

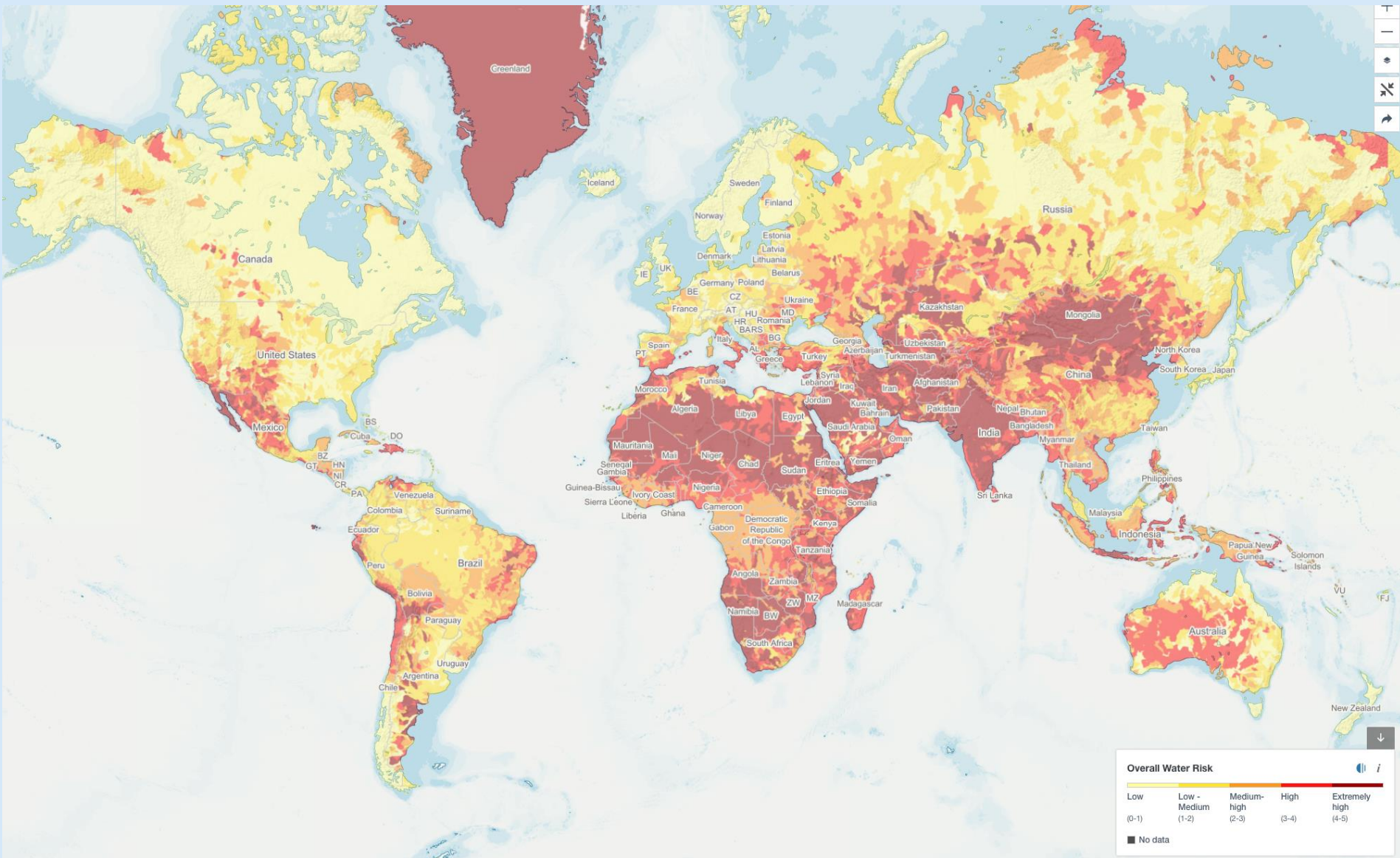
Mortenson Center in Global Engineering

UNIVERSITY OF COLORADO **BOULDER**

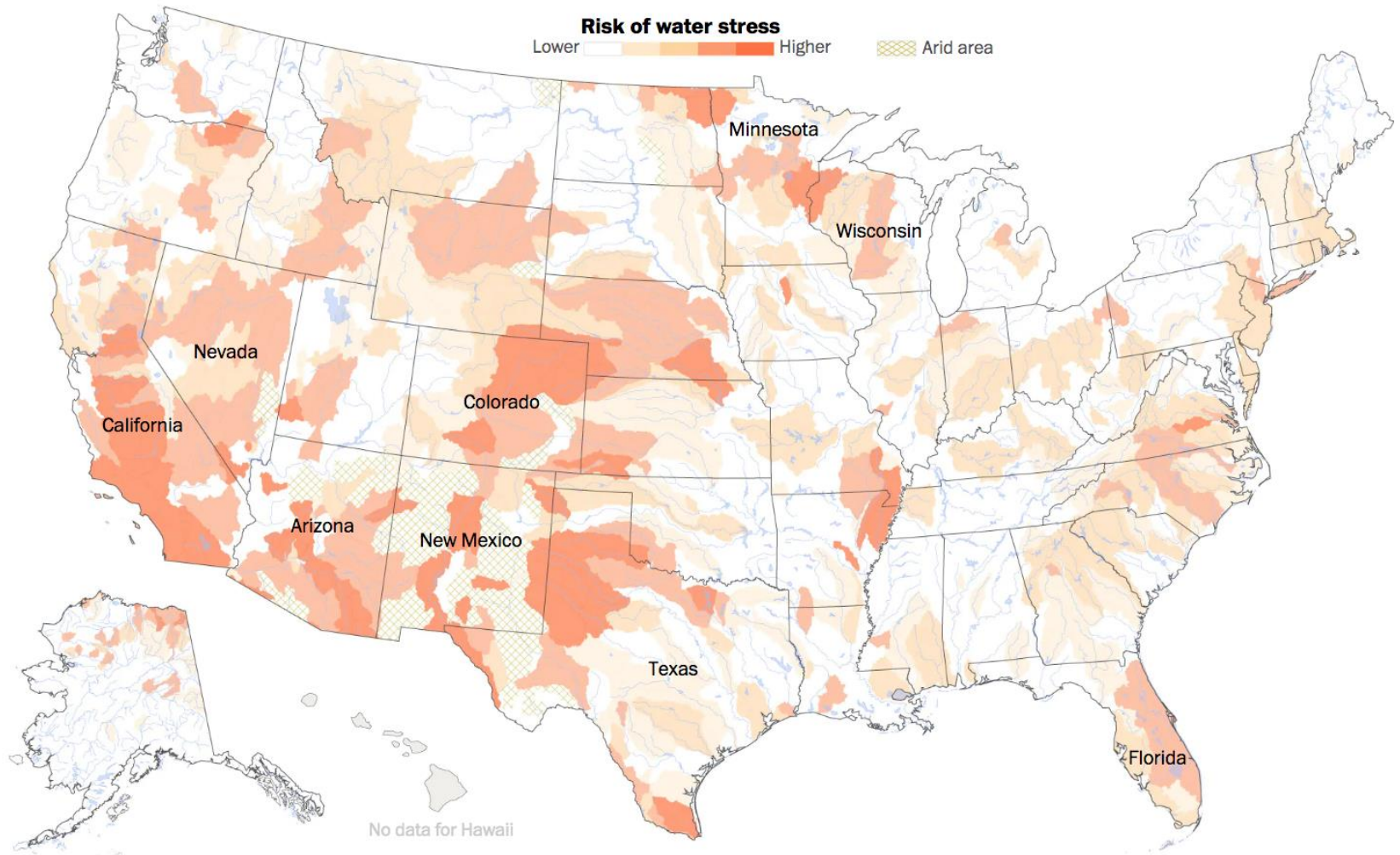
Evan A. Thomas, PhD, PE, MPH
Director, Associate Professor
evan.thomas@colorado.edu

A Quarter of Humanity Faces Looming Water Crises

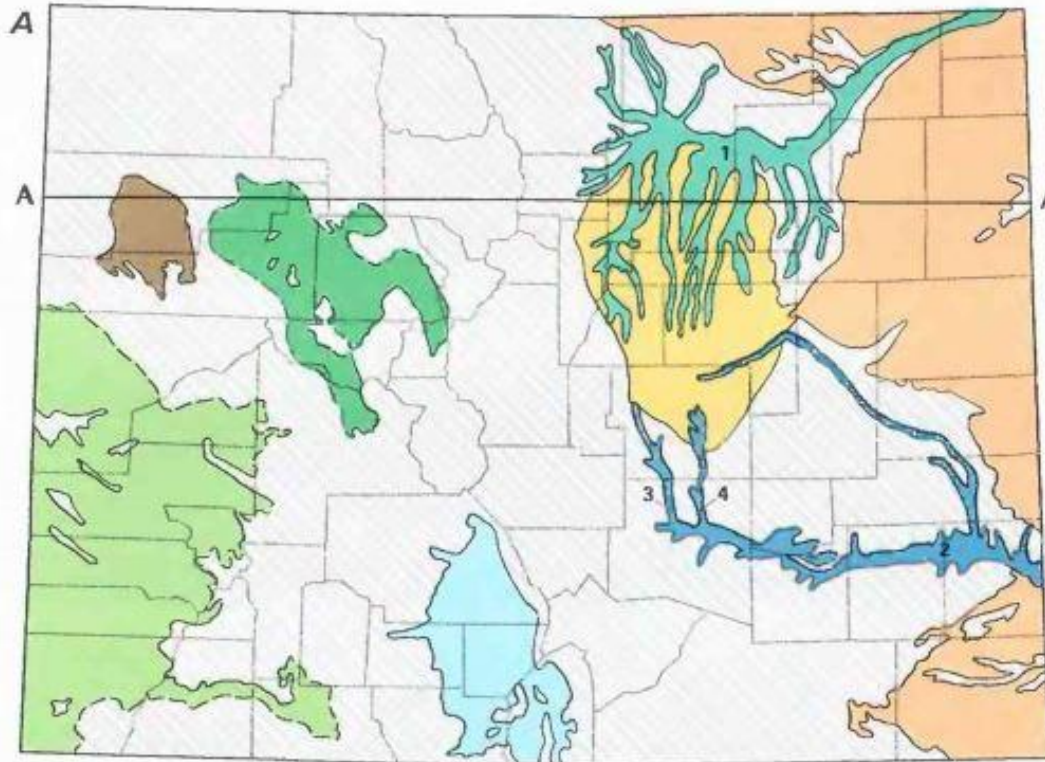
NYTimes – August 6, 2019



Water Stress



Colorado's Principle Aquifers



PRINCIPAL AQUIFER AND SUBDIVISIONS – Numeral is aquifer number in figure 2C

UNCONSOLIDATED SEDIMENTARY ROCK AQUIFERS

- South Platte alluvial (1)
- Arkansas alluvial (2-4)
 - Alluvium of Arkansas River (2)
 - Alluvium of Fountain Creek (3)
 - Alluvium of Black Squirrel Creek (4)
- High Plains (5)
- San Luis Valley aquifer system (6-7)
 - Unconfined (6)
 - Confined (7)

CONSOLIDATED SEDIMENTARY ROCK AQUIFERS

- Denver Basin aquifer system (8-11)
 - Dawson (8)
 - Denver (9)
 - Arapahoe (10)
 - Laramie-Fox Hills (11)
- Piceance Basin aquifer system (12-15)
 - Upper aquifer, upper part (12)
 - Upper aquifer, intermediate part (13)
 - Upper aquifer, lower part (14)
 - Lower aquifer (15)
- Leadville Limestone (16)
- Other – Dakota, Morrison, Entrada
- Not a principal aquifer

A—A' Trace of hydrogeologic section



The Global Pain

Climate change driven drought is increasing around the world.

East Africa has experienced 30% less rainfall annually over the past 30 years.

- 2011 drought killed 250,000 people and impacted 10 million.

Increasing drought in Costa Rica, Nicaragua, El Salvador, Honduras, Guatemala and Mexico are helping to drive migration and immigration crises.

California is expecting 20% less rainfall over the next 20 years.

- 2011-2017 drought cost the state over 15 billion dollars in economic damage.
- Sustainable Groundwater Management Act requires capping of all groundwater use.

Uncertain changes in precipitation expected in Colorado.

There are few technologies to meter and monitor surface and groundwater use.

Technologies for Distributed and Rapid Monitoring, Management and Trading of Water Resources

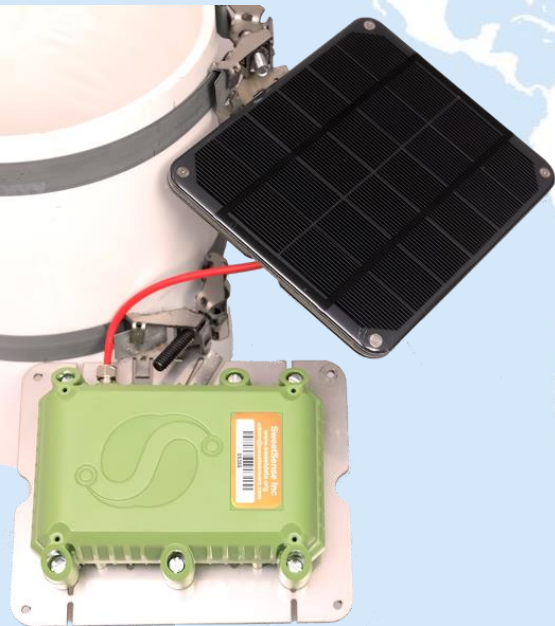
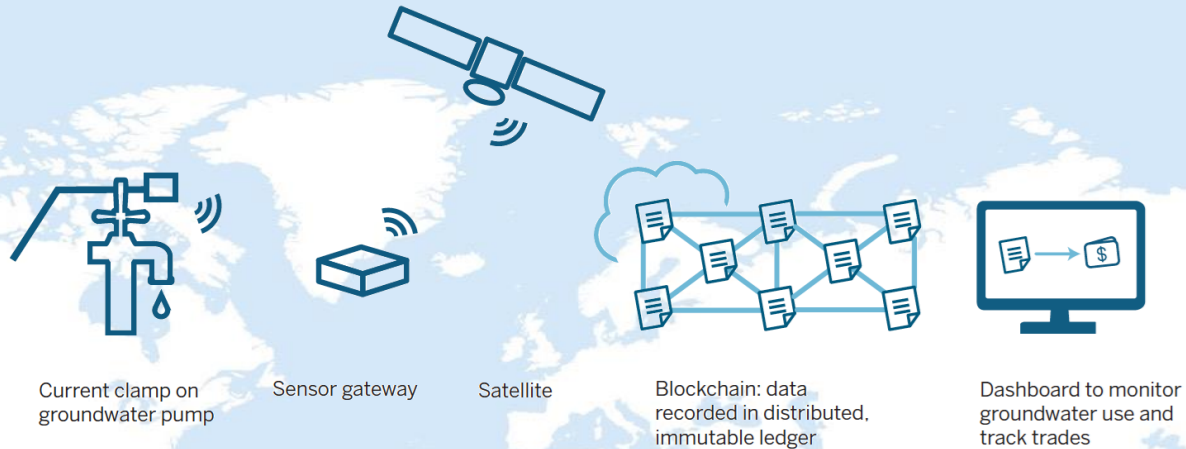
Technology	Application
Water Use Sensors	Measure surface and groundwater use
Water quality Sensors	Compliance, runoff, alarms
Satellite and Cellular Telemetry	Remote reporting of water data to stakeholders
Satellite Remote Sensing	Forecasting of surface and groundwater availability
Blockchain	Distributed, transparent, rapid trading of water use and conservation

Groundwater

- Groundwater is the world's most extracted raw material - nearly 1,000 km³ /year.
- Groundwater provides almost half of all drinking water worldwide.
- About 70% of groundwater withdrawn worldwide is used for agriculture.
- Globally, about 38% irrigation is with groundwater.
- Central Valley in California has sunk 30 feet since the 1920s.



Internet of Things for Water Services



Low-power, cellular or satellite enabled fully integrated instrument customized for installation in water systems.

Accessory sensors include low and self-powered transmitters, including custom designs and off-the-shelf products from other vendors.

Monitor groundwater use; surface water use; water quality; water trading.

Data is transmitted directly to online dashboards.

Machine learning algorithms analyze trends, alarms, and trigger actions.

Ending Drought Emergencies



Groundwater Sensor Fleet

Map of Latest Summary Status

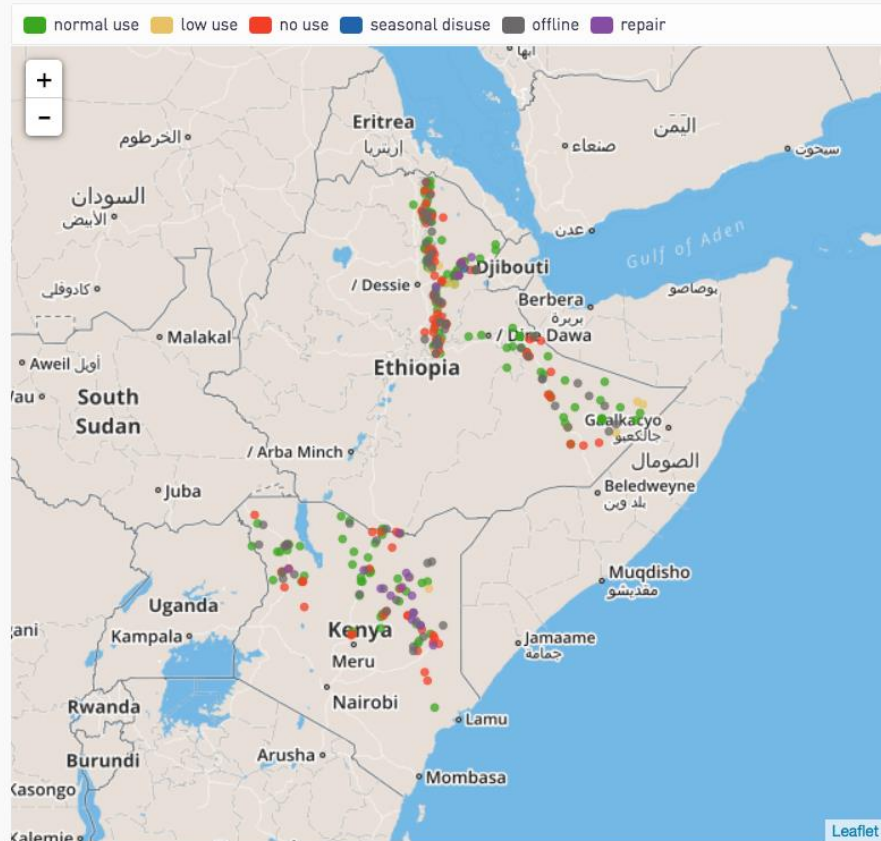
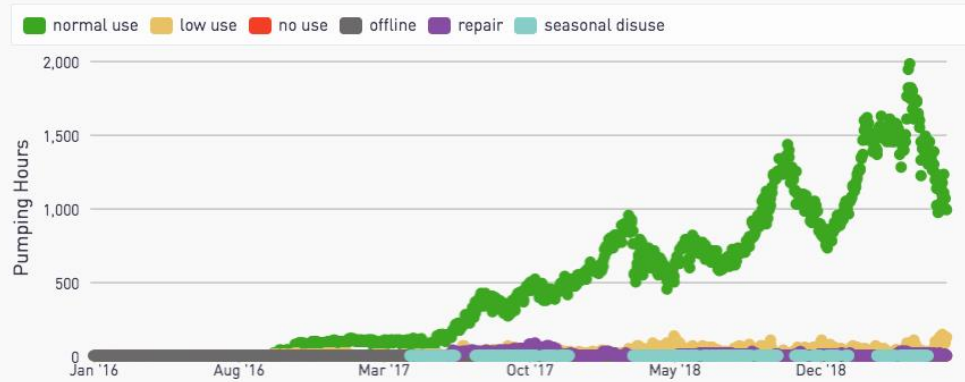


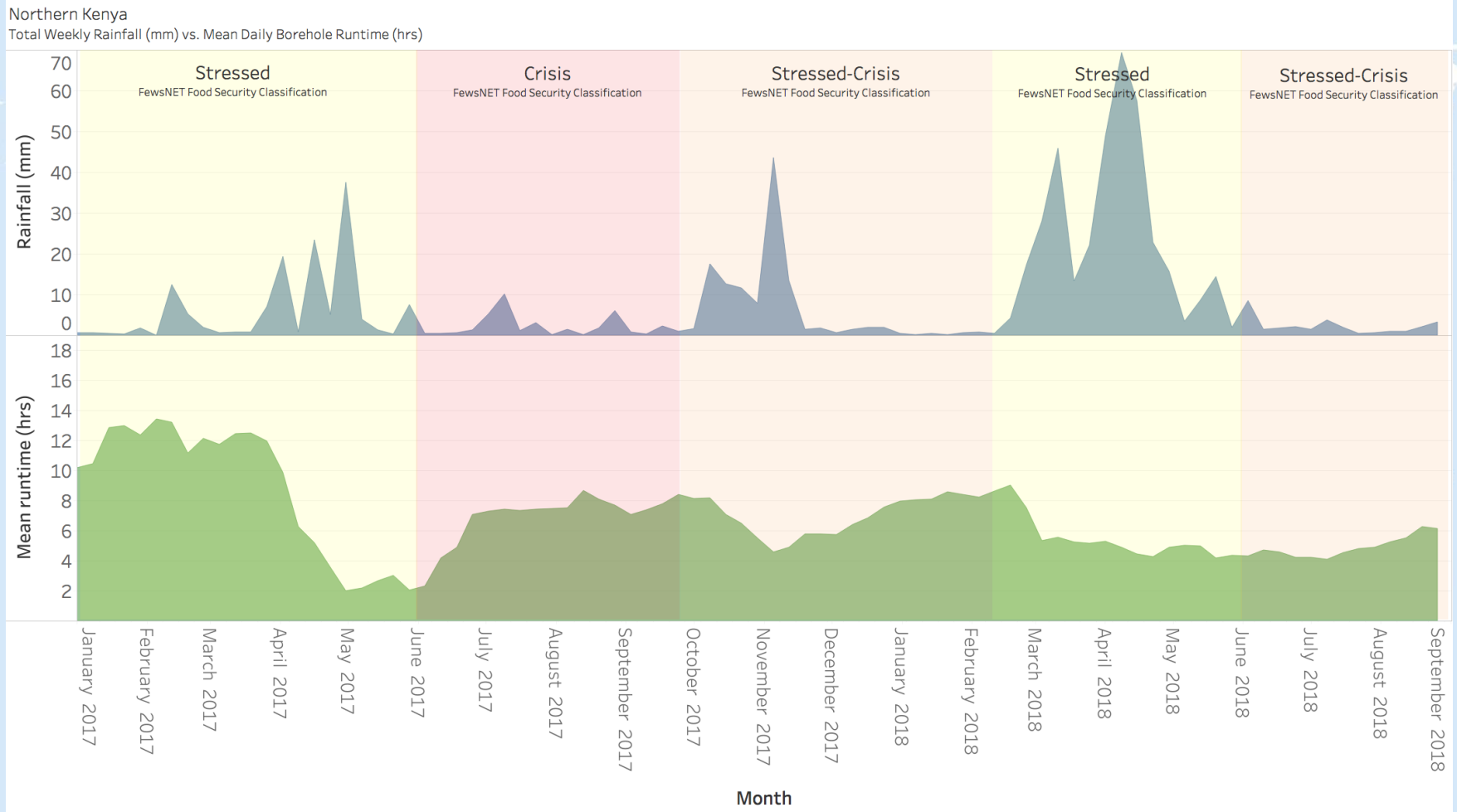
Table of Latest Site Summary Status

SITE NAME	MWATER ID	SUMMARY STATUS	STATUS DATE	LAST HEARTBEAT
Aba-barahabe3	36274783	no use	2019-06-03	2019-06-03
Ababarahabe - Baeeda, Gewane	21009406	offline	2019-06-03	2019-03-18
Ababarhabe	13952217	normal use	2019-06-03	2019-06-03
Ababerahbe	8826954	no use	2019-06-03	2019-06-02
Abakebra Deep well	13951962	normal use	2019-06-03	2019-06-03
Abala - Adaele	27416460	no use	2019-06-03	2019-06-03
Abala - Adikalu Mebrekubi	27416350	no use	2019-06-03	2019-06-03
Abala - Gorara	27416446	no use	2019-06-03	2019-06-03
Abala - Haramele	27416453	no use	2019-06-03	2019-06-03
Abda Water Scheme	19848439	offline	2019-06-03	2018-11-20

Scatter Chart of Total Pumping Hours per Day vs. Date by Summary Status



Partnering with USAID / NASA Famine Early Warning System Network (FEWS NET)



California Groundwater Monitoring and Crediting

GORDON AND BETTY
MOORE
FOUNDATION

WATER
FOUNDATION

The
Freshwater Trust®

SweetSense

- Contracted by the Moore Foundation, Water Foundation, and the Freshwater Trust to deploy our sensors in Solano County, California
- Assist Solano County GSA with SGMA compliance.
- Link sensor data to blockchain water credit trading platform.



Prototype Concept/Design



Current clamp on groundwater pump



Sensor gateway



Satellite

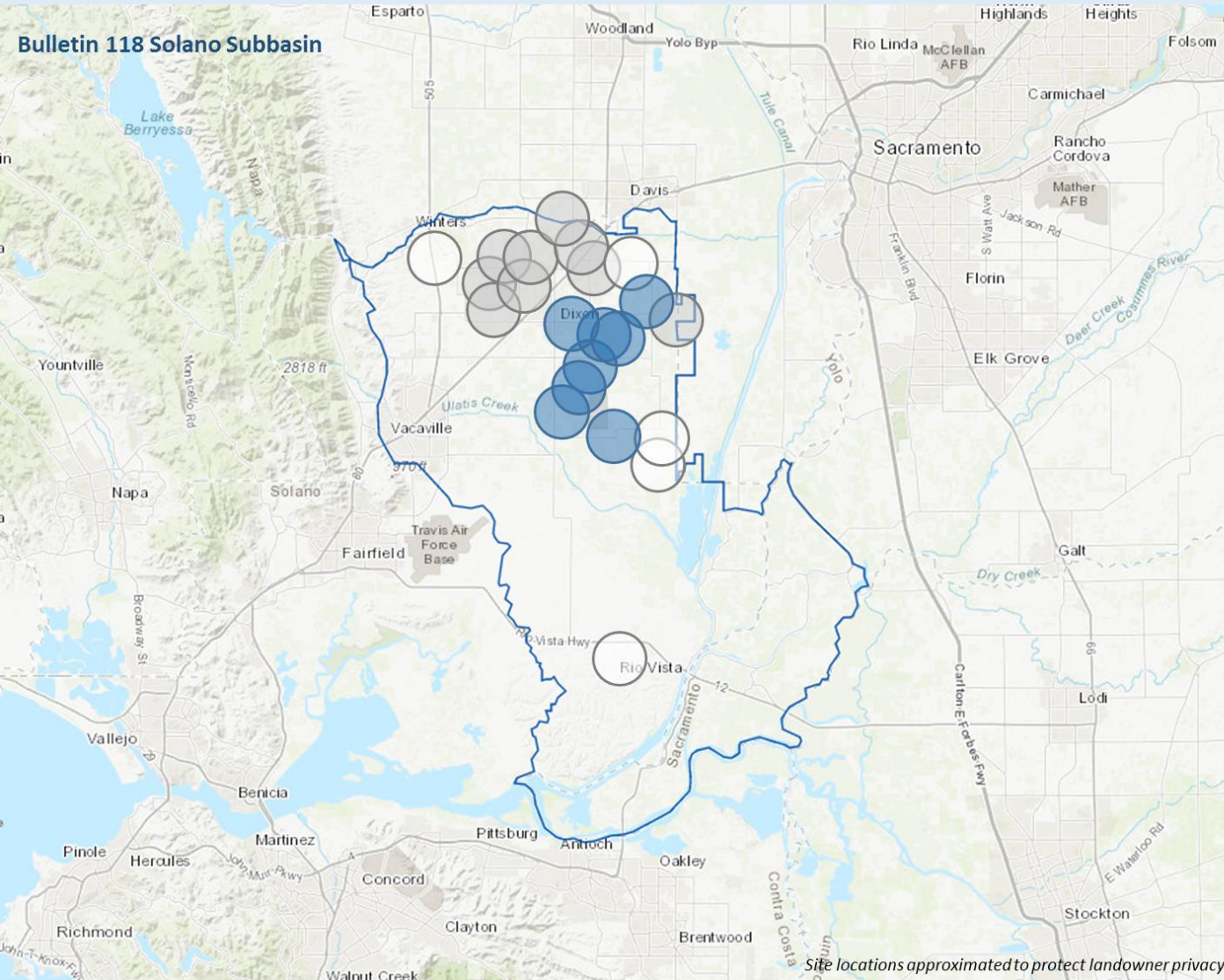


Blockchain: data recorded in distributed, immutable ledger



Dashboard to monitor groundwater use and track trades

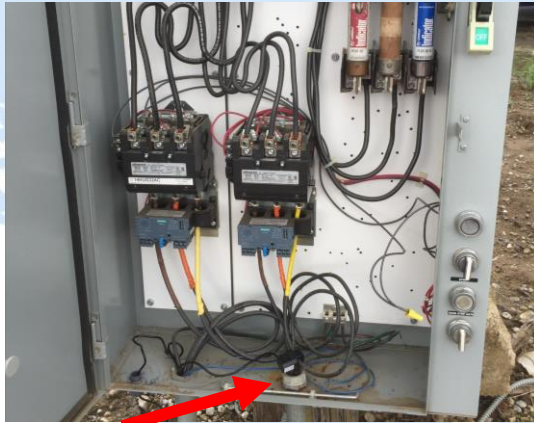
IoT Sensor Deployment



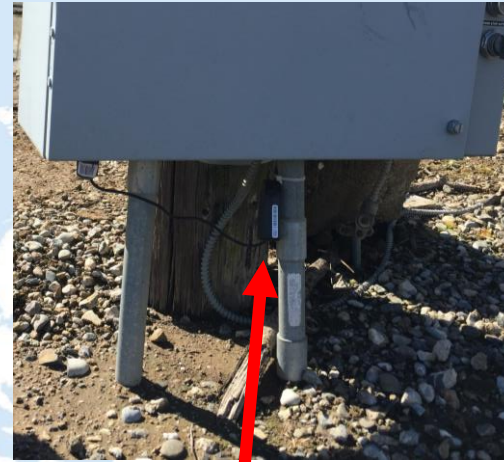
Installations



Implemented IoT Components



Current Clamp



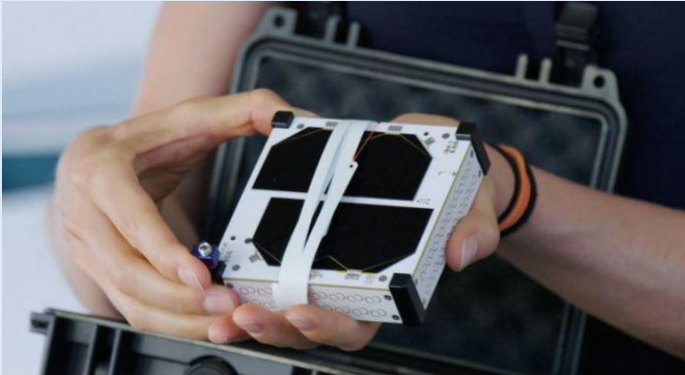
Local Transmitter



Gateway
Transmitter to
Satellite Network

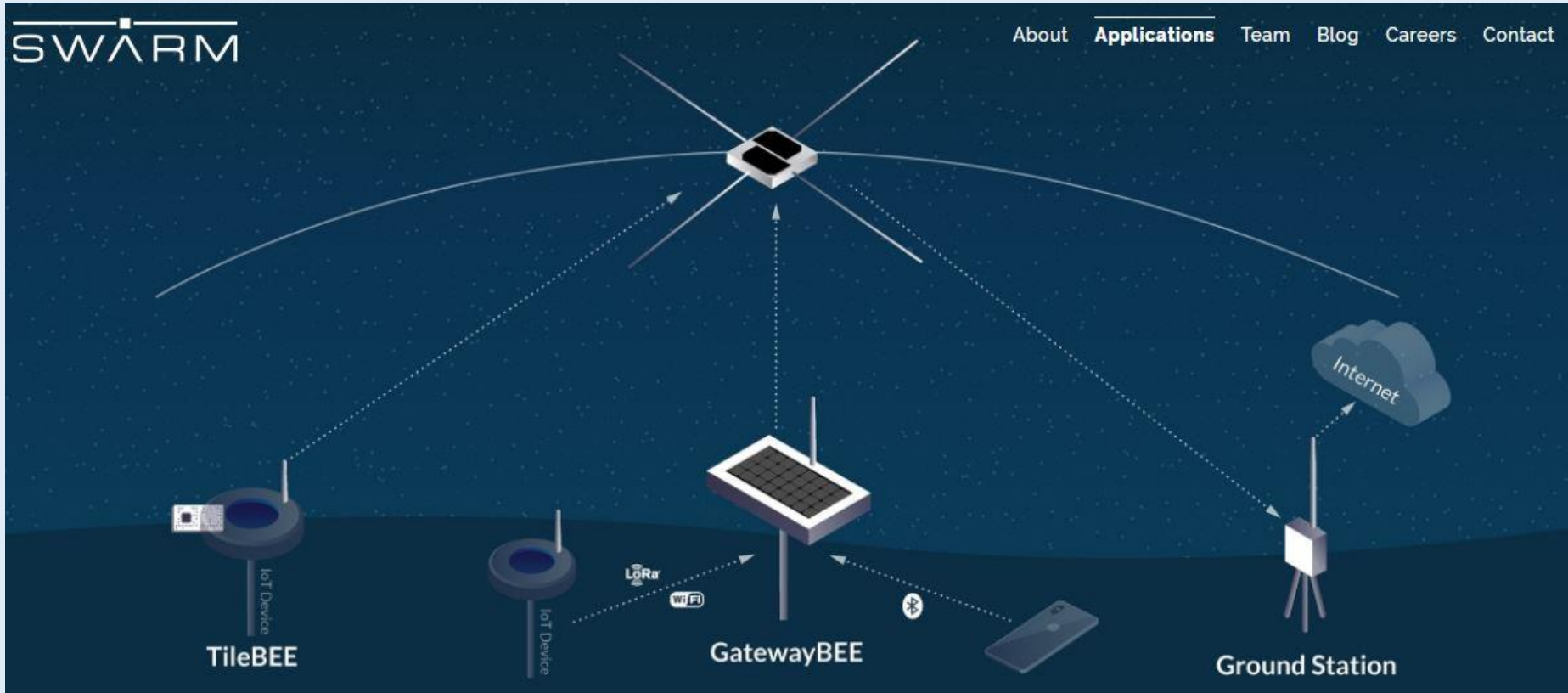
Solar panel

Low-Cost Satellite Network

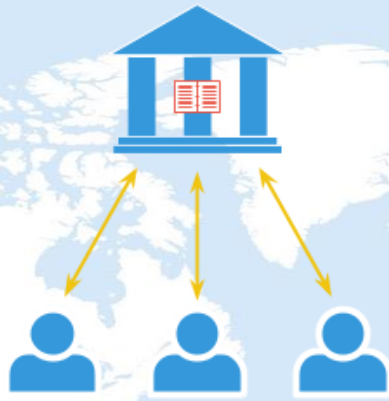


Swarm Technologies: startup in Palo Alto, CA

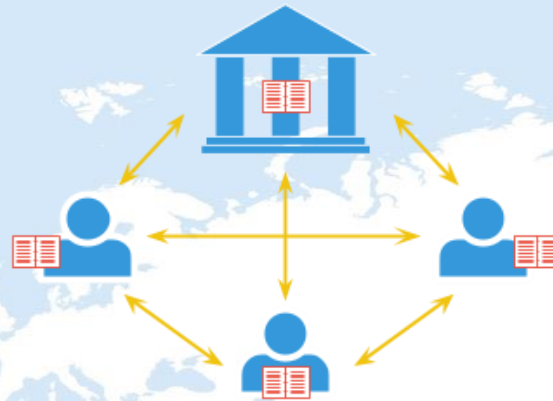
Use of satellite connectivity (via Swarm or Iridium network) an improvement over cellular



Blockchain 101



Centralized Ledger

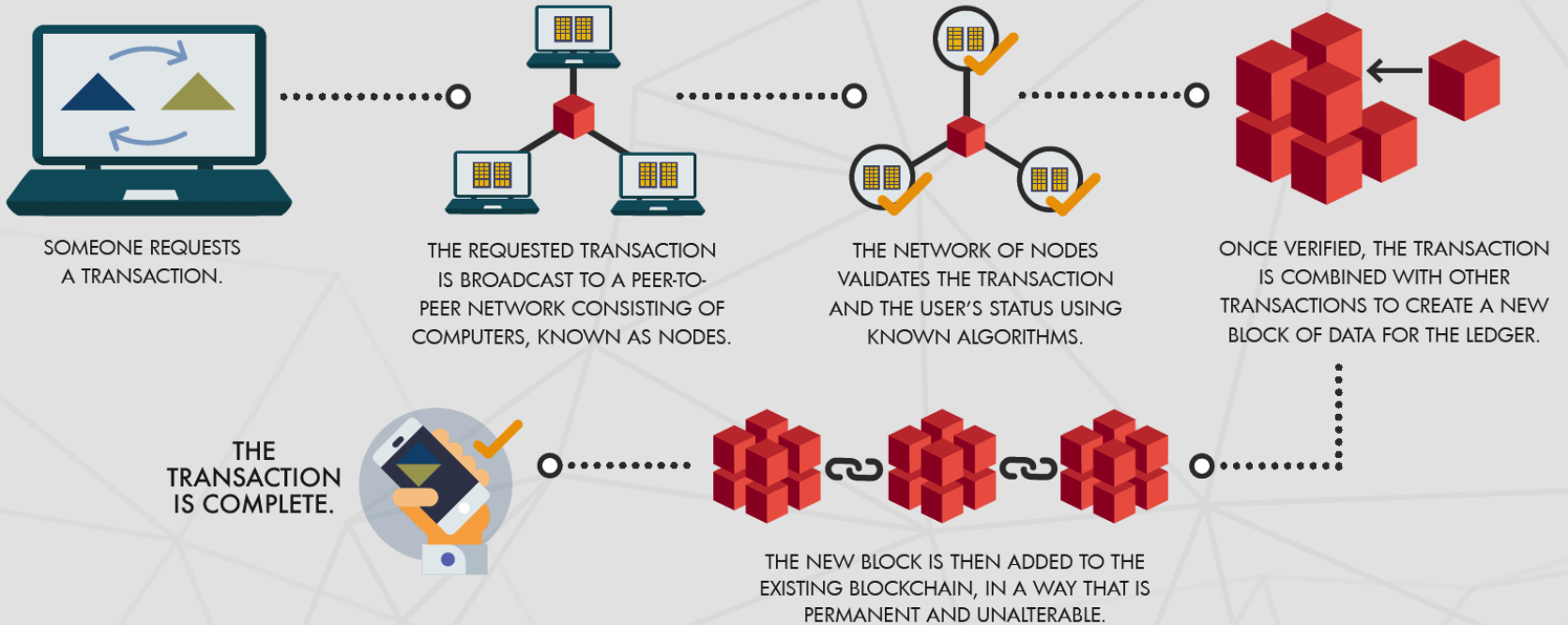


Distributed Ledger

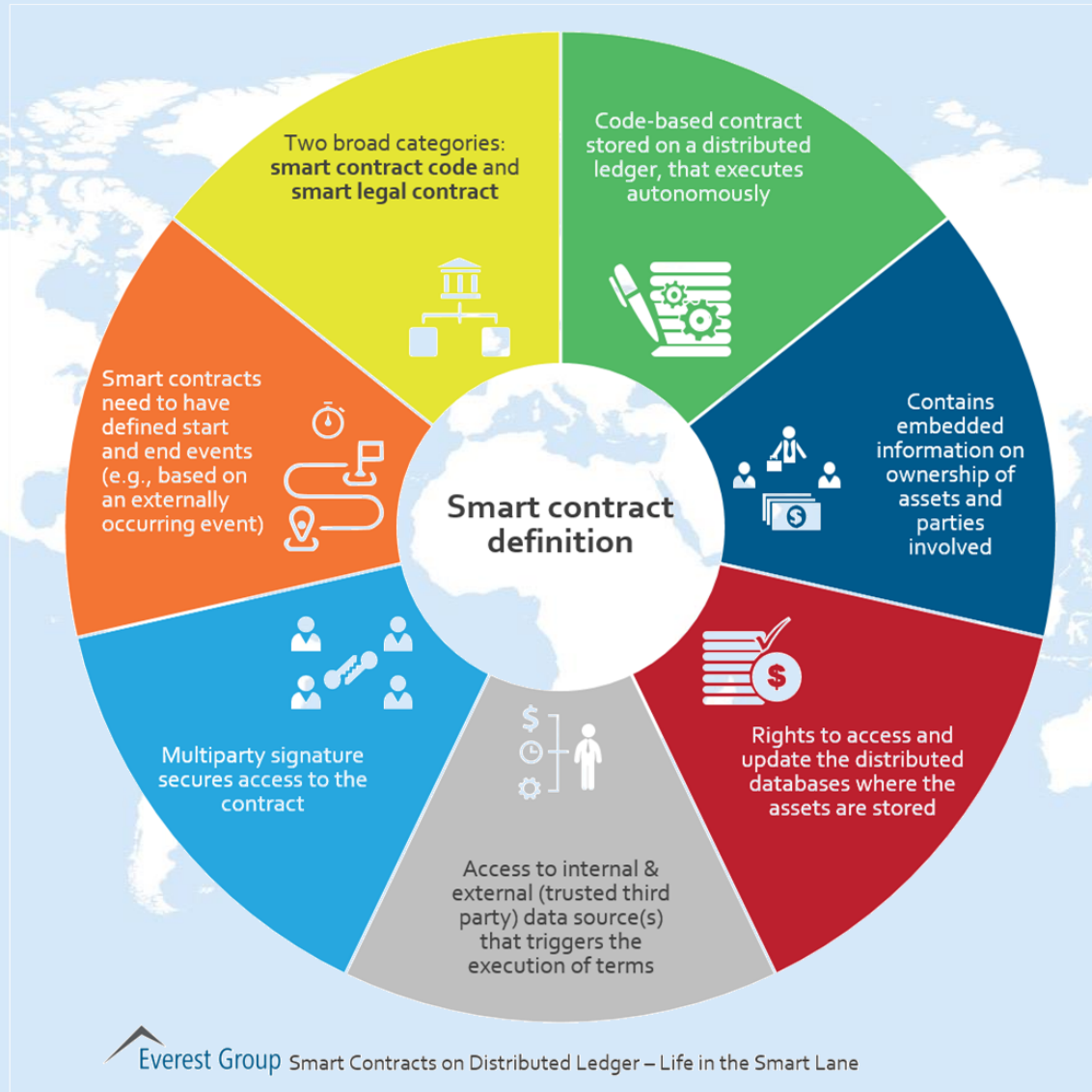
- Faster Settlement
- Increased network Capacity
- Secure
- Taperproof and Immutable
- No single authority

Blockchain 101

HOW DOES IT WORK?



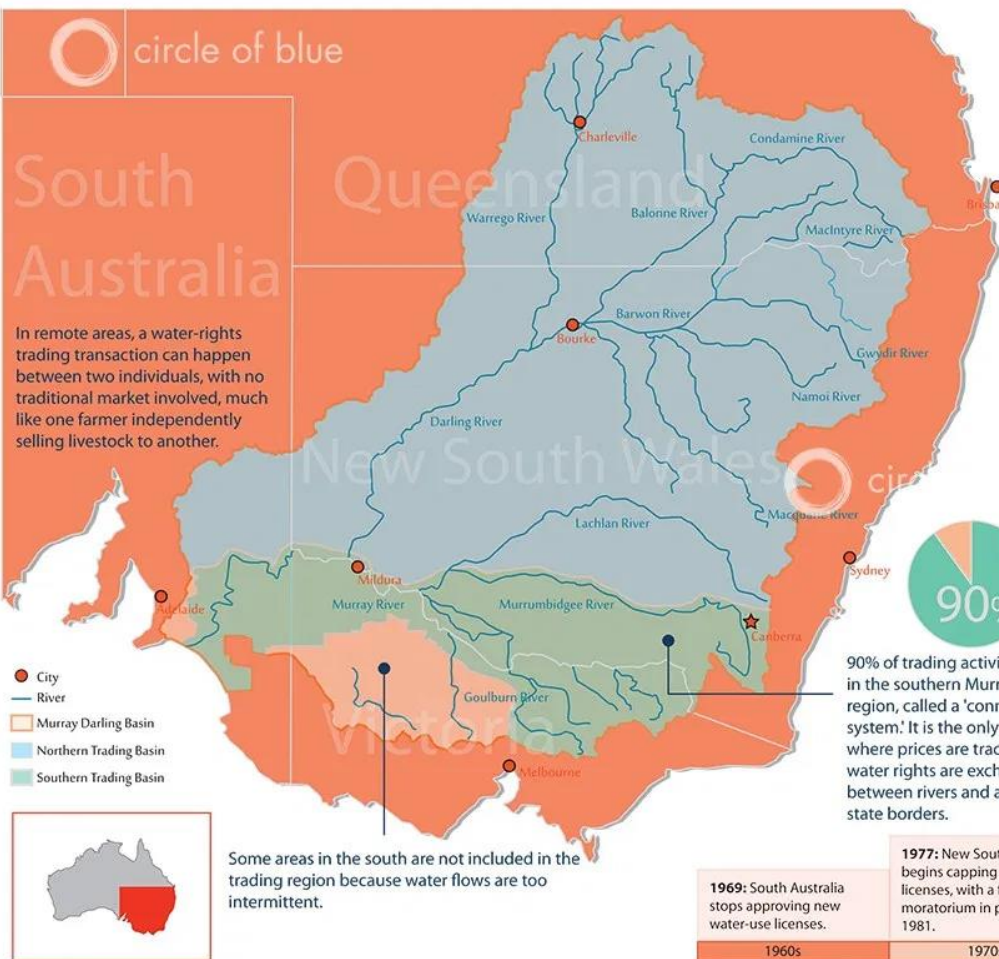
Blockchain Smart Contracts



Australia Smart Water Trading

Trading Water in Australia

Australia boasts the world's only large-scale system of water-rights trading, concentrated into three geographical regions: the southern and northern Murray-Darling Basin, and the territory outside the Basin's boundaries.



1982-1983: Widespread drought in Australia.

1983: Entitlement and allocation trading between private water users begins in South Australia's southern Murray-Darling Basin region.

1983: New South Wales allows trading of allocations.

1988: Establishment of the Murray-Darling Basin Commission, facilitating collaboration between state governments within the Basin, in addition to involvement by the national government.

1989: New South Wales allows trading of private entitlements by private users.

1989: After a lengthy review process and several major reports, water-rights trading begins in Victoria's southern Murray-Darling Basin region.

1989: South Australia allows trading of entitlements and allocations within publicly owned irrigation districts.

1992: Enactment of the first *Murray-Darling Basin Agreement*, which managed a comprehensive range of water- and land-use issues.

1994: Ratification of the Council of Australian Governments *Water Reform Framework*, intending to create a series of water markets within catchment areas while considering the health of the national water supply.

1994: Victoria allows trading of entitlements between publicly owned irrigation districts.

1995: South Australia allows trading between water users publicly owned irrigated land and private land.

1997: Total water extractions are capped in the Murray-Darling Basin for the first time.

2002-2003: Both state and federal governments refocus on sustainability as a wave of major drought hits, marking the early stages of the 10-year drought called *The Big Dry*.

2004: Establishment of the National Water Commission.

2007: Federal government passes *Water for the Future* plan containing three pieces:

1. Creates the *Murray-Darling Basin Plan*, guiding integrated management of the entire Basin by setting limits for water use and protecting flows for the environment.
2. Starts the *Restoring the Balance* program, which funds federal entitlement purchases from private users and reserves that water for the environment.
3. Promises extensive irrigation-system investment.

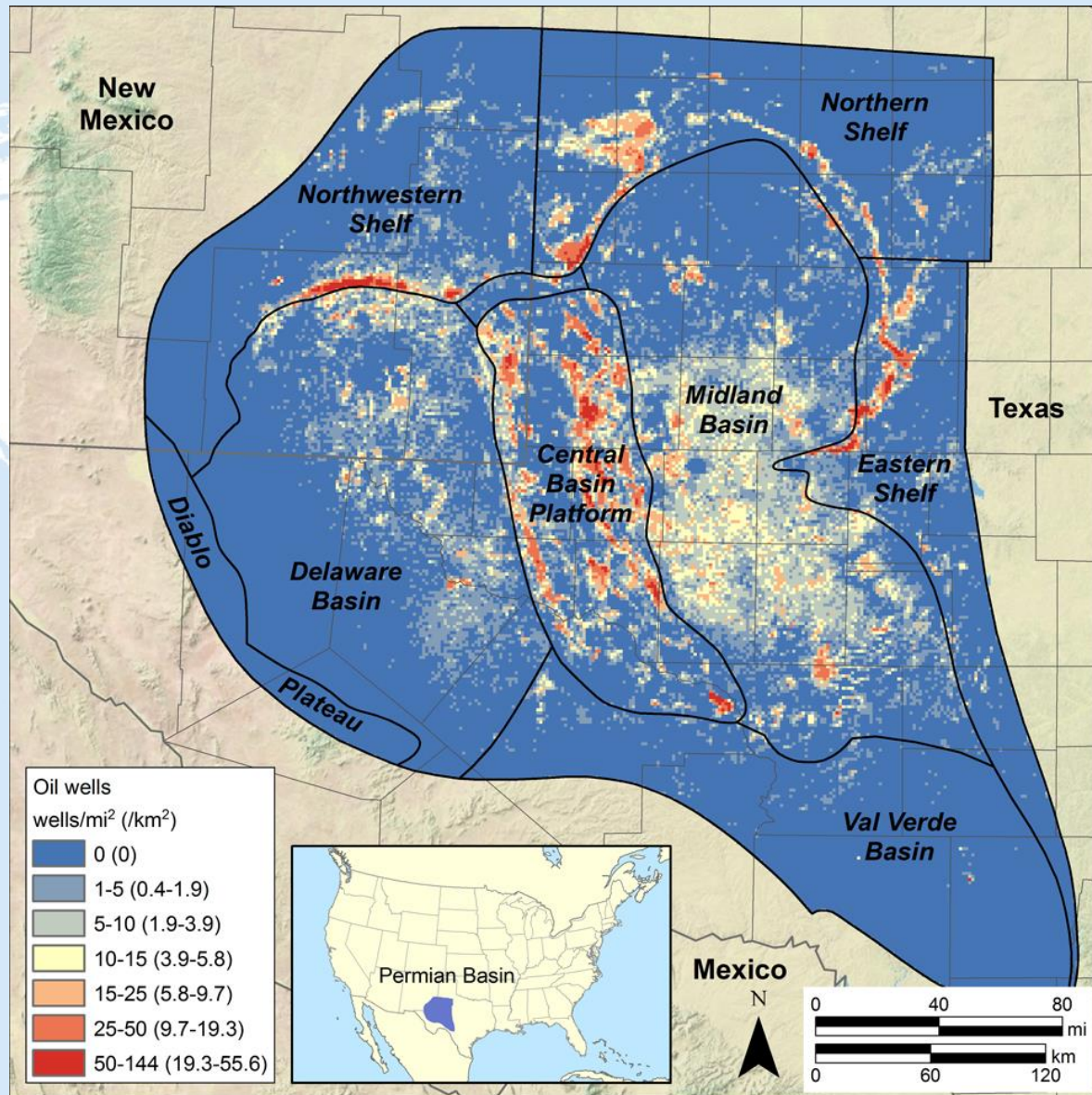
2011: End of the 10-year drought called *The Big Dry*.

April 2012: Australia's federal government purchases SUS 3.1 billion of water rights in the Murray-Darling Basin under the *Restoring the Balance* program.

November 2012: Federal government passes a new *Murray-Darling Basin Plan*, setting a target to return 2.75 billion cubic meters of surface water to the environment by 2019, primarily through entitlement purchases, and an additional 450 million cubic meters by 2024, through irrigation-system investments and efficiency upgrades.

Permian Basin

Blockchain Water Monitoring and Trading




Monitoring of Water Diversions in Colorado



Proposed Colorado Legislation





CREATIVE PLANNING IS DIFFERENT.



LEARN MORE >

DISCLOSURE



Yogita Khatri  

🕒 Mar 7, 2019 at 09:00 UTC • Updated Mar 7, 2019 at 09:05 UTC

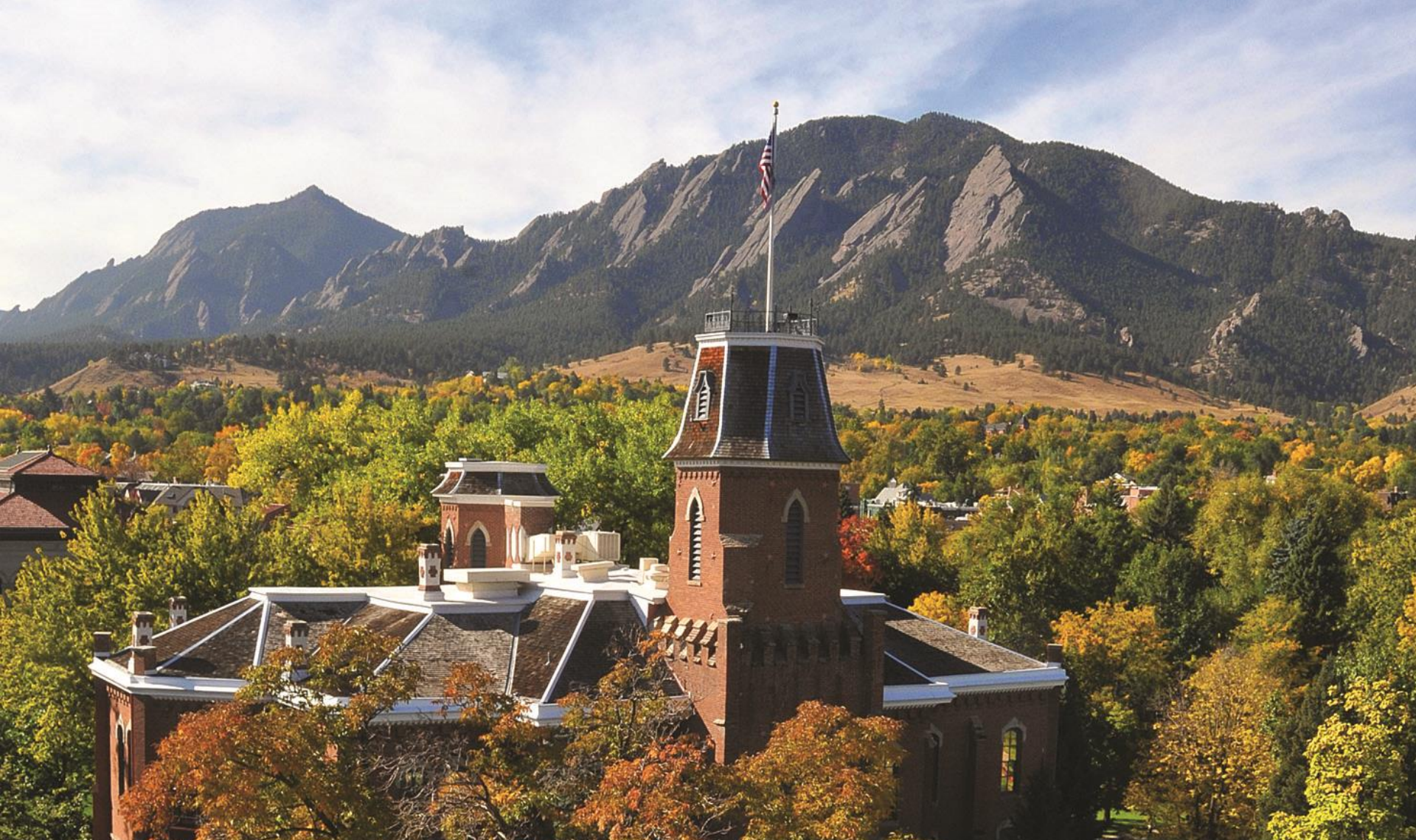
NEWS

Lawmakers in Colorado want the U.S. state to study the potential of blockchain technology in water rights management.

Republican senator Jack Tate, along with representatives Jeni James Arndt (Democratic) and Marc Catlin (Republican), filed [senate bill 184](#) on Tuesday, proposing that the Colorado Water Institute should be granted authority to study how blockchain technology can help improve its operations.

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