Routes to Sustainability: Natural Gas Development and Air and Water Resources in the Rocky Mountain Region

University of Colorado Boulder

California State Polytechnic University Pomona

Colorado School of Mines

Colorado School of Public Health

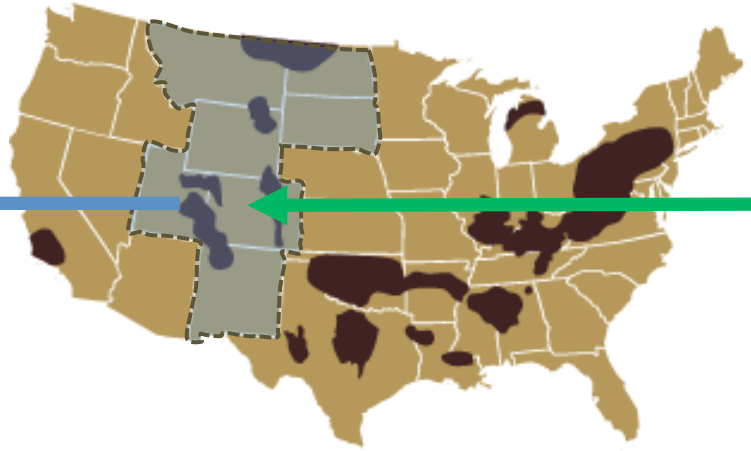
Colorado State University

National Oceanic and Atmospheric Administration

National Renewable Energy Laboratory

University Corporation for Atmospheric Research

University of Michigan



Social-Ecological Systems Framework
CSU
UC Boulder

Natural Gas Infrastructure
CSM

Water Quantity
UC Boulder
CSU

Water Quality
CA Poly Pomona
UC Boulder
CSM

Air Quality
NOAA
UC Boulder
NREL

Data Management
UC Boulder

Health Effects
CO School of Public Health

Embedded Tech
University of Michigan
UC Boulder

Social-Ecological Systems Framework
CSU
UC Boulder

Outreach Education
UC Boulder
UCAR
CSU

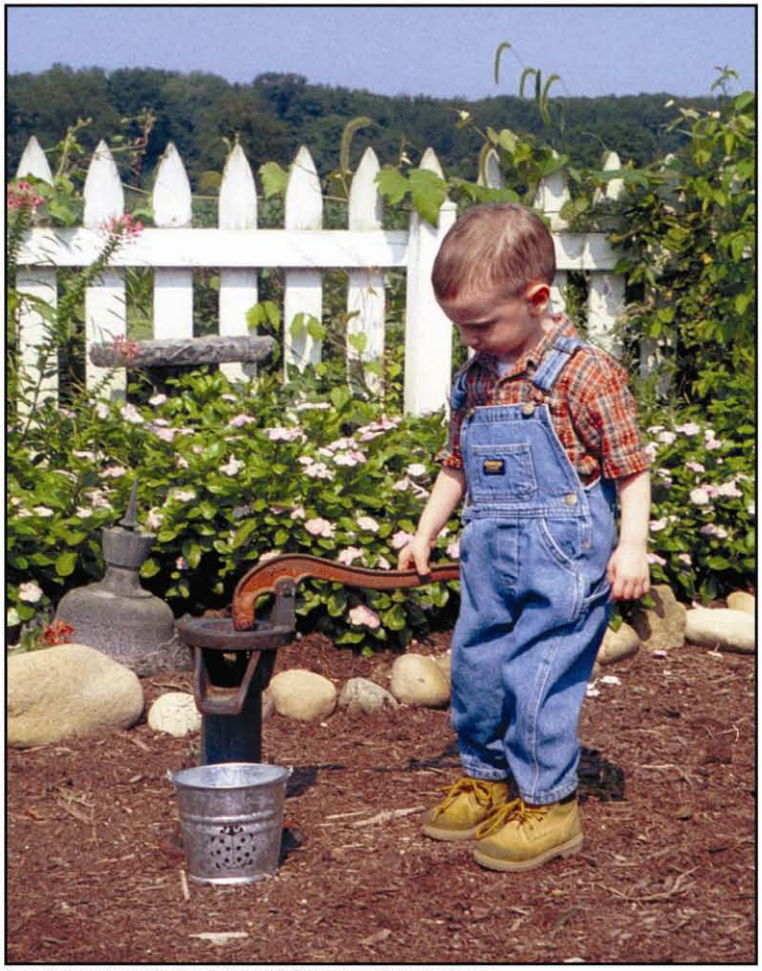
Assessment
UC Boulder


Social Studies
STEM
Sustainability

Protecting Drinking Water Resources

swn Southwestern Energy®

Drinking Water From Household Wells

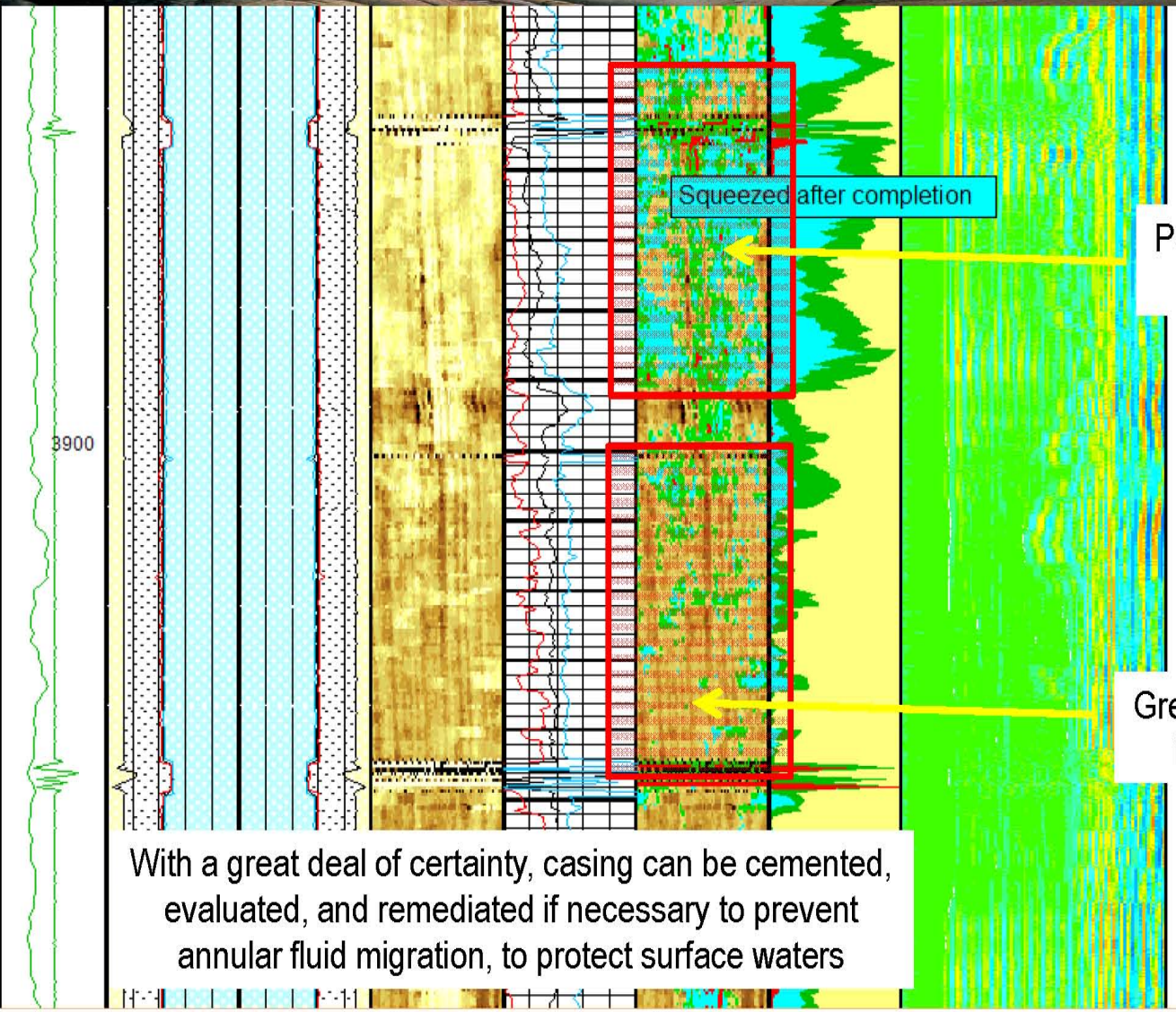


Cover photo courtesy of Charlene E. Shaw, U.S. Environmental Protection Agency

Well Integrity Is the Key!

(James Bolander, Southwestern Energy)

Ultrasonic Image of the Cement Sheath



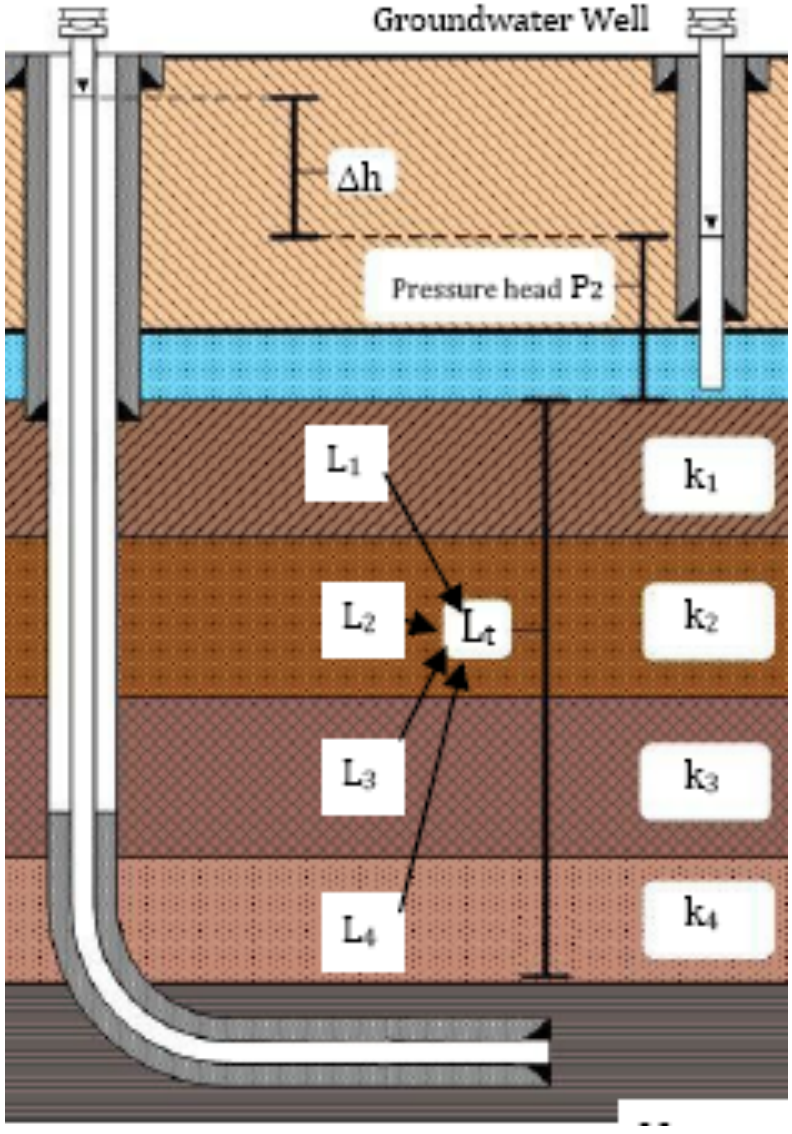
Poor cement isolation

Great cement isolation

With a great deal of certainty, casing can be cemented, evaluated, and remediated if necessary to prevent annular fluid migration, to protect surface waters

Natural Gas Infrastructure

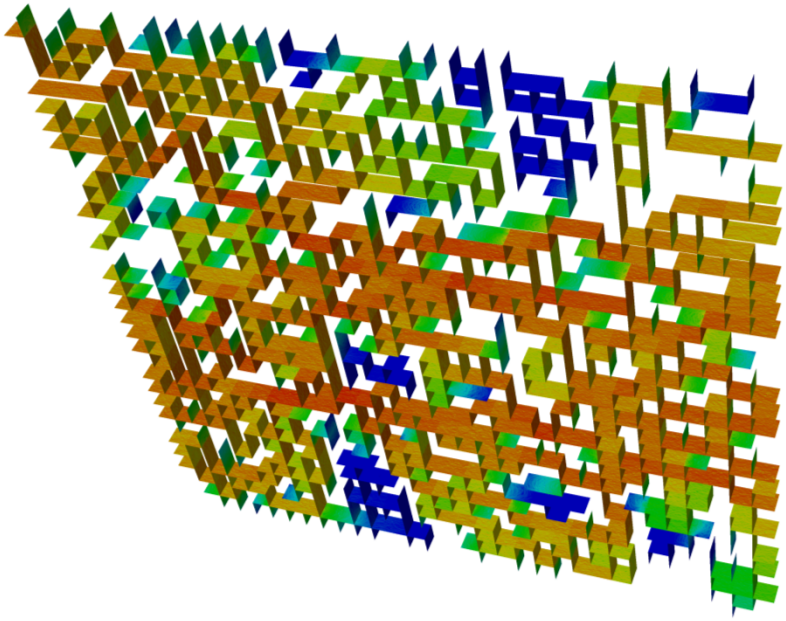
- Obtain well-integrity data from industry
- Ultrasonic imagery
- Quantitative risk assessment of “black swan” events
- Quantitative assessment of fracture migration (modelled)



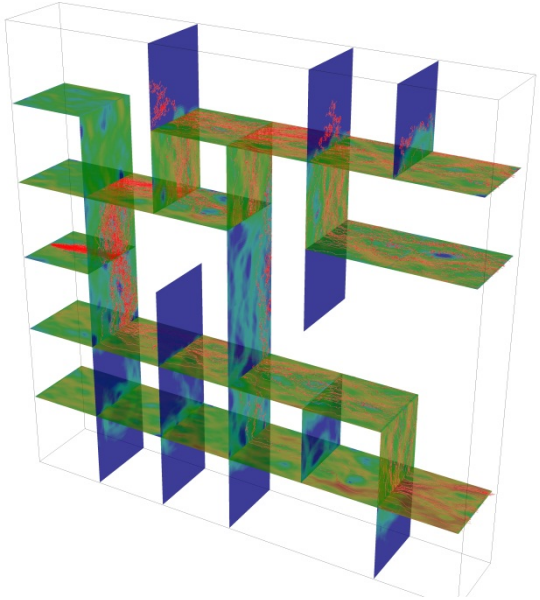
Water Quantity

- Alterations of groundwater flow
- Portfolios of future water supply
- Comparative assessments of regulations
- Risk assessment
- Hari Rajaram, Reagan Waskom, Kevin Doran, Mark Williams

Experience w/ Contaminant Transport



Discrete-Fracture Network and Matrix Transport Models for Nevada Test Site scale applications, with ~ 1 Billion computational nodes

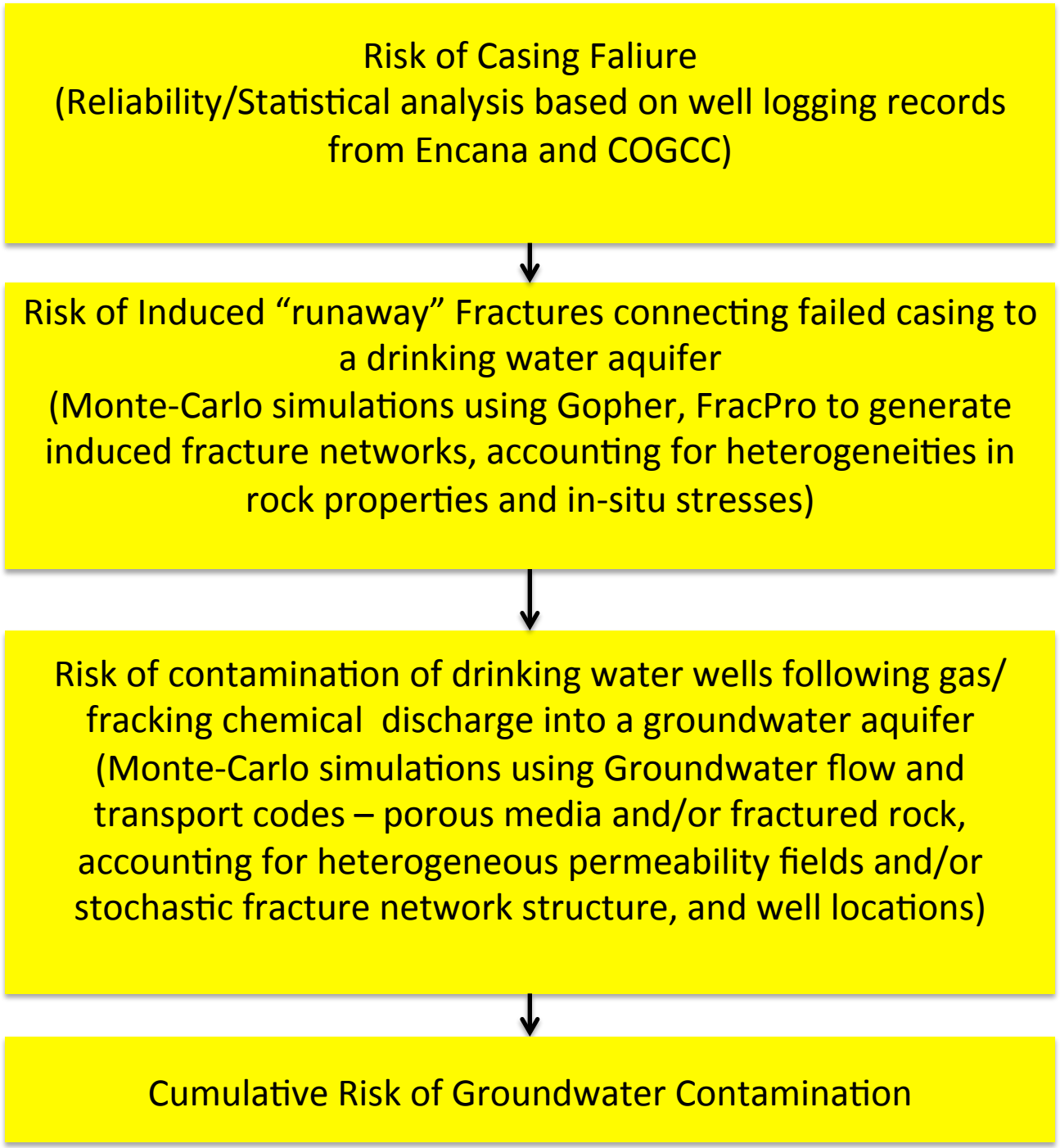


Preferential high-flow channels and dead-end fractures (right figure zooms in to show particle traces in red)

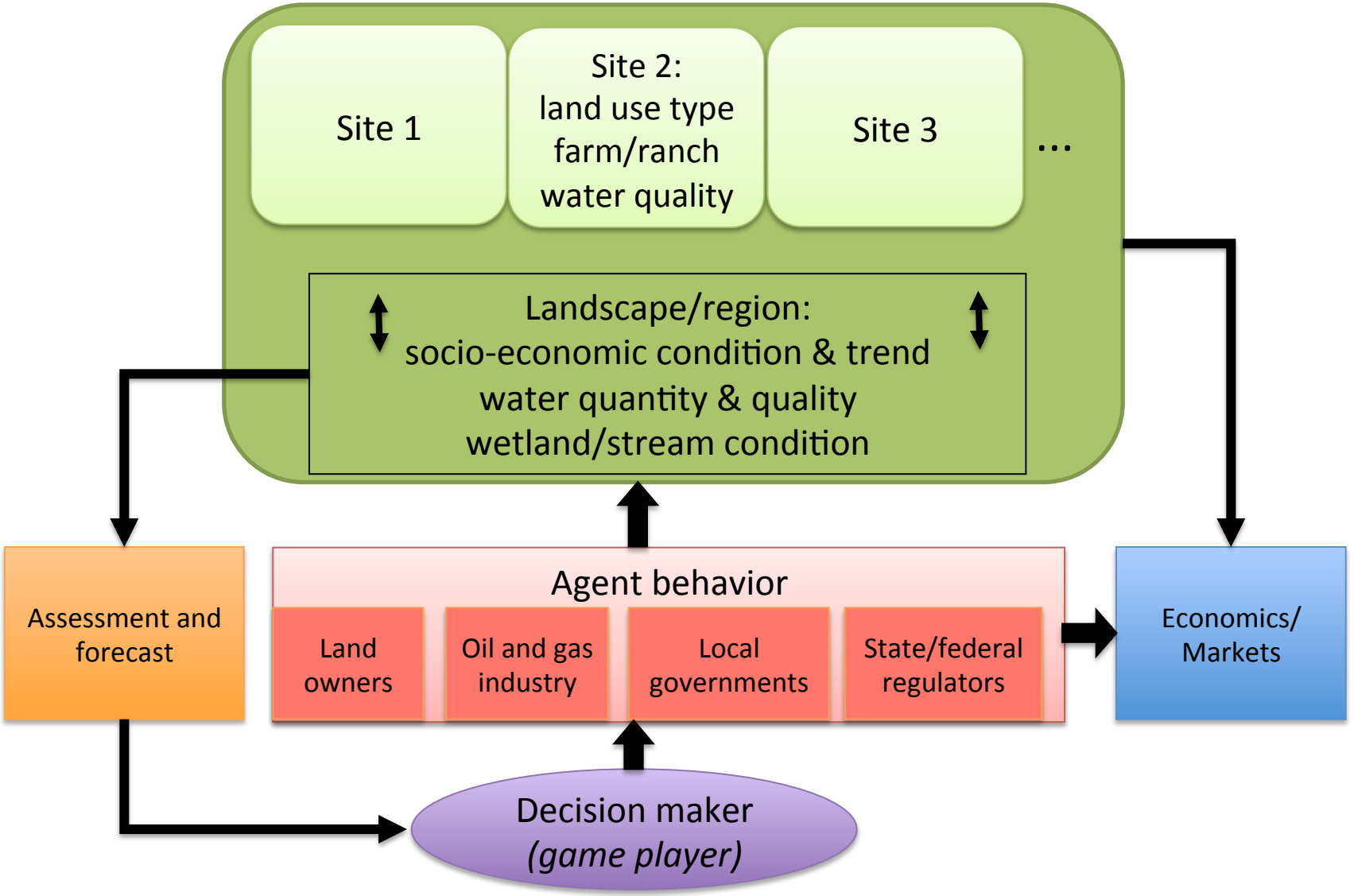
Combine these cutting edge computational tools with readily accessible open-source software such as NETL's FRACGEN/ NFFLOW

Sustainable Water Use and Reuse

- Past and present industry partners:
  - Anadarko Petroleum Corporation
  - Chevron
  - Marathon Oil Company
  - Petro-Canada Resource (USA), Inc.
  - Pioneer Natural Resources
  - Pinnacle Gas Resources
  - Triangle Petroleum Corporation
  - Bear Creek Services
  - CGRS Inc.
- http://aqwatec.mines.edu/produced_water/ for more information

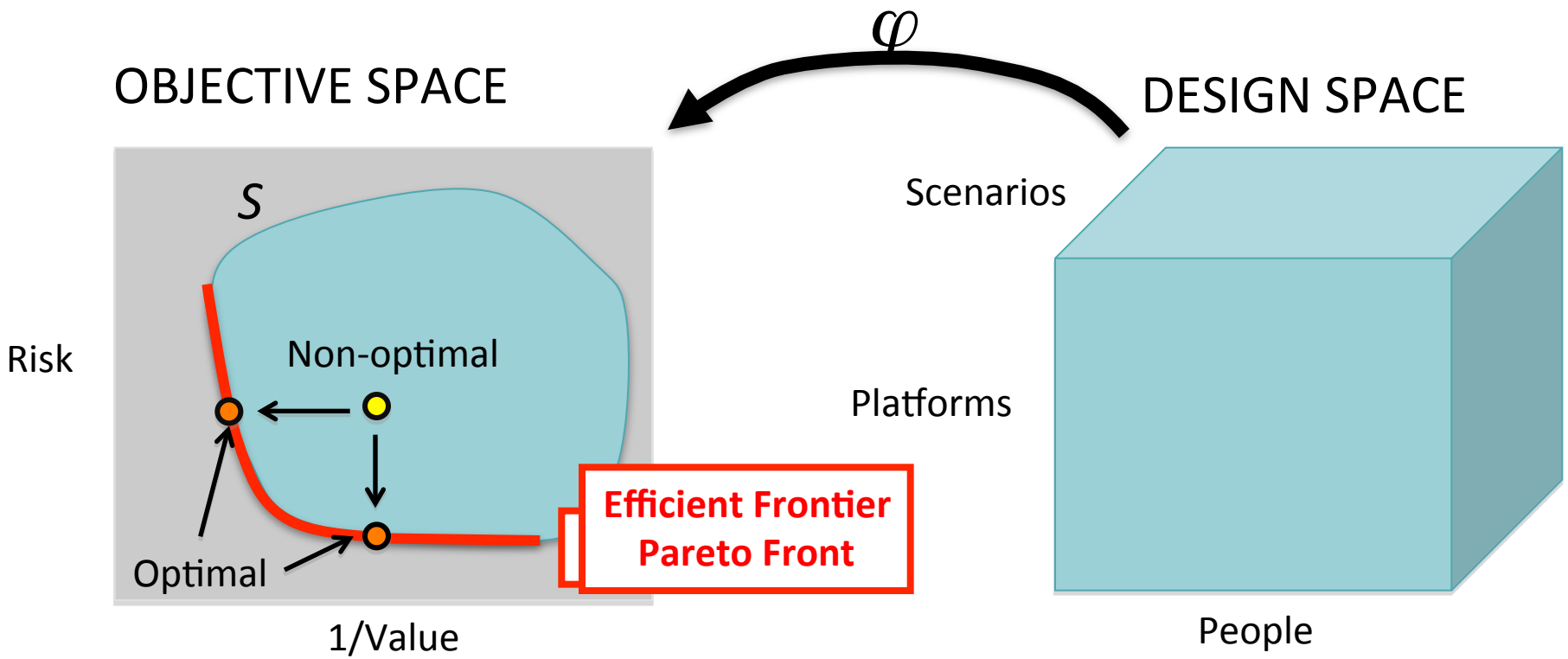

Risk of Casing Faliure
(Reliability/Statistical analysis based on well logging records from Encana and COGCC)
Risk of Induced “runaway” Fractures connecting failed casing to a drinking water aquifer
(Monte-Carlo simulations using Gopher, FracPro to generate induced fracture networks, accounting for heterogeneities in rock properties and in-situ stresses)
Risk of contamination of drinking water wells following gas/ fracking chemical discharge into a groundwater aquifer
(Monte-Carlo simulations using Groundwater flow and transport codes – porous media and/or fractured rock, accounting for heterogeneous permeability fields and/or stochastic fracture network structure, and well locations)
Cumulative Risk of Groundwater Contamination

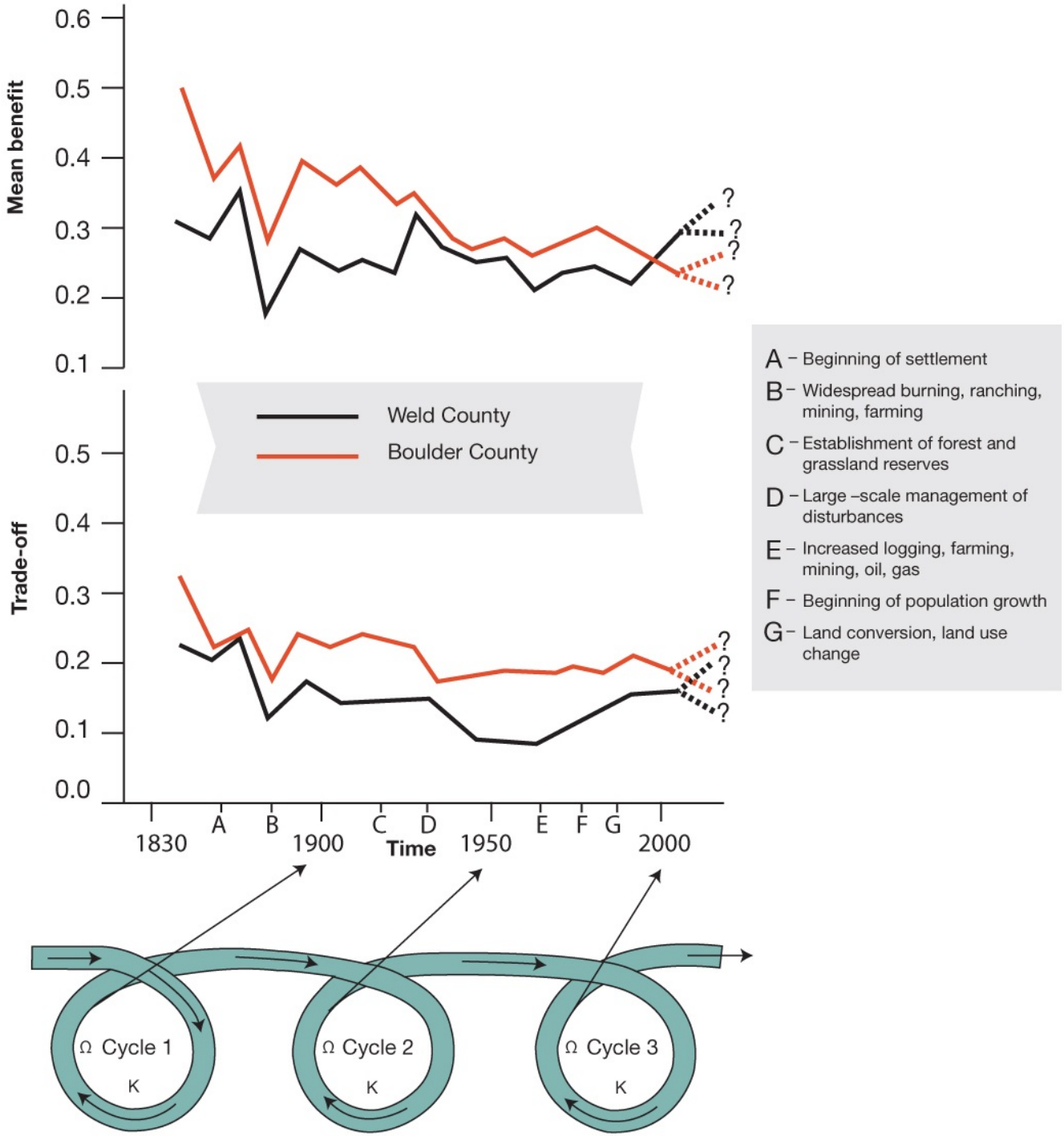
Social-Ecological System Modeling



Social-Ecological System Model

- Optimal outcomes?
  - less risk ⇔ less value; more value ⇔ more risk
  - best event for a risk-value combination

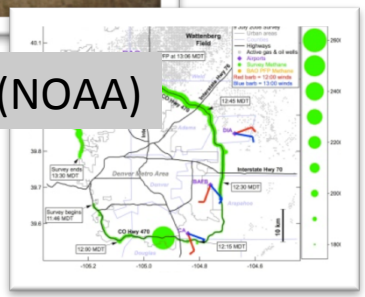



Mean benefit
0.6
0.5
0.4
0.3
0.2
0.1
Trade-off
0.5
0.4
0.3
0.2
0.1
0.0
Weld County
Boulder County
1830
A
B
1900
C
D
1950
E
F
G
2000
Time
A – Beginning of settlement
B – Widespread burning, ranching, mining, farming
C – Establishment of forest and grassland reserves
D – Large –scale management of disturbances
E – Increased logging, farming, mining, oil, gas
F – Beginning of population growth
G – Land conversion, land use change
Ω Cycle 1
K
Ω Cycle 2
K
Ω Cycle 3
K

Air Quality

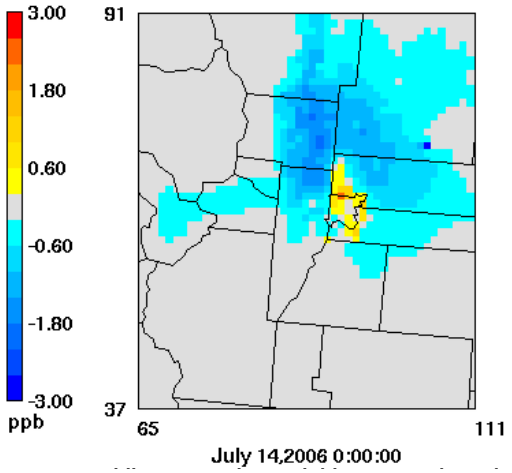
Emissions Measurements

Gaby Pétron (NOAA)



Air Quality & Energy Modeling

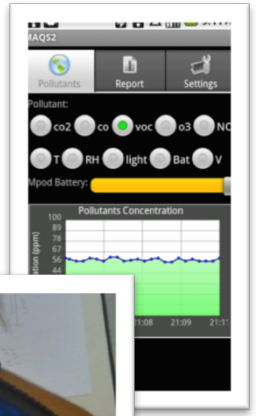
How will our energy future impact air quality?



Difference in O_3 concentration

Jana Milford (UCB) and Greg Brinkman (NREL)

Ambient & Exposure Measurements



Mike Hannigan (UCB)