WESTCARB Phase II Overview

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Regional Partnership Review Meeting
October 13, 2005

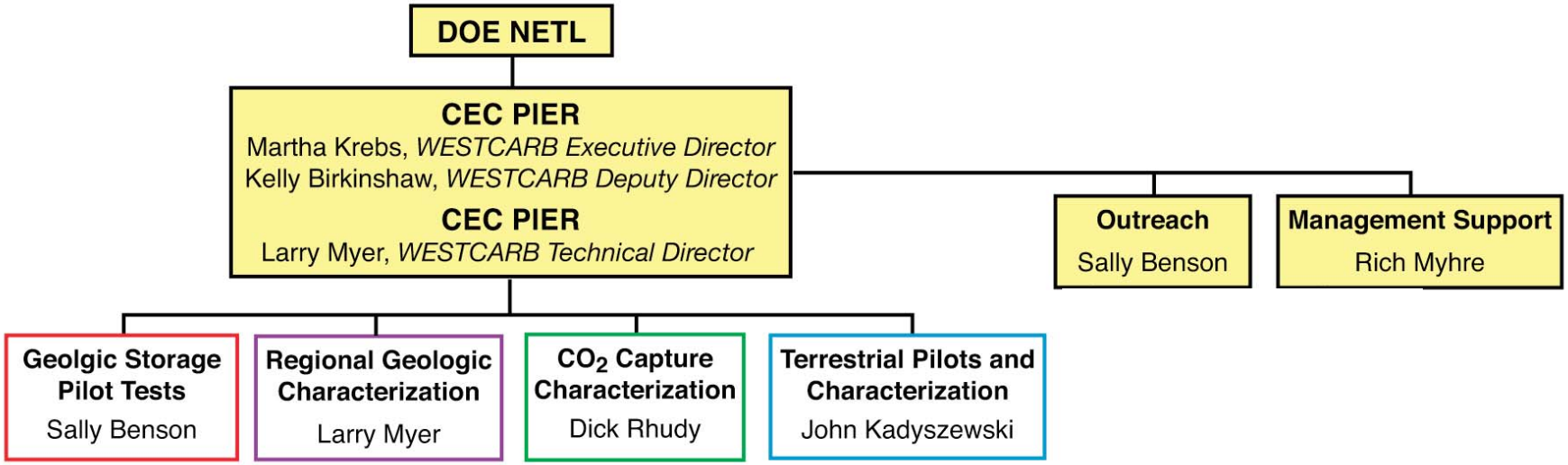
Outline

- **Project overview**
- Geologic storage pilot tests
- CO_2 capture characterization
- Terrestrial pilots and characterization

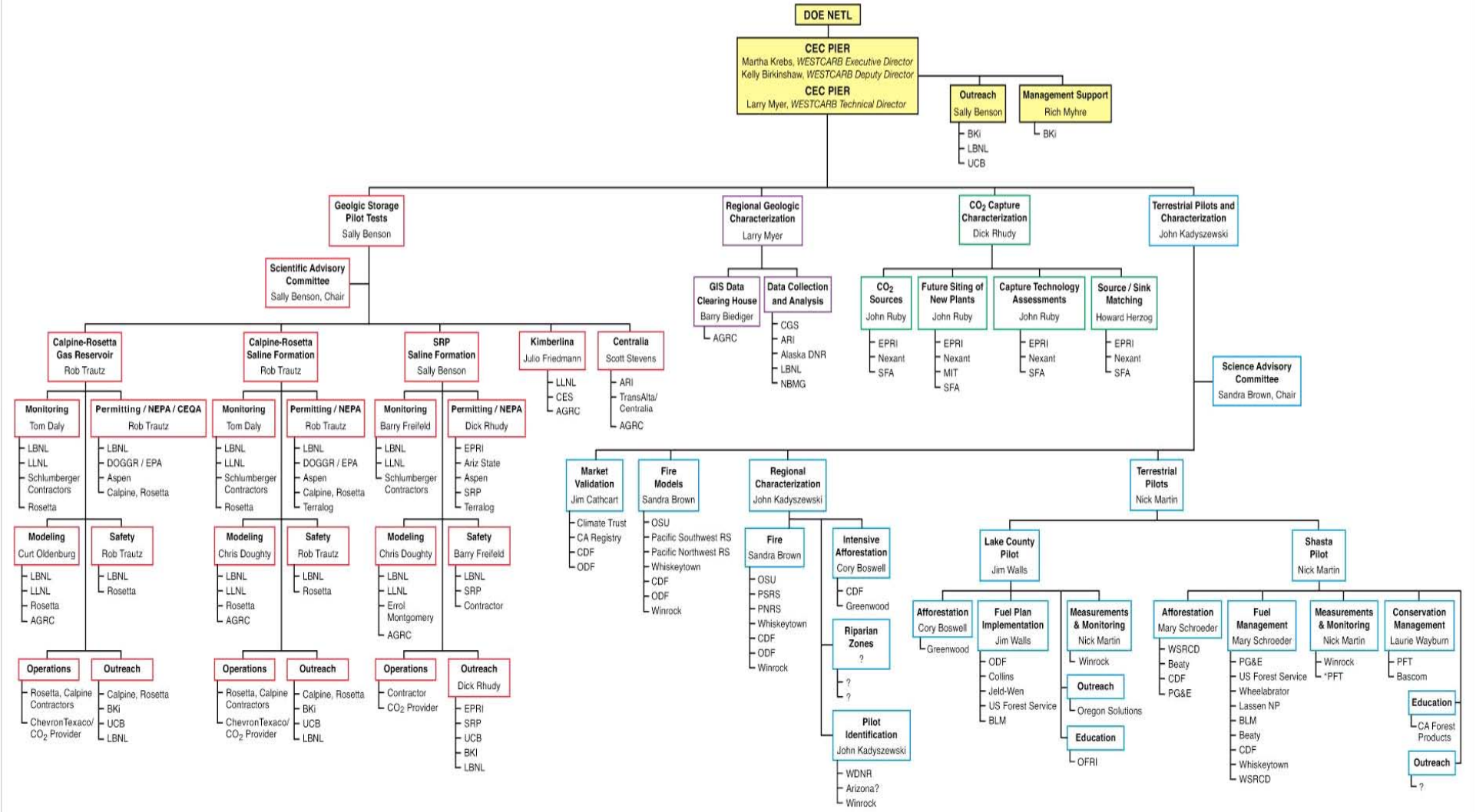
WESTCARB Phase II Participation

- New WESTCARB partners boost membership to 70: Air Liquide, Alaska Department of Natural Resources, Bascom Pacific LLC, California Forest Products Commission, Calpine, Collins Company, DNV Research—Det Norske Veritas, Greenwood Resources, Jeld-Wen Timber and Ranch, Lake County Resources Initiative, Oregon Forest Resources Institute, Oregon State University, Pacific Gas & Electric, Portland General Electric, Rosetta Resources Inc., Schlumberger, USDA Forest Service, US National Park Service, University. of California–Berkeley, Western Shasta Resource Conservation District, Wheelabrator Shasta Energy Company, W.M. Beaty and Associates
- 14 organizations providing cash and in-kind cost share of >$11.5M

WESTCARB Phase II Management Team

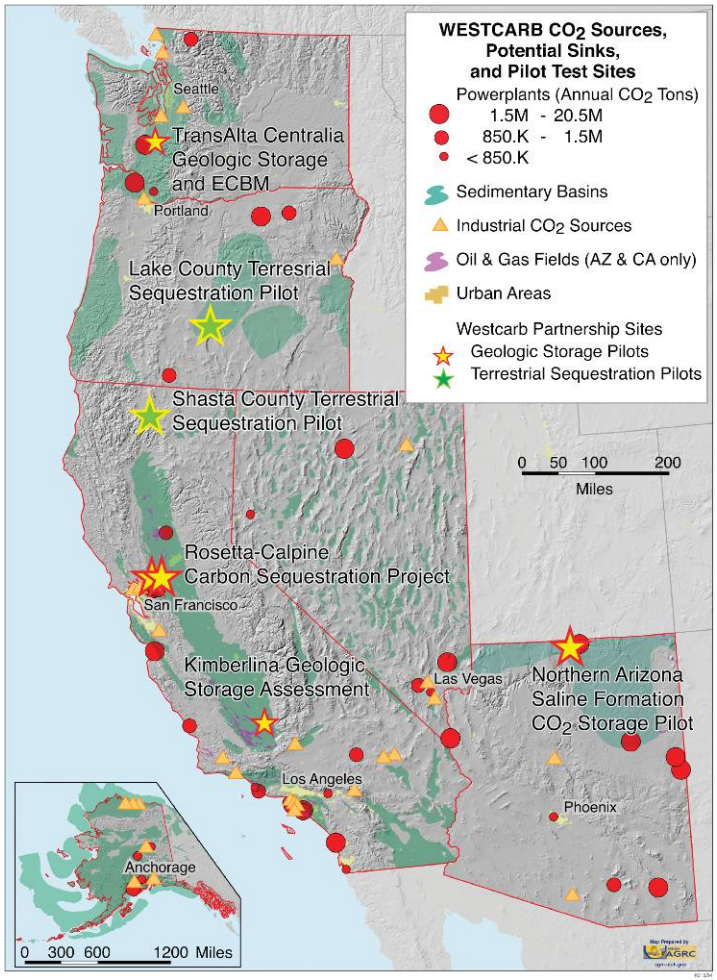


Technical Task Management Structure



Pilots Planned in Arizona, California, Oregon, and Washington

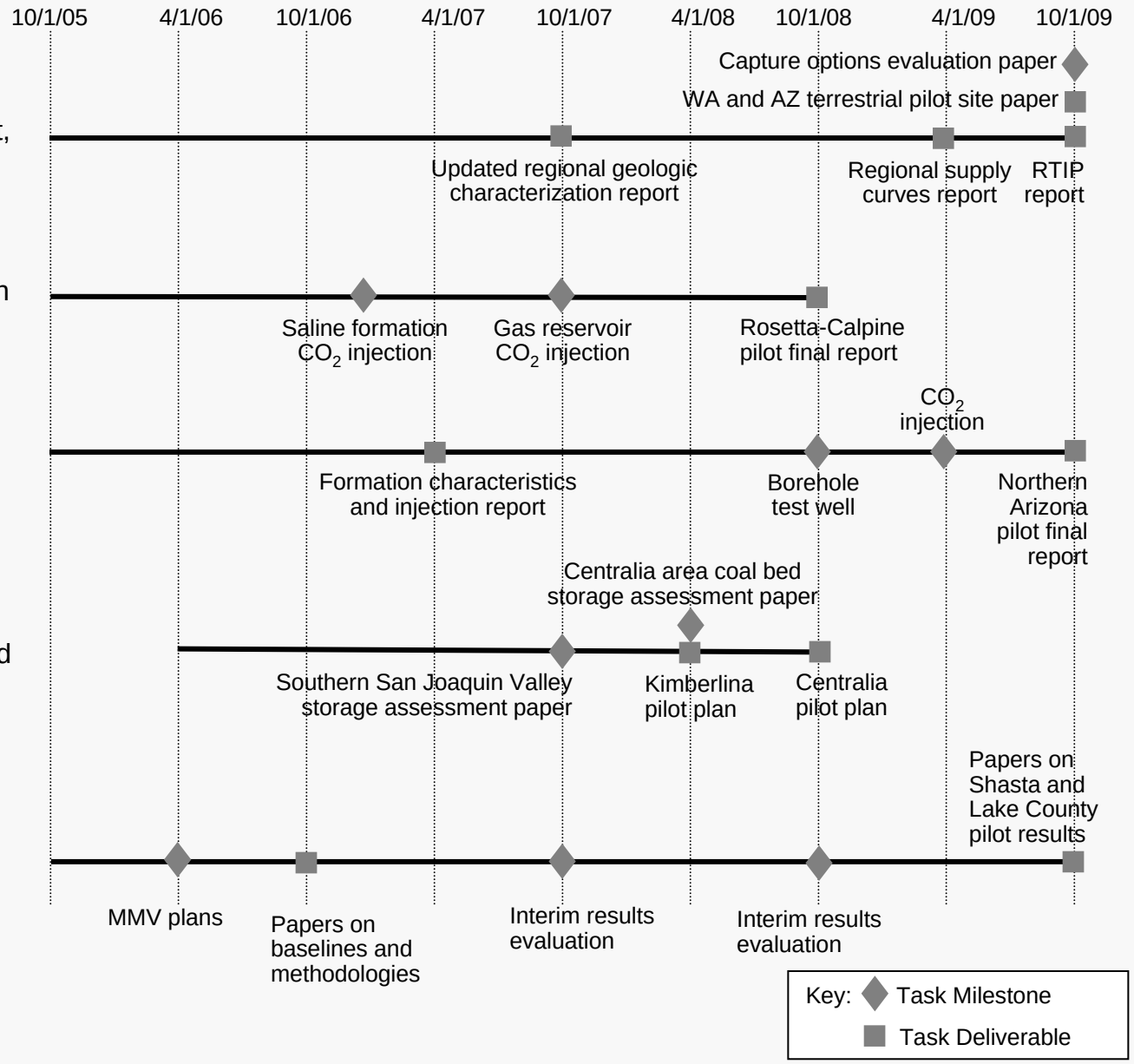
- Pilots are representative of best sequestration options, unique technologies and approaches, in region
- Pilots involve site-specific focus for
  - Testing technologies
  - Assessing capacity
  - Defining costs
  - Assessing leakage risks
  - Gauging public acceptance
  - Testing regulatory requirements
  - Validating monitoring methods



WESTCARB PHASE II SCHEDULE

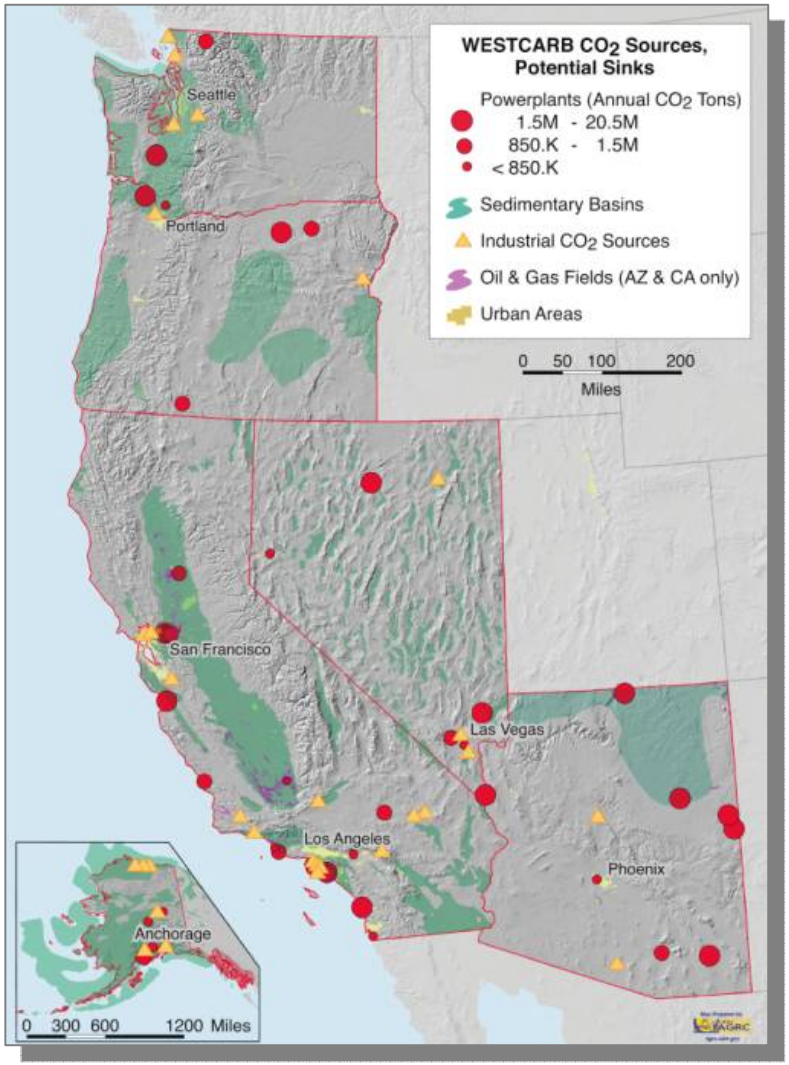
Tasks

1. Continued Regional Characterization, CO_2 Capture Technology Assessment, and Regional Technology Implementation Plan (RTIP)
2. Rosetta-Calpine Carbon Sequestration Saline Formation and Gas Reservoir Pilots
3. Northern Arizona Saline Formation CO_2 Storage Pilot
4. Investigations for Additional CO_2 Storage Pilots (Centralia Coal Bed and Kimberlina Saline Formation/Oilfield)
5. Terrestrial Sequestration Pilots



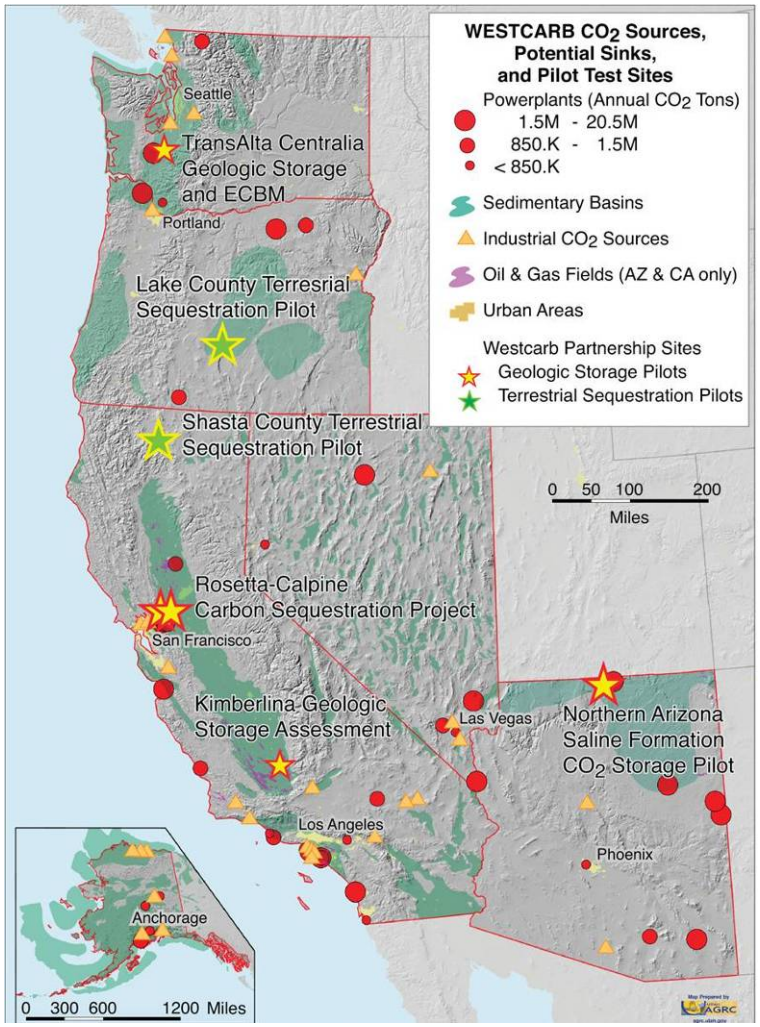
Regional Geologic Characterization Will Be Enhanced

- Additional geologic characterization of sedimentary basins
- Calculation of storage capacity
- GIS data made available through Utah AGRC and NATCARB



WESTCARB Geologic Storage Pilots

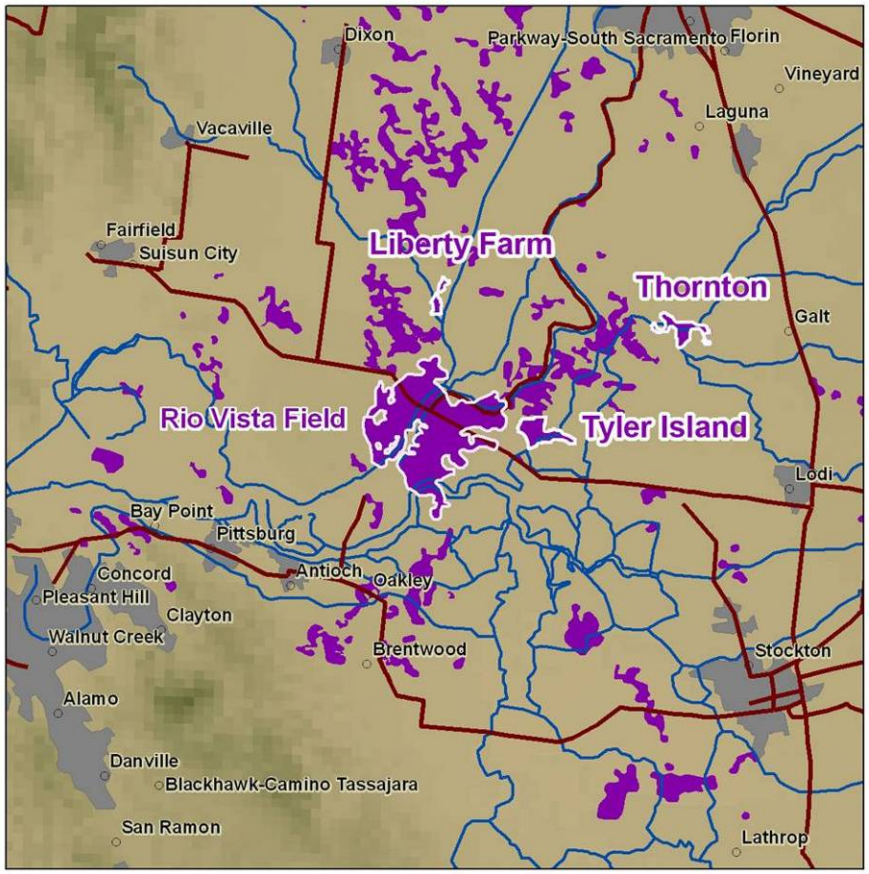
- Rosetta-Calpine Carbon Sequestration Project
- Northern Arizona Saline Formation CO_2 Storage Pilot
- Kimberlina Geologic Storage Assessment
- TransAlta Centralia Geologic Storage and ECBM Assessment



Outline

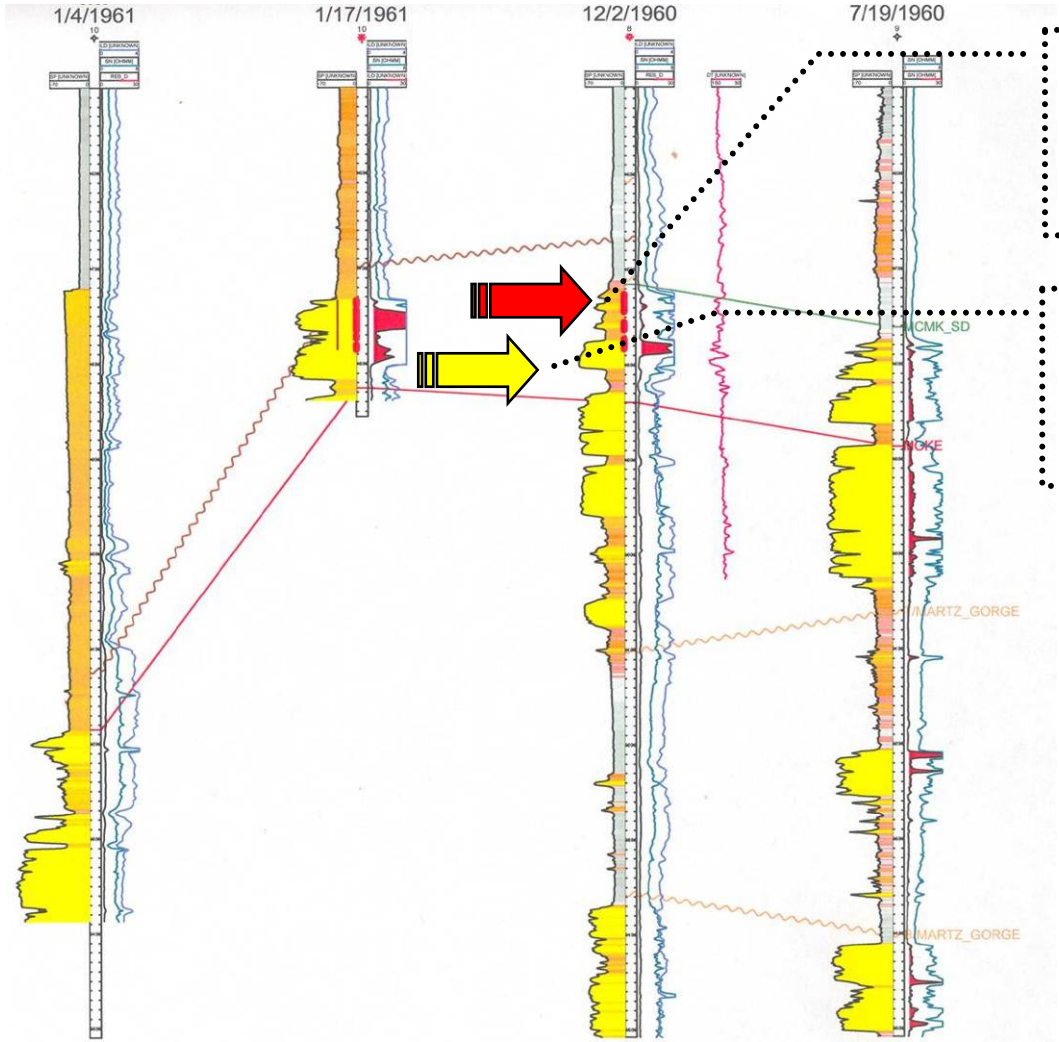
- Project overview
- **Geologic storage pilot tests**
- CO_2 capture characterization
- Terrestrial pilots and characterization

Rosetta-Calpine Carbon Sequestration Project



- Preliminary estimate of 1.8 $GtCO_2$ storage capacity in depleted gas fields in Sacramento Valley (128 fields)
- Preliminary estimate of 140-840 $GtCO_2$ storage capacity in saline formations in California, based on ten largest basins

Rosetta-Calpine: Geological Cross-Section



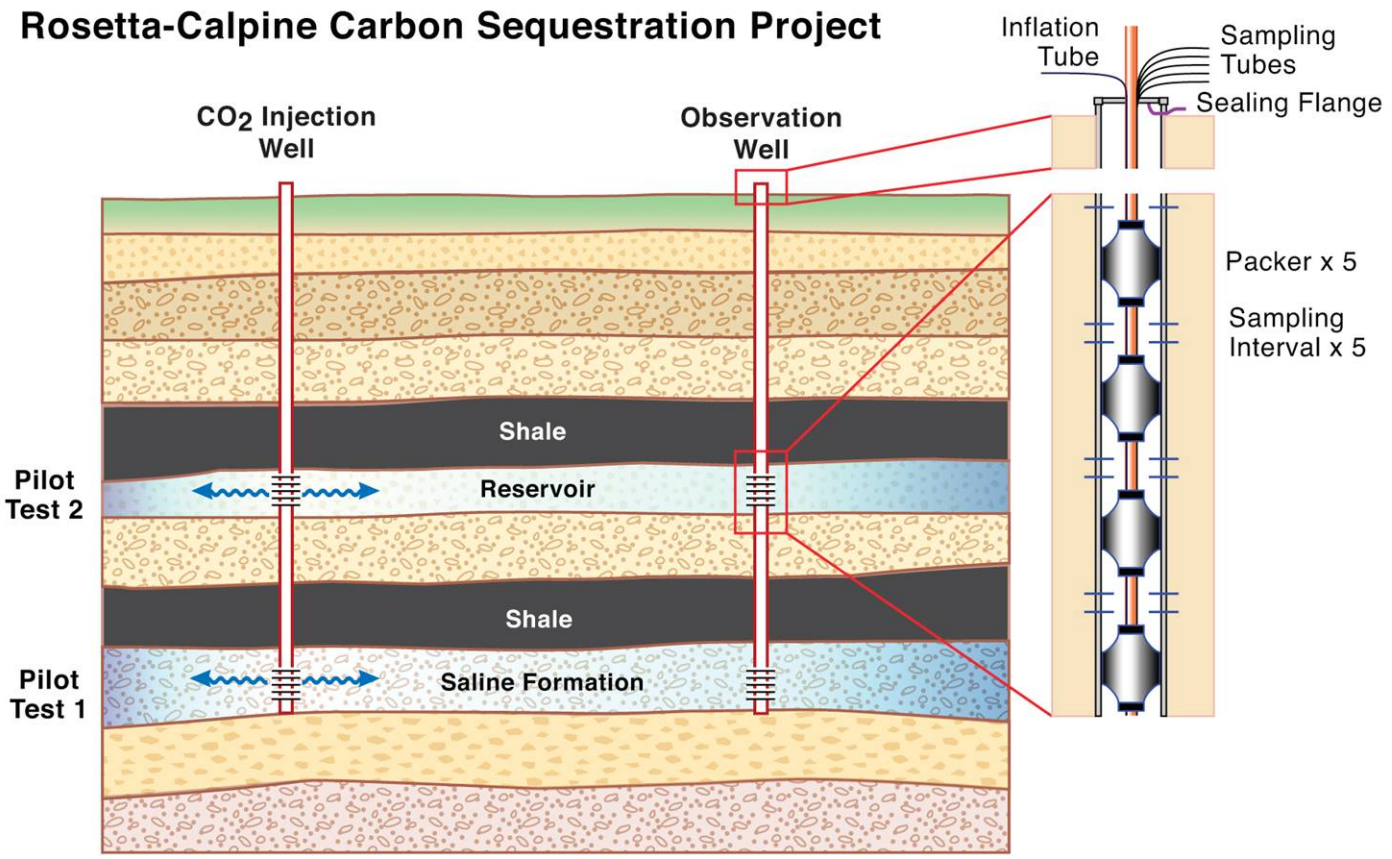
Depleted gas and EGR pilot test (~2000 tonnes CO_2 injection)

Saline formation pilot test (~2000 tonnes CO_2 injection)

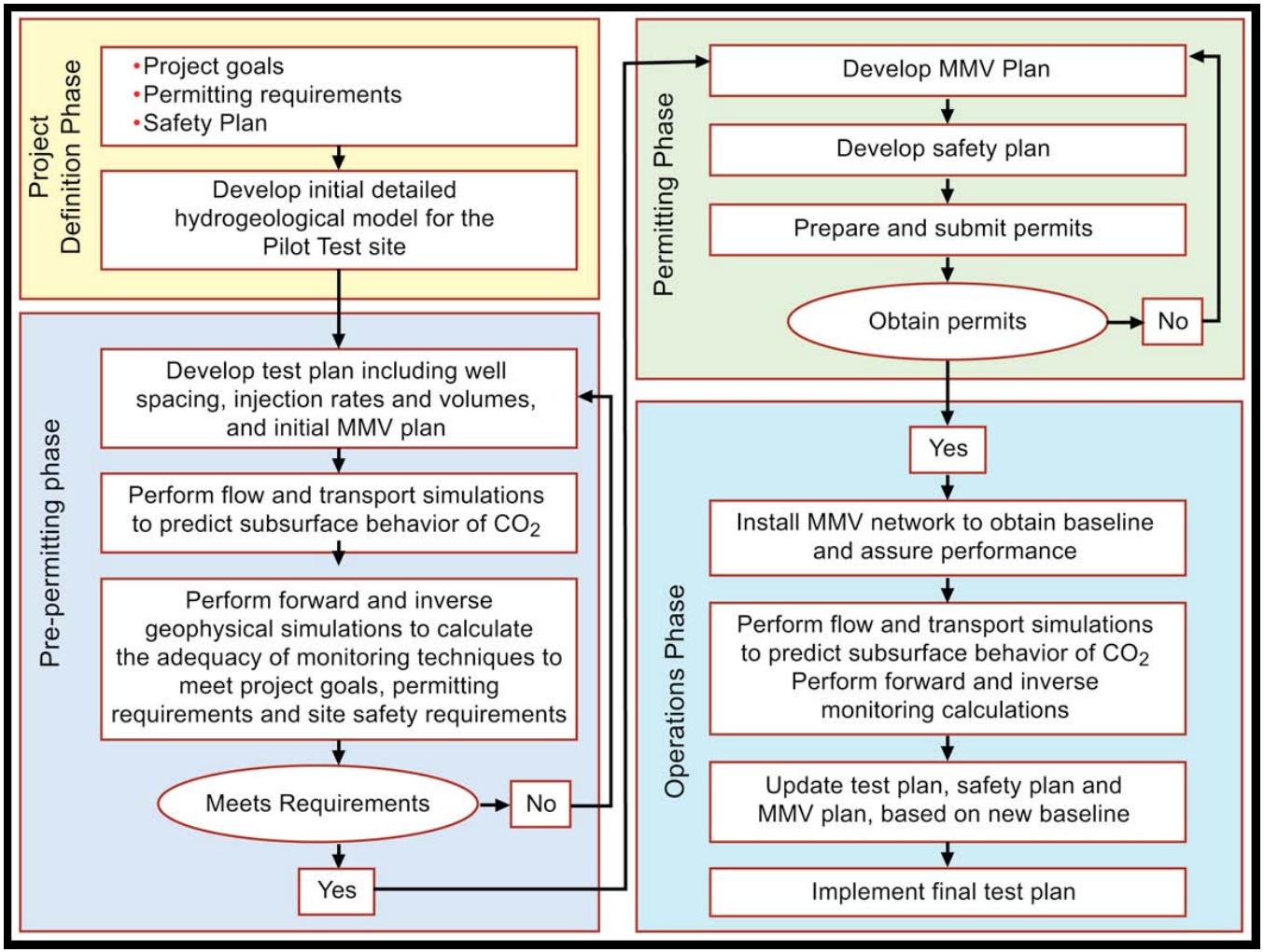
Compliments of Rob Trautz, LBNL

Rosetta-Calpine: Two-Well Pilots

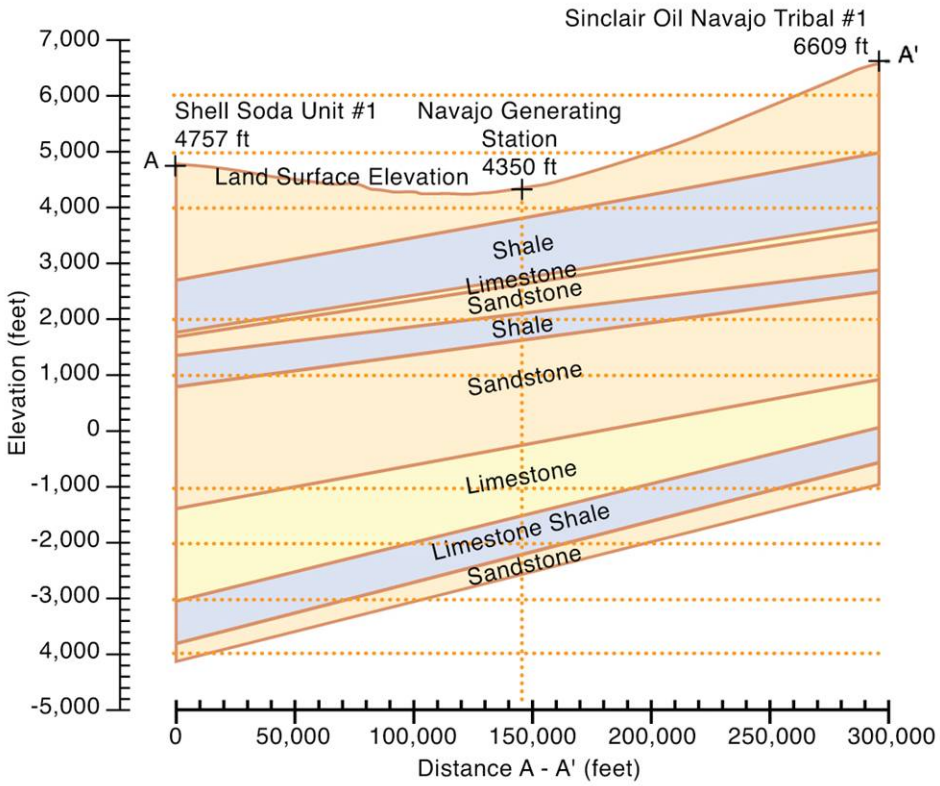
- Fluid and gas sampling
- Cross-well seismic
- VSP
- Reservoir pressure and temperature
- Well logs, including possible RST



Rosetta-Calpine: Project Plan



Northern Arizona Saline Formation CO_2 Storage Pilot

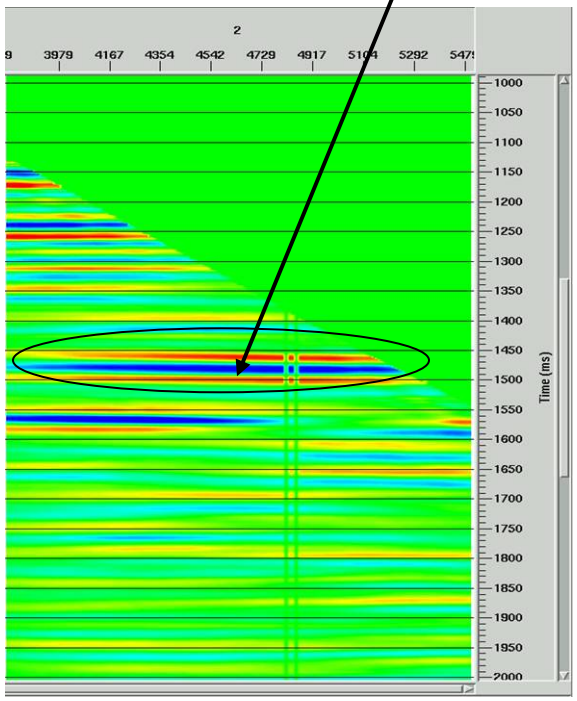


Large but uncharacterized storage capacity in the Colorado Plateau and basins of northern Arizona

Northeastern Arizona

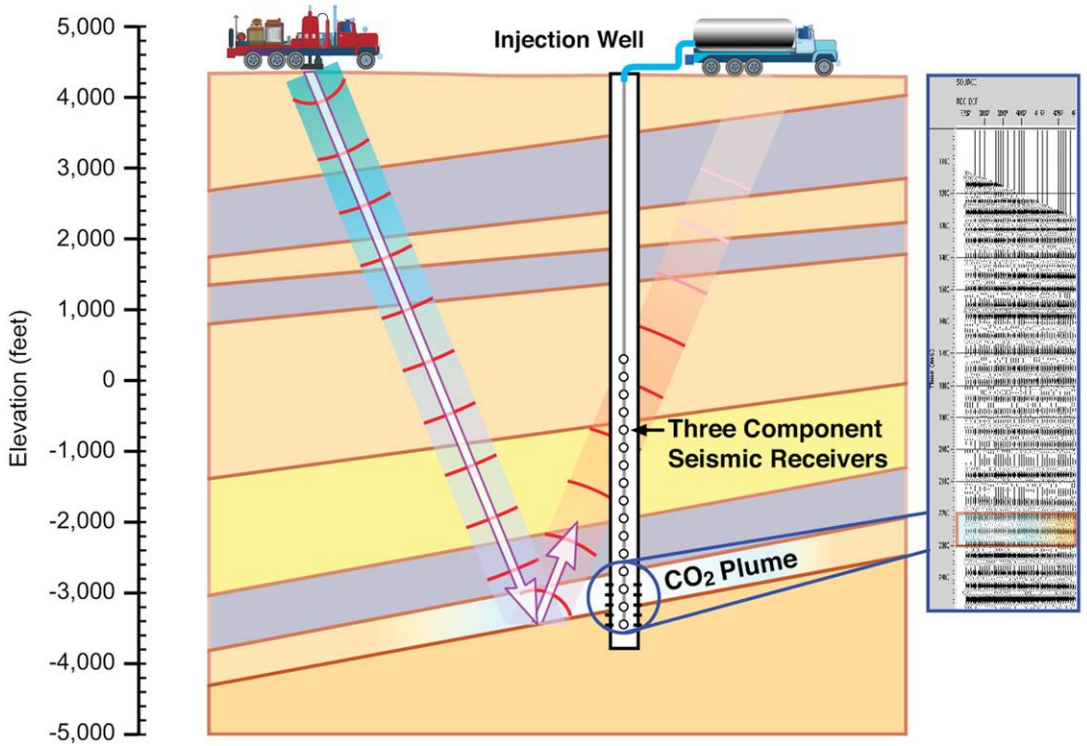
Northern Arizona Saline Formation CO_2 Storage Pilot (cont'd)

Reflection from 1600 tonne CO_2 plume



VSP Results from Frio Formation

Single-well test plan



2000 tonne CO_2 injection

TransAlta Centralia Geologic Storage and ECBM Assessment

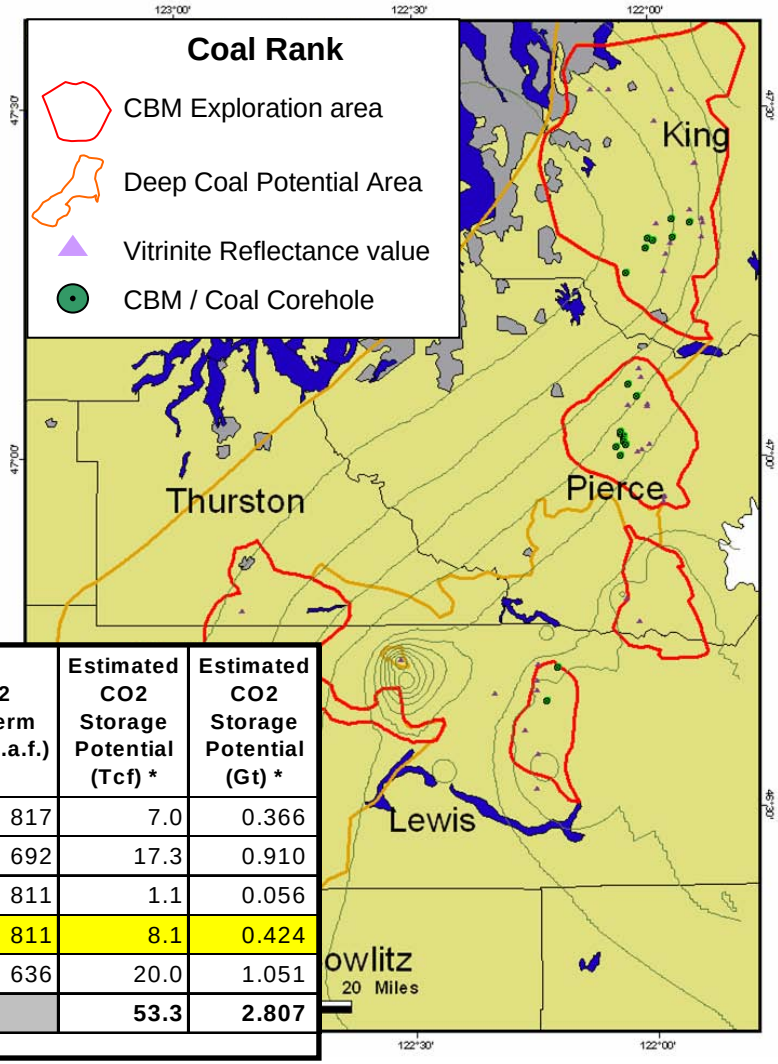
Centralia Generating Station

Assess ECBM and storage potential

Coal bed

Puget, WA Deep Coals Could be Sink for Centralia Plant

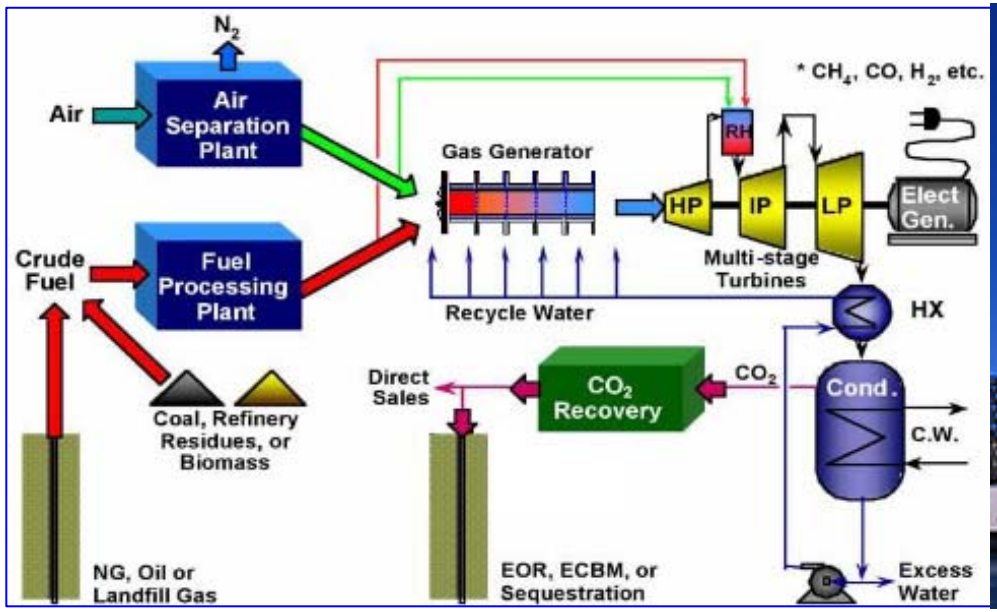
- Favorable coal rank: subbituminous in the W to anthracite in E
- El Paso Production pilot tested 5 md permeability in coals



Sub-Basin	Area (sq mi)	Avg Coal Thickness (ft)	Ash + Moisture (%)	Net Coal Tonnage (million tonnes)	Avg Depth (ft)	CO2 Isotherm (scf/t d.a.f.)	Estimated CO2 Storage Potential (Tcf) *	Estimated CO2 Storage Potential (Gt) *
Carbonado	125	130	57%	8,513	1,691	817	7.0	0.366
Black Diamond	466	110	60%	24,979	1,550	692	17.3	0.910
Storm King	57	65	71%	1,309	1,860	811	1.1	0.056
Centralia	209	100	61%	9,930	1,860	811	8.1	0.424
Rest of Puget Region	1,777	50	71%	31,391	1,500	636	20.0	1.051
Totals	**2,634**			**76,122**			**53.3**	**2.807**

* Represents TOTAL available potential for each region; actual Stored volume would be significantly less (~15-50%)

Kimberlina Geologic Storage Assessment



CES power plant

Images from Clean Energy Systems, Inc.
http://www.cleanenergysystems.com/

Kimberlina: Assess Storage and EOR Opportunities

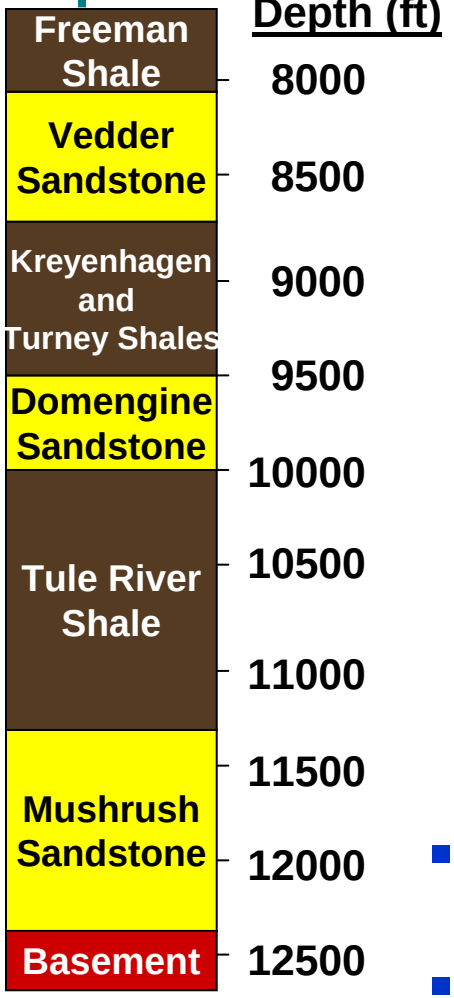
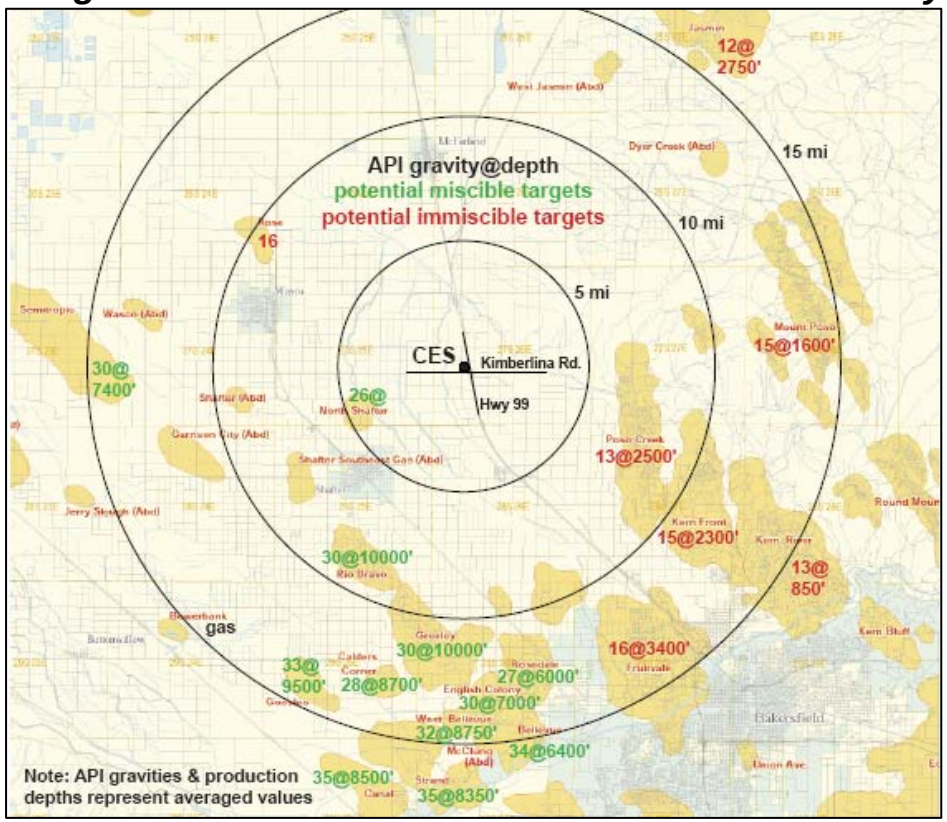


Image from Lawrence Livermore National Laboratory



- Preliminary estimate of 3.4 $GtCO_2$ storage capacity in 121 oil fields in California
- Potential for 5.4 billion barrels of oil production with CO_2-EOR in California

DOE Roadmap Goals for Geological Storage of CO_2 and WESTCARB Contributions

Storage Security and Permanence	Storage Capacity and Optimization	Measurement Mitigation and Verification
▪ Demonstrate safe and secure storage in a depleting gas reservoir ▪ Demonstrate safe and secure injection into 2 saline formations ▪ Improve understanding and modeling of multi-phase flow and residual gas trapping in a saline formation ▪ Improve understanding and modeling of solubility trapping ▪ Predict mineral trapping rates and quantities in two different geologic settings	▪ Perform the first ever test of CO_2-EGR in a natural gas reservoir ▪ Improve understanding and modeling of CO_2 storage capacity in heterogeneous high permeability sandstones ▪ Improve understanding and modeling of storage capacity in lower permeability, highly consolidated sandstones ▪ Develop methods for predicting storage capacity in depleting gas reservoirs ▪ Improve capacity estimation methodology by history matching the injection pilots	▪ Develop methods for monitoring CO_2 storage in gas reservoirs ▪ Test methods for monitoring permeability changes due to CO_2 injection ▪ Enhance and demonstrate the utility of VSP for monitoring CO_2 mitigation from single-well pilot tests ▪ Demonstrate and refine the use of cross-well seismic monitoring to achieve high resolution images of CO_2 migration ▪ Demonstrate and expand the utility of down-hole pressure measurements for monitoring CO_2 injection operations

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- Project overview
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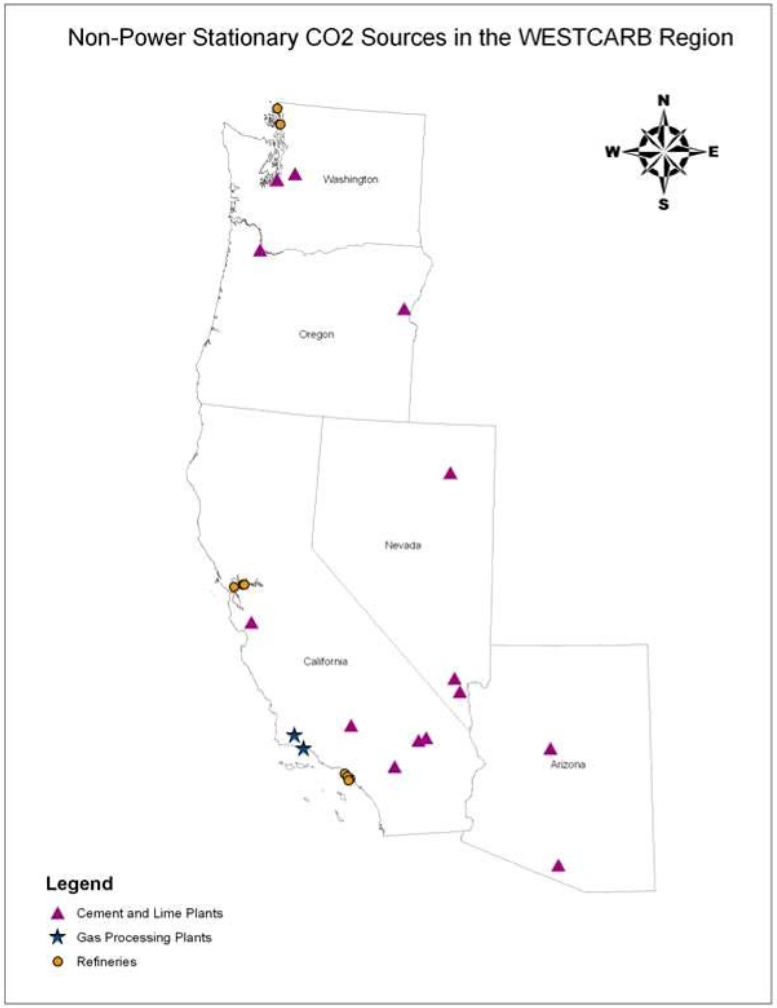
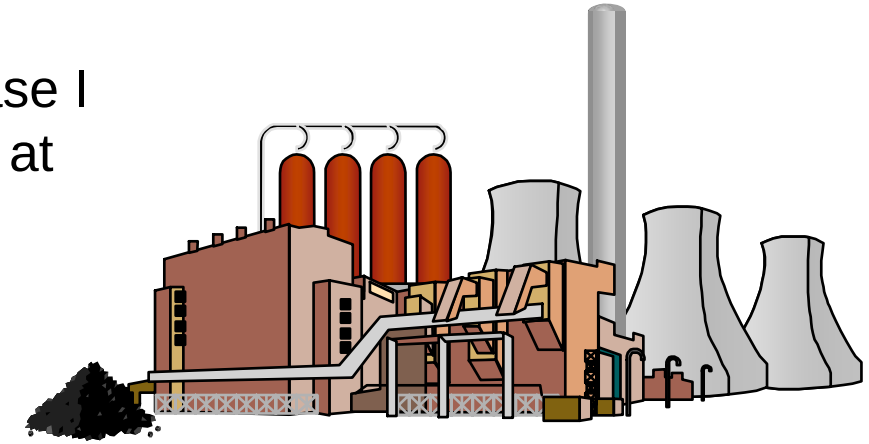
Phase II Activities—Sources

- Power generation data will be updated and expanded to include new and planned facilities
- Non-power-generation industry sources will be asked to provide data for CO_2 and other emissions
- If the industries are reluctant to provide data, as was the case in Phase I, several plants will be selected and examined individually



Phase II Activities—Sources (cont'd)

- Our current assumptions in Phase I are that new plants will be sited at existing plant locations
- To test this assumption, a study will be initiated on future siting of new plants



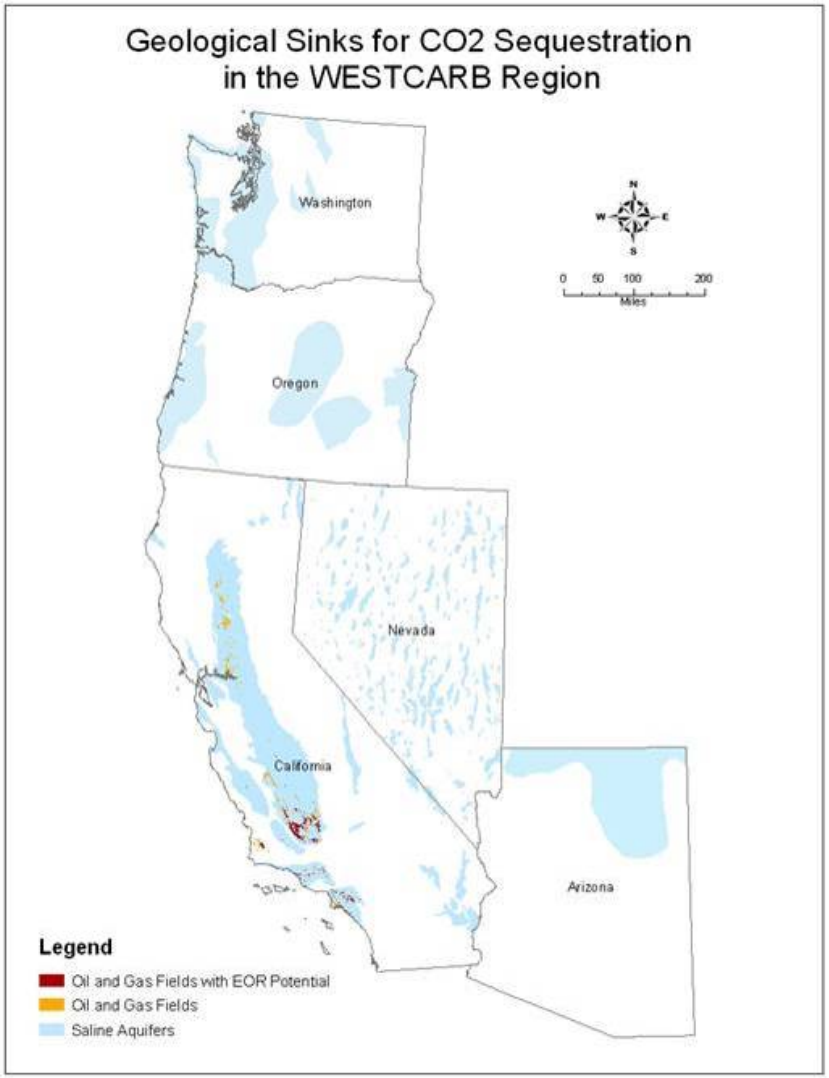
- Consideration will be given to the tradeoffs between fuel, power load location, and CO_2 storage location in siting new plants
- Three types of plants will be evaluated—natural gas, coal, and a refinery producing coke as fuel
- Sites for consideration will be near the CO_2 validation test locations

Phase II Activities—Site-Specific Studies of Capture

- To gain a better understanding of how the options at a specific plant differ from the generic evaluation used for the regional options study, several site-specific studies will be undertaken
- Currently planned for plant sites being considered for the CO_2 storage validation projects
- Each evaluation will examine the appropriate separation and capture technologies and estimate the impacts of their installation on the performance and costs of existing plants
- Separation and capture technology developers will be contacted to update estimates of performance, costs, and commercial readiness of their processes
- Engineering documents to be produced include process energy and material balances, major equipment lists, cost estimates, and drawings to show how separation and capture facilities will be arranged on-site
- Results will be compared to the generic evaluations to help determine the uncertainty in results from the regional options work

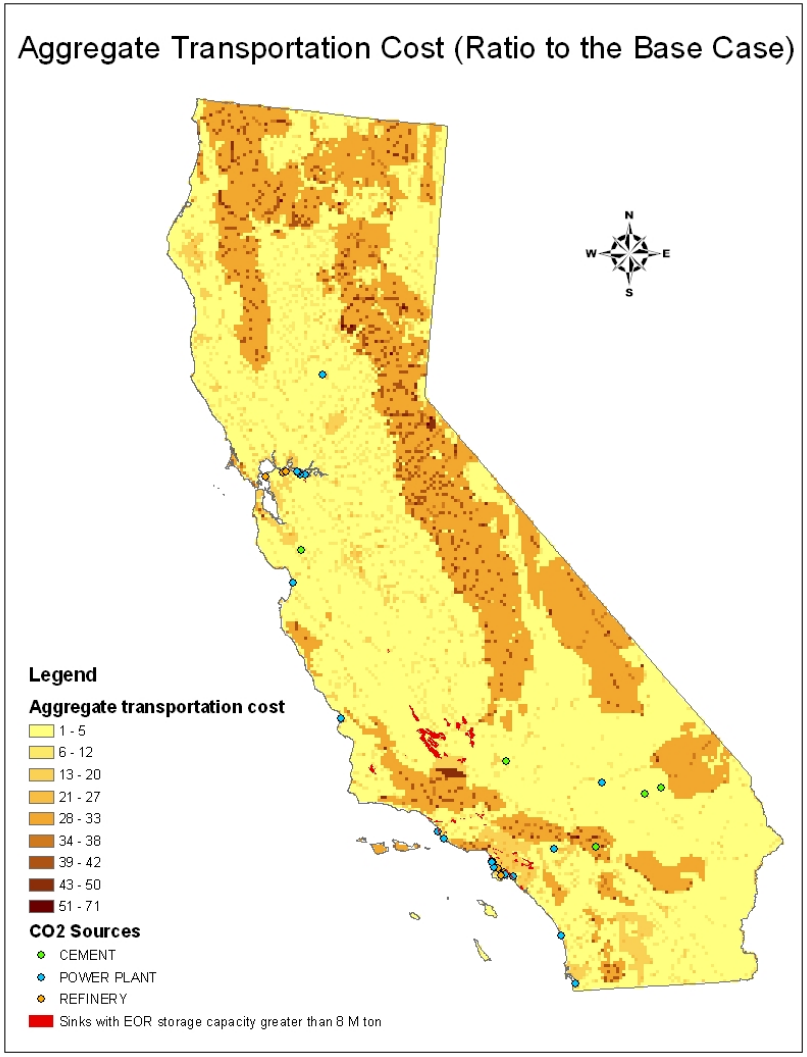
Phase II Activities—Source-Sink Matching

- Improved screening criteria (to determine best prospective reservoirs)
  - Phase I: limited to EOR and ECBM
  - Phase II: expand to gas reservoirs, saline formations, and coal beds
- Improved data for reservoirs (spatial extent, thickness, porosity)
- Improved methodology to determine fraction of pore space accessible for storage



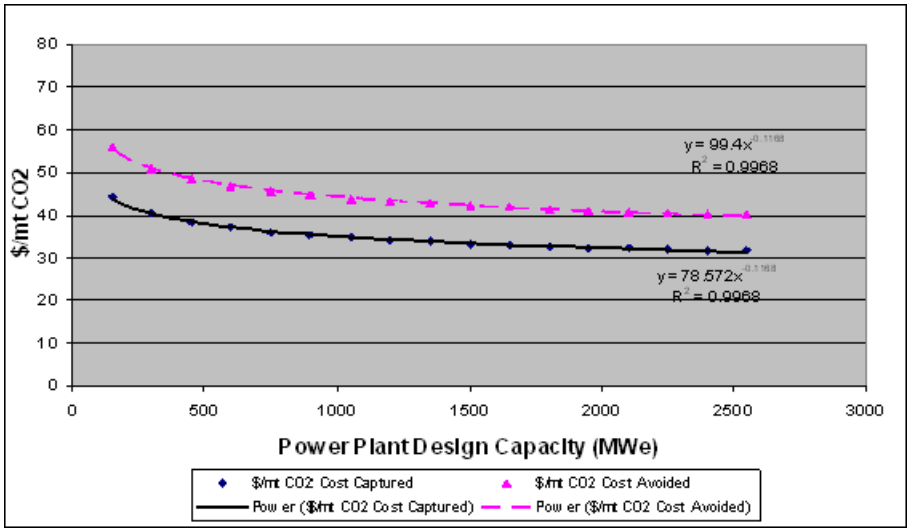
Phase II Activities—Source-Sink Matching (cont'd)

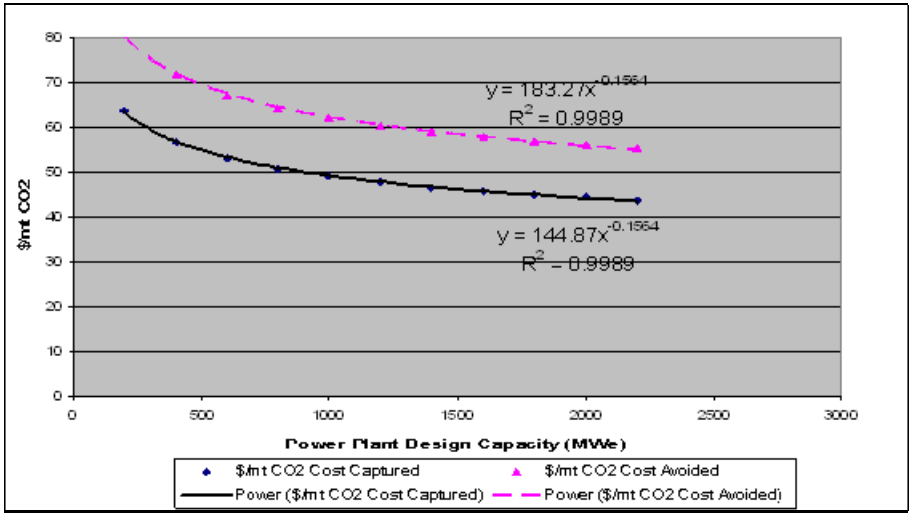
- Consider topography and existing rights-of-way in determining paths between sources and sinks
- Balance capacities of sources and sinks when doing match



Phase II Activities—Source-Sink Matching (cont'd)

- Review all capture algorithms and update with current information
- Revise capture cost algorithm from generic model used in Phase I to specific models for each type of CO_2 source





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- Project overview
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Phase II Terrestrial Sequestration Overview

- Objectives
- Shasta County Pilot
  - Afforestation
  - Fuel treatments to reduce uncharacteristically severe fires
  - Conservation management on timberlands
- Lake County Pilot
  - Fuel treatments to reduce uncharacteristically severe fires
  - Assess sequestration potential for hybrid poplars
- Additional Characterization Activities
  - Enhanced fire analysis
  - Sequestration potential of fast-growing species
  - Improved baseline methodologies for conservation and fire

Phase II Objectives: Terrestrial Sequestration

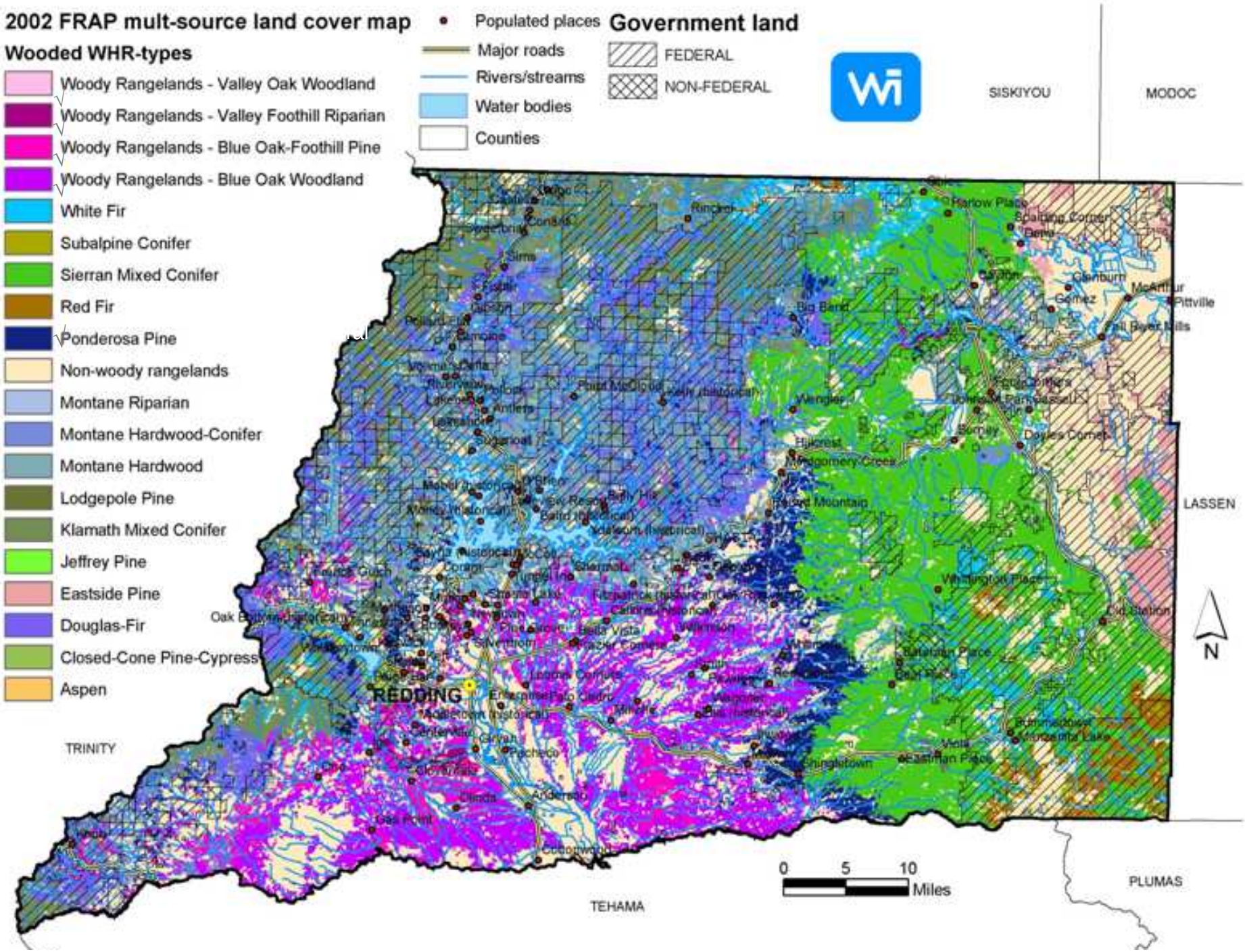
- Validate afforestation potential for rangelands
  - Determine baselines
  - Use plantings of native species across suitable rangeland site classes to establish sequestration potential on rangelands
  - Determine growth rates and establishment costs for fast-growing species adapted for dry sites
- Develop and implement methodology for determining credits for reducing emissions from uncharacteristically severe fires
  - Assess sequestration benefits and costs for implementing new fire management methods
  - Achieve market recognition of methodology for measuring and reporting carbon benefits from changing fire management
- Implement project to reduce emissions through conservation and sustainable management of forest lands

Shasta County Partners

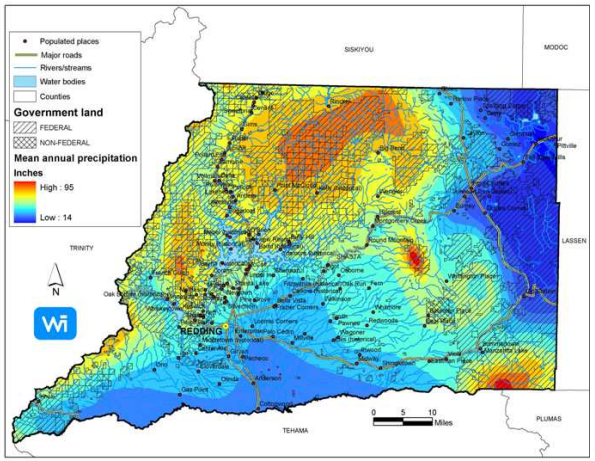
- Western Shasta RCD
- WM Beaty and Associates
- Pacific Forest Trust
- Wheelabrator Shasta
- California Climate Action Registry
- Climate Trust
- California Department of Forestry and Fire Protection
- California Energy Commission
- California Forest Products Commission
- US Forest Service
  - Pacific Southwest Research Station
  - Pacific Northwest Research Station (Pacific Wildland Fire Sciences Laboratory, FERA)
  - Shasta Trinity National Forest
- National Park Service
  - Whiskeytown National Recreation Area
  - Lassen Volcanic National Forest
- Bureau of Land Management
- Pacific Gas & Electric
- Bascom Pacific LLC

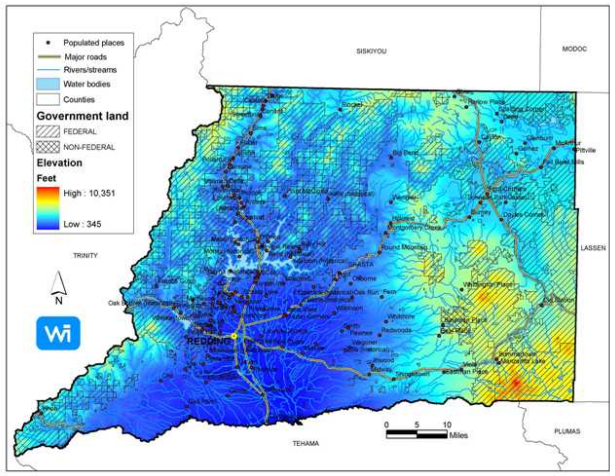
Validate Afforestation Potential of Rangelands

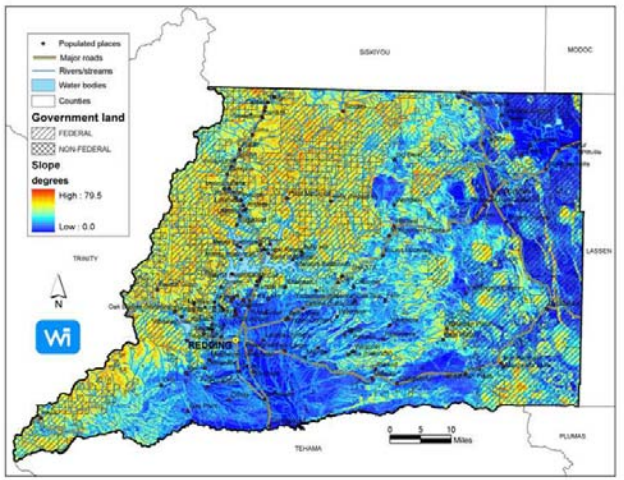
- Classify lands according to potential for afforestation
- Set criteria for distribution of pilot plantings
- Prepare plan for planting
- Convene technical panel to review choices
- Review site history and take initial field measurements (baseline)
- Collect data on establishment and maintenance costs

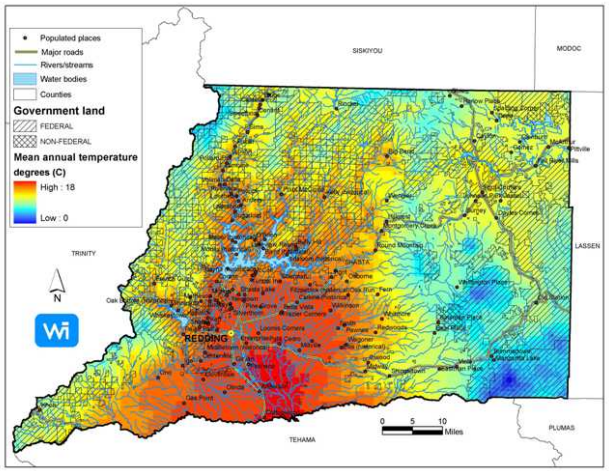

2002 FRAP mult-source land cover map
Wooded WHR-types
Woody Rangelands - Valley Oak Woodland
Woody Rangelands - Valley Foothill Riparian
Woody Rangelands - Blue Oak-Foothill Pine
Woody Rangelands - Blue Oak Woodland
White Fir
Subalpine Conifer
Sierran Mixed Conifer
Red Fir
Ponderosa Pine
Non-woody rangelands
Montane Riparian
Montane Hardwood-Conifer
Montane Hardwood
Lodgepole Pine
Klamath Mixed Conifer
Jeffrey Pine
Eastside Pine
Douglas-Fir
Closed-Cone Pine-Cypress
Aspen
Populated places
Major roads
Rivers/streams
Water bodies
Counties
Government land
FEDERAL
NON-FEDERAL
SISKIYOU
MODOC
LASSEN
PLUMAS
TEHAMA
TRINITY
REDDING
N
0 5 10
Miles

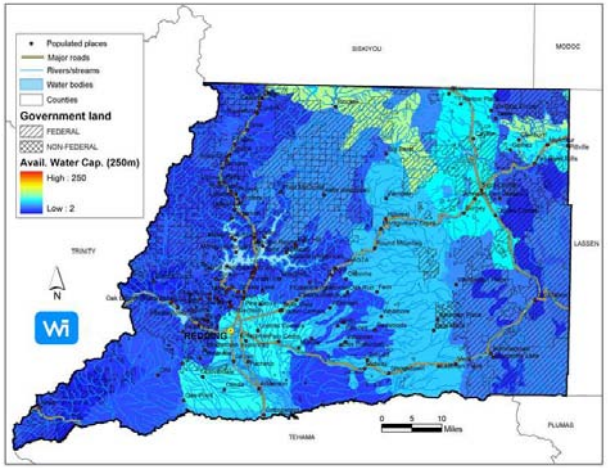
Inputs for Classification





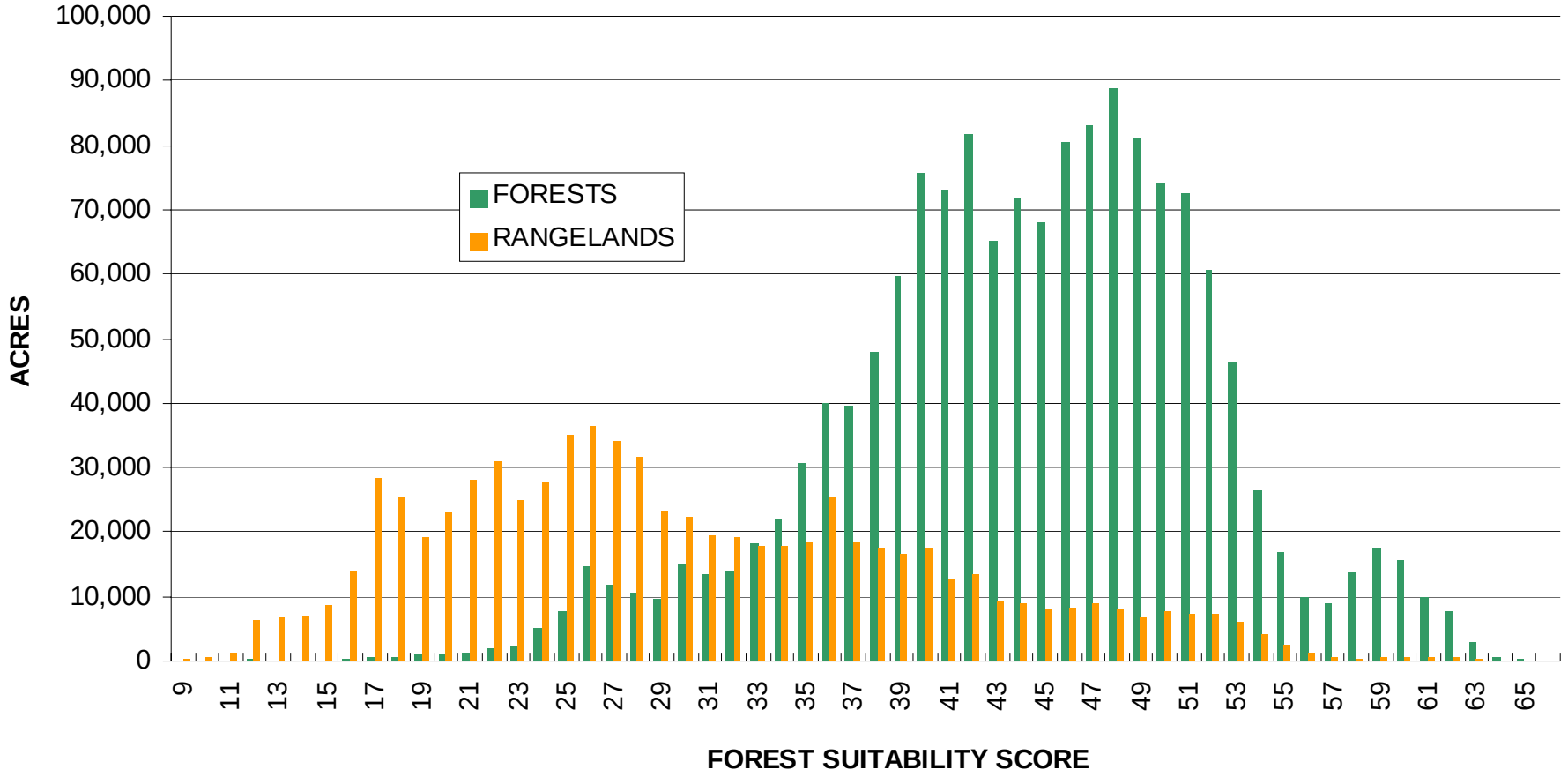




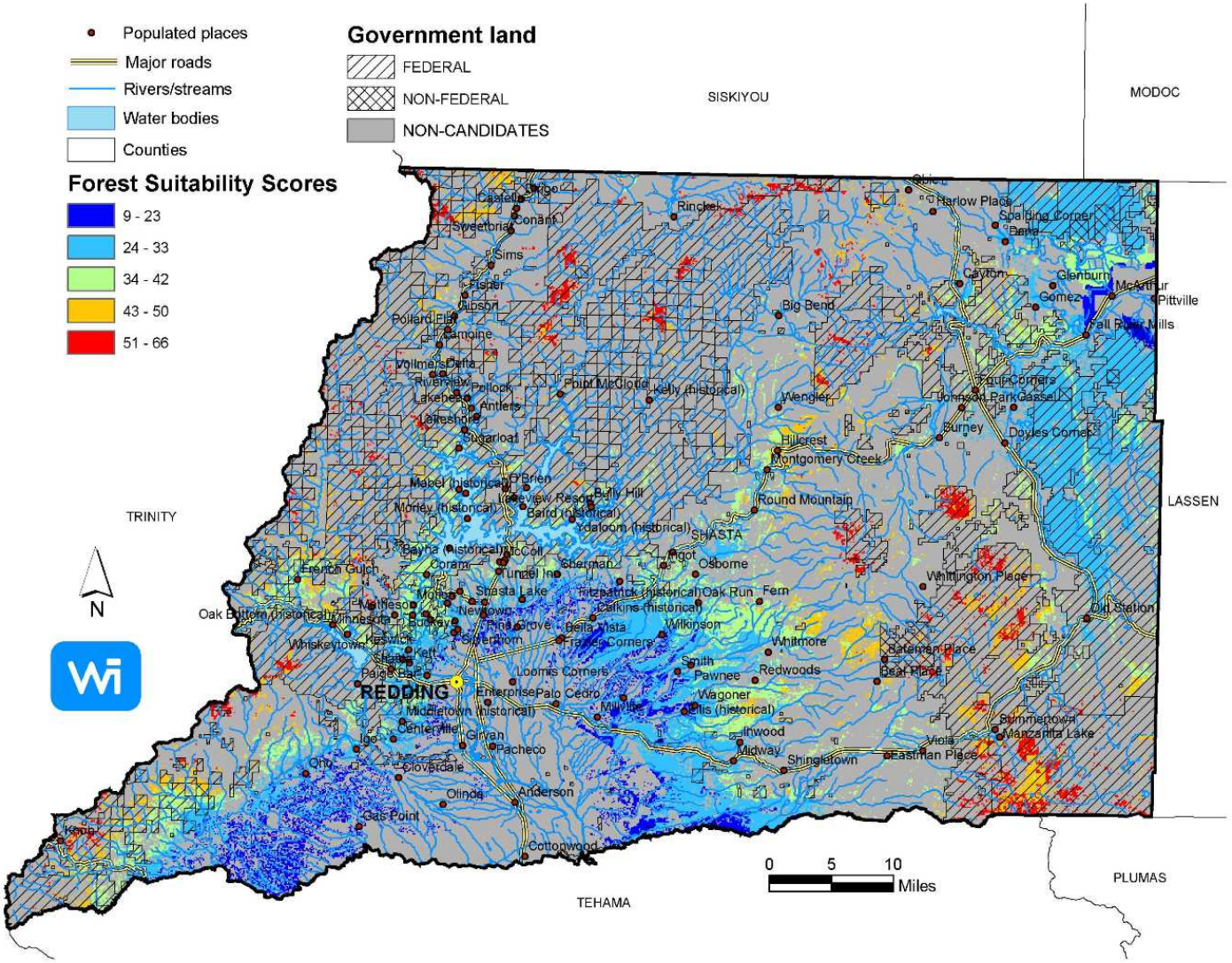


Shasta County Forest Suitability

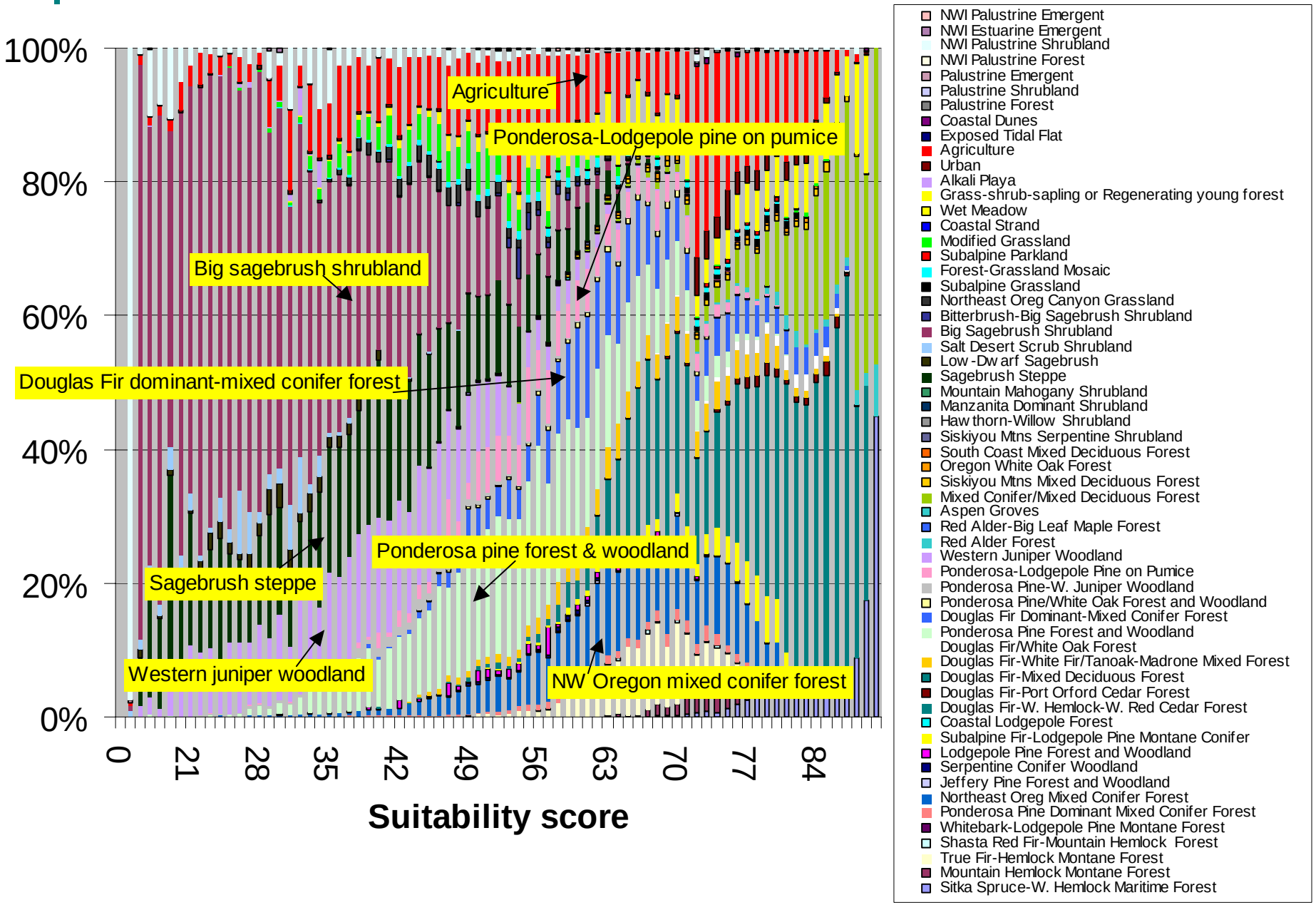
Overlap of rangeland classes in Shasta County (with canopy closure <40%) that have the same biophysical characteristics as current forests ~550,000 acres or 73% of rangelands in county



Existing Rangelands Suitable for Forests



Species Mix for Various Suitability Scores



Site History and Initial Carbon Stocks

Lake County Partners

- Lake County Resources Initiative
- Oregon Department of Forestry
- Oregon State University
- Greenwood Resources
- California Climate Action Registry
- Climate Trust
- Oregon Forest Resources Institute
- Collins Company
- Jeld-Wen Timber and Ranch
- US Forest Service, Fremont National Forest
- Bureau of Land Management

Develop Methodology for Fire Credits from Reducing Hazardous Fuels

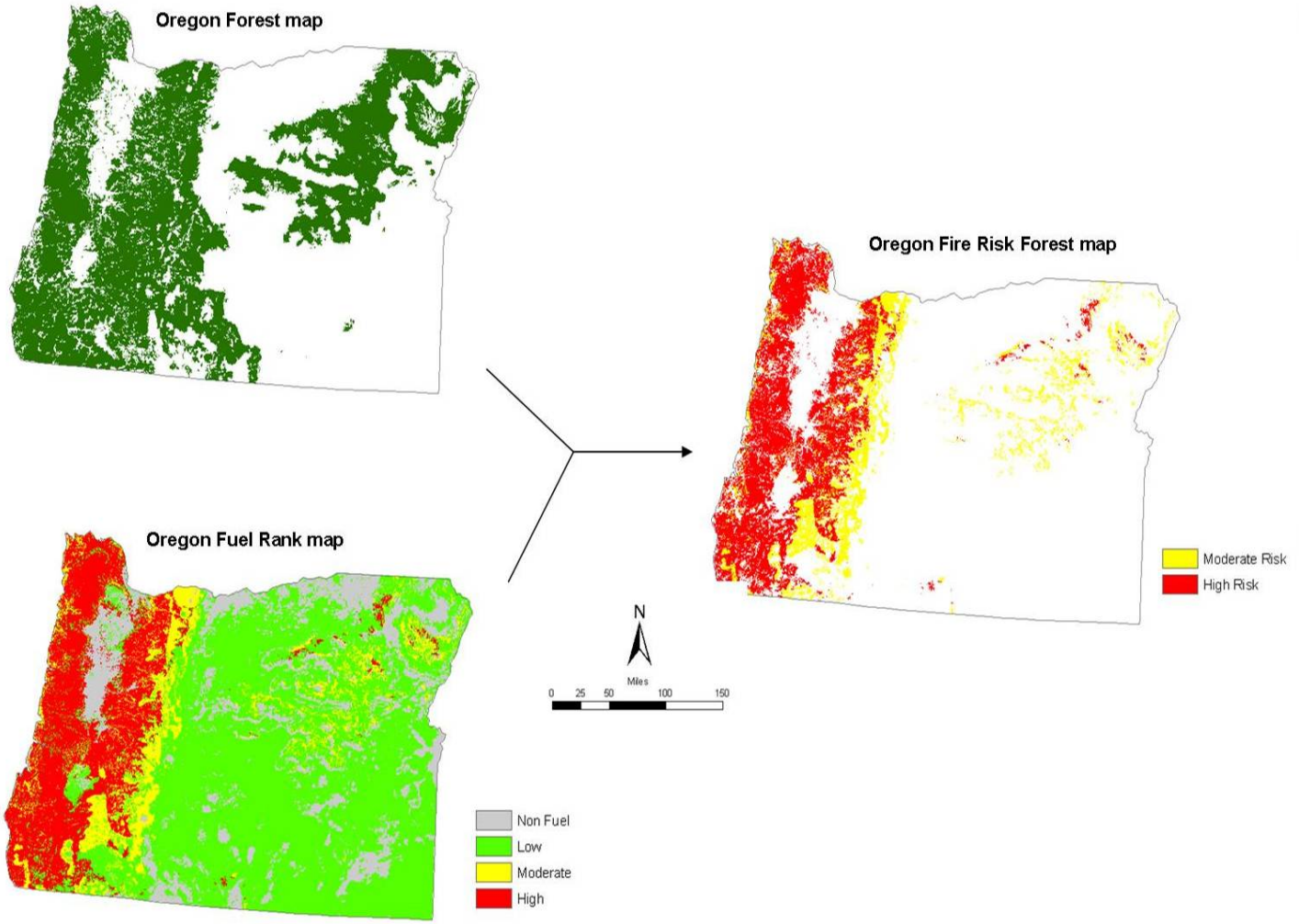
- Convene technical panel to identify available data and relevant models that assess the effect of fire on carbon stocks
- Review and test relevant models
- Prepare draft methodology
- Review pilot site characteristics
- Collect field data from chronosequenced sites
- Use field data to validate methodology

First Challenge—Setting Baseline

2004 French Gulch Fire

- Assign fire risk and set rules to predict intensity
- Quantify loss of carbon stocks due to fires of different intensities
- Predict fire return intervals
- Determine existing carbon stocks on lands at risk

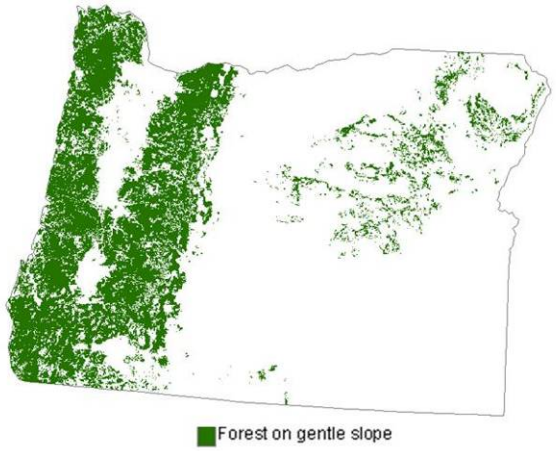
Fire Risk

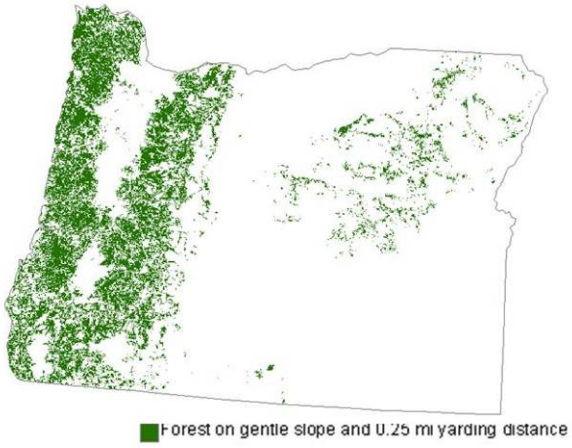

Oregon Forest map
Oregon Fuel Rank map
Oregon Fire Risk Forest map
Moderate Risk
High Risk
N
Miles
0 25 50 100 150
Non Fuel
Low
Moderate
High

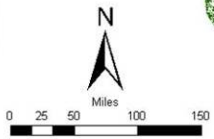
Fuel Treatments to Reduce Uncharacteristically Severe Fires

- Review and classify lands where fuel treatments will occur
- Design measurement and monitoring plan
  - Measure overall carbon stocks
  - Measure removals of hazardous fuels
- Carry out fuel treatments
  - Transport fuels to biomass energy facility
  - Collect data on transport and treatment costs
  - Analyze carbon benefits from biomass energy component

Suitability of Sites for Fuel Treatment

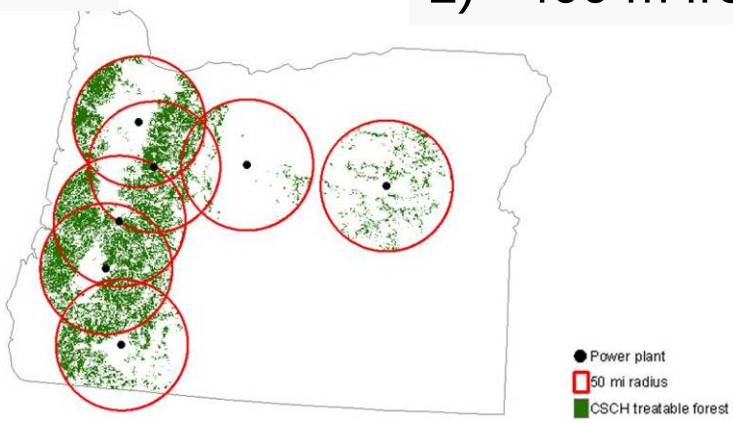






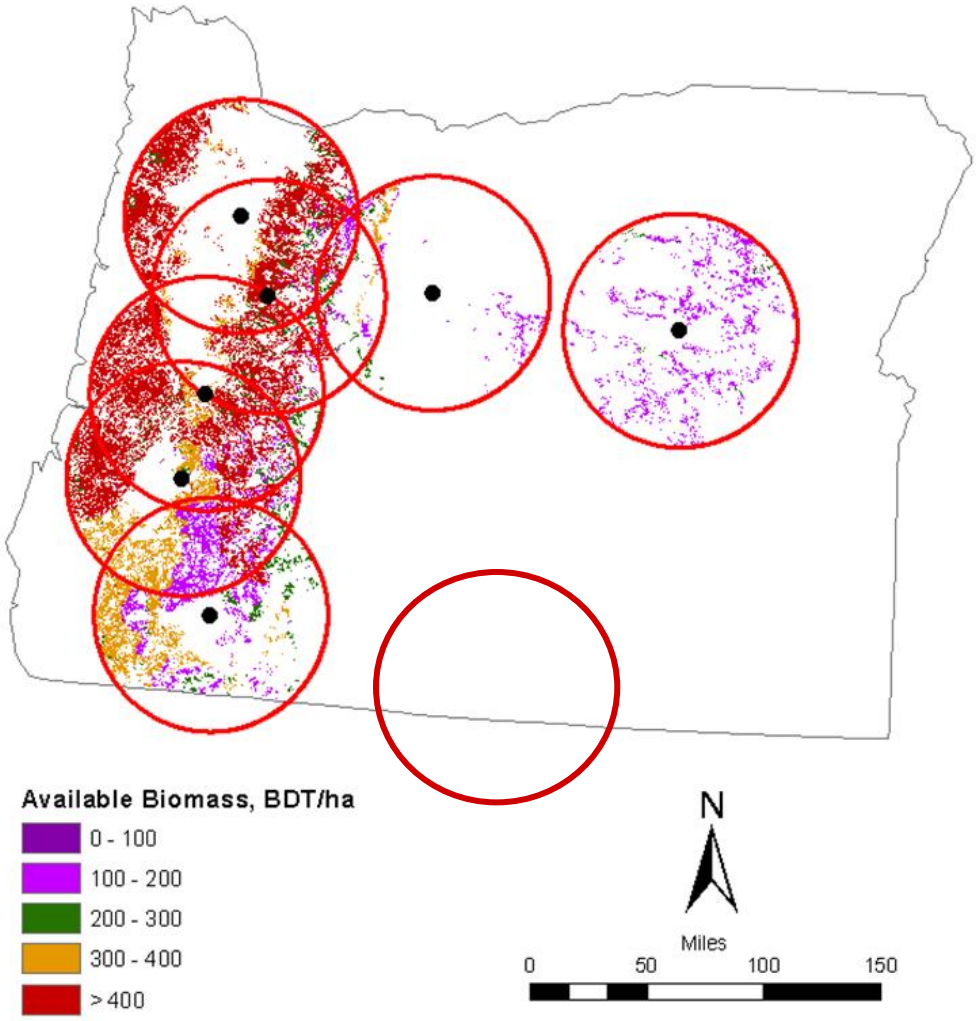
1) Slope <40%

2) <400 m from road



3) Within 50 miles of power plant

Available Biomass Fuels Near Power Plants



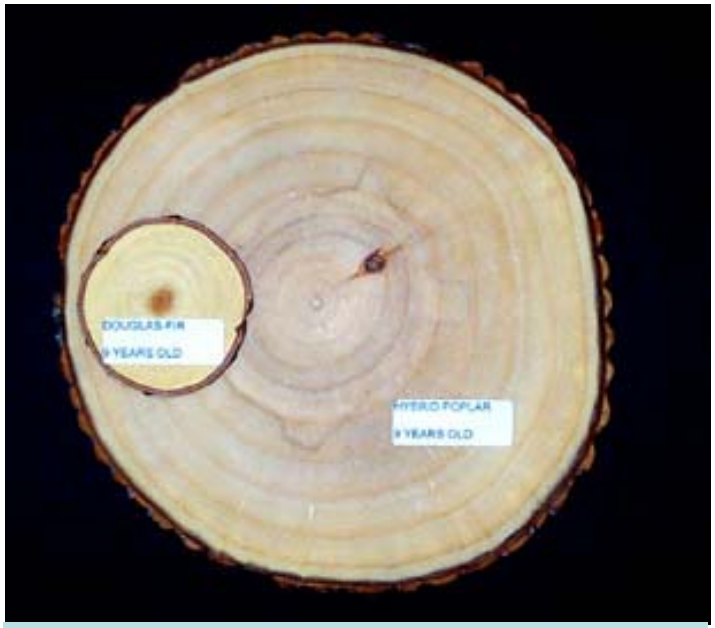
Lake County does not currently have a biomass energy plant. The Oregon Solutions Project is trying to identify sufficient fuel to attract a private investor to build a plant.

Additional Characterization

- Extend fire analysis to other sites
  - Collect field data from chronosequenced sites to improve accuracy of emission estimates across various forest types found in the region
  - Review opportunities for new sites where forest lands are at moderate to severe risk of fire on lands with <40% slope within 400 meters of existing roads and sufficient potential fuel within 50 miles

Additional Characterization Activities

Evaluate sequestration potential for fast-growing species



9 years diameter growth

- ***Douglas Fir*** 4 dry t/acre/yr
  ~50 year rotation
- ***Hybrid Poplar*** 10 dry t/acre/yr
  6-8 year rotation

Source: Jon Johnson Associate Professor
Washington State University

Achieve Market Recognition and Validation

- Climate Trust
- California Climate Action Registry

Outreach

- Stakeholder meetings
- California Forest Products Commission
- Oregon Forest Resources Institute