aquifer

Not under the Influence of Water

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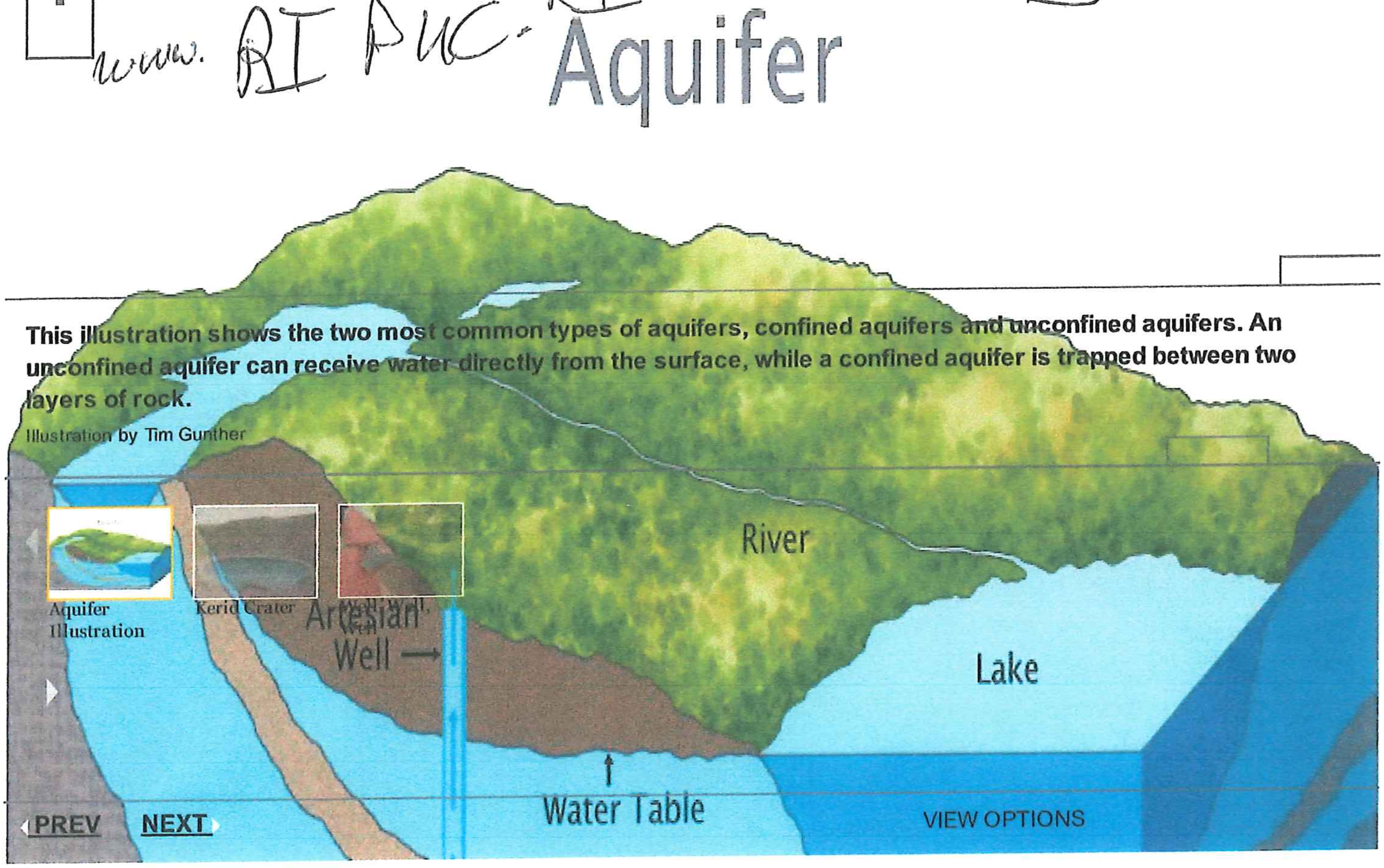

This illustration shows the two most common types of aquifers, confined aquifers and unconfined aquifers. An unconfined aquifer can receive water directly from the surface, while a confined aquifer is trapped between two layers of rock.

Illustration by Tim Gunther

Aquifer Illustration | Kerid Crater

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Encyclopedic Entry Vocabulary

An aquifer is an underground layer of water-bearing rock. Water-bearing rocks are permeable, meaning that they have openings that liquids and gases can pass through. Sedimentary rock such as sandstone, as well as sand and gravel, are examples of water-bearing rock. The top of the water level in an aquifer is called the water table.

An aquifer fills with water from rain or melted snow that drains into the ground. In some areas, the water passes through the soil on top of the aquifer; in others, it enters through joints and cracks in rocks. The water moves downward until it meets less permeable rock.

Aquifers act as reservoirs for groundwater. Water from aquifers sometimes flows out in springs. Wells drilled into aquifers provide water for drinking, agriculture, and industrial uses. Aquifers can dry up when people drain them faster than nature can refill them. Because aquifers fill with water that drains from the surface of the Earth, they can be contaminated by any chemical or toxic substance found on the surface.

There are two types of aquifers. An unconfined aquifer is covered by permeable rock and can receive water from the surface. The water table of an unconfined aquifer rises or falls depending on the amount of water entering and leaving the aquifer. It is only partly filled with water.

In contrast, a confined aquifer lies between two layers of less permeable rocks and is filled with water. Water trickles down through cracks in the upper layer of less permeable rock, a nearby water source, such as an underground river or lake, or a nearby unconfined aquifer.

An artesian well is a type of confined aquifer that flows upward to the Earth's surface without the need for pumping. The artesian well sits below the water table at the bottom of U-shaped aquifers. Pressure from water in the long sides of the aquifer pushes the water up the well shaft.

Articles & Profiles

- National Geographic News: Underground 'Fossil Water' Running Out

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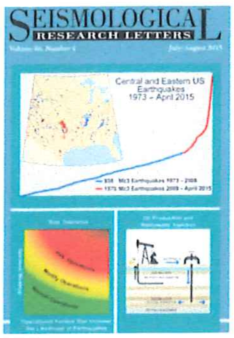
USGS
science for a changing world

Earthquake Hazards Program

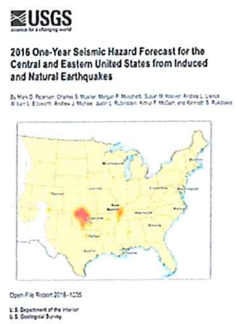
Induced Earthquakes

In the News



Introduction to Induced Seismicity

Learn what causes induced earthquakes.



New Hazard Model for Induced Earthquakes

USGS Releases First Ever Assessment of Hazard from Induced Earthquakes.

Myths and Misconceptions

What you do and don't know about induced seismicity

Frequently Asked Questions

- Earthquakes induced by fluid injection
- Hydraulic fracturing (fracking)

Within the central and eastern United States, the number of earthquakes has increased dramatically over the past few years. Between the years 1973–2008, there was an average of 21 earthquakes of magnitude three and larger in the central and eastern United States. This rate jumped to an average of 99 M3+ earthquakes per year in 2009–2013, and the rate continues to rise. In 2014, alone, there were 659 M3 and larger earthquakes. Most of these earthquakes are in the magnitude 3–4 range, large enough to have been felt by many people, yet small enough to rarely cause damage. There were reports of damage from some of the larger events, including the M5.6 Prague, Oklahoma earthquake and the M5.3 Trinidad, Colorado earthquake.

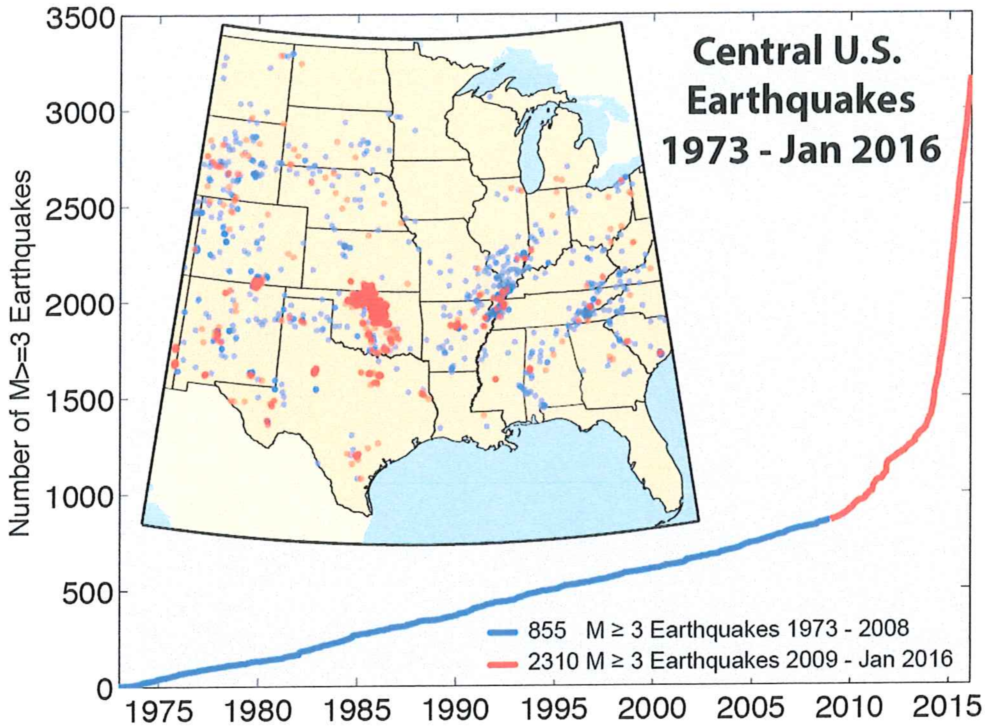
This increase in earthquakes prompts two important questions:

- Are they natural, or man-made?
- What should be done in the future as we address the causes and consequences of these events to reduce associated risks?

Oilfield waste arrives by tanker truck at a wastewater disposal facility near Platteville, Colo. After removal of solids and oil, the wastewater is injected into a deep well for permanent storage underground. Photo by Bill Ellsworth, USGS.

Increasing Rate of Earthquakes Beginning in 2009

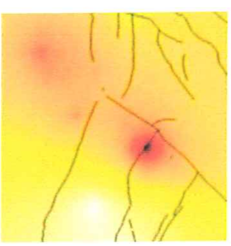
Cumulative number of earthquakes with a magnitude of 3.0 or larger in the central and eastern United States, 1970–2016. The long-term rate of approximately 29 earthquakes per year increased sharply starting around 2009.



Current Research

Observational Studies

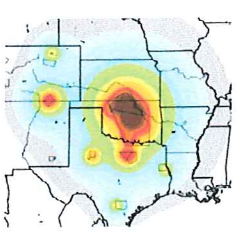
The USGS is currently studying seismicity that may be induced at 6 locations across the United States. These studies involve earthquake monitoring, examining industrial data, and evaluating any relationships between seismicity and industrial actions. Previous USGS studies have shown a strong connection in many locations between the deep injection of fluids and increased earthquake rates.



Numerical Modeling

The USGS uses numerical simulations of earth processes to:

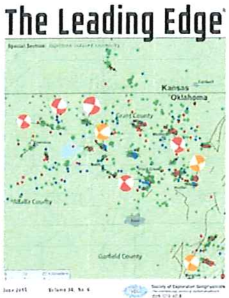
- Evaluate the physical relationships between fluid injection and earthquakes at specific sites
- Simulate possible future behaviors of new and ongoing injection projects



Hazard Estimation

The USGS is currently developing new methods to evaluate the hazard due to induced earthquakes. These methods will account for the rapid changes in earthquake rate that we have witnessed in the past few years.

Special Issues on Induced Seismicity



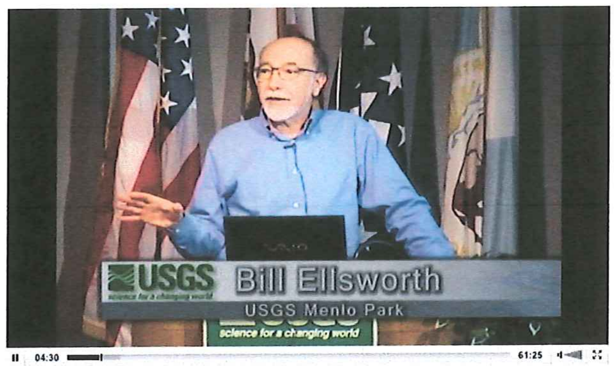
[The Leading Edge](#)

The June issue of The Leading Edge features a special section on Injection-induced seismicity. Four USGS studies were included as part of this issue.

Yes, Humans Are Causing Earthquakes

USGS scientist Justin Rubinstein gives an overview on human-caused earthquakes.

Injection-Induced Seismicity



USGS scientist Bill Ellsworth discusses the science behind induced earthquakes.

See Also

- USGS Energy Program: Geologic Carbon Sequestration
- USGS Publications on Induced Seismicity

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California's Central Valley has seen a dramatic rise in well-drilling this year to compensate for surface water lost from the drought.

PHOTOGRAPH BY PETER ESSICK, NATIONAL GEOGRAPHIC

A severe drought in California—now approaching four years long—has depleted snowpacks, rivers, and lakes, and groundwater use has soared to make up the shortfall. A new report from Stanford University says that nearly 60 percent of the state's water needs are now met by groundwater, up from 40 percent in years when normal amounts of rain and snow fall.

Relying on groundwater to make up for shrinking surface water supplies comes at a rising price, and this hidden water found in California's Central Valley aquifers is the focus of what amounts to a new gold rush. Well-drillers are working overtime, and asBrian Clark Howard reported here last week, farmers and homeowners short of water now must wait in line more than a year for their new wells.

In most years, aquifers recharge as rainfall and streamflow seep into unpaved ground. But during drought the water table—the depth at which water is found below the surface—drops as water is pumped from the ground faster than it can recharge. As Howard reported, Central Valley wells that used to strike water at 500 feet deep must now be drilled down 1,000 feet or more, at a cost of more than $300,000 for a single well. And as aquifers are depleted, the land also begins to subside, or sink.

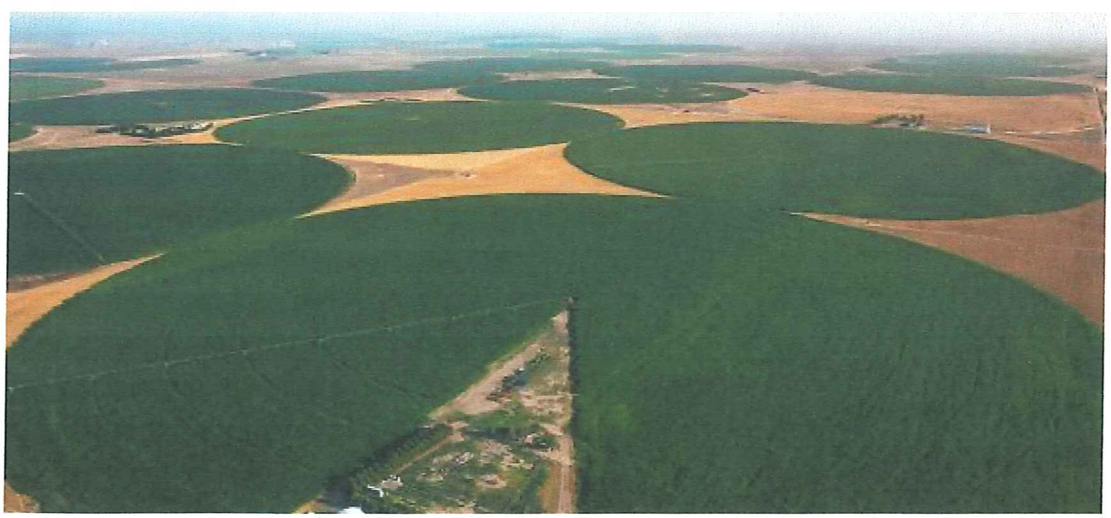
Unlike those in other western states, Californians know little about their groundwater supply because well-drilling records are kept secret from public view, and there is no statewide policy limiting groundwater use. State legislators are contemplating a measure that would regulate and limit groundwater use, but even if it passes, compliance plans wouldn't be required until 2020, and full restrictions wouldn't kick in until 2040. California property owners now can pump as much water as they want from under the ground they own.

California's Central Valley isn't the only place in the U.S. where groundwater supplies are declining. Aquifers in the Colorado River Basin and the southern Great Plains also suffer severe depletion. Studies show that about half the groundwater depletion nationwide is from irrigation. Agriculture is theleading use of water in the U.S. and around the world, and globally irrigated farming takes more than 60 percent of the available freshwater.

The Colorado River Basin, which supplies water to 40 million people in seven states, is losing water at dramatic rates, and most of the losses are groundwater. A new satellite study from the University of California, Irvine and NASA indicates that the Colorado River Basin lost 65 cubic kilometers (15.6 cubic miles) of water from 2004 to 2013. That is twice the amount stored in Lake Mead, the largest reservoir in the U.S., which can hold two years' worth of Colorado River runoff. As Jay Famiglietti, a NASA scientist and study co-author wrote here, groundwater made up 75 percent of the water lost in the basin.

Farther east, the Ogallala Aquifer under the High Plains is also shrinking because of too much demand. When the Dust Bowlovertook the Great Plains in the 1930s, the Ogallala had been discovered only recently, and for the most part it wasn't tapped then to help ease the drought. But large-scale center-pivot irrigation transformed crop production on the plains after World War II, allowing water-thirsty crops like corn and alfalfa for feeding livestock.

But severe drought threatens the southern plains again, and water is being unsustainably drawn from the southern Ogallala Aquifer. The northern Ogallala, found near the surface in Nebraska, is replenished by surface runoff from rivers originating in the Rockies. But farther south in Texas and New Mexico, water lies hundreds of feet below the surface, and does not recharge. Sandra Postel wrote here last month that the Ogallala Aquifer water level in the Texas Panhandle has dropped by up to 15 feet in the past decade, with more than three-quarters of that loss having come during the drought of the past five years. A recent Kansas State University study said that if farmers in Kansas keep irrigating at present rates, 69 percent of the Ogallala Aquifer will be gone in 50 years.



The Ogallala Aquifer supplies the water for center-pivot irrigation on farms in western Kansas.

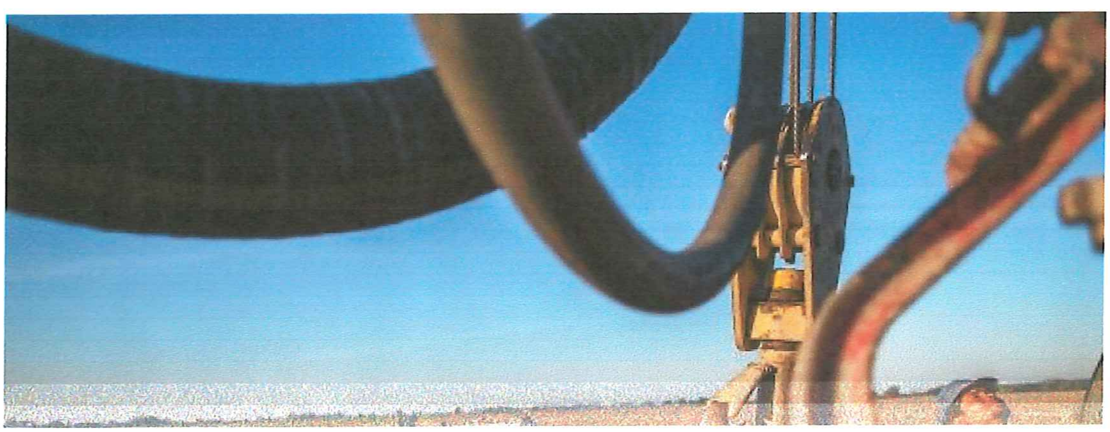
PHOTOGRAPH BY GEORGE STEINMETZ, NATIONAL GEOGRAPHIC CREATIVE

This coincides with a nationwide trend of groundwater declines. A 2013 study of 40 aquifers across the United States by the U.S. Geological Survey reports that the rate of groundwater depletion has increased dramatically since 2000, with almost 25 cubic kilometers (six cubic miles) of water per year being pumped from the ground. This compares to about 9.2 cubic kilometers (1.48 cubic miles) average withdrawal per year from 1900 to 2008.

Scarce groundwater supp

warming the planet. Because the surface of the sea is all we see, it's difficult to understand that we already have taken most of the large fish from the ocean, diminishing a major source of food. Neither of these crises are visible—they are largely out of sight, out of mind—so it's difficult to get excited and respond. Disappearing groundwater is another out-of-sight crisis.

Groundwater comes from aquifers—spongelike gravel and sand-filled underground reservoirs—and we see this water only when it flows from springs and wells. In the United States we rely on this hidden—and shrinking—water supply to meet half our needs, and as drought shrinks surface water in lakes, rivers, and reservoirs, we rely on groundwater from aquifers even more. Some shallow aquifers recharge from surface water, but deeper aquifers contain ancient water locked in the earth by changes in geology thousands or millions of years ago. These aquifers typically cannot recharge, and once this "fossil" water is gone, it is gone forever—potentially changing how and where we can live and grow food, among other things.



Home > Renewable Energy Information

Wind

Energy Efficiency

RIWINDS Phase I Report

Wind Turbine Siting in Narragansett

State/ Narragansett Wind Turbine Partnership RFP

DEM Wind Turbine Siting Guidelines

Narragansett Clean Energy Survey Results

Narragansett Survey Mailing

Narragansett Beach Clean Energy Survey

Simulation Photos of Potential Narragansett Sites

Meterological Tower

New England Greenstart

Narragansett Wind Turbine

Renewable Energy Information

Rhode Island's Future:

Issues dealing with energy, energy supply, and demand for energy currently and within the immediate and distant future are becoming increasingly relevant. In a time in which the supply of non-renewable fuel (oil, gas, coal or nuclear energy) is inconstant, expensive, and un-assured, the energy independence offered by renewable energy (wind, solar, hydrodynamic) is of great value. Additionally reduction of our demand through smart energy efficiency measures (proper seasonal design, green building, efficient appliances and practices) helps Rhode Island stay energy-independent and saves us money.

Rhode Island is in a unique position to lead the rest of New England, and the Nation, in becoming a leader in renewable energy technologies, in its production, installation, maintenance. Supporting this blossoming industry will create an example of a new green economy that brings sustainable jobs while also bringing energy independence, economical savings and reducing environmental impact. Wind, solar, energy efficiency, and other projects are being built all over the nation; this is Rhode Island's chance to be ahead of the pack, as a leader, when it comes to energy.

DEM:

The RI Department of Environmental Management's mission is to protect and manage the precious and valuable environment and resources Rhode Island has to offer. As energy use and environmental quality are intrinsically linked, DEM seeks to truly "walk the talk" when it comes to the smart use of energy.

DEM has begun to look at ways to reduce its use of energy through improvements in building design that are energy efficient. DEM is also looking at designing buildings that make use of solar and wind technologies that help minimize our use of non-renewable fuels.

In order to be a leader and serve as an example of successful environmental protection and smart energy usage, DEM currently has several clean energy projects underway. These include a wind energy partnership with the Town of Narragansett, and the installation of a LEED silver certified energy efficient green building at Salty Brine State Beach. DEM seeks to adapt its Narragansett facilities in order to save taxpayer money through these measures, as well as to promote the use and prove the viability of renewable energy technology in Rhode Island.

DEM's renewable vision:

We all need to act now to slow global warming and other changes to Rhode Island's climate. Scientists predict that the climate of Rhode Island will be more like that of Georgia by the year 2100 leading to unwelcome changes such as more heat-related death and illness, more powerful and frequent storms, more high ozone days, more water shortages, more warm weather species, etc.

DEM recognizes that as a state we can not solve the global warming problem by ourselves. DEM has been actively involved in regional organizations that seek to mitigate global warming pollution by reducing greenhouse gas emissions throughout the region. DEM is also supportive of the governor's

Update	goal to require renewable sources of energy to provide energy to the state.
Contact and Comment	There are things we can do to reduce our carbon footprint. DEM has increased its efforts to reduce its energy consumption through smart efficiency measures. Through support of the renewable energy industry in Rhode Island and the new jobs it brings; DEM's vision is to reduce greenhouse emissions and to save tax payer money with reliable energy independence. Realization of this vision would see Rhode Island truly become a "green energy" state, with all of the benefits that entails.

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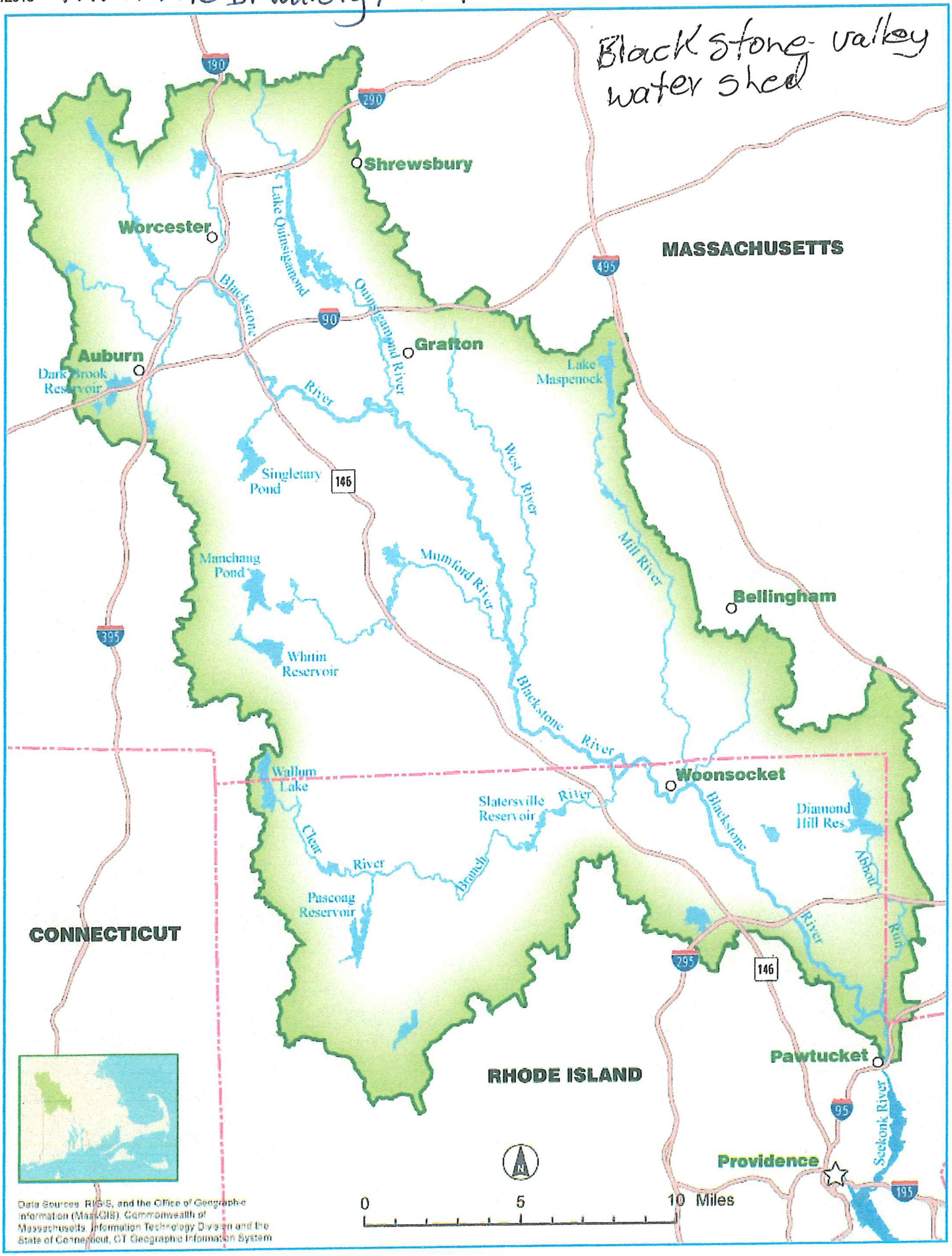
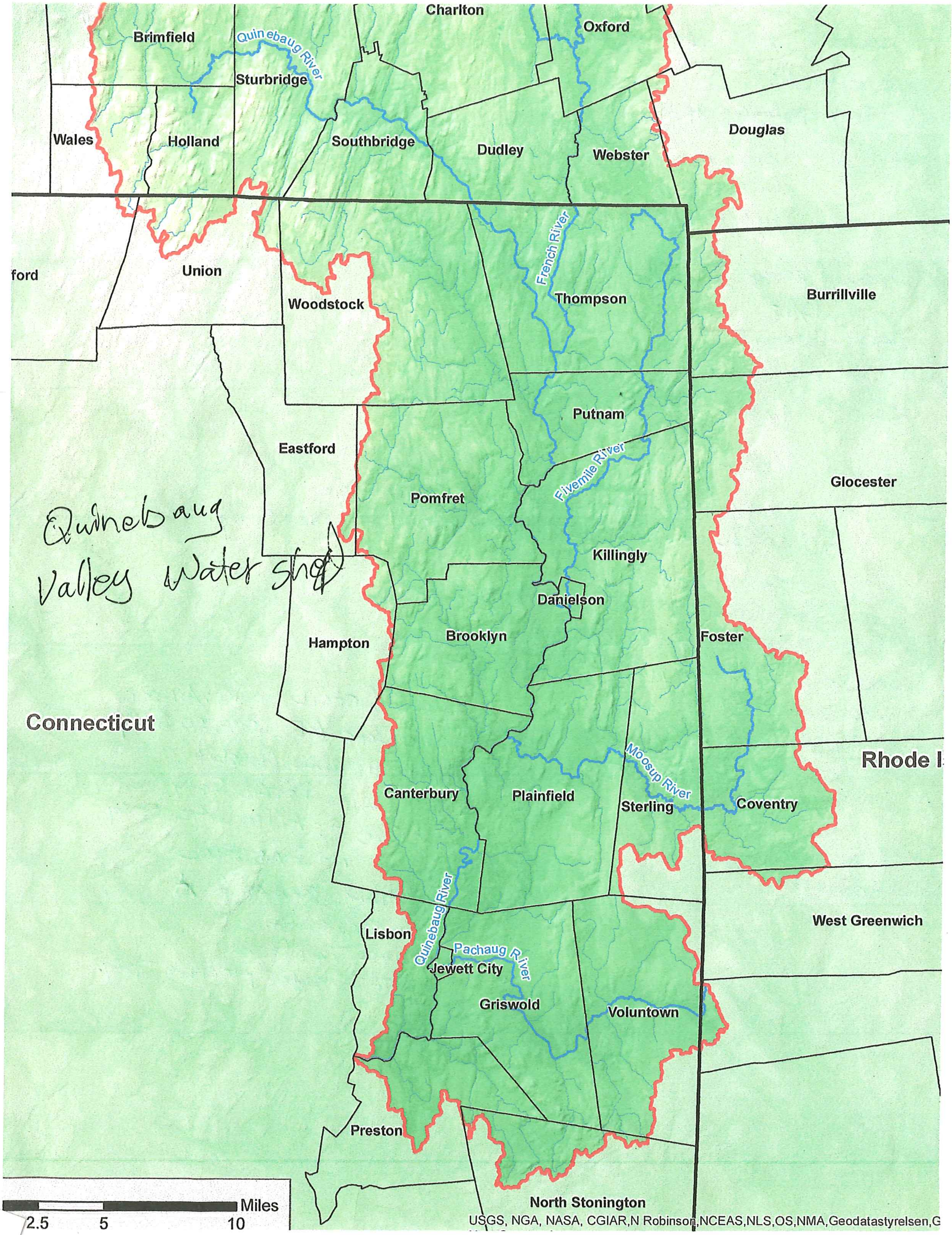


Blackstone River Watershed Association, 271 Oak Street, Uxbridge, MA 01569 Telephone: 508-278-5200 Email: info@thebrwa.org


Quinebaug Valley Water Shed
Charlton
Oxford
Brimfield
Quinebaug River
Sturbridge
Wales
Holland
Southbridge
Dudley
Webster
Douglas
Union
ford
Woodstock
French River
Thompson
Burrillville
Putnam
Eastford
Fivemile River
Pomfret
Glocester
Killingly
Danielson
Hampton
Brooklyn
Foster
Connecticut
Moosup River
Canterbury
Plainfield
Sterling
Coventry
Rhode I
Lisbon
Quinebaug River
Pachaug River
Jewett City
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