a result, an estimated 76B liters of water per year are lost. Much is stolen from utility lines by people who cannot afford water or lack in-home service. Sumaya, once serving 80,000 people was serving over 200,000 in 2014. The pump station at Sumaya is in disrepair, losing 75% of its water during distribution, and reflects the chronic decay of the broader system. Prior years saw large-scale investment in deeper wells and bigger pipelines. Though this bought Jordan some time, the limited potential of these projects are becoming more acute. Expensive new pump stations exacerbate the problem by overwhelming the overworked and aging system. Water demand has quadrupled in some communities and supply has not kept pace due to the crumbling water distribution system. [109]

Government and Institutions

King Abdallah implemented significant economic reforms, expanding foreign trade and privatizing state-owned companies, in the first decade of the 2000s. This attracted foreign investment and contributed to

[108] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.
[109] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.

the 8% growth Jordan enjoyed through 2008.[110] In 2011, Kind Abdallah II responded to the Arab Spring demonstrations by dismissing the cabinet and ceding greater authority to the judiciary and parliament. Since then, constitutional amendments have been made to restore power to the crown and have raised concerns about sustainability of governmental reforms. Lack of institutional checks and balances undermine efforts to combat widespread corruption.[111] The government is supported by foreign loans, international aid, and remittances from expatriate works. The ongoing conflict in Syria has severely disrupted traditional economic activities, adding to the challenges of governing a diverse population.

Local Government. The use of family, business, or other personal connection to advance business and interests, known as "wasta" in the Middle East, is endemic in Jordan.[112] Water management is delegated to the local utility companies, staffed by private contractors. Water resource providers are under-resourced and under-manned, adding to the need for an increase in human capital capacity. For example, Yarmouk Water Company has only six engineers to support an area the size of Hawaii, making the management of water resources a challenge to both maintain and operate. Labor disputes over wages and working hours add to the difficulties as management tries to avoid labor strikes. Frustration with the government is growing, with anger being focused directly at Amman.[113] Those in government and on the street say the situation is precarious, with the Arab Awakening weighing heavily on people's minds. Long-standing grievances over public corruption and lack of representation in the government, as well as elaborate procurement procedures, have been further strained by refugee pressures. Water shortages create a potential catalyst of unrest.[114]

Economy

Strategically positioned, at the crossroads of the MENA/LEVANT region, free trade in Jordan is vulnerable to regional conflict. The 1967 war showed the vulnerability of Jordan to a closing of the Strait of Tiran, the single gateway to Jordan's seaport in the Gulf of Aqaba, due to regional conflict.[115] In the past 20 years, the closing of the border with Iraq and Syria has stressed Jordanian trade, tourism, and logistics infrastructure.[116]

Jordan's economy is the smallest in the Middle East, with insufficient supplies of water, oil, and other natural resources. International trade is critically important to the Jordanian economy, with the value of exports and imports equal to 98% of GDP. Primary trade partners are the European Union (20%), Saudi Arabia (20%), China (11%) and the United States (6%).[117] US exports to Jordan were $247M in 2014 and $256M in 2013; representing $4.27B in total trade value.[118]

[110] www.cia.gov/library/publications/the-world-factbook/geos/jo.html
[111] www.heritage.org/index/country/jordan
[112] www.heritage.org/index/country/jordan
[113] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.
[114] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.
[115] Sosland, J.K.; "Cooperating Rivals: The Riparian Politics of the Jordan River Basin", p. 90.
[116] www.export.gov
[117] www.export.gov
[118] www.export.gov Jordan-Agricultural Sectors, 22 February 2017.

The country is nearly completely dependent on imported energy; though it is exploring opportunities to develop domestic energy capacity.[119] As well, as a net food-importing country, Jordan imports up to 98% of its consumable food items from abroad. The scarcity of water has prevented Jordan from developing substantial food production capacity. Increasing water scarcity has resulted agriculture being a declining component of the Jordanian economy for years. While the agriculture sector consumes 65-75% of the country's water resources, it only contributes to 2.5% of GDP and employs 15% of the total labor force. This highlights the vulnerability of Jordan to disruptions in its logistics supply chain and the importance of regional stability and open sea lines of communication.

The economy is adversely impacted by high rates of poverty, unemployment, and government debt. Economic freedom has suffered in recent years due to rising public debt and persistent deficits. Jordanian debt is in excess of $1.3B and servicing the debt is the largest item on the budget, equivalent to 91.7% of GDP. Running a deficit of $310M, with a 3-year bond carrying an 8.5% interest rate, the country is strapped for cash.[120] As a result, public sector wages for engineers and other skilled labor are low; contributing to the "brain drain" that limits the quality of labor being hired. Reforms have been carried out in recent years that make business formation and operation more efficient and dynamic. The International Monetary Fund concluded a fiscal consolidation and structural reform effort in August 2016. Future efforts will focus on targeted capital spending and private-sector development. However, until the brain drain trend can be reversed, Jordan will continue importing human capital to support industries requiring skilled labor and incentivize multinational corporation investments in the Jordanian market.

Summary

Addressing the conflict and promoting conservation is important if Jordan is to avoid deteriorating social conditions, resource mismanagement, and violence. Years of over-pumping have put Jordan on schedule to exhaust underground all fresh water resources by 2060. Due to the influx of refugees, groundwater depletion has accelerated, with water tables declining, salinity rising; degrading the quality of water that remains.[121] Large infrastructure projects, like the $1.1B Disi aquifer project, take years to bring online and are not sufficient to close the water demand gap. Desalination projects are not ideally suited for Jordan, due to the short coastline along the Gulf of Aqaba. As well, water produced along the coastline must be pumped uphill to communities hundreds of miles away. The "Red-Dead" agreement with Israel and the Palestinian Authority has untold ramifications for the rich marine ecosystems and could affect mineral mining in the Dead Sea.[122] However, this is still years away, may not provide supplies soon enough, and will be vulnerable to the impacts of regional conflict.

The refugee issue will persist in Jordan for the foreseeable future and is likely to lead to enduring demographic changes in the country. As the water crisis becomes progressively more acute, tensions will certainly build between the Jordanians and the refugee populations. As outlined above, there are several variables that could ultimately spark violence. While water-related issues may not be seen as the primary cause of that violence, it will certainly play a significant and contributing role.

[119] www.cia.gov/library/publications/the-world-factbook/geos/jo.html
[120] Interview of Basem Telfah, the MWI General Secretary, 13 January 2014.
[121] Mercy Corps, "Tapped Out, Water Scarcity and Refugee Pressures in Jordan," March 2014.
[122] Columbia University, Earth Institute, "Water Shortages in Jordan," 20 June 2012.

Recommendation

The Jordanian water crisis is being accelerated and aggravated by the continued conflict in Syria and the enduring refugee support requirements. Jordan is a key regional ally and its stability is crucial to maintaining the balance of power in the region. Therefore, it is strategically important for the United States to thoroughly understand the role water-related tensions are playing in Jordan and to take proactive steps to protect our national security and national military interests in the country and region. Investments of aid and support clearly highlight our enduring commitment to supporting Jordan. However, in order to get "left of the bang," viable alternatives need to be more aggressively pursued. Renewable groundwater supplies should be identified and developed, to increase the water production capacity and facilitate the stabilization of the water supply system. Rehabilitation of the Jordanian water and waste water systems cannot be delayed. In addition, gaining an understanding of, and proactively planning for, the post-war reconstruction effort in Syria should be pursued aggressively. Having a comprehensive and continually updated assessment of the total water budget in Jordan is imperative to preventing system collapse and enabling sound strategic and tactical DOTMLPF-P functional solutions analysis.

- Focus foreign aid on water-related infrastructure rehabilitation and improvement projects that address non-revenue water issues
- Identify high risk areas experiencing water-related violence
- Assess the potential impacts of water-related violence on the stability of government
- Integrate domestic crisis response into regular joint operations with the Jordanian Public Security Force, National Police, and Armed Forces
- Support providing foreign aid and human capital towards training and education of high-skilled labor to support water system operation, maintenance, and management
- Assist in system triage; analyzing and prioritizing projects that support water production, waste water treatment, and distribution systems.
- Enable the identification and monitoring of existing groundwater wells and systems, via web-enabled sensors and meters, to more accurately track groundwater extraction rates a distribution system health
- Engage Jordanian leadership and incentivize the development of available renewable groundwater resources
- Facilitate water supply facility and system rehabilitation through localized renewable groundwater distribution systems

Supporting these actions requires the kind of high-fidelity, timely, and tailored water resource information the TGE / ECHO-GPM AI/ML platform is focused on providing. Integrating the platform with relevant planning tools will enhance the value and accuracy of the strategic and tactical planning processes.