

# West-Wide Analysis of the Energy-Water Nexus

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*Sandia National Laboratories  
Albuquerque, New Mexico*

Energy and Water 2011

Efficiency, Generation, Management and Climate Impact

*Water Environment Federation*

*Chicago, IL*

*August 2, 2011*



Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.



# Project Objectives

- Develop an integrated Energy-Water Decision Support System (DSS) that will enable planners to analyze the potential implications of water stress for transmission and resource planning.
- Pursue the formulation and development of the Energy-Water DSS through a strongly collaborative process between Western Electricity Coordinating Council, Electric Reliability Council of Texas, Western Governors' Association, and Western States Water Council.
- Exercise the Energy-Water DSS to investigate water transmission planning scenarios.



# Project Partners

- Sandia National Laboratories

- Vincent Tidwell
- Barbie Moreland
- Howard Passell



Sandia  
National  
Laboratories

- Argonne National Laboratory

- John Gasper
- John Veil
- Chris Harto



- Electric Power Research Institute

- Robert Goldstein



- National Renewable Energy Laboratory

- Jordan Macknick
- Robin Newmark
- Daniel Inman
- Kathleen Hallett



**NREL**

National Renewable Energy Laboratory

- Idaho National Laboratory

- Gerald Sehlke
- Randy Lee



Idaho National Laboratory

- Pacific Northwest National Laboratory

- Mark Wigmosta
- Richard Skaggs
- Ruby Leung

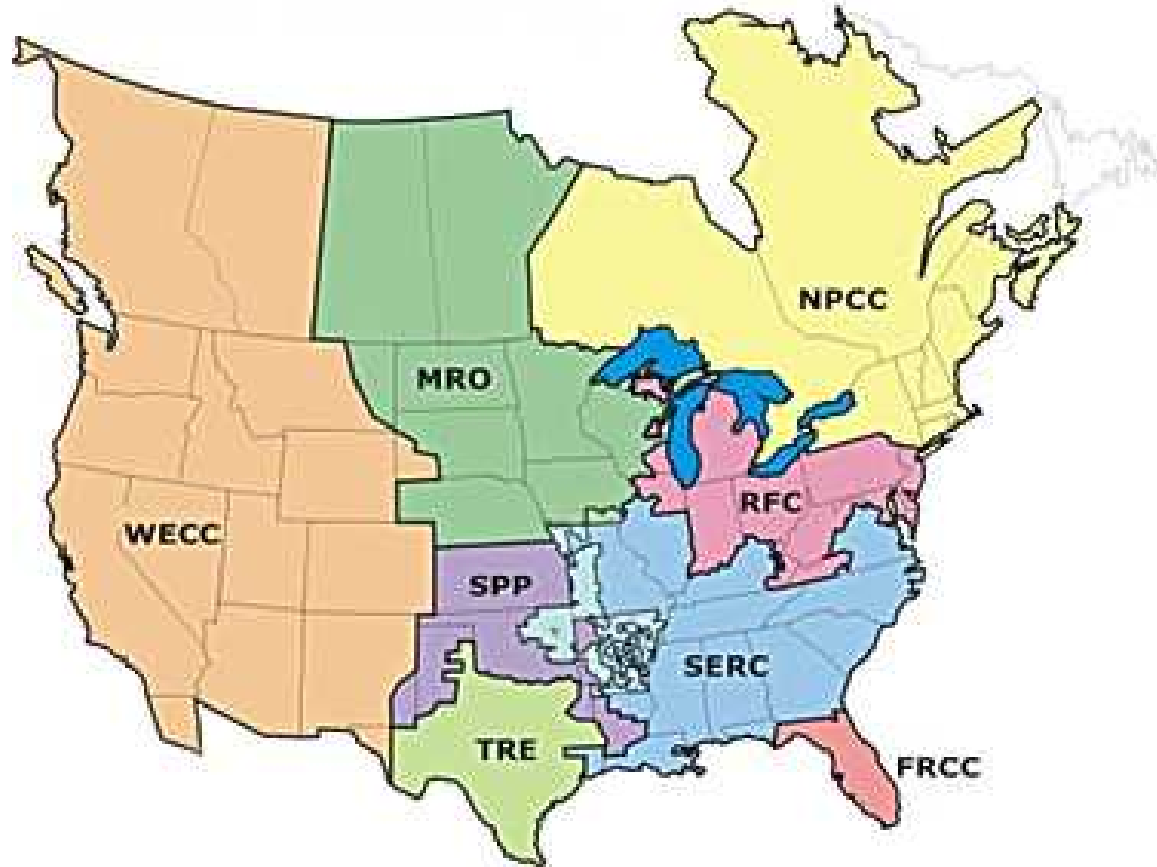


- University of Texas

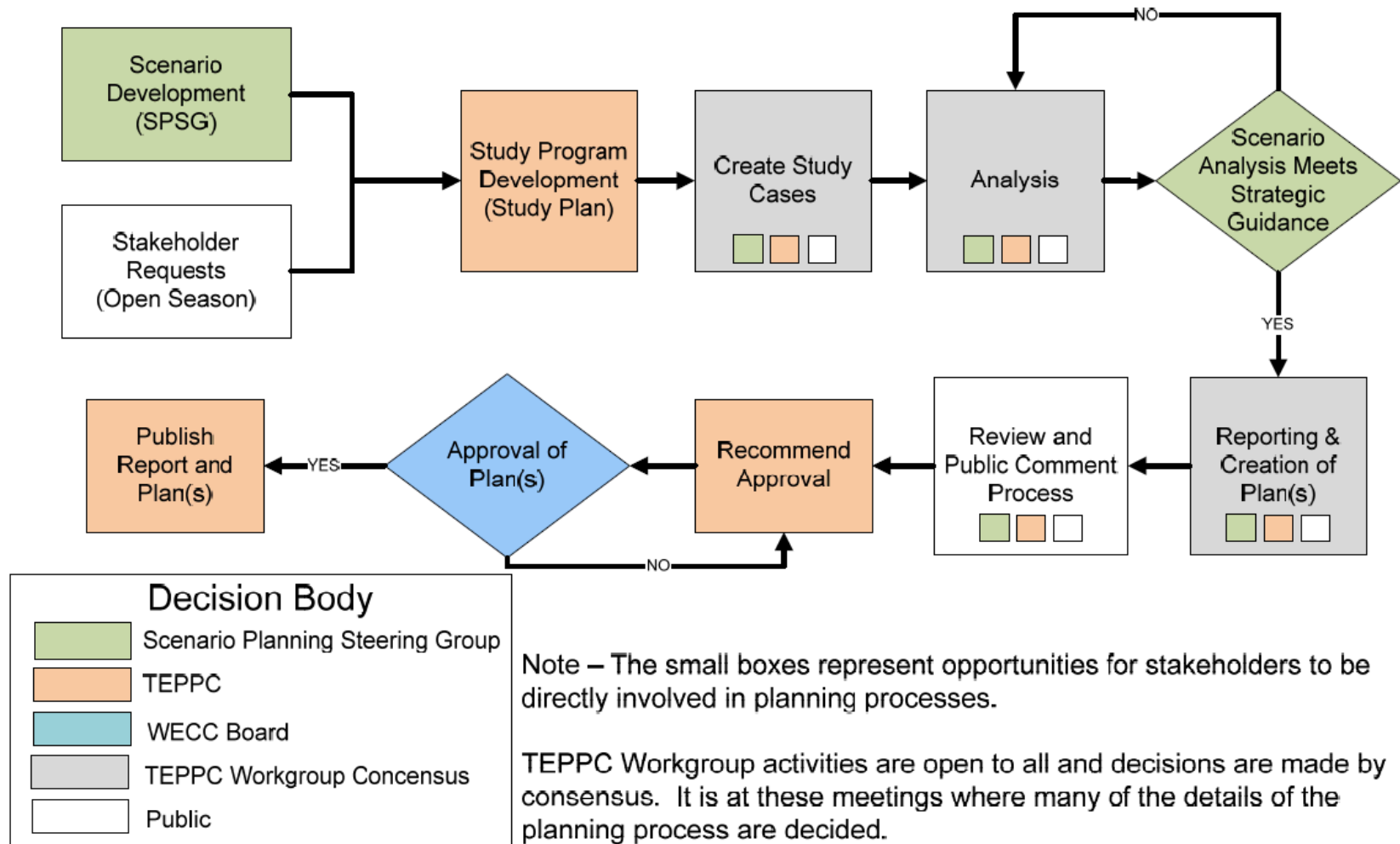
- Michael Webber
- Carey King

# Project Domain

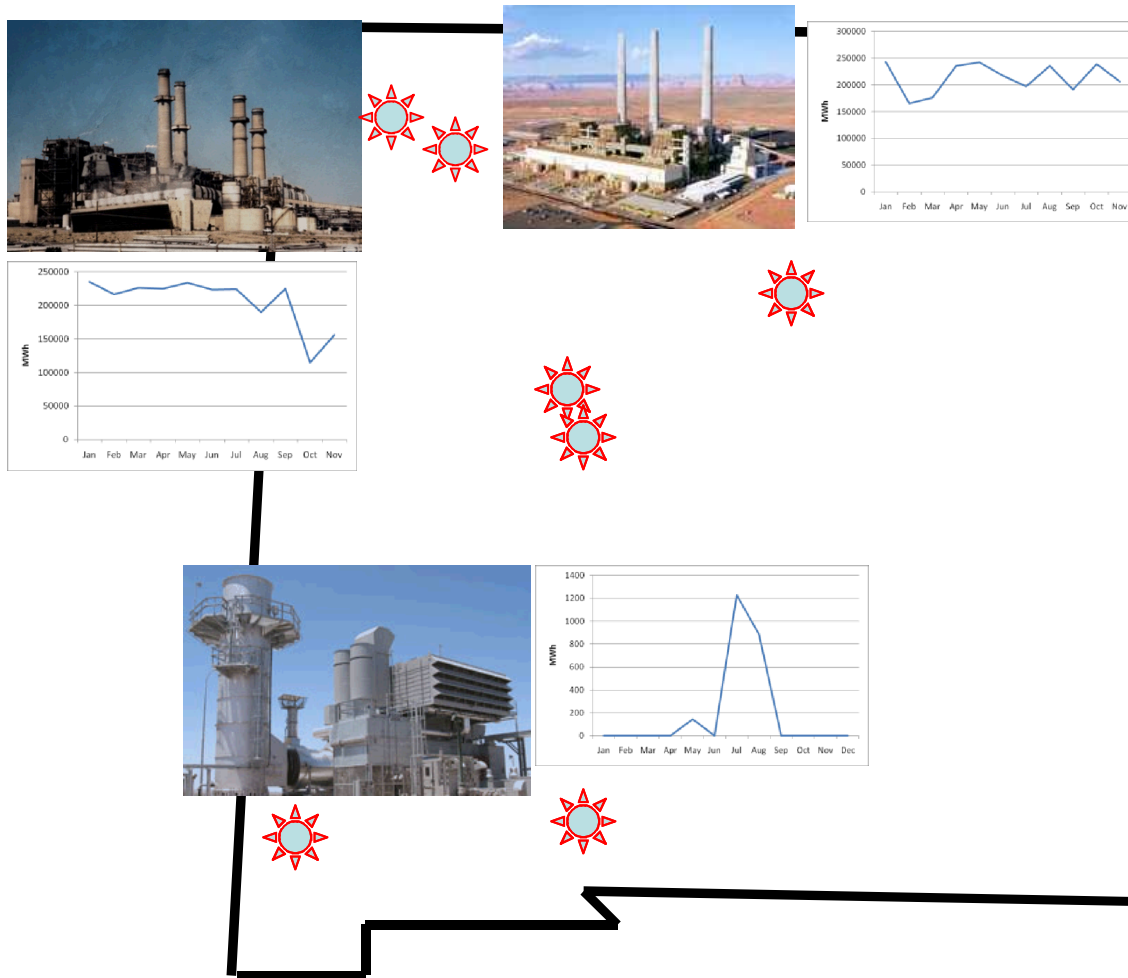
- Project duration:
  - 24 months for WECC
  - 18 months for ERCOT
- Planning horizon is to 2030



# Transmission Planning

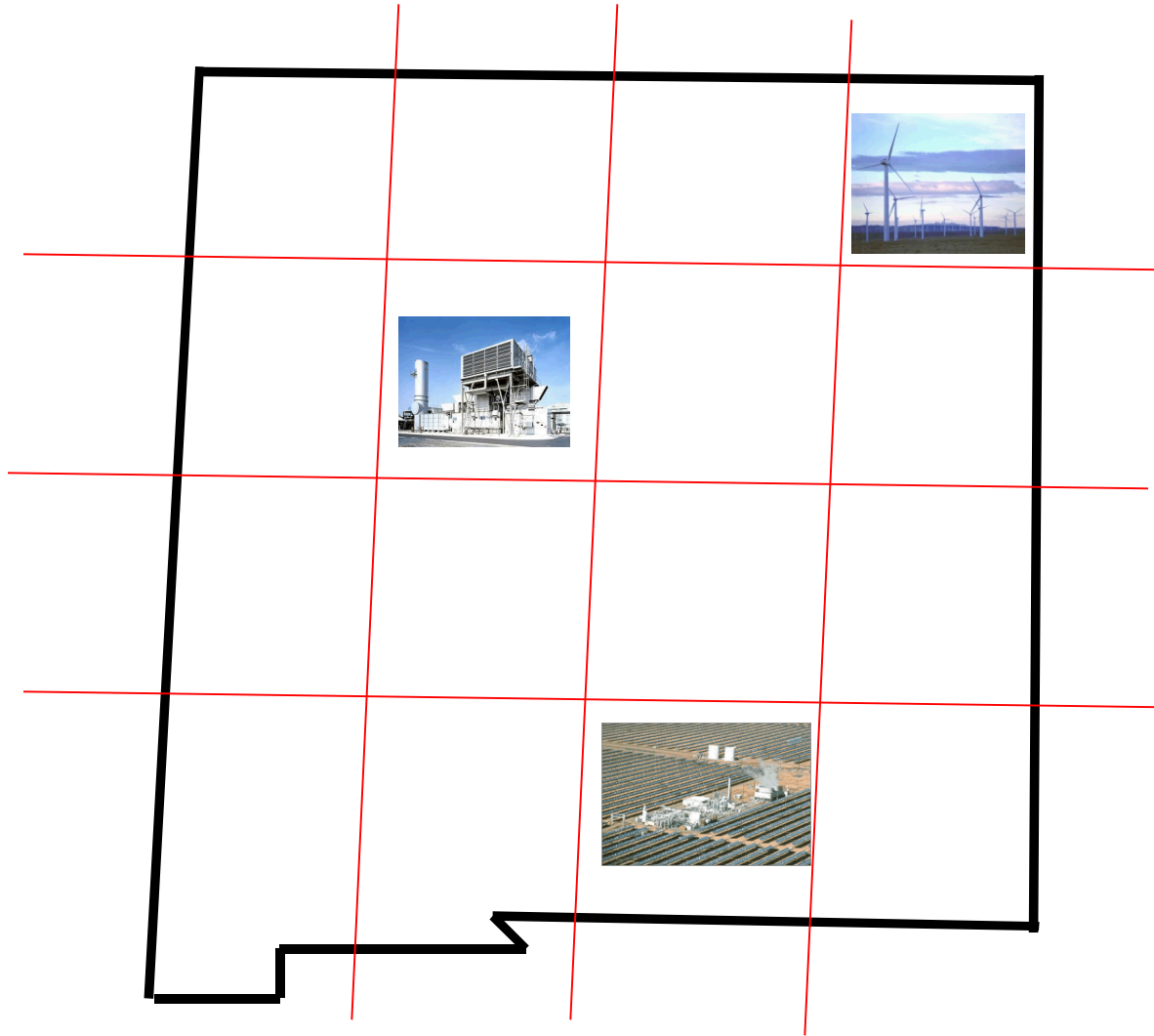


# Transmission Planning Output: Operations at Existing Plants



- **Plant Characteristics**
  - **System Upgrades, and**
  - **Production, or**
  - **Retirement**

# Transmission Planning Output: New Power Plant Siting



- ***Plant Characteristics***
  - ***Location,***
  - ***Fuel Type,***
  - ***Size, and***
  - ***Production***

# Plant Level Evaluation/Tradeoffs

## Cooling Options

## Plant Options



Fuel Type and Location



Dry-Cooled



Wet Cooling



Ground Water



Surface Water



Non-Potable

## Source Options

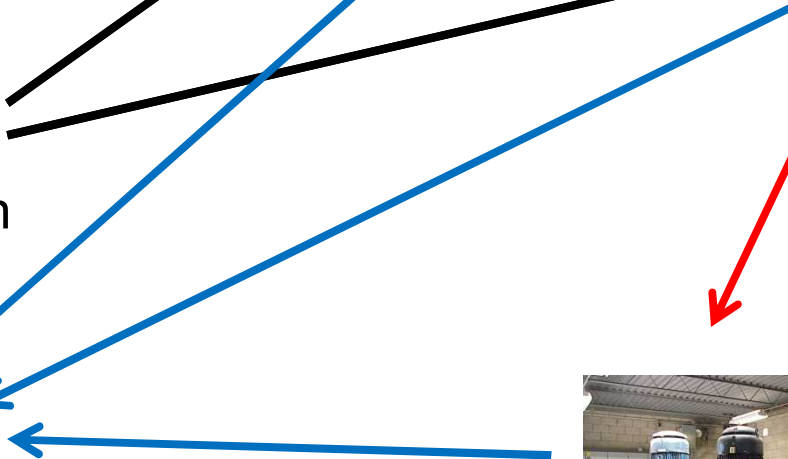
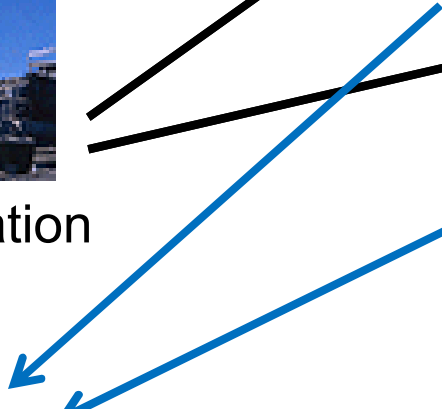
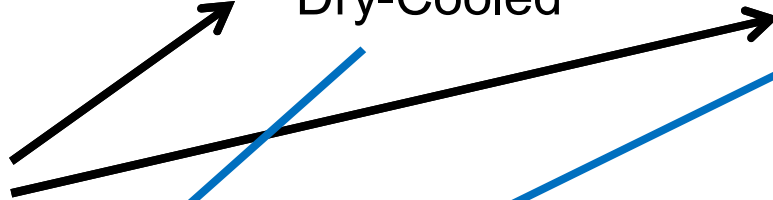
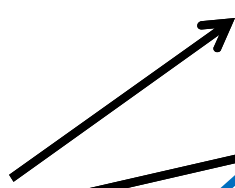
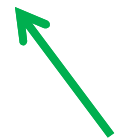
## Evaluation Metrics



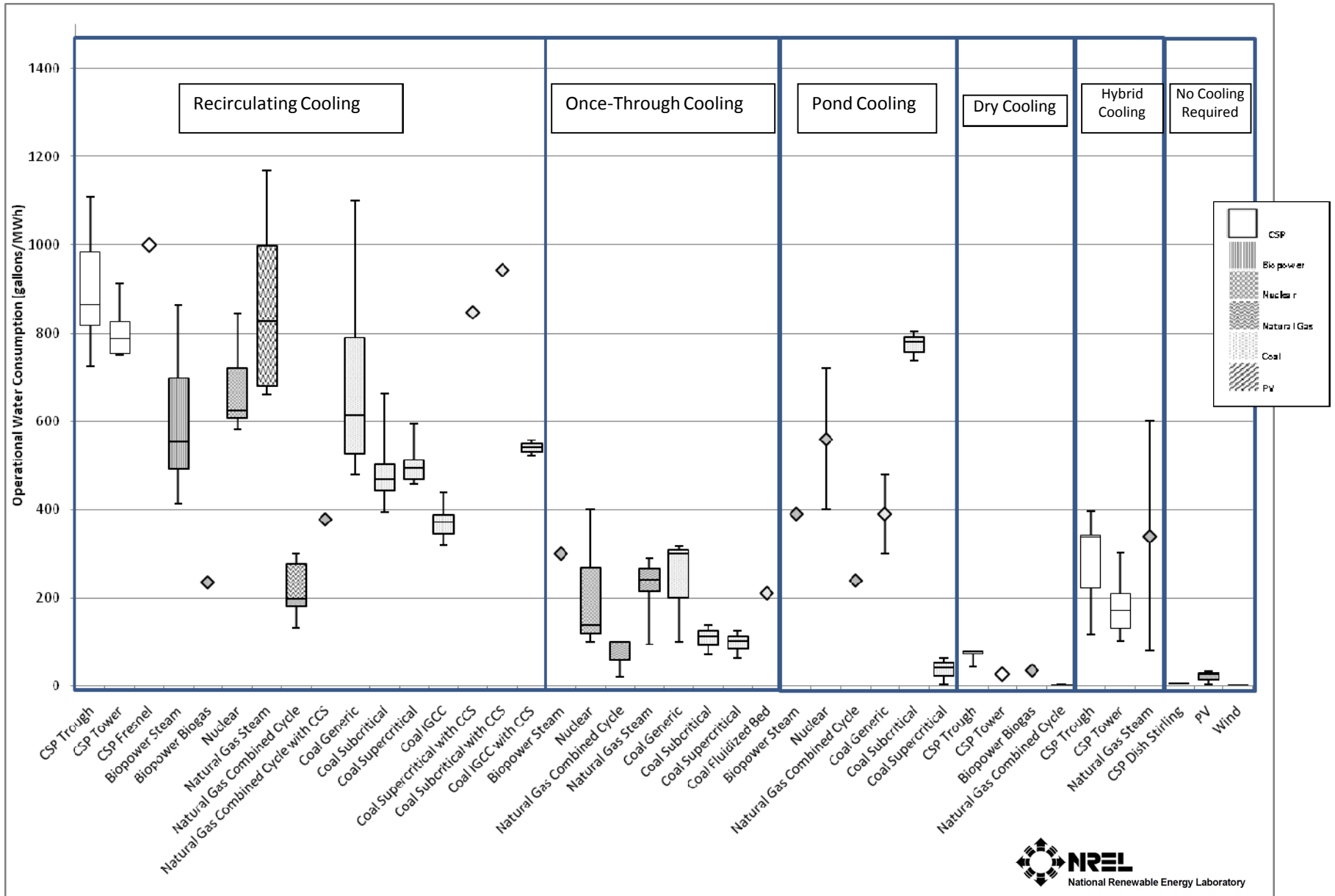
Reliability



Cost

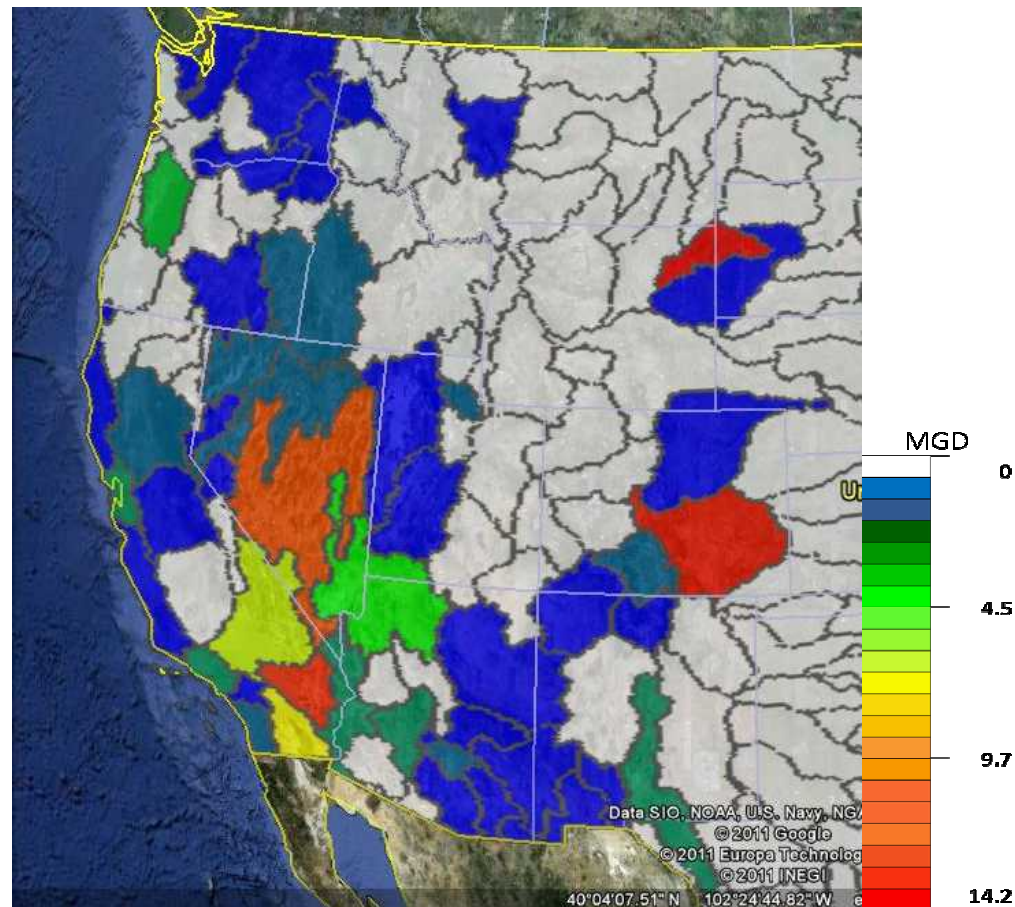


# Thermoelectric Water Use



# Thermoelectric Water Use 2020

Consumption due to New Construction 2010-2020

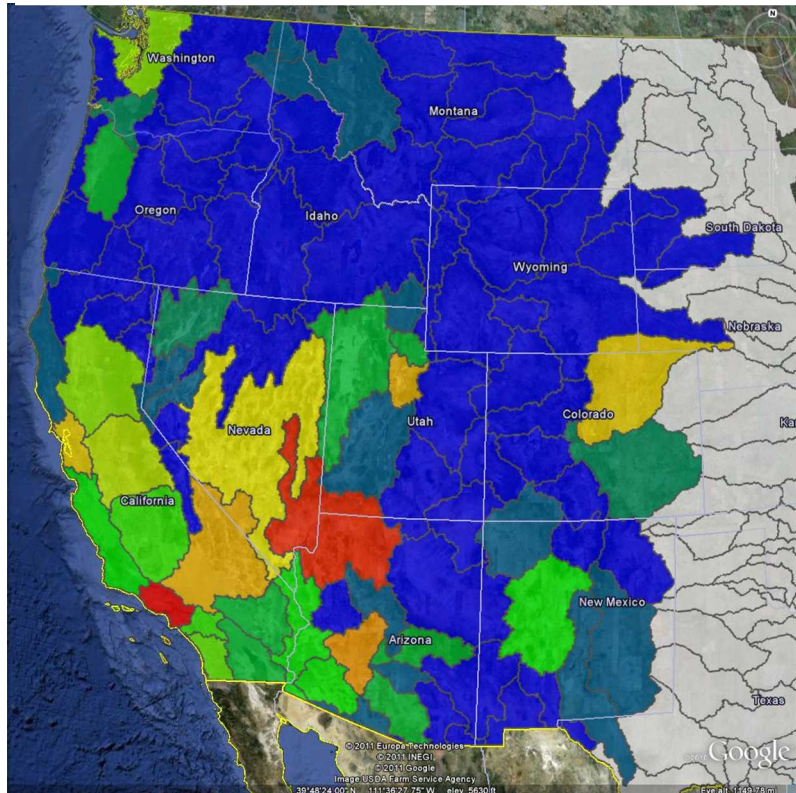


# Driving Questions

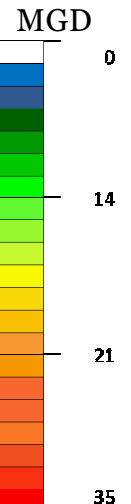
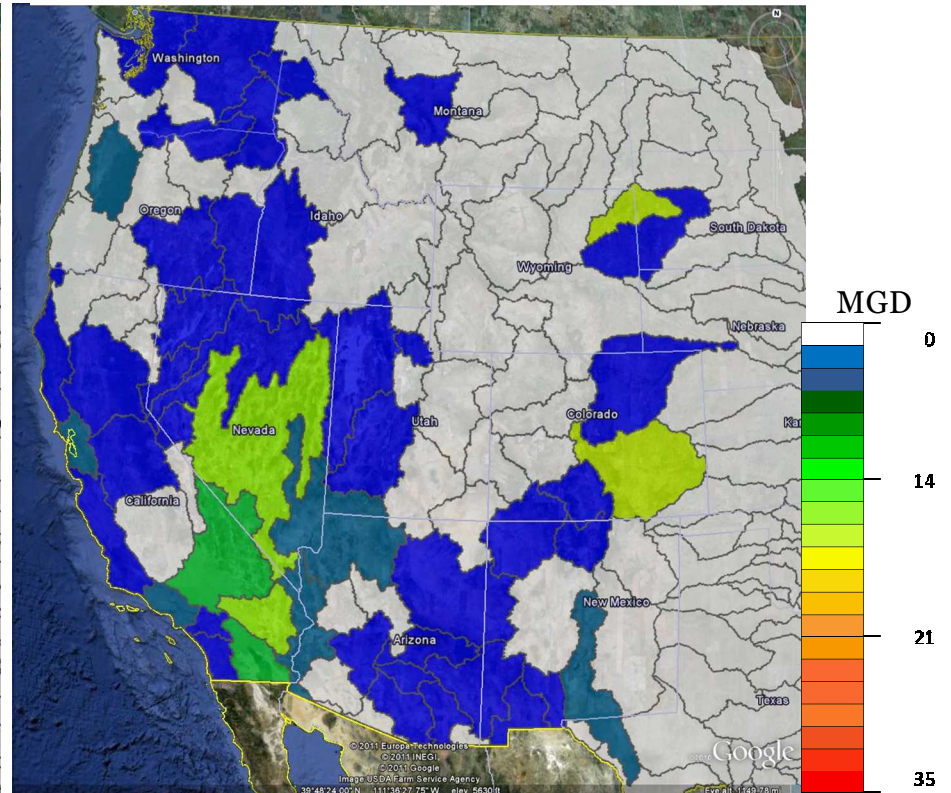
- ***How “difficult” would it be to acquire new water in a given basin?***
- ***How “vulnerable” are existing plants to drought related water supply disruptions?***
- ***What limited set of metrics best characterize answers to these questions?***

# Competition for Water

Non-Thermoelectric Consumption  
New Demand 2010-2020

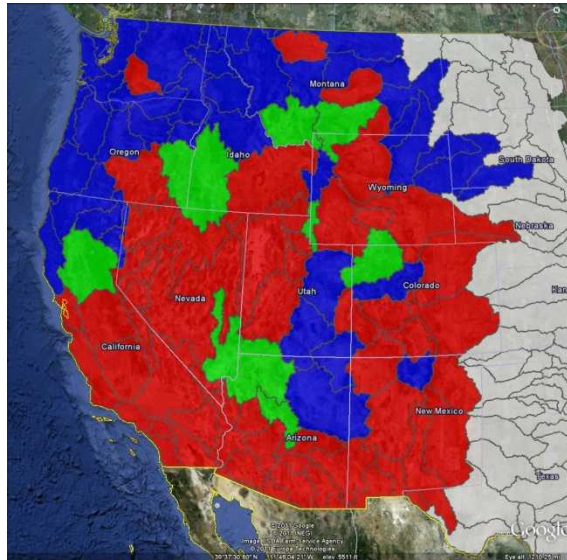


Thermoelectric Consumption  
New Demand 2010-2020

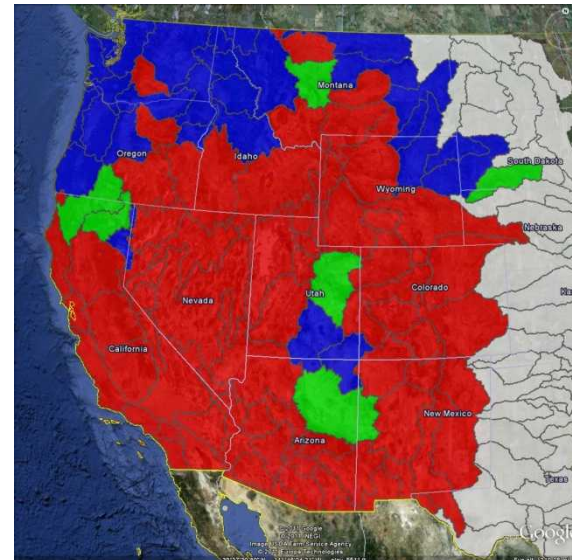


# Water Availability Metrics

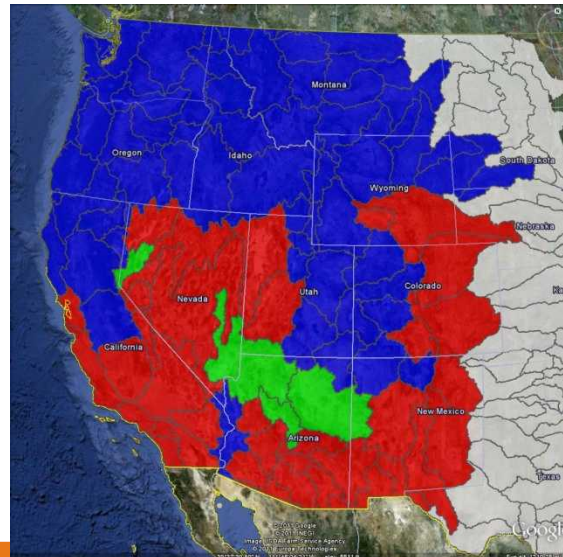
## Surface Water Stress



## Low Flow Stress



## Groundwater Stress



Supply  
Consumption

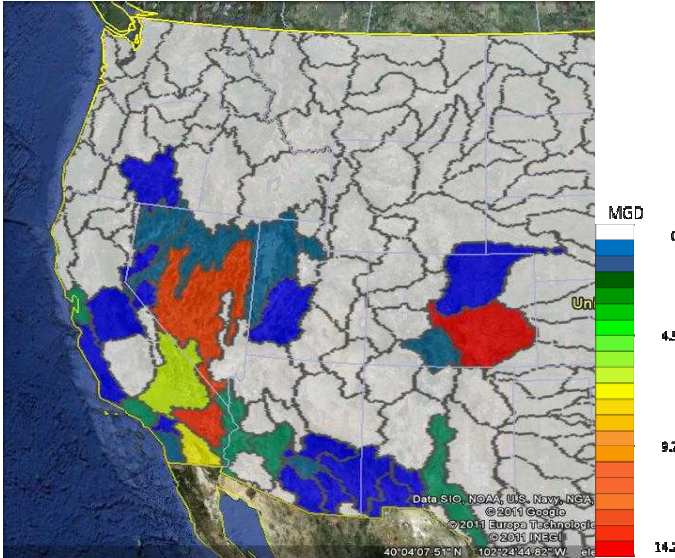
1-2

2-3

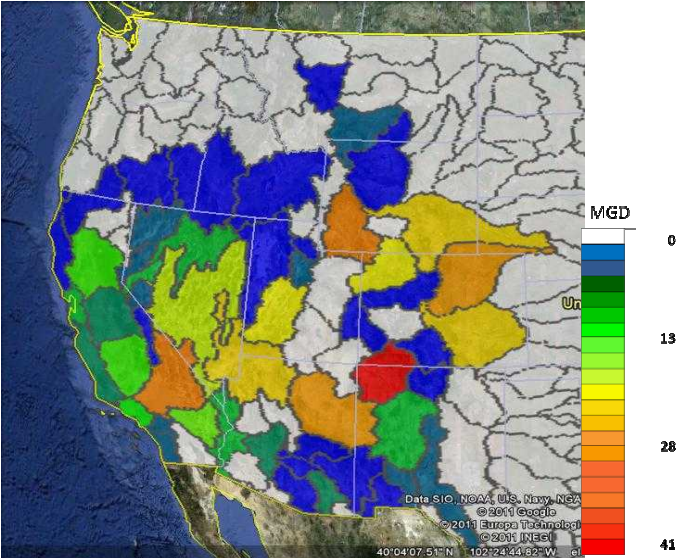
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# “At Risk” Water for Power Production

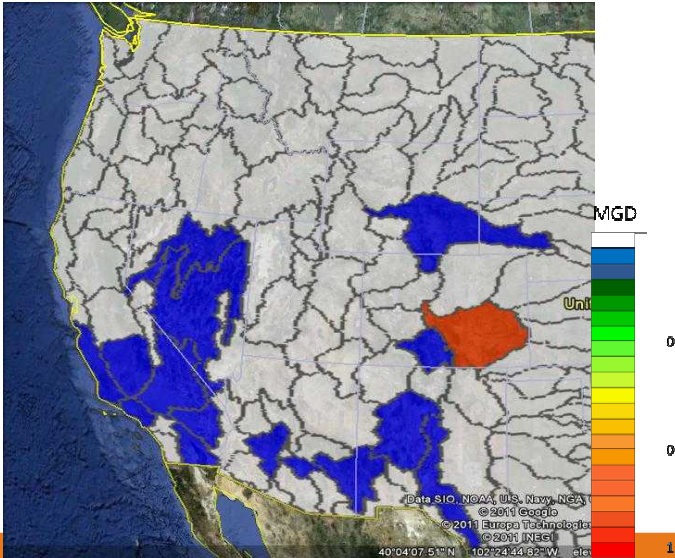
### Surface Water Stress



### Low Flow Stress



### Groundwater Stress



# Water Availability: Phase II

- ***Desire to improve on Phase I analysis***
  - ***Integrate state level data into analysis***
  - ***Expand breadth of water availability metrics***
- ***Approach for Phase II Analysis***
  - ***Conduct pilot study for four states***
    - ***Colorado,***
    - ***Arizona,***
    - ***Oregon, and***
    - ***Texas***
  - ***Create analysis template based on pilot study findings***
  - ***Vet plans with WSWC and state water managers***

# Water Availability Indicators

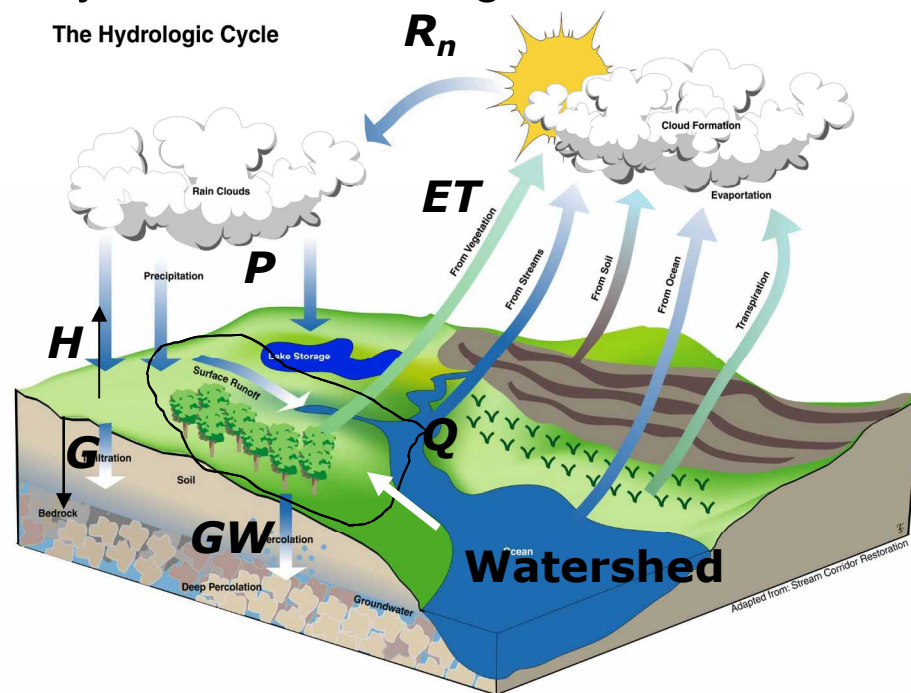
- ***Water Demand***
- ***Water Supply***
- ***Drought Vulnerability***
- ***Institutional Factors***
- ***Value of Water***



Physical Water

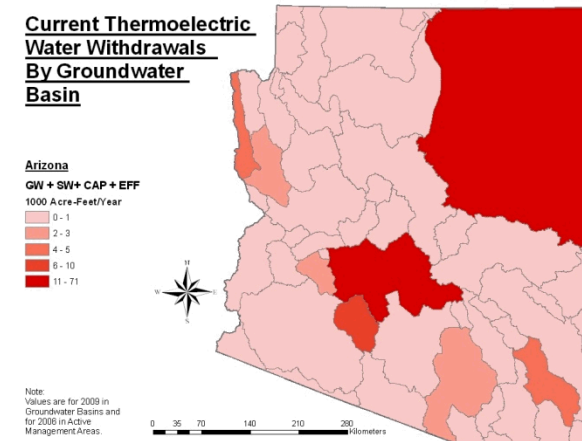
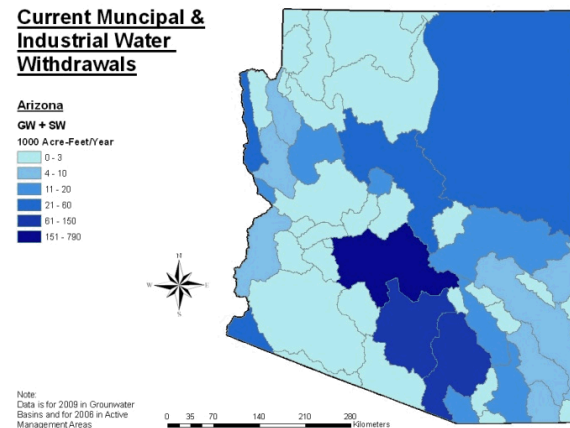
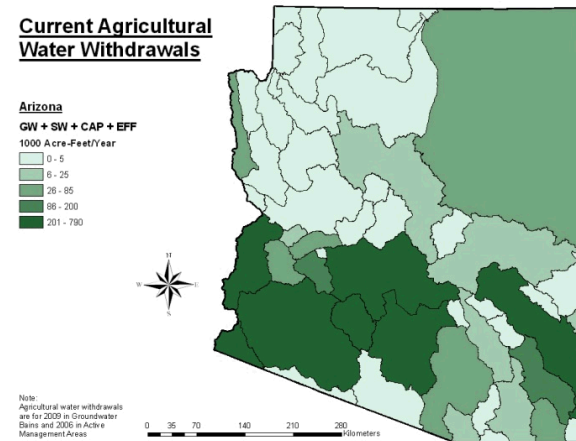
## Physical Water Budget

The Hydrologic Cycle



# Water Availability Indicators: Demand

- **Focus on withdrawals**
- **Estimate consumption from withdrawals**
- **Disaggregate by:**
  - **8-digit watershed**
  - **Sector**
    - ❖ **M&I**
    - ❖ **Agriculture**
    - ❖ **Evaporative**
    - ❖ **Instream**
  - **Water source**



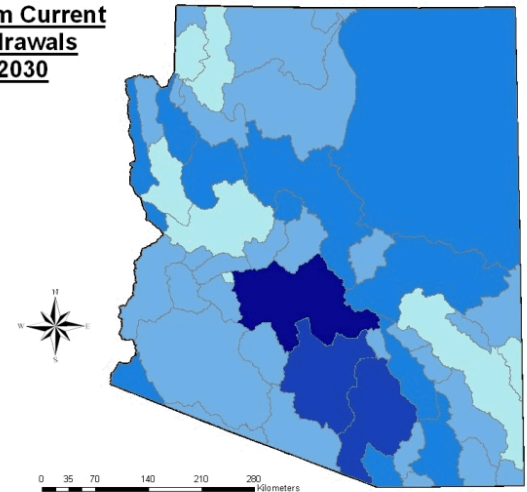
# Water Availability Indicators: Demand

- **Projected growth**
  - **High and**
  - **Low cases**
- **Identify state projected growth areas for power production**

**Change from Current Water Withdrawals for M & I in 2030**

**Arizona**  
GW + SW  
1000 Acre-Feet/Year

|               |           |
|---------------|-----------|
| Lightest Blue | -3 - 0    |
| Light Blue    | 1 - 5     |
| Medium Blue   | 6 - 40    |
| Dark Blue     | 41 - 150  |
| Darkest Blue  | 151 - 580 |

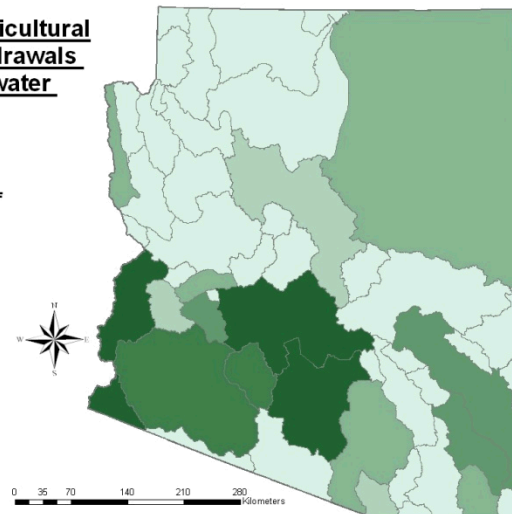


Note:  
Values were projected using population data from the Arizona Water Atlas

**Current Agricultural Water Withdrawals By Groundwater Basin**

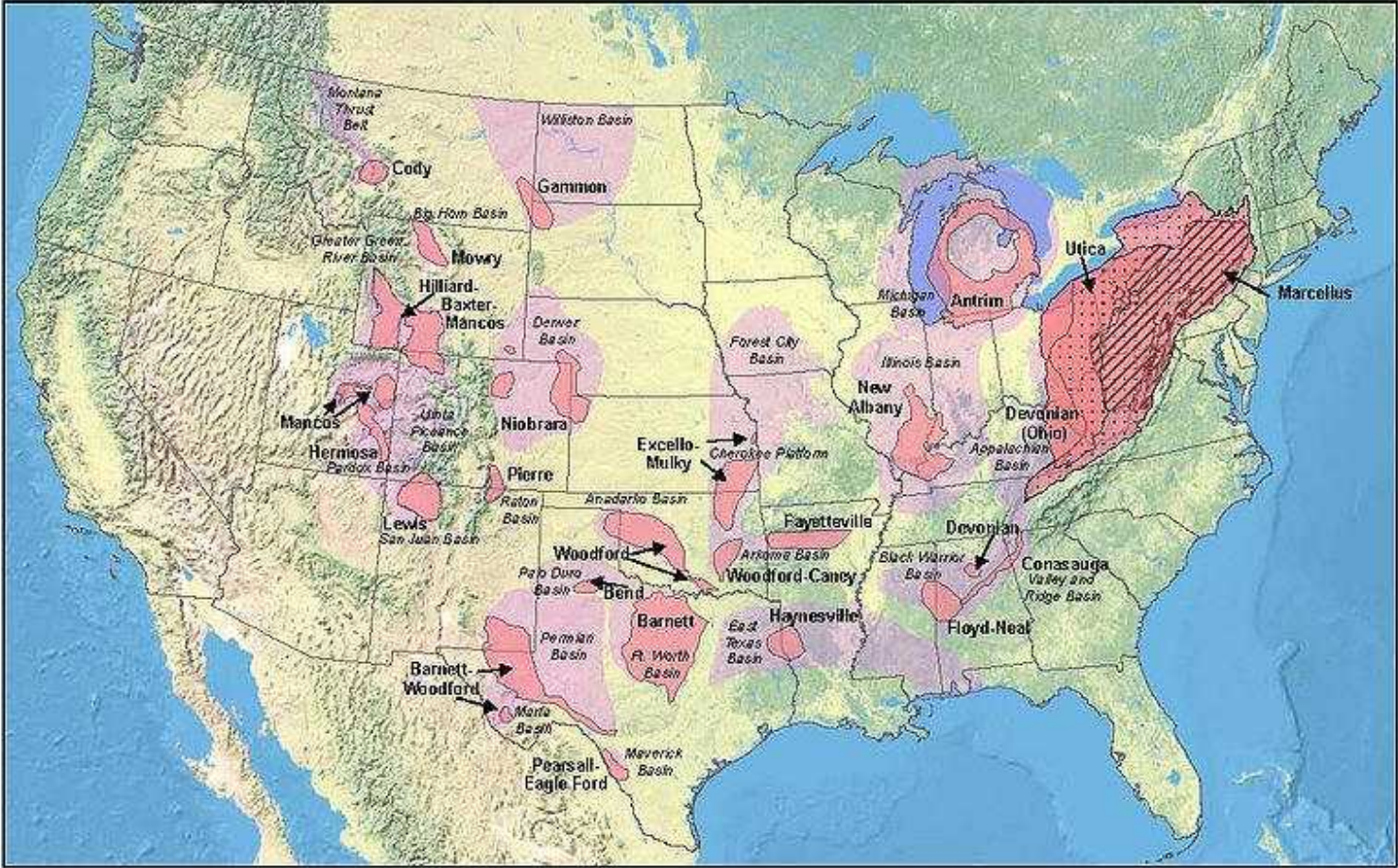
**Arizona**  
GW + SW + CAP + EFF  
1000 Acre-Feet/Year

|                 |           |
|-----------------|-----------|
| Lightest Green  | 0 - 10    |
| Light Green     | 11 - 30   |
| Medium Green    | 31 - 85   |
| Dark Green      | 86 - 205  |
| Very Dark Green | 206 - 525 |
| Darkest Green   | 526 - 790 |



Note:  
Values are for 2008 in Groundwater Basins and for 2008 in Active Management Areas.

# Water Availability Indicators: Demand



United States Shale Gas Plays



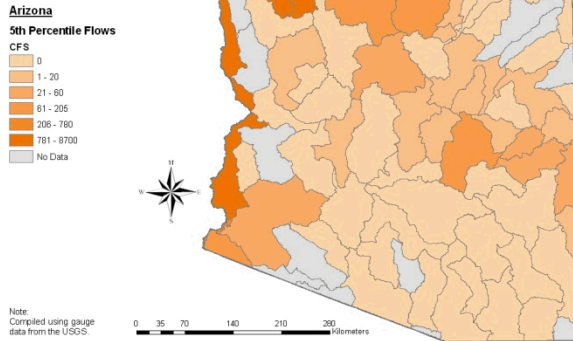
Shale Gas Plays  
Basins

Stacked Appalachian Plays  
 Marcellus  
 Utica  
 Devonian (OH shale)



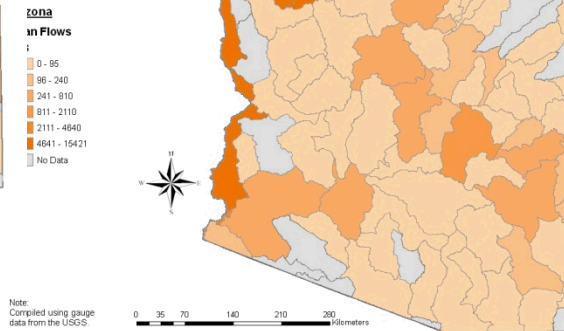
# Water Availability Indicators: Supply

**5th Percentile Stream Flows in Watersheds**



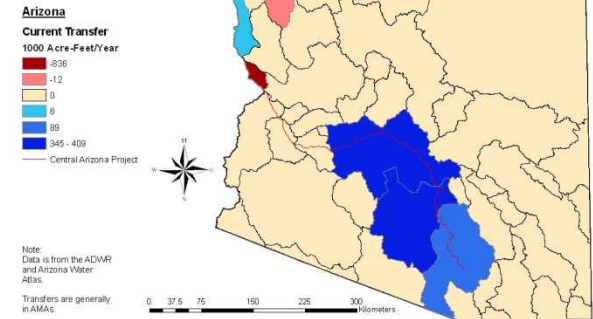
Mean Gauged Streamflow

**Mean Stream Flows in Watersheds**



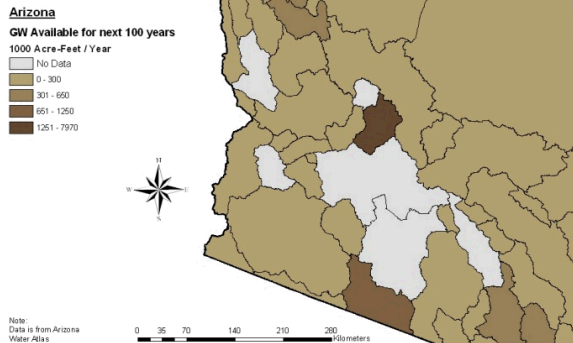
Annual Low Flow

**Interbasin Transfers By Groundwater Basin & AMA**



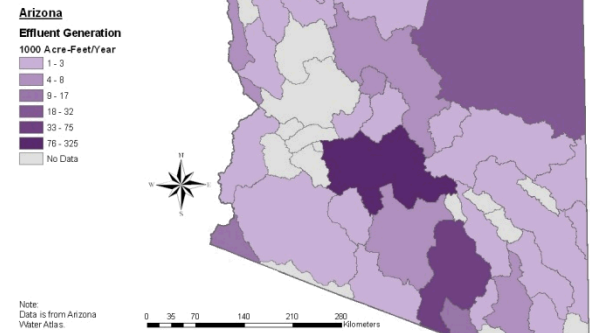
Interbasin Transfers

**Current Groundwater Availability per year**



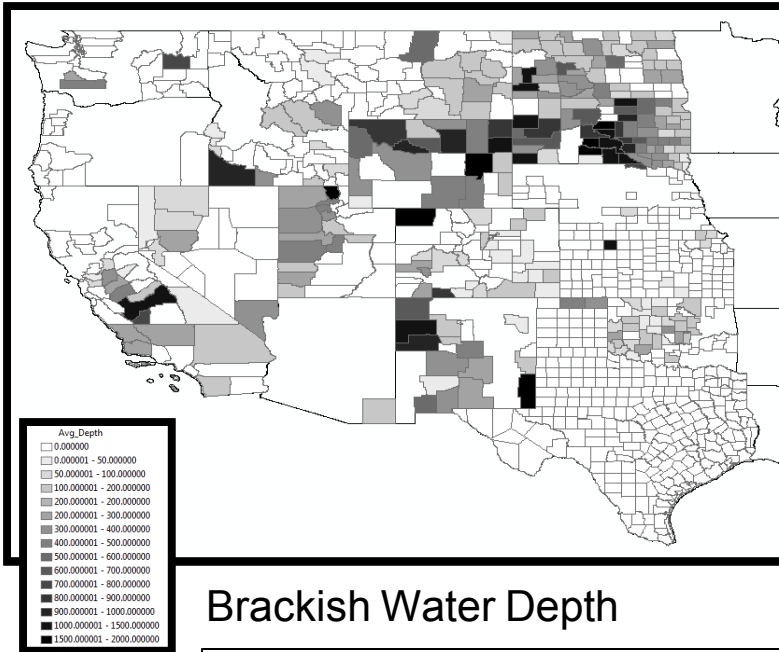
Non-Tributary Groundwater

**Effluent Generation By Groundwater Basin**

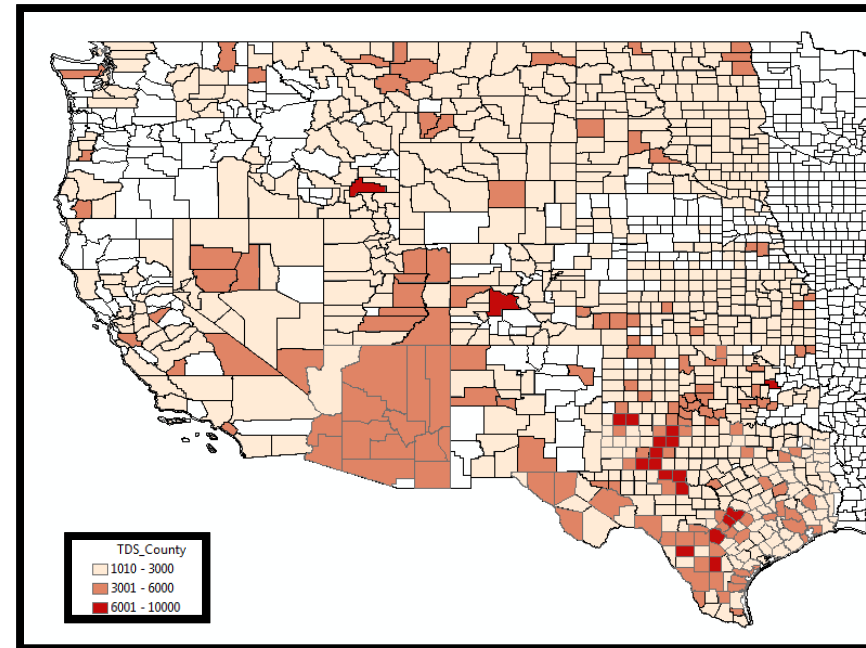


Accessible Non-Potable Sources

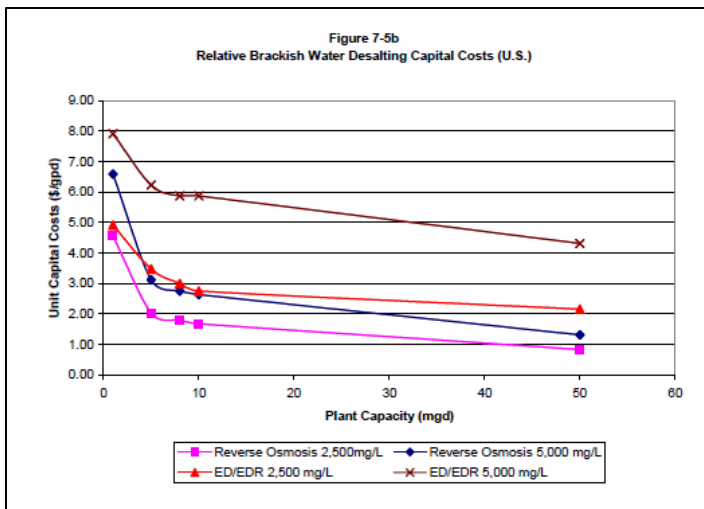
# Water Availability Indicators: Supply



Brackish Water Depth



Brackish TDS Levels



Brackish Water Treatment

# Water Availability Indicators: Drought Vulnerability



Plant Vulnerabilities

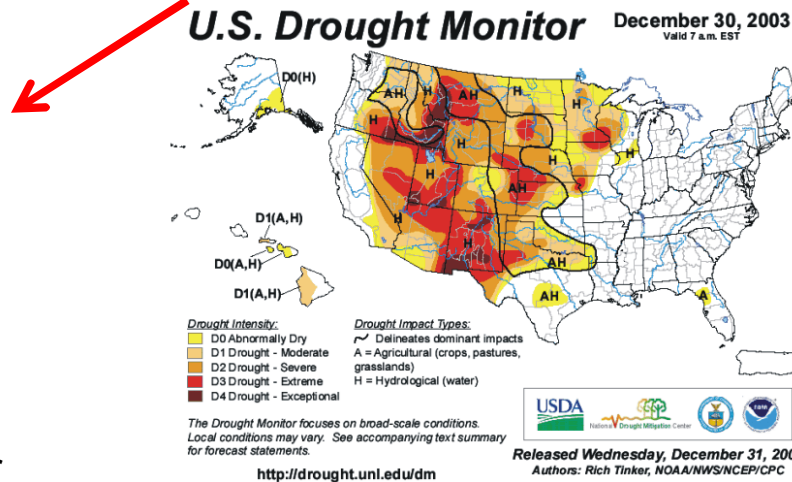
- Physical factors,
- Water rights,
- Environmental constraints



Increased Power Demand



Reduced Streamflow  
Reduced Supply



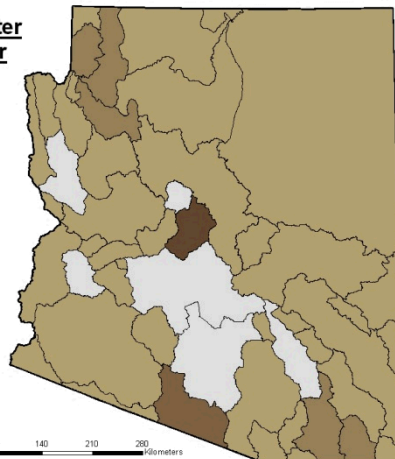
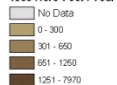
Decreased Hydropower  
Production

# Water Availability Indicators: Institutional Factors

## Current Groundwater Availability per year

### Arizona

GW Available for next 100 years  
1000 Acre-Feet / Year



Note:  
Data is from Arizona  
Water Atlas

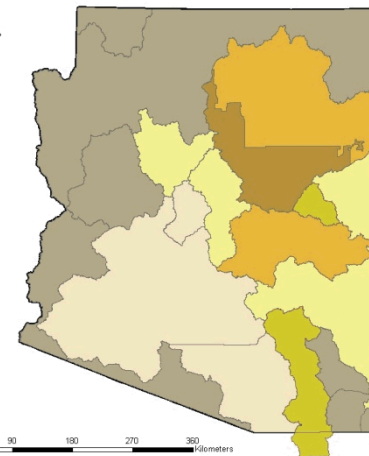
0 35 70 140 210 280 kilometers

Unappropriated Water

## Adjudicated Surface of Water Basins

### Arizona

Status of Adjudication Process



Note:  
Includes agreements with  
other states and Mexico

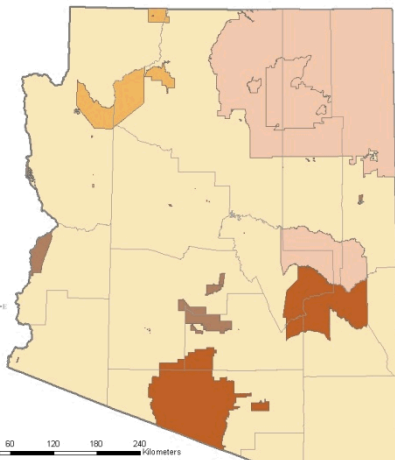
0 45 90 180 270 360 kilometers

Adjudication Status

## Status of Water Claims for Indian Communities

### Arizona

Status



Note:  
Settled/Unresolved = Portions  
of claims have been settled,  
while others remain unresolved.  
Status as of Sept. 2010

0 30 60 120 180 240 kilometers

Indian Water

## Groundwater Basins & Special Management Areas

### Arizona

Type

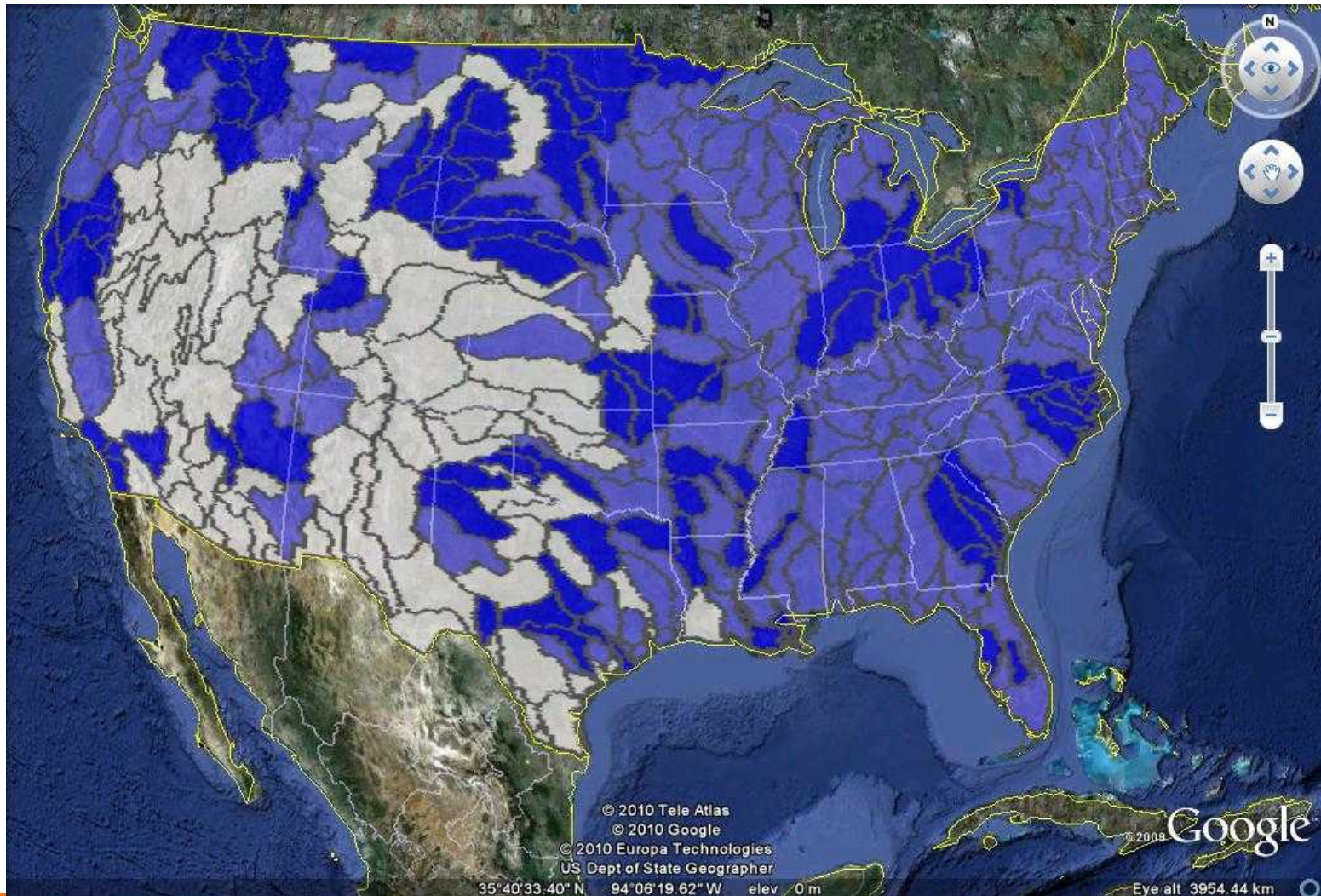


Note:  
INA = Irrigation Non-Expansion Area  
AMA = Active Management Area

0 35 70 140 210 280 kilometers

Administrative Control Areas


# Water Availability: Environmental Flows



**Mean Flow  
Env. Flow**

 <1

 1-1.25

 >1.25

# Water Availability Indicators: Drought Vulnerability



Plant Vulnerabilities

- Physical factors,
- Water rights,
- Environmental constraints



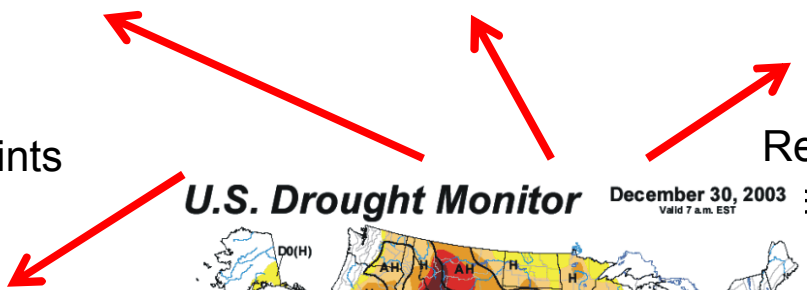
Increased Power Demand



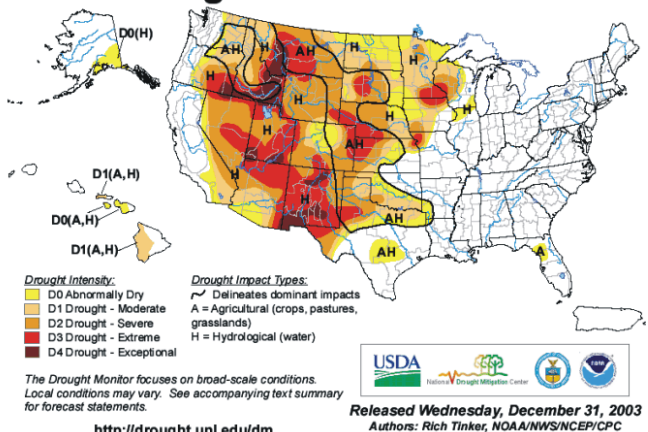
Reduced Streamflow  
Reduced Supply



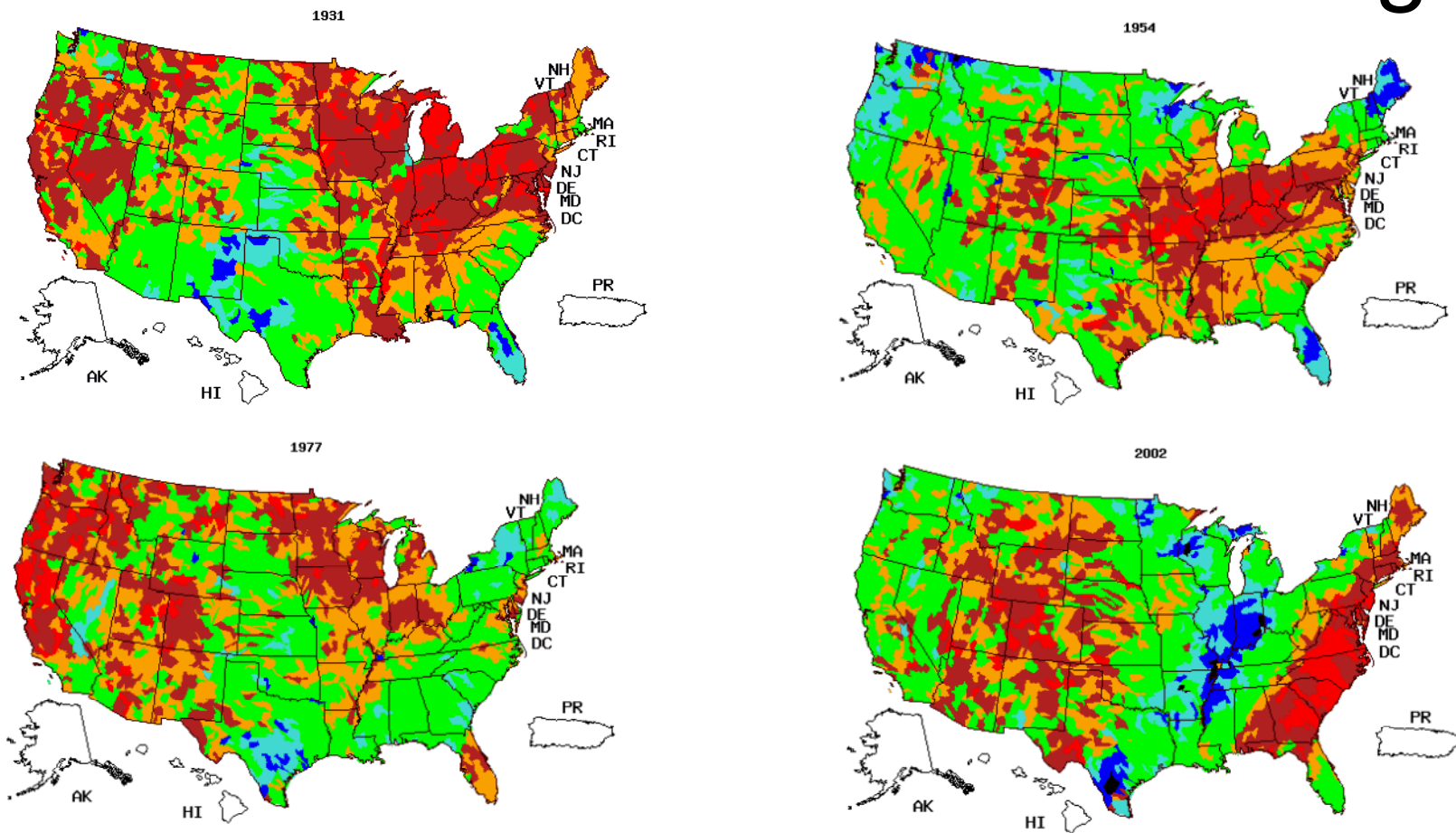
Decreased Hydropower  
Production



**U.S. Drought Monitor** December 30, 2003  
Valid 7 a.m. EST



# Regional Pattern of Severe Drought

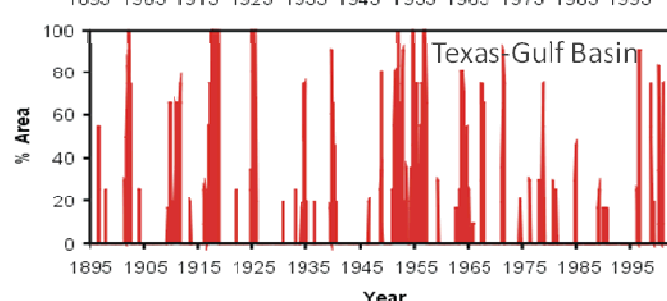
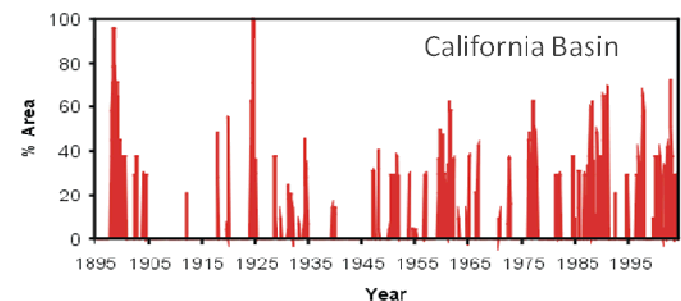
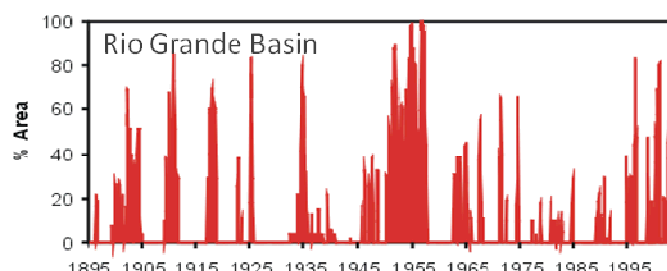
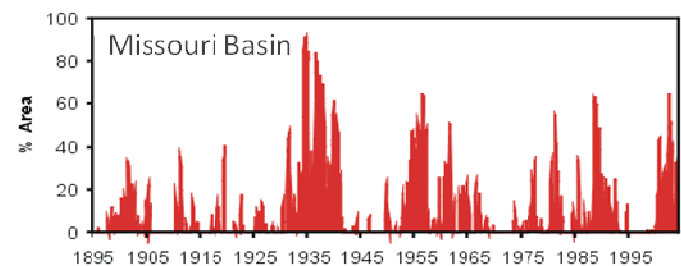
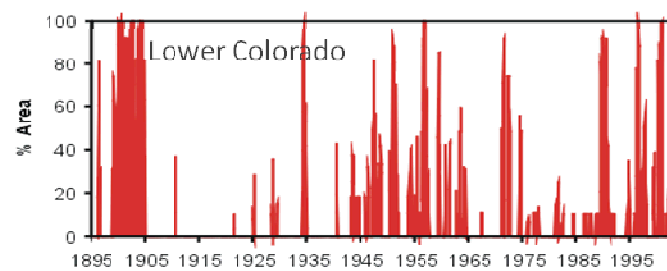
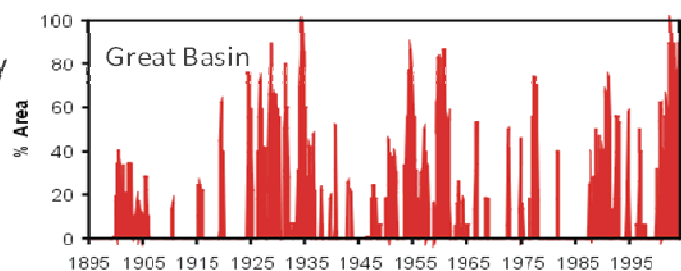
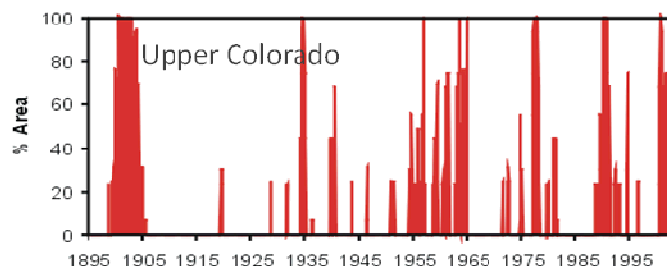
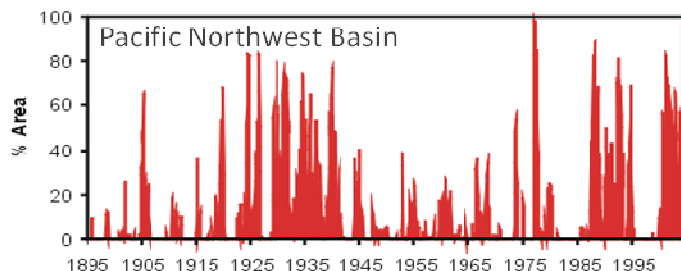


| Explanation -- Percentile Range |      |         |         |         |     |         |         |
|---------------------------------|------|---------|---------|---------|-----|---------|---------|
| Lowest                          | < 10 | 10 - 24 | 25 - 75 | 76 - 90 | >90 | Highest | No data |

Eugene Yan, May 2011

# Regional Pattern of Severe Drought

Long  
duration  
Low  
frequency



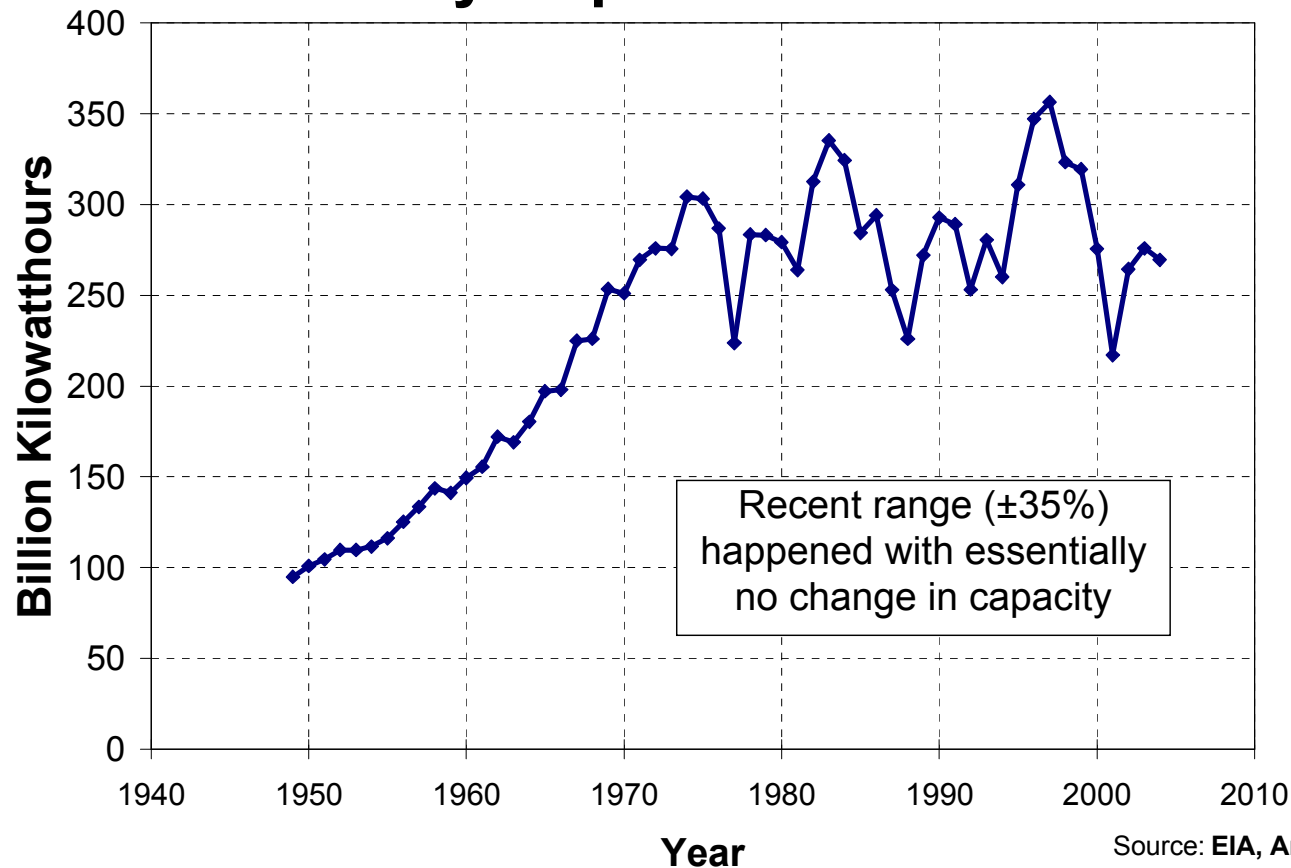
Short  
duration  
High  
frequency

Eugene Yan for Drought Analysis Progress Report, May 19, 2011

National Drought Mitigation Center 2006

# Hydroelectric Power at Risk of Drought

## U.S. Hydropower Production



- Supplies 6%-10% of US electricity

Source: EIA, Annual Energy Review, 2005

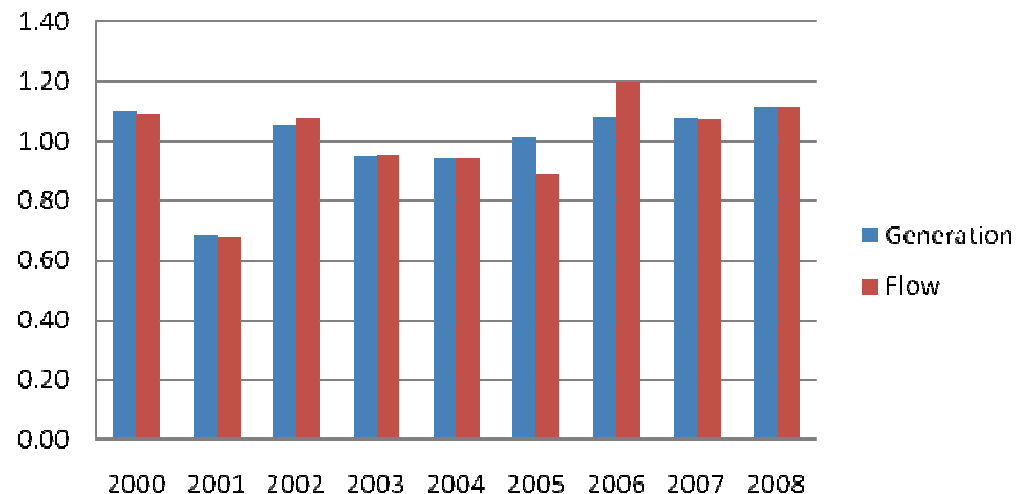
# Hydroelectric Power at Risk of Drought

## Lower CO

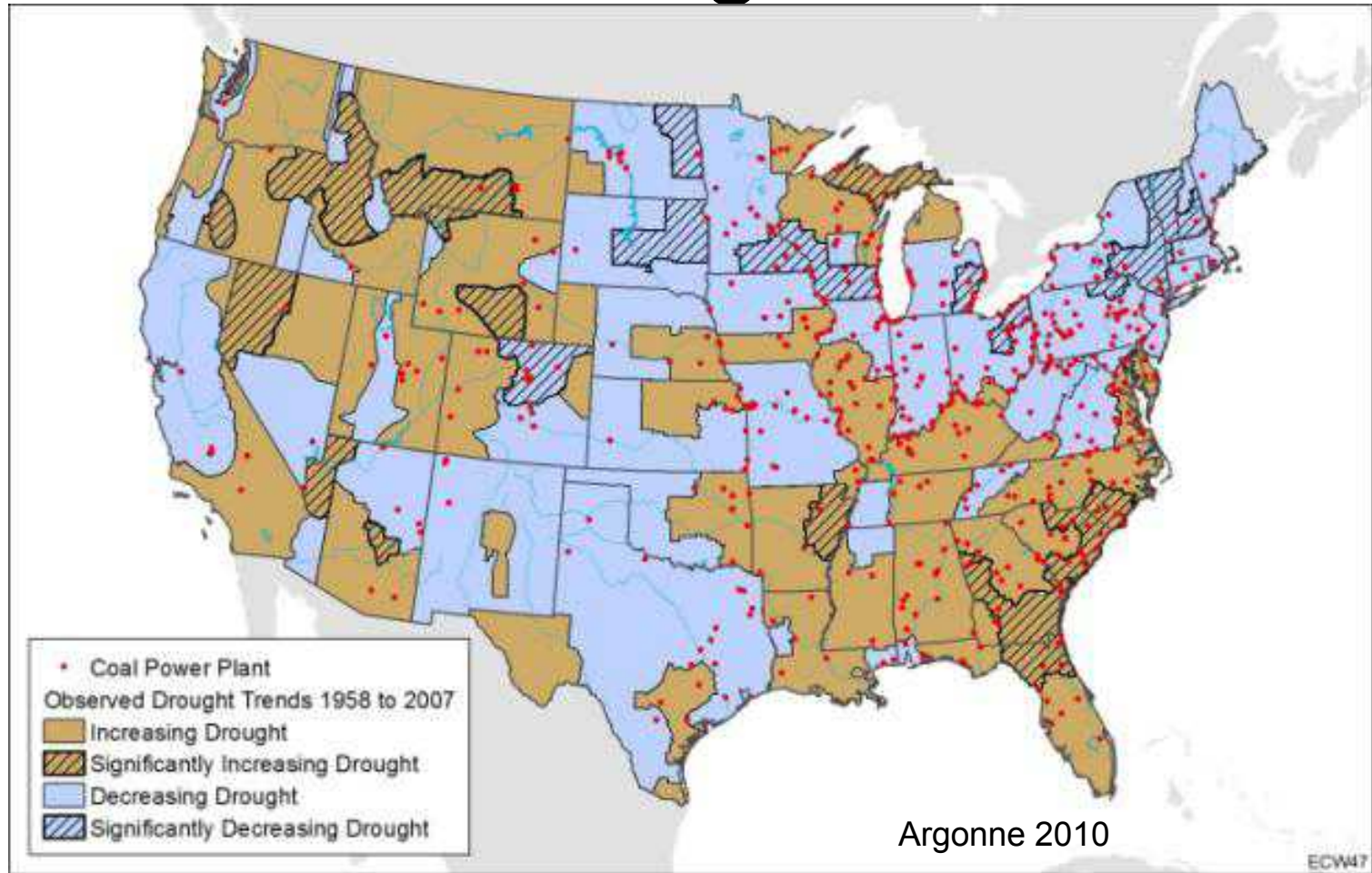


## Generation vs. Streamflow for different basins

## Pacific NW



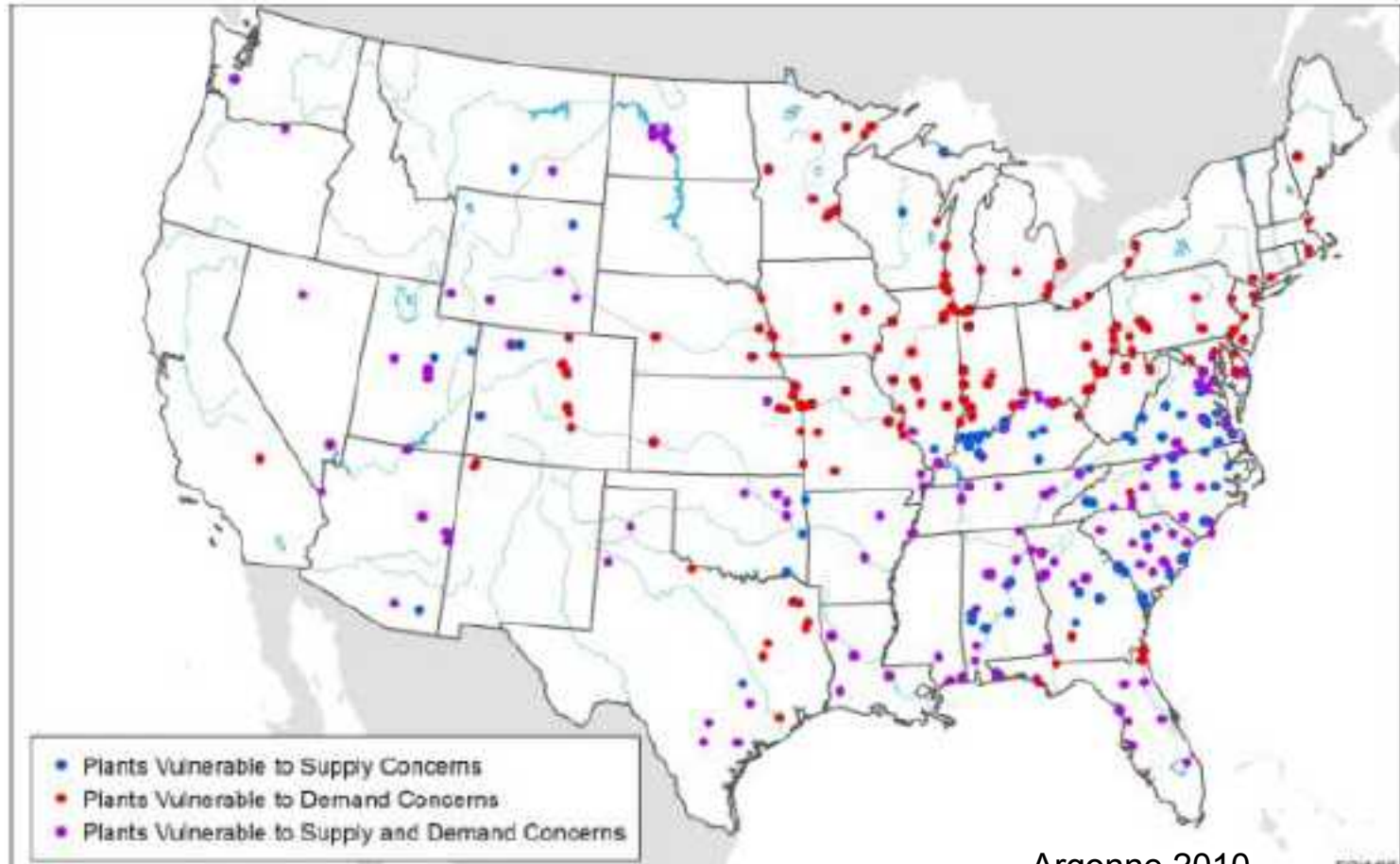
# Thermoelectric Power at Risk of Drought



Argonne 2010

ECW47

# Thermoelectric Power at Risk of Drought



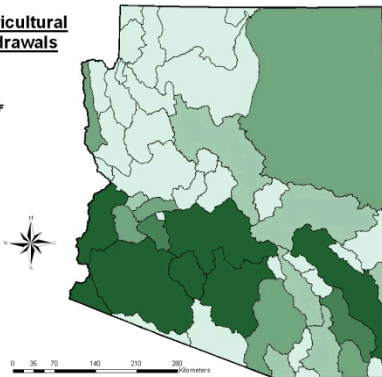
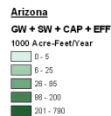
Argonne 2010

# Water Availability Indicators: Value of Water

- Historic value of leased and sold water rights
- Economic value of water
- Cost of backstop technology



## Current Agricultural Water Withdrawals

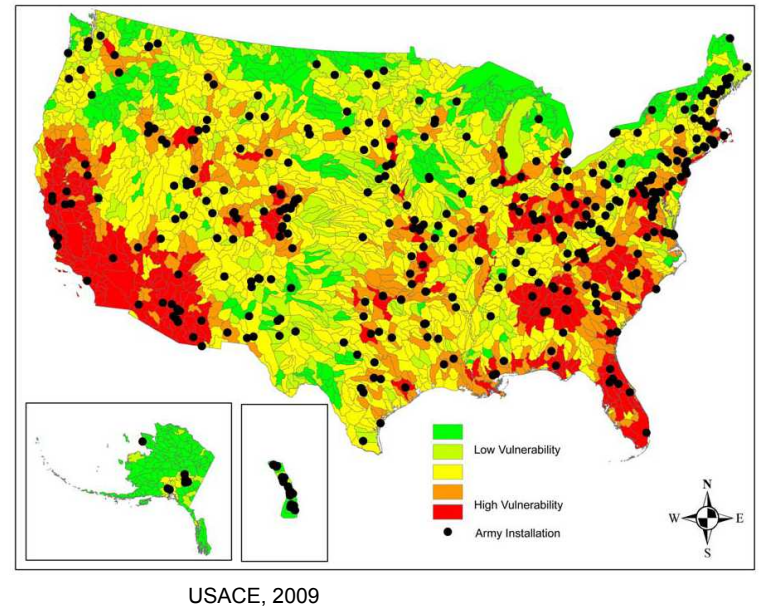
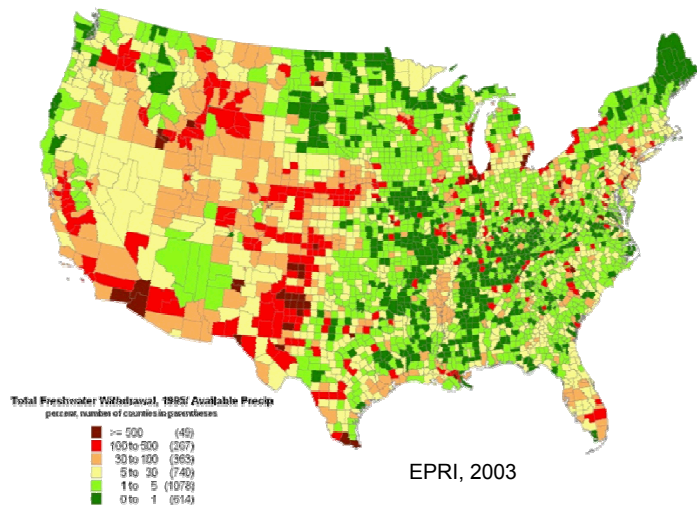
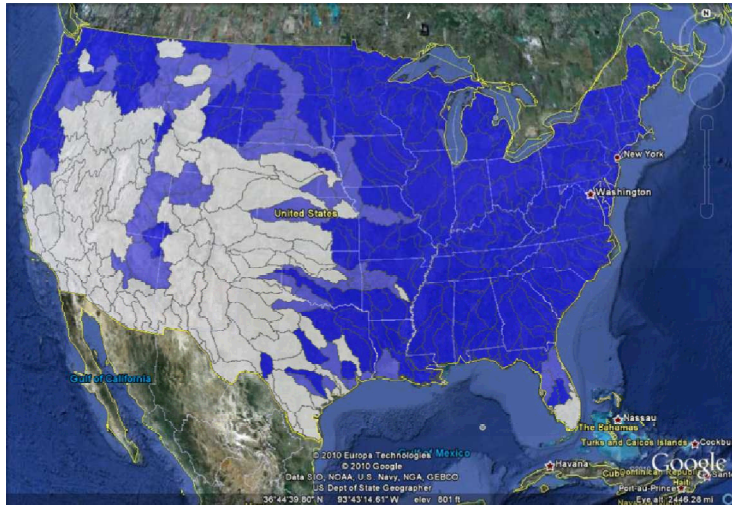


Note:  
Agricultural water withdrawals  
are for 2008 in Groundwater  
Bans and 2009 in Active  
Management Areas



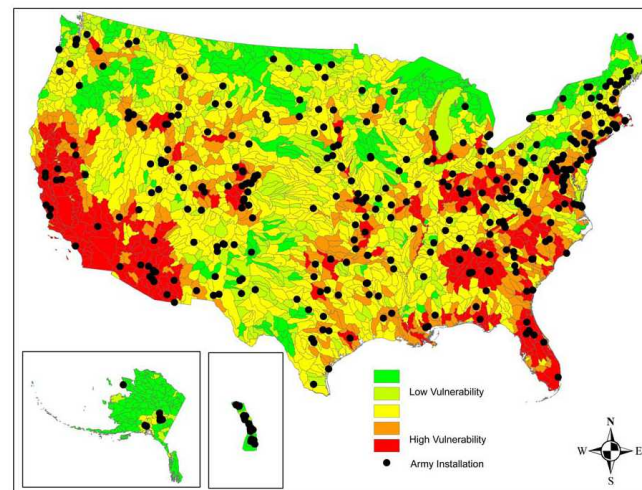
# Water Availability Indicators

- No perfect metric
- Need to develop consensus metric(s)
- Propose to establish a working group



# Summary

- Proposed general matrix of water availability indicators:
  - *Water Demand*
  - *Water Supply*
  - *Drought Vulnerability*
  - *Institutional Factors*
  - *Value of Water*
- Request support in developing a set of “consensus metrics” for use in interconnection wide transmission planning



# US Energy Sustainability

A critical piece is missing

## Contact:

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## More Information at:

[www.sandia.gov/mission/energy/arra/energy-water.html](http://www.sandia.gov/mission/energy/arra/energy-water.html)