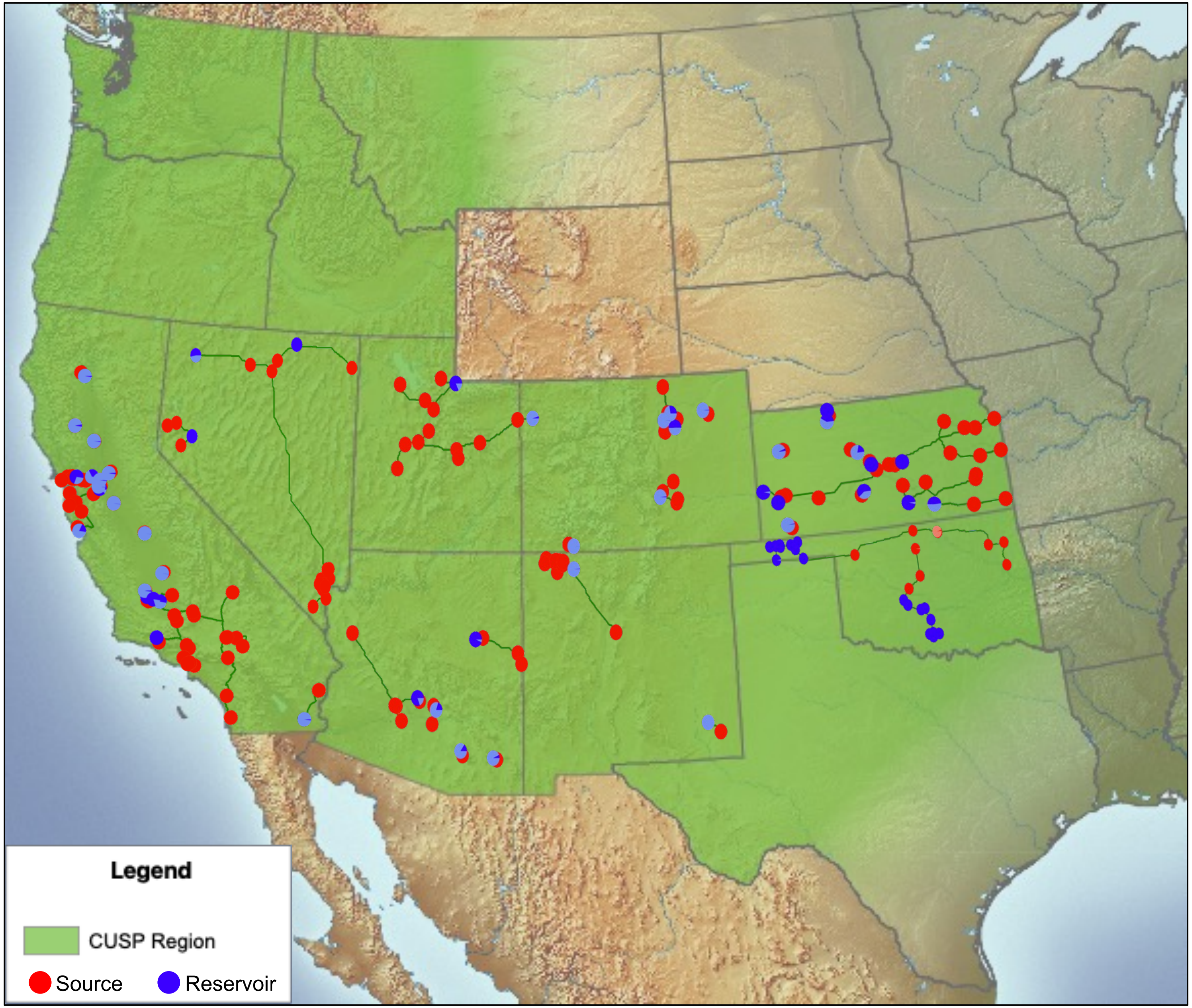
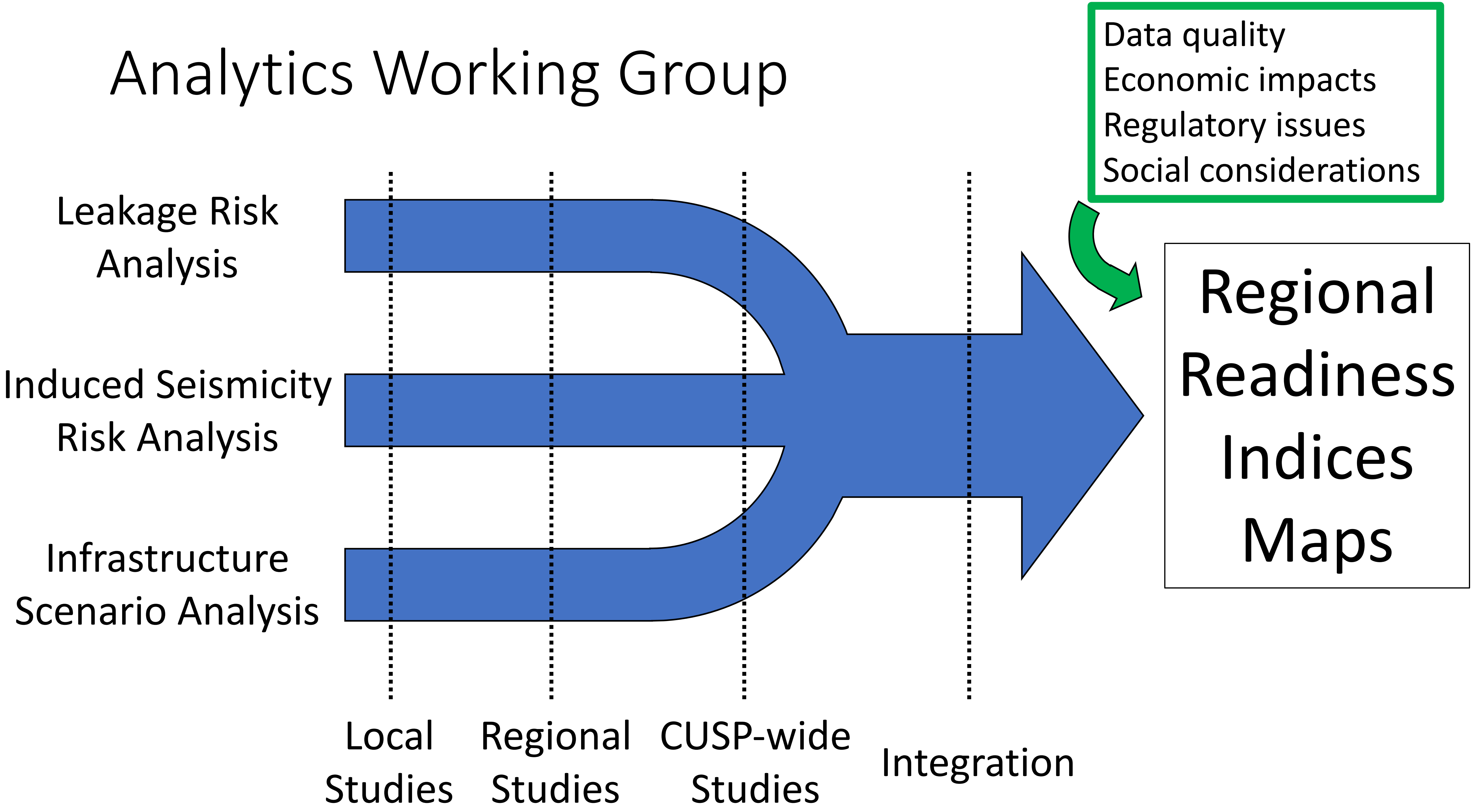


CUSP

Analytics Working Group

Sean Yaw
Montana State University

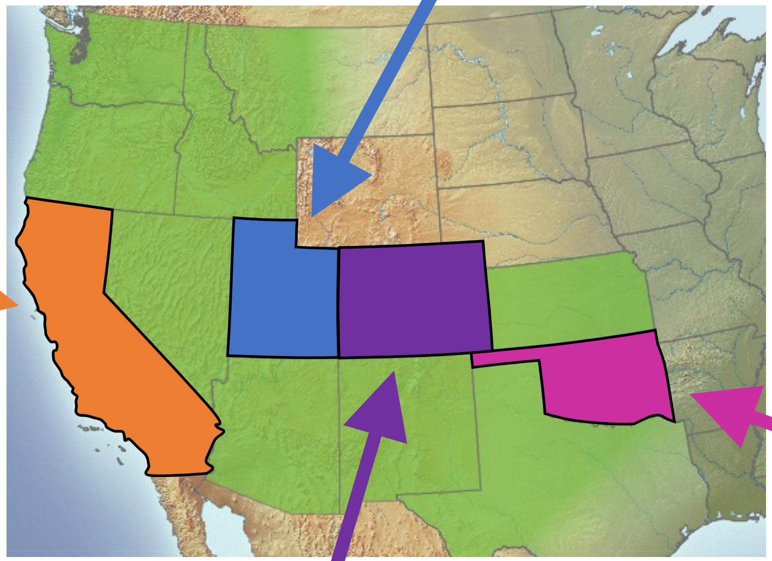
Analytics Working Group



NRAP – Leakage Risk

Importing data into NRAP-Open-IAM and collecting legacy wells information at Buzzards Bench site in Utah.

Collecting data for a quantitative risk assessment of a potential site in California.

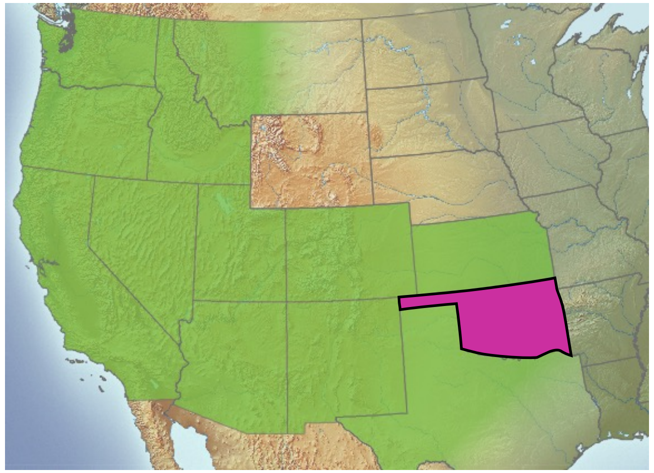


Completed Simple Reservoir risk analysis for Oklahoma case study and continuing work using heterogeneous reservoir site simulation.

Completed comprehensive risk calculations and analyzed impacts on overlay aquifer for a selected storage formation in Colorado.

Lead Organization: LANL

NRAP – Seismic Risk



Concept

- Use NRAP State of Stress Assessment Tool (SOSAT) to compute probability of fault activation at native pore pressure and elevated pressure with fluid injection
- Convert difference in probabilities of fault activation into seismic readiness index

Scope

- Create areal discretization of region
- Compute lithostatic, native pore, and elevated pore pressure at each cell
- Use SOSAT to determine probability of fault activation

Lead Organization: PNNL

Infrastructure Scenario Analysis Approach:

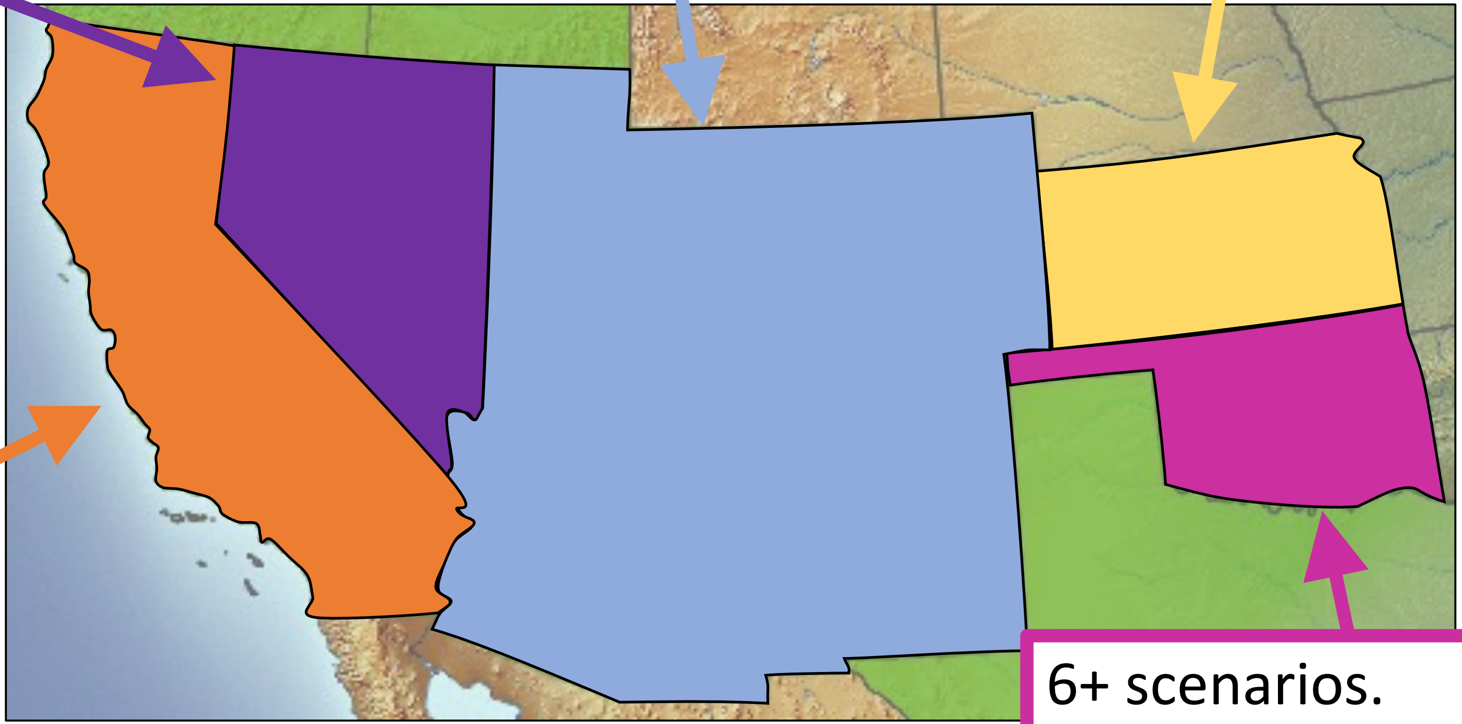
1. Conduct case studies of localized regions (KS, OK, NV, CA, Four Corner region currently).

Case Studies

2 scenarios.
- Objective sensitivity

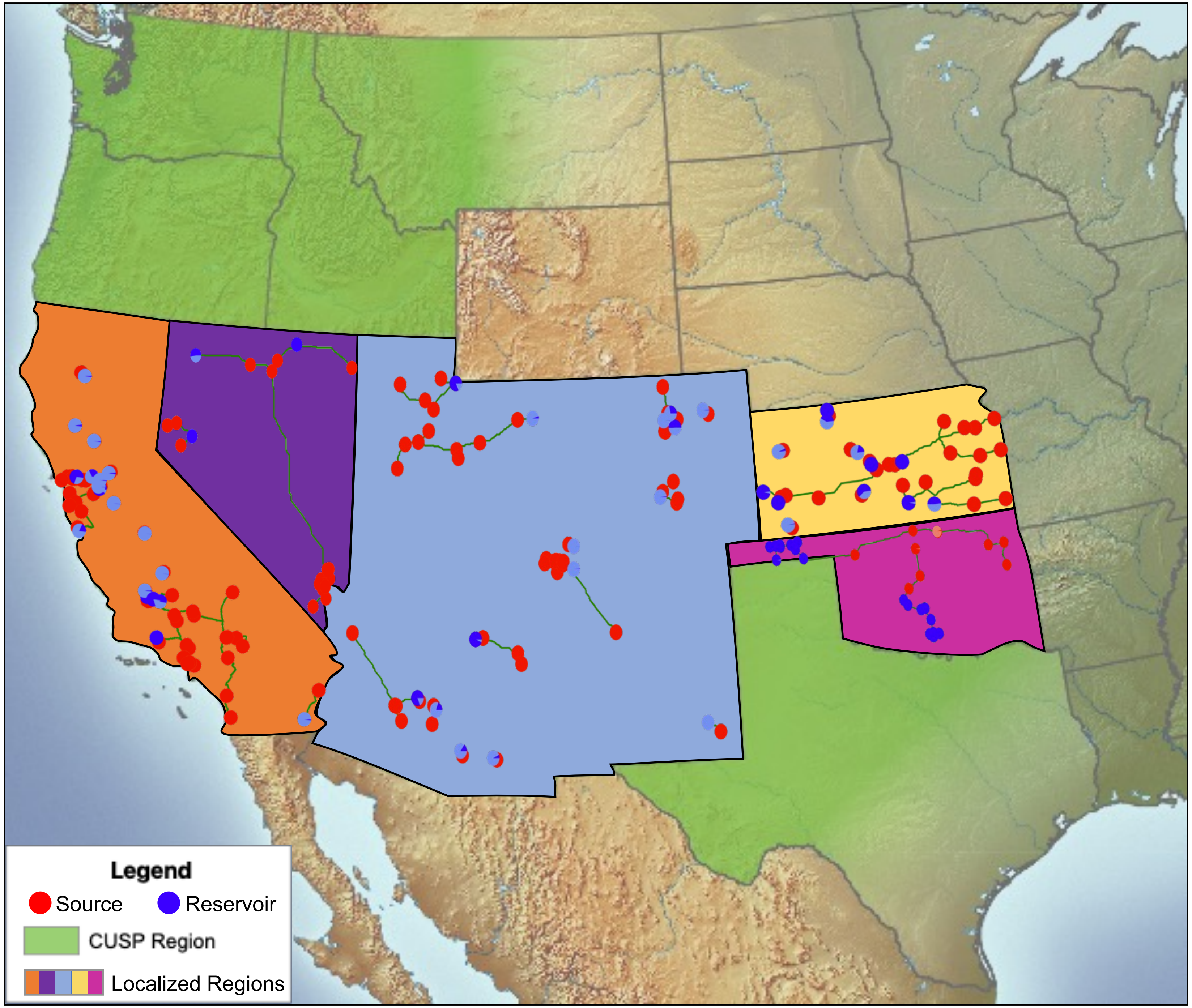
2 scenarios.
- Objective sensitivity

54 scenarios.
- Industry phasing
- Spatial phasing/targeting
- 45Q credit sensitivity
- LCFS options



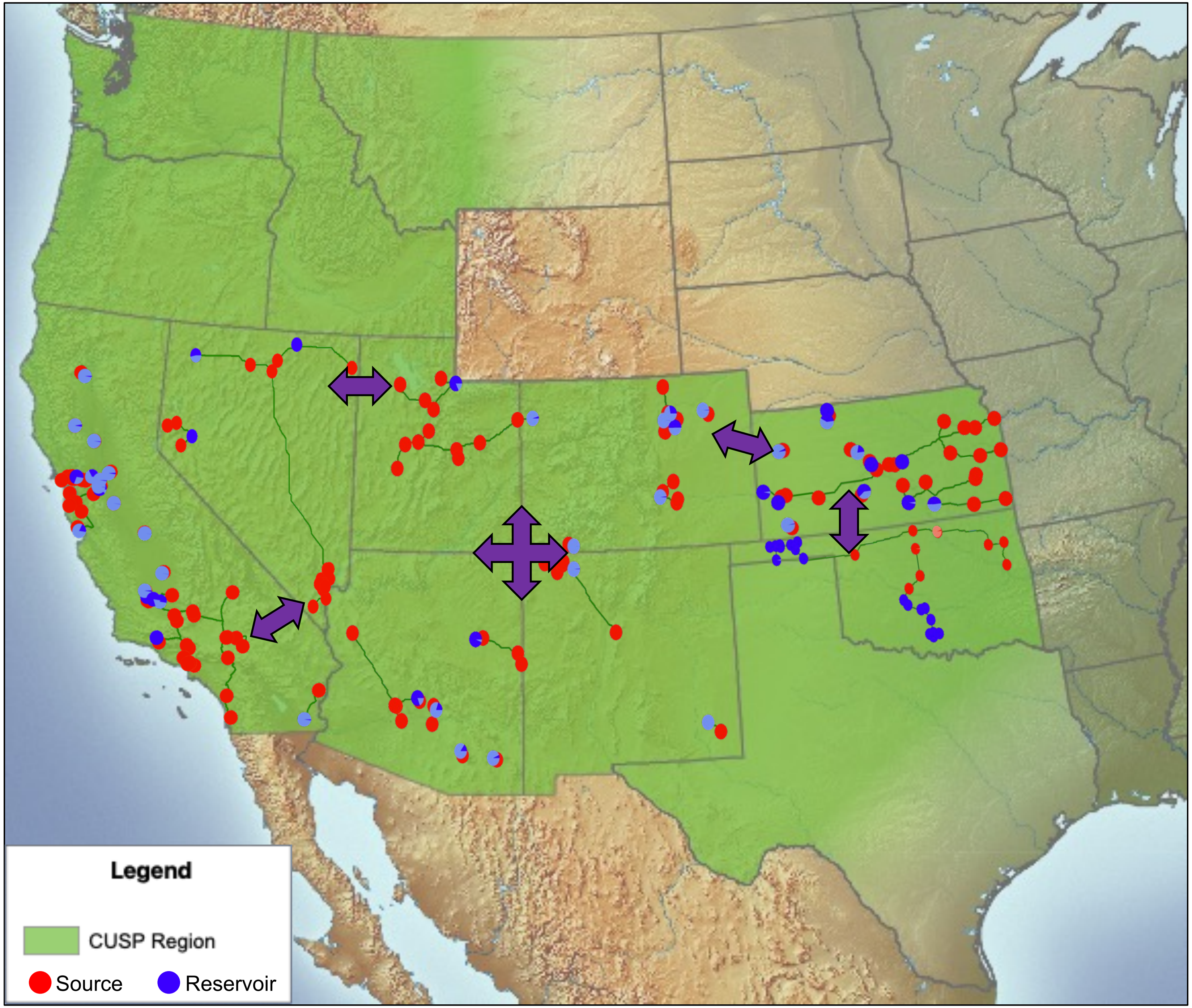
121 scenarios.
- EOR dependency
- 45Q emission criteria
- Cost surface sensitivity
- Industry sensitivity
- LCFS sensitivity

6+ scenarios.
- Industry availability
- Existing pipelines



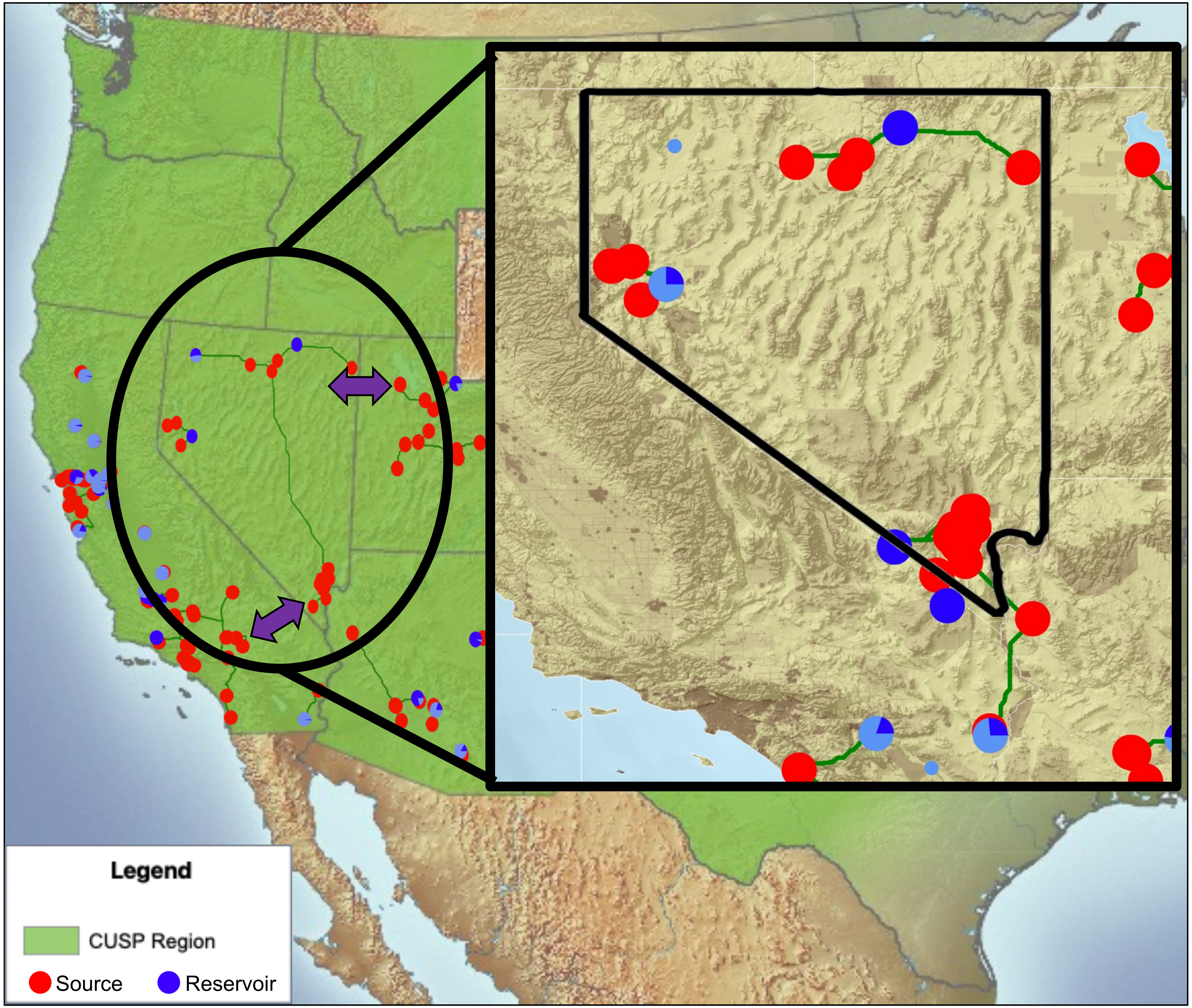
Infrastructure Scenario Analysis Approach:

1. Conduct case studies of localized regions (KS, OK, NV, CA, Four Corner region currently).
2. Identify potential hubs and opportunities for localized regions.



Infrastructure Scenario Analysis Approach:

1. Conduct case studies of localized regions (KS, OK, NV, CA, Four Corner region currently).
2. Identify potential hubs and opportunities for localized regions.
3. Explore cross-region integration.

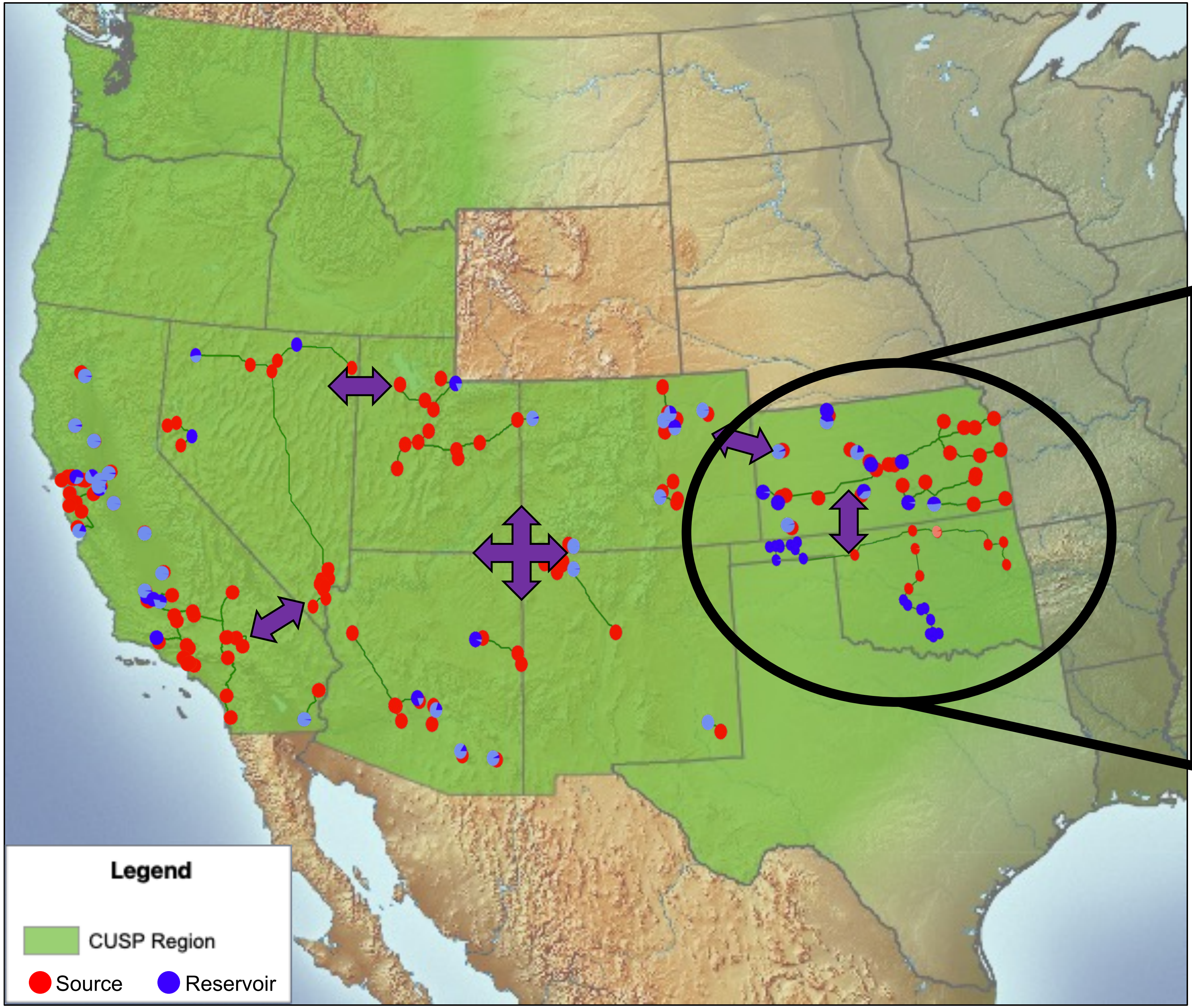


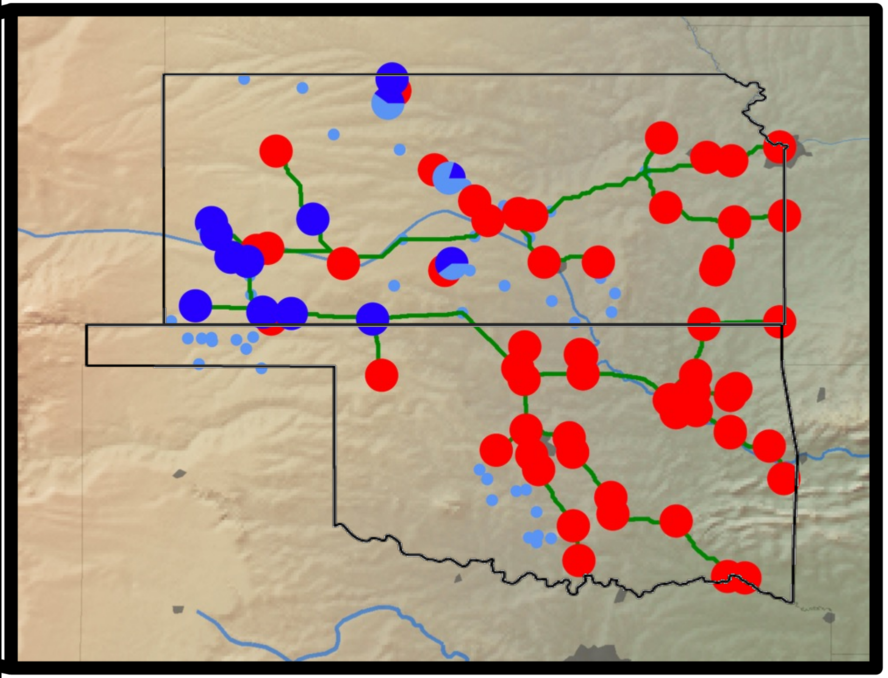
Infrastructure Scenario Analysis Approach:

1. Conduct case studies of localized regions (KS, OK, NV, CA, Four Corner region currently).
2. Identify potential hubs and opportunities for localized regions.
3. Explore cross-region integration.

Infrastructure Scenario Analysis Approach:

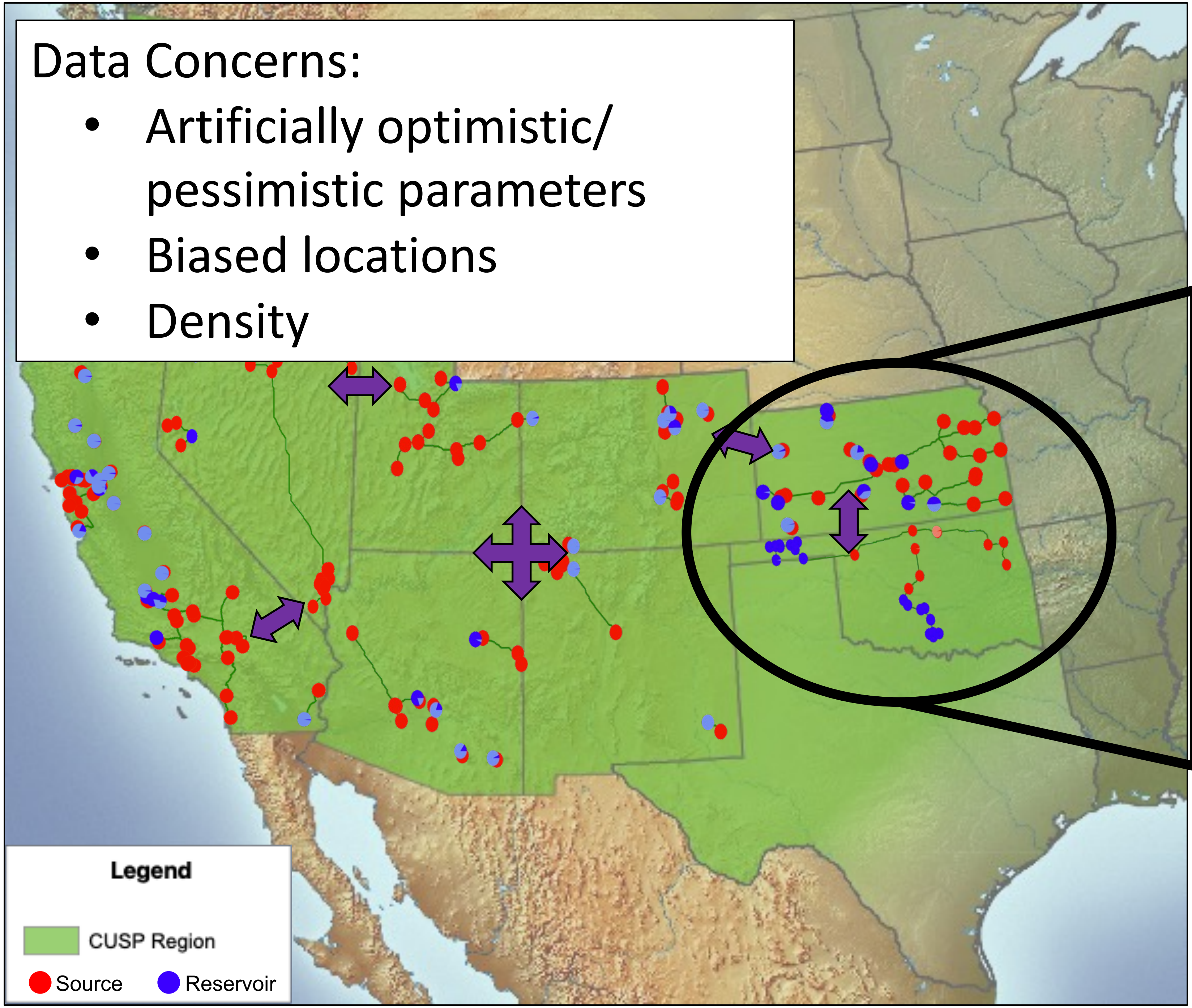
1. Conduct case studies of localized regions (KS, OK,





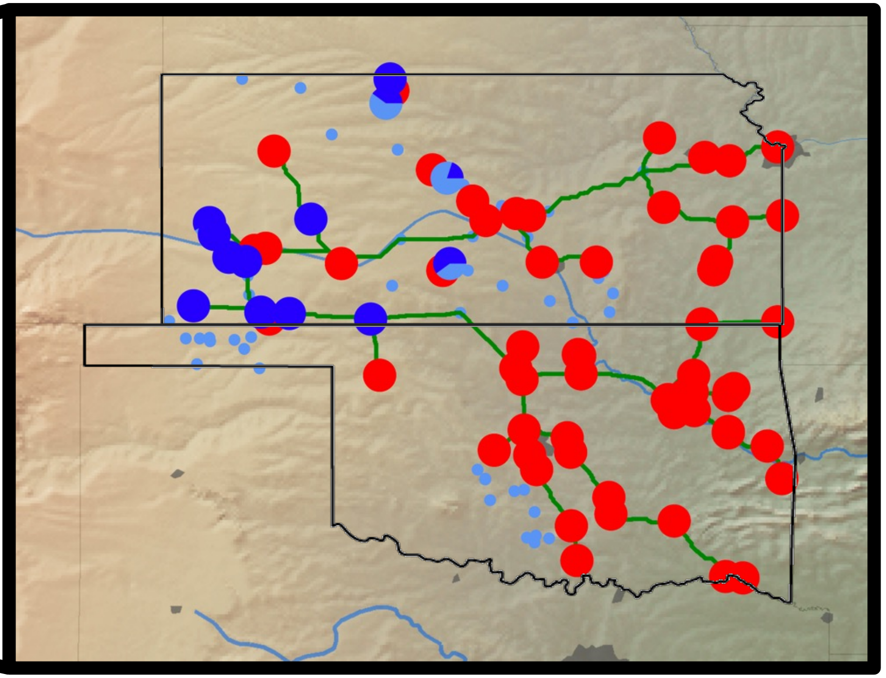
Data Concerns:

- Artificially optimistic/ pessimistic parameters
- Biased locations
- Density



Infrastructure Scenario Analysis Approach:

1. Conduct case studies of localized regions (KS, OK,



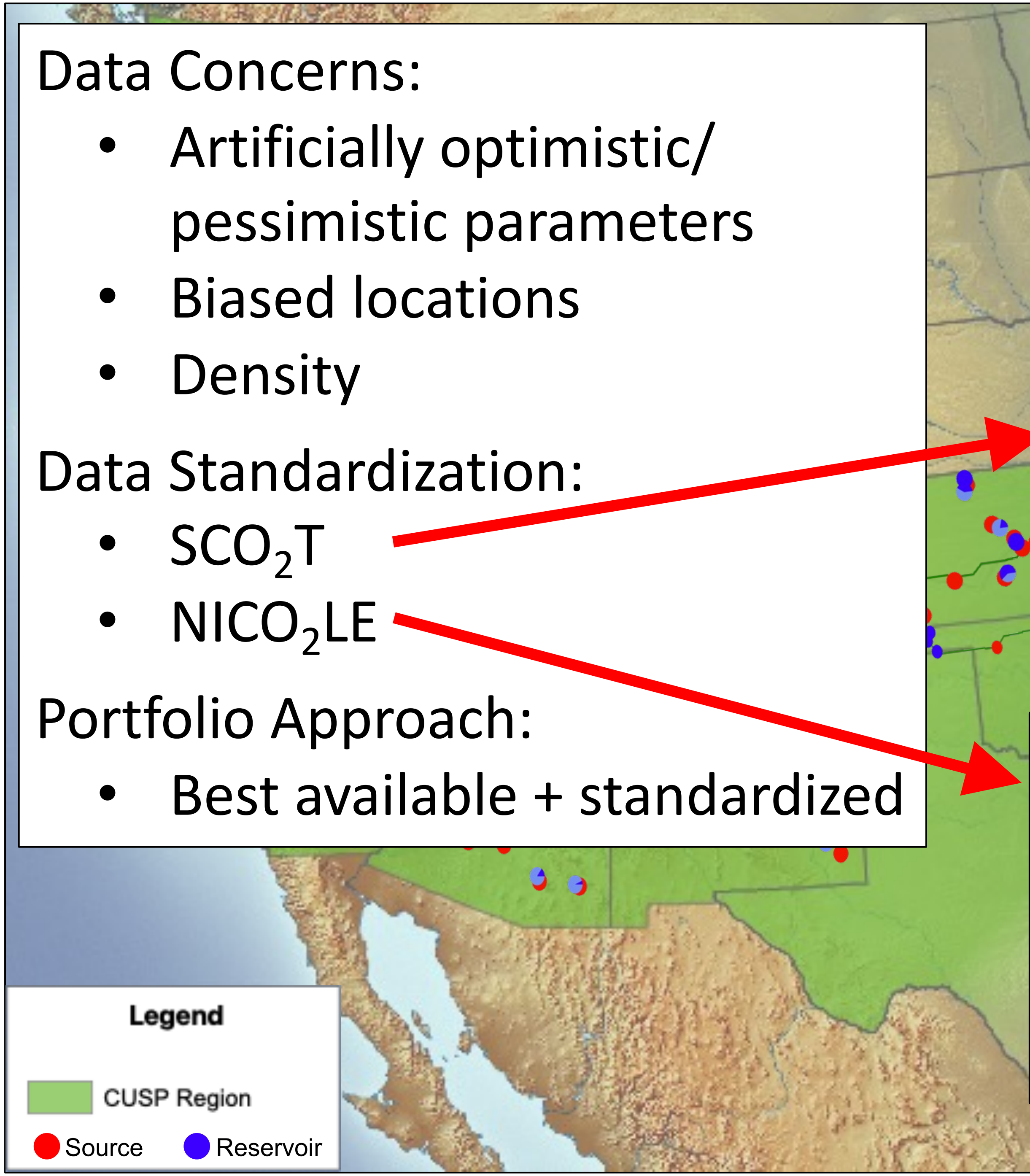
Infrastructure Scenario ...ysis Approach:

...duct case studies of ...lized regions (KS, OK, ...CA, Four Corner ...on currently).

...tify potential hubs and opportunities for localized regions.

3. Explore cross-region ...ration.

...uct CUSP-wide ...oyment ...ssments.



Data Concerns:

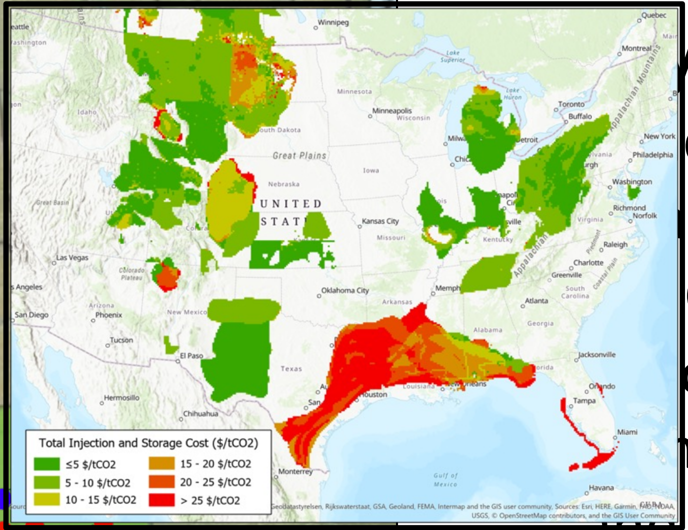
- Artificially optimistic/ pessimistic parameters
- Biased locations
- Density

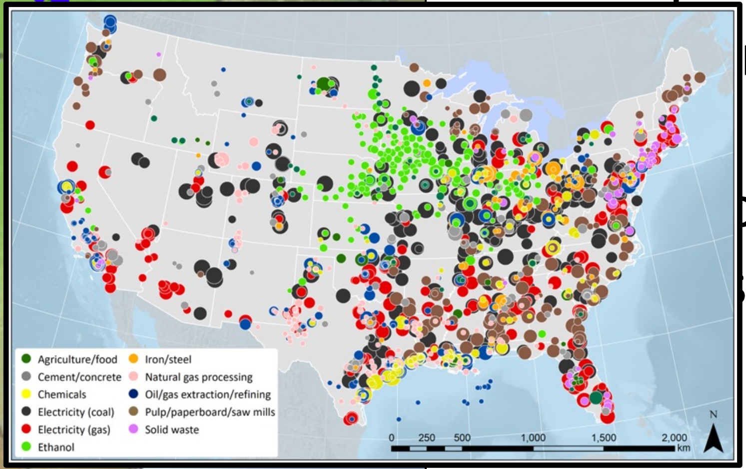
Data Standardization:

- SCO_2T
- $NICO_2LE$

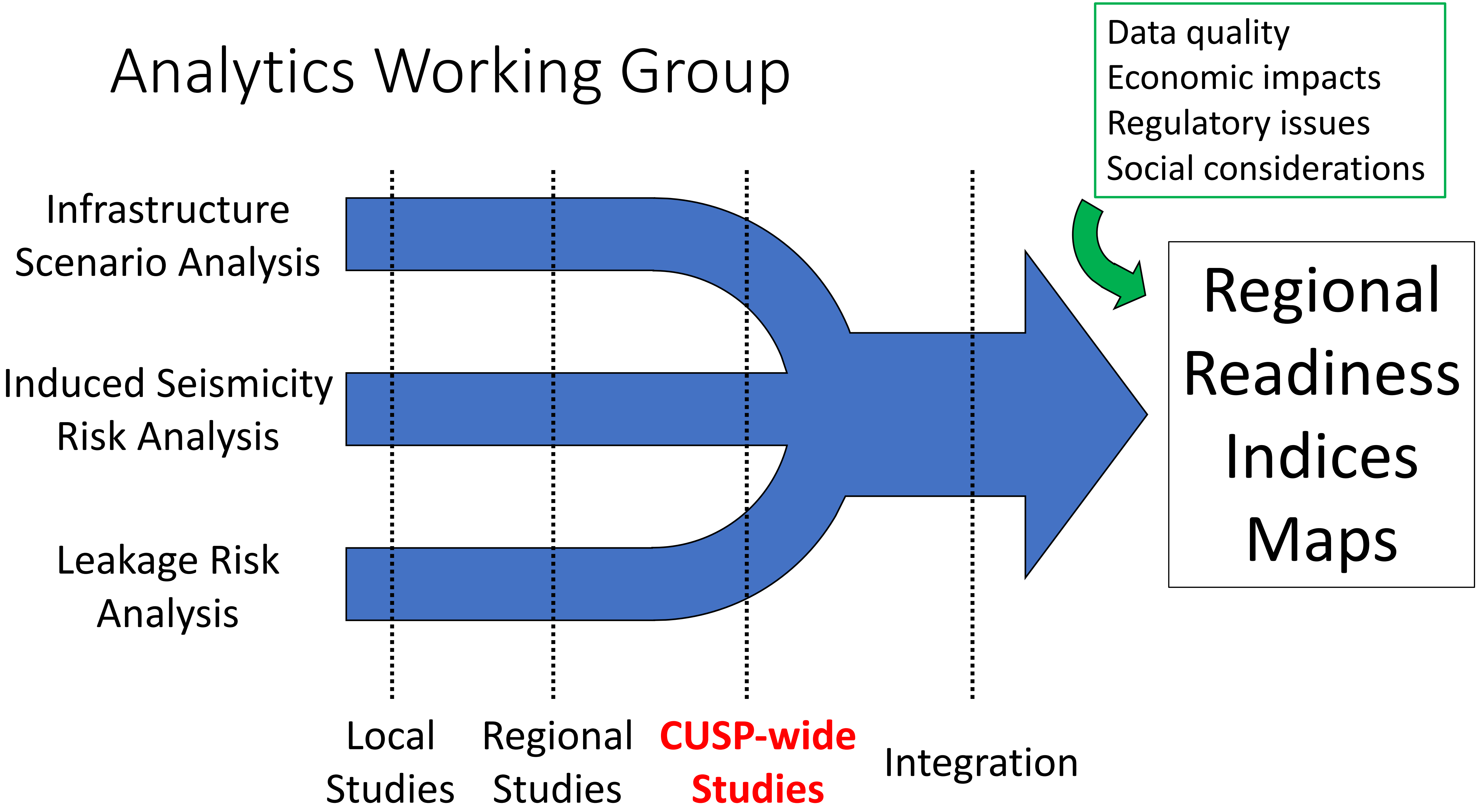
Portfolio Approach:

- Best available + standardized





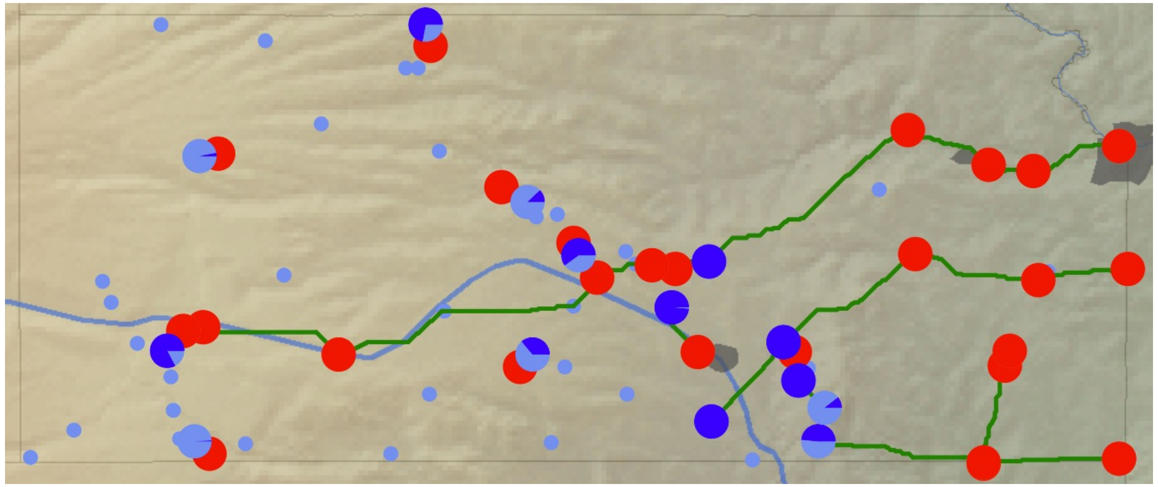
Analytics Working Group



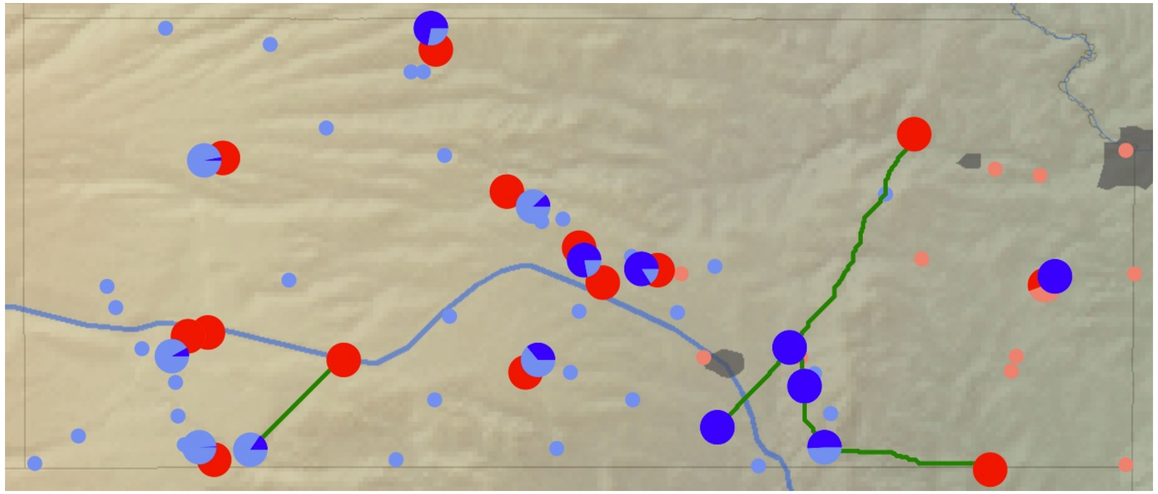
Backup

Example Case Study: Kansas

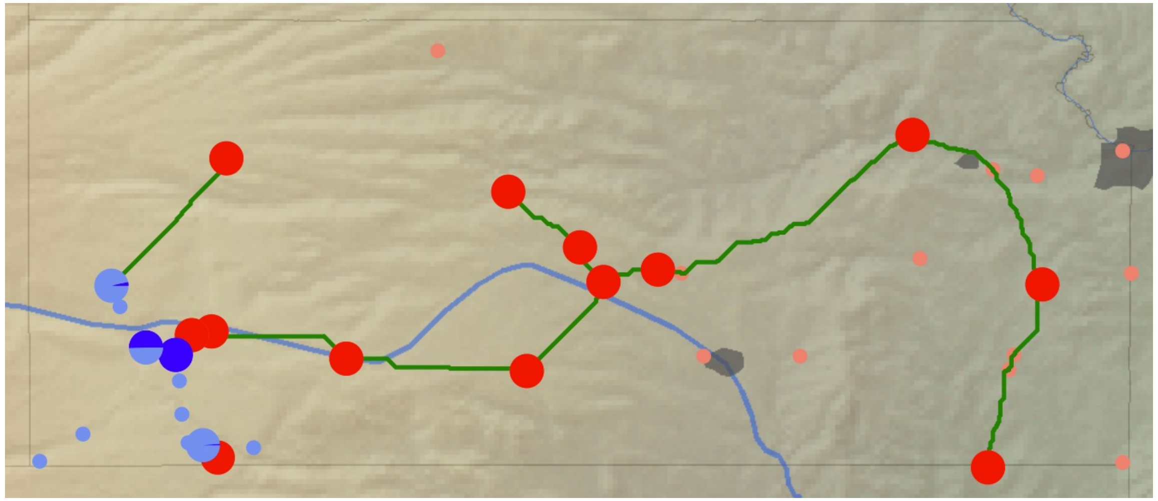
Source Reservoir



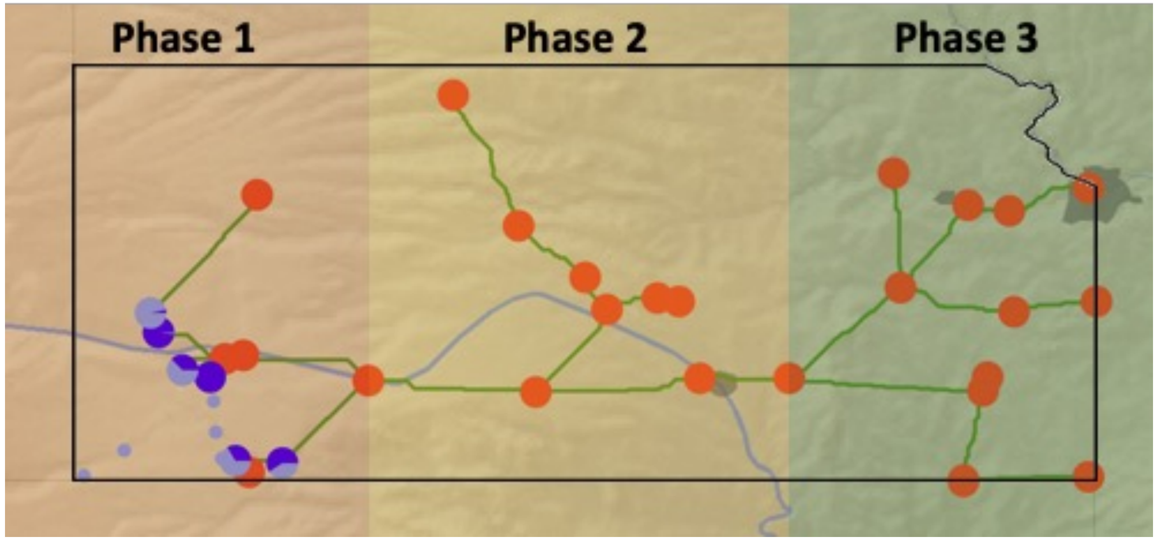
Scenario: Process all capturable emissions.



Scenario: Process all profitable emissions.

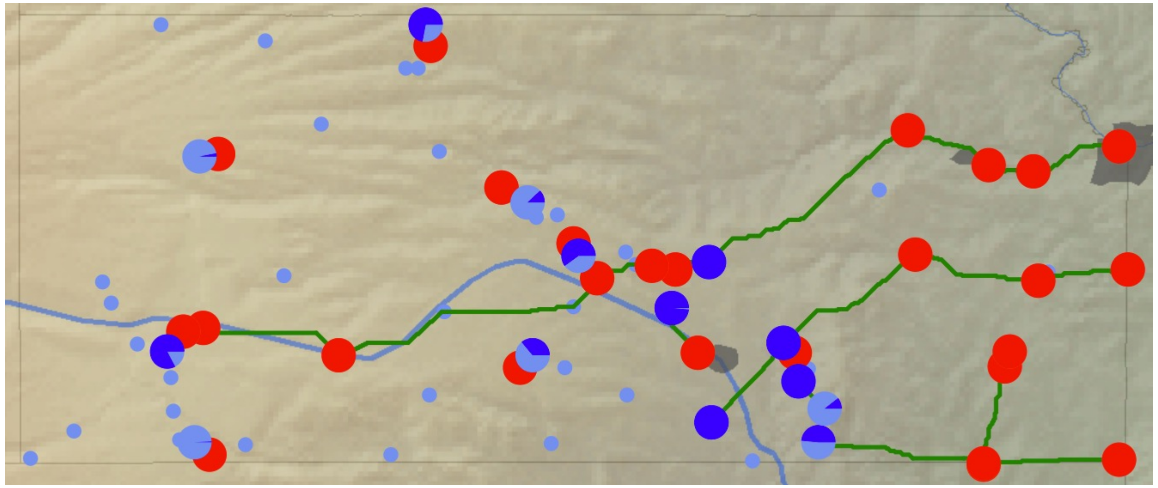


Scenario: Spatially targeted storage.



Scenario: Phased infrastructure deployment.

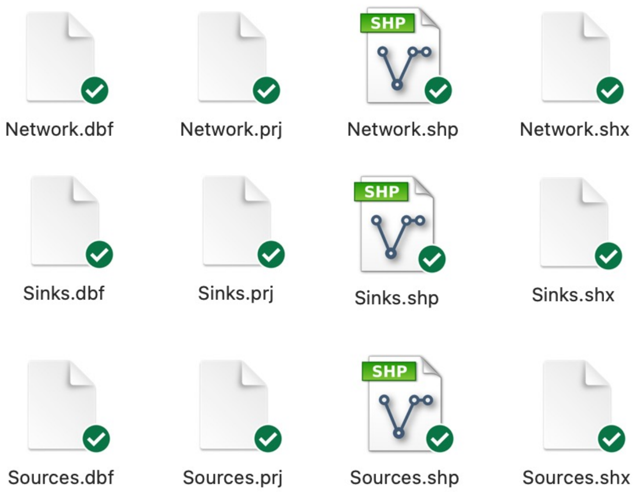
SimCCS Output



1. GUI image.

Project Length	20				
CRF	0.10954648				
Annual Capture Amount (MTCO2/yr)	16.78				
Total Cost ($M/yr)	-218.05711				
Capture Cost ($M/yr)	623.77				
Transport Cost ($M/yr)	75.5185877				
Storage Cost ($M/yr)	-917.3457				
Source	Capture Amc	Capture Cost ($M/yr)			
Jeffrey Energy Center	11	495			
Coffeyville Fertilizer	1.26	20.16			
Holcomb Center	1.57	54.95			
…	…	…			
Sink	Storage Amc	Storage Cost ($M/yr)			
Box	1.96	-101.9592			
Pleasant Prairie	1.87	-106.777			
Wellington	4	-226.8			
…	…	…			
Edge Source	Edge Sink	Amount (MT	Trend	Transport Co	Length (km)
5170361	5174624	11	1	0.21981	1.17179968
5852020	5860546	0.3	0	0.120576	2.36022029
6223497	6240553	4.74	0	0.4037084	3.70649756
…	…	…	…	…	…

2. CSV file.



3. Shapefiles.

Analytics Working Group - Deliverables

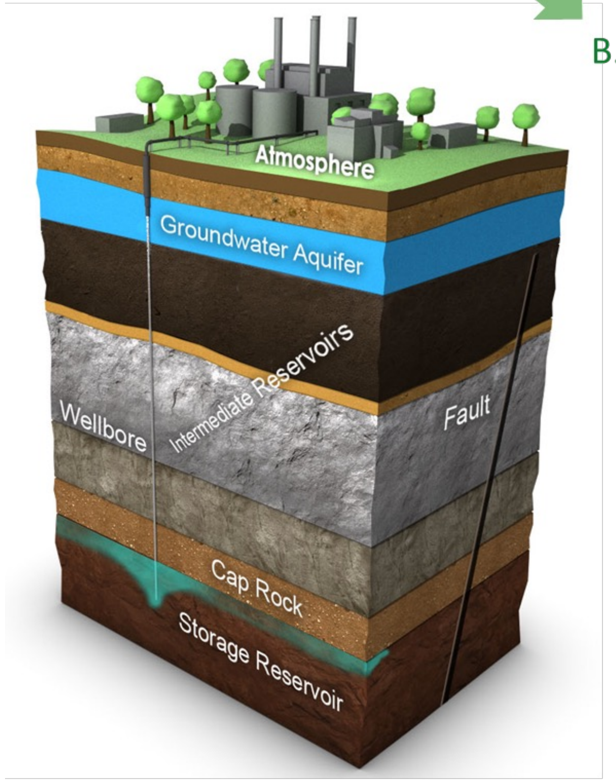
Task / Subtask Number	Deliverable Title	Due Date
1.0	Project Management Plan.	Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager.
2.1	Catalog of significant stacked/unconventional storage options from each state.	6/30/2021
3.1	CCUS assessment database for CUSP region.	9/30/2021
3.2	Report: NRAP testing and validation on candidate sites	9/30/2022
4.4	Report: Nontechnical Impact Assessment on CCUS potential in CUSP region.	12/31/2023
4.5	Report: Focused scenario analysis results on candidate sites in CUSP region	6/30/2024
5.0	Report: Documentation of process diagrams/workflows/templates/etc for development of CCS/CCUS projects (with guided steps that illustrate SimCCS analyses and results, accessible via CUSP Dashboard)	3/31/2023
5.1	Regional readiness indices maps	6/30/2024

Leakage Risk Assessment Using NRAP Tool – Accomplished to date

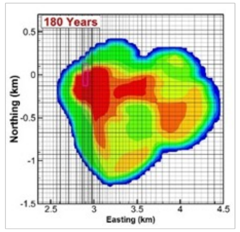
- Carried out comprehensive leakage risk calculations and analyzed their impact to overlay aquifer for a selected storage formation in Colorado.
- Completed Simple Reservoir risk analysis for Oklahoma case study; working with Oklahoma team on risk assessment using heterogeneous reservoir site simulation to cover both injection and PISC period.
- Working with Utah team on importing Eclipse reservoir pressure and CO_2 saturation results into NRAP-Open-IAM, and collecting legacy wells information for leakage risk assessment at Buzzards Bench site.
- Working with California team on data collection for setting up quantitative risk assessment of a potential storage site at California.

NRAP's Approach for Rapid Prediction of Whole-system Risk Performance

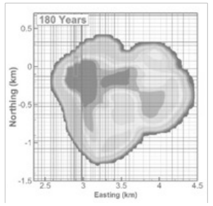
A. Divide system into discrete components



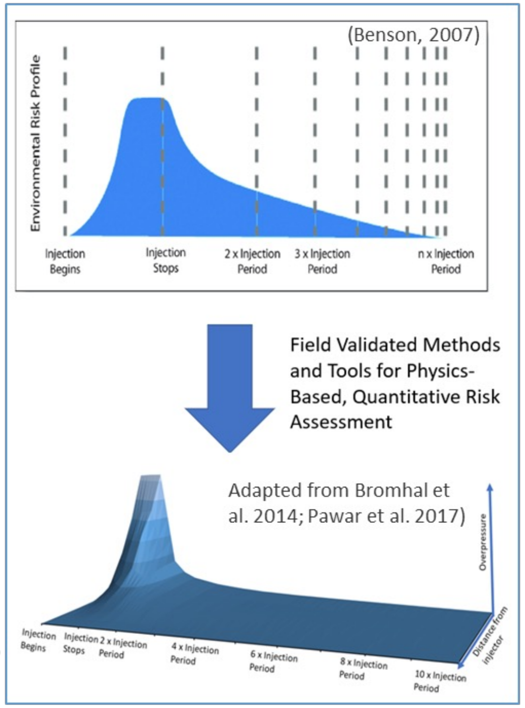
B. Develop detailed component models that are validated against lab/field data



C. Develop reduced-order models (ROMs) that rapidly reproduce component model predictions



D. Link ROMs via integrated assessment models (IAMs) to predict system performance

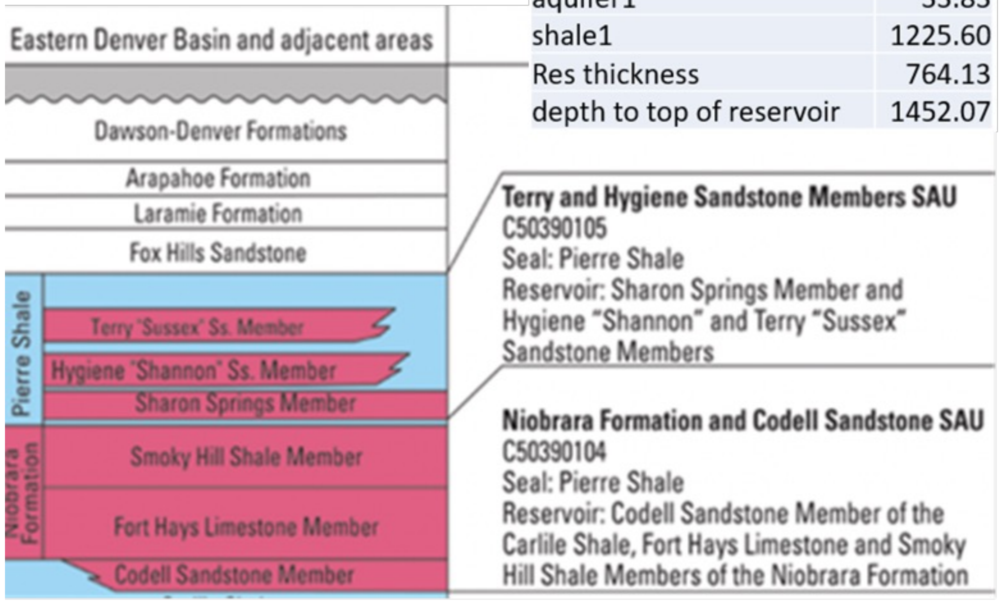


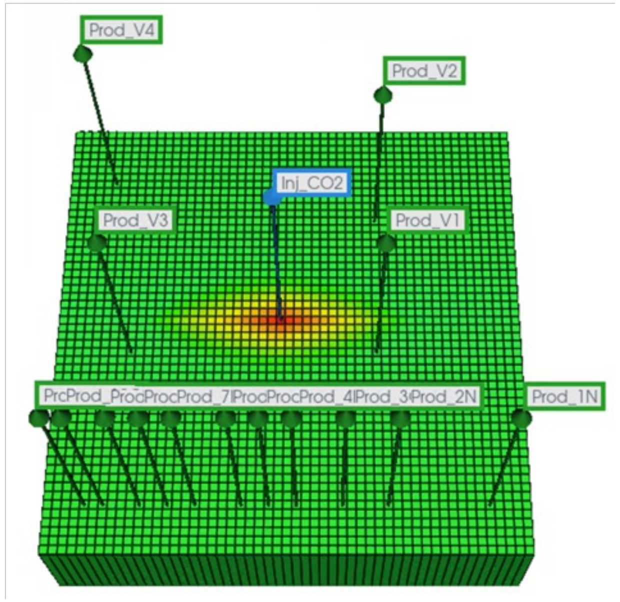
E. Exercise whole system model to explore risk performance

Leakage Risk Assessment – CO Case Study in CUSP

Stratigraphy (m)

shale3	10.36
Shallow Aquifer	67.67
shale2	114.60
aquifer1	33.83
shale1	1225.60
Res thickness	764.13
depth to top of reservoir	1452.07

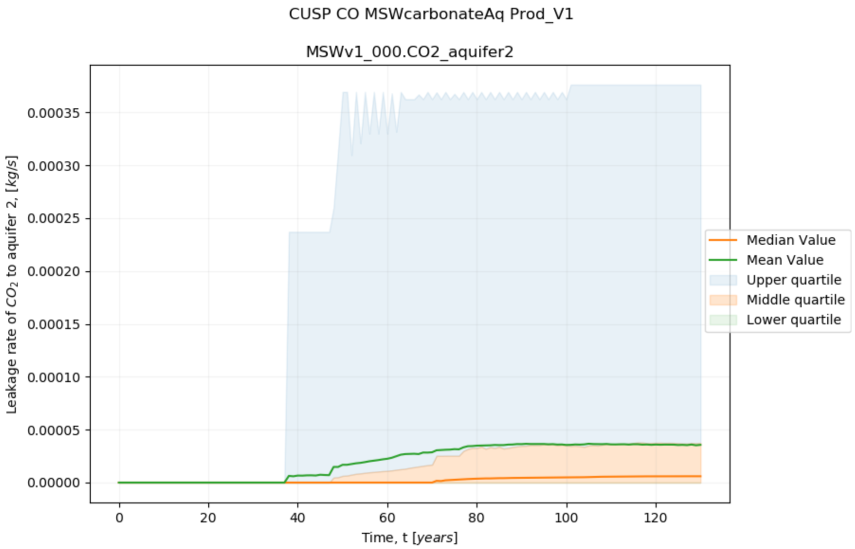


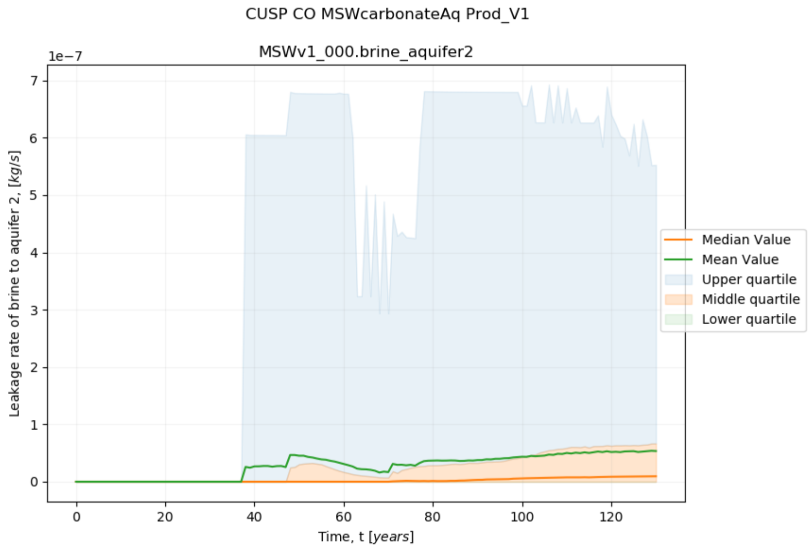


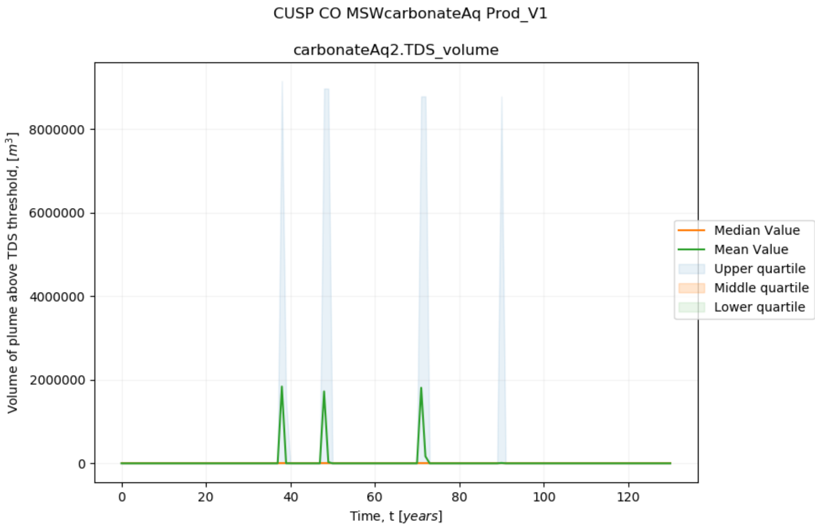
- Time frame considered:
  30 year injection + 100 year post-injection
- CMG simulations:
  reservoir pressure and CO_2 saturation
- Lookup Table Reservoir
- Multi-segmented Wellbore ROM
- Carbonate aquifer ROM
- Injection rate: 1MT/year
- Distance of existing well (Prod_v1) to injector: 348 m
- Probabilistic simulations to account for parameter variability and uncertainty

- **Storage reservoir**: Pierre sandstone
- **Receptors of concern**: Arapahoe (USDW) and atmosphere
- **Potential leakage pathways**: 4 vertical and 11 horizontal production wells

Leakage Results – CO Case Study in CUSP (worst case existing well: prod_v1)

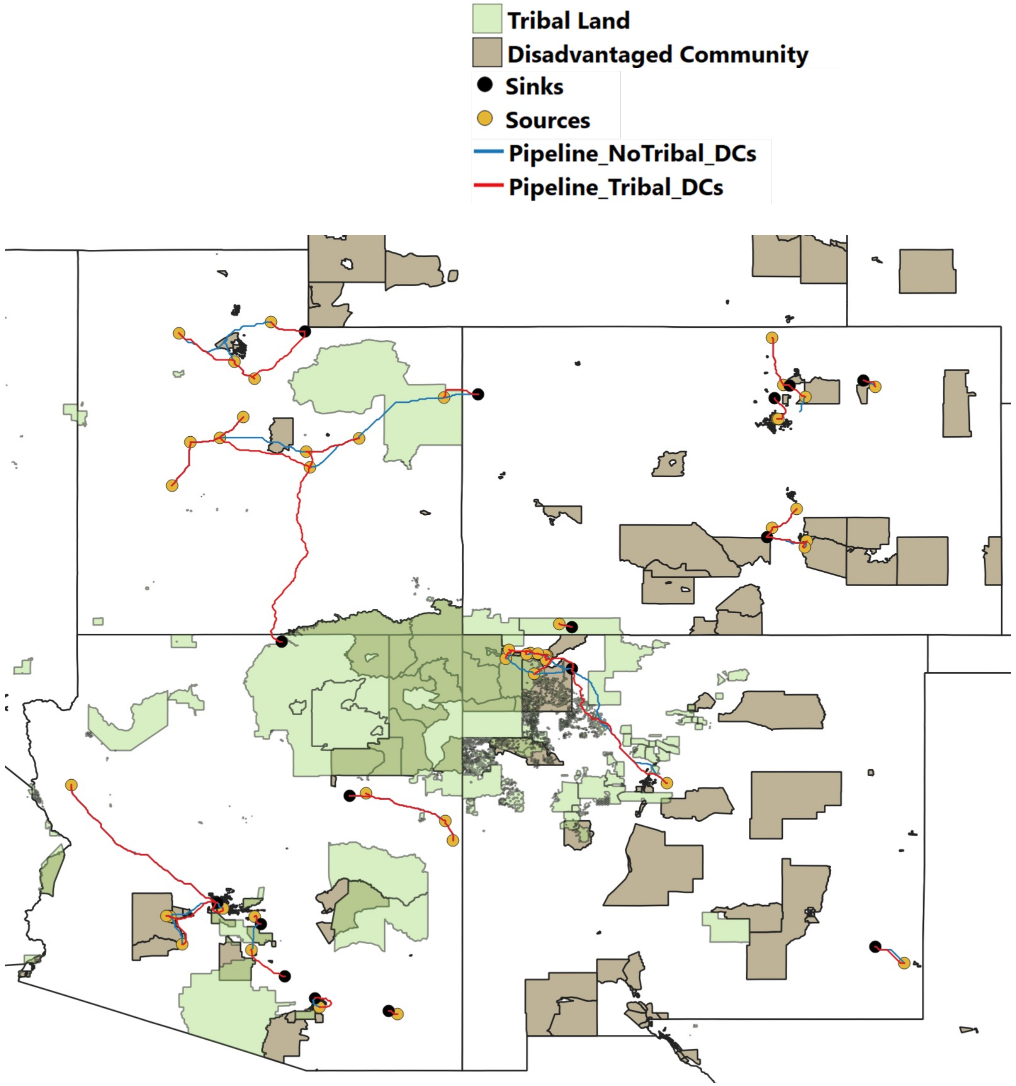






- There are small CO_2 (< 4e-4 kg/s) and brine (<7e-7 kg/s) leakage to USDW, the leakage breakthrough starting after injection stopped, and the mean leak rates flattened towards the end of 130 year simulation duration.
- USDW impact above and beyond natural background variability (pH not less than 6.7 and TDS not greater than 450 mg/L) : There is no impact to pH; impacted TDS plume radius is less than ~200m for a few worst scenarios.
- Comparing to total amount CO_2 injected (1MT/yr over 30 years), the amount of CO_2 leaked to USDW through 100 years PISC period is peaked at ~year 90 and less than 2.86e-05 % (worse case), with mean less than 1.52e-6 %.

Impact of tribal lands and disadvantaged communities restrictions on pipeline routes



Capture target: 96 Mt

	Without Tribal lands & DCs restriction	With Tribal lands & DCs restriction
Pipeline length (km)	2198	2433 (10.7% longer)
Transport cost ($/t$CO_2$)	1.8	2.6
Storage cost ($/t$CO_2$)	5	5
Capture Cost ($/t$CO_2$)	57.8	57.8
Tax credits ($/t$CO_2$)	50	50
Total cost ($/t$CO_2$)	14.6	15.4

- Overall pipeline length and average transport cost is increased in order to avoid tribal lands and disadvantaged communities

Readiness indices:

- Map layers of different risks/readiness (e.g., induced seismicity risk, storage potential, capture potential, social concerns, endangered species habitat) with selectable values.
- Infrastructure modeling runs displayed based on selected values.
- Heat maps of deployments across many risk/readiness values.

Data requirements:

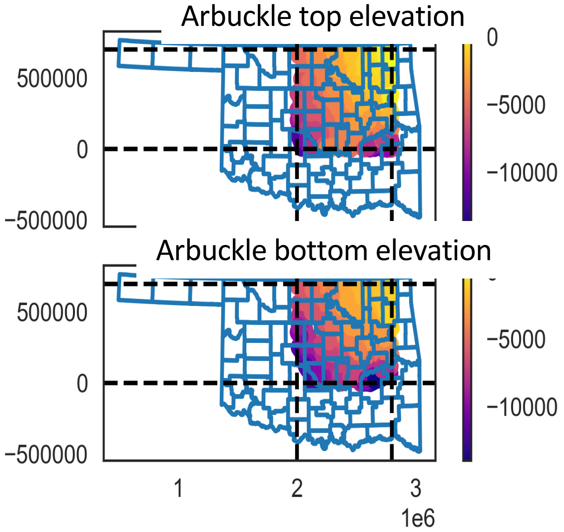
- SCO_2T/$NICO_2LE$.
- Data quality/resolution appropriate for regional assessment.
- Comparable data. Generated consistently across regions.

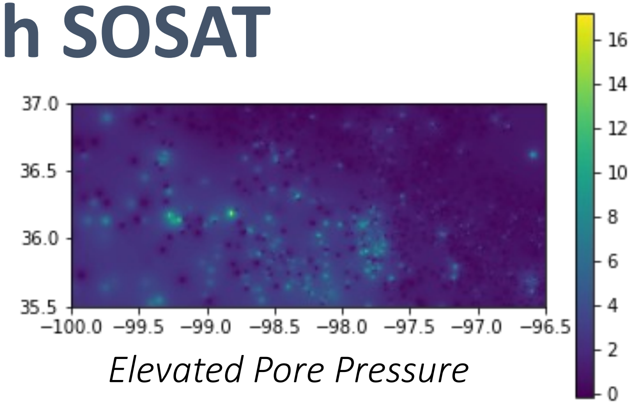
Seismic Risk Based Readiness Index for SimCCS
Regional Modeling of Seismic Risk with SOSAT

Concept
- Use the NRAP State of Stress Assessment Tool (SOSAT) to compute the probability of fault activation at the native pore pressure and elevated pressure with fluid injection
- Convert the difference in probabilities of fault activation into a seismic readiness index

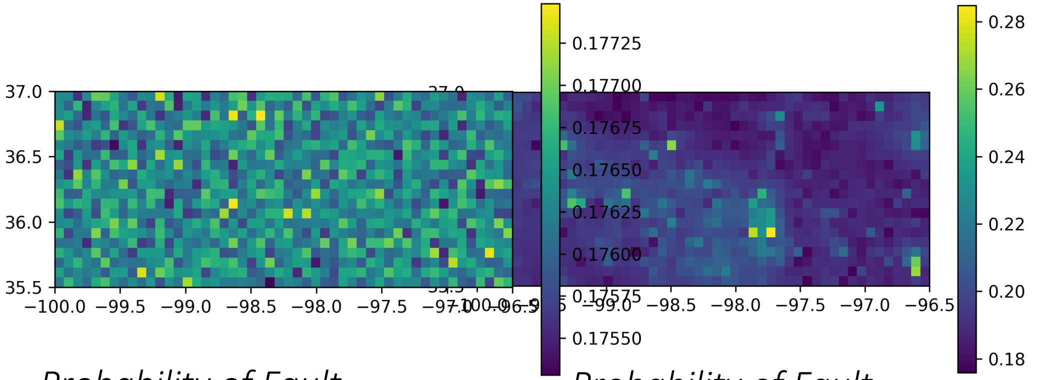
Scope
- Create areal discretization of region
- Compute lithostatic, native pore, and elevated pore pressure at each cell
- Use SOSAT to determine probability of fault activation

Example
- Arbuckle formation in Oklahoma



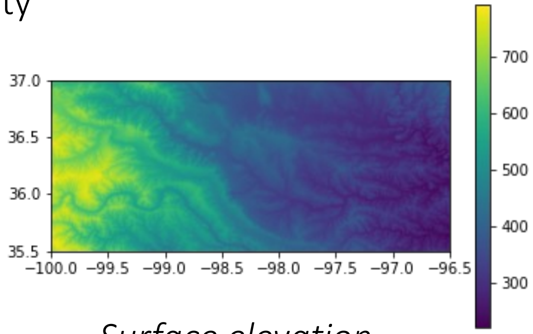


Elevated Pore Pressure

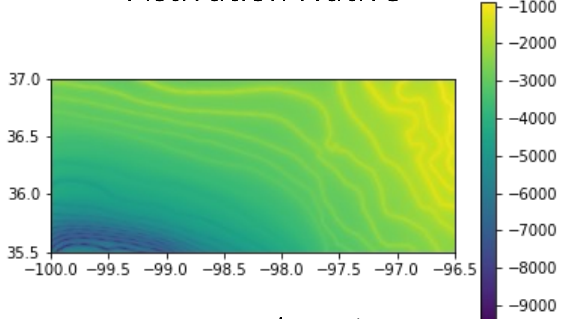


Probability of Fault Activation Native

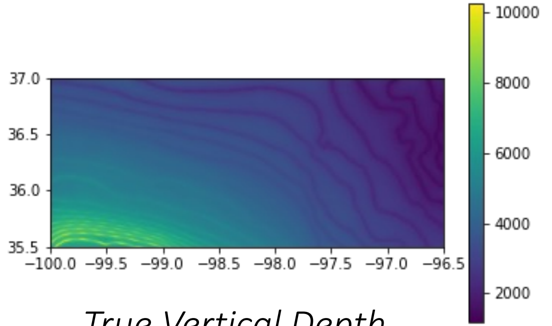
Probability of Fault Activation Elevated



Surface elevation



Basement elevation



True Vertical Depth