

SBX2 1 (2008, Perata)

**UC Davis Report to State Water Board
for its Report to the Legislature**

**ADDRESSING NITRATE IN
CALIFORNIA'S DRINKING WATER,
TULARE LAKE BASIN AND SALINAS VALLEY**

Tulare Lake Basin Meeting
May 3, 2012

Thomas Harter & Jay Lund, *Principal Investigators*

Jeannie Darby, Graham Fogg, Richard Howitt, Katrina
Jessoe, Jim Quinn, Stu Pettygrove, Joshua Viers,
Co-Investigators

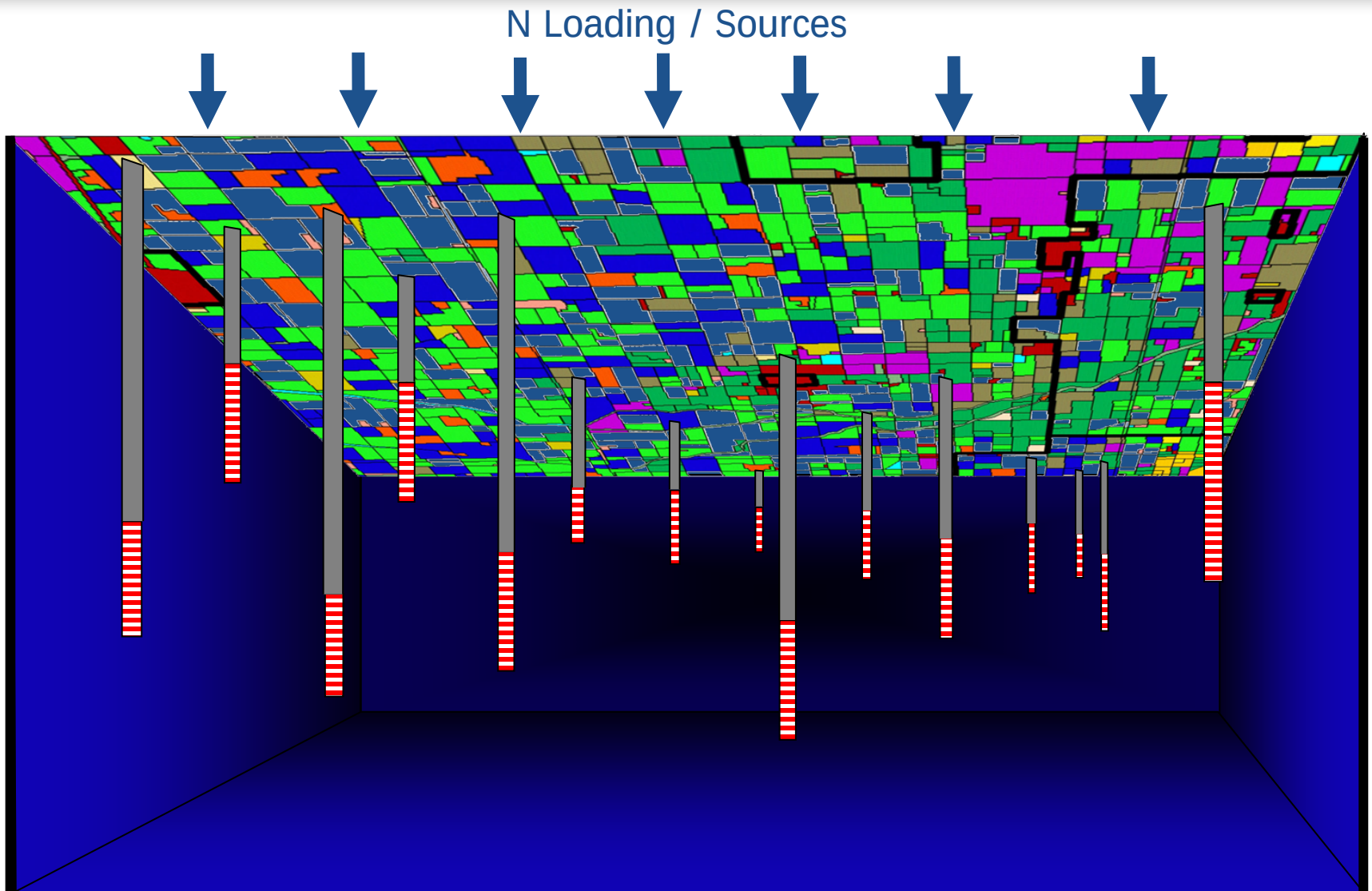


Aaron King, Allan Hollander, Alison McNally, Anna
Fryjoff-Hung, Cathryn Lawrence, Daniel Liptzin, Danielle
Dolan, Dylan Boyle, Elena Lopez, Giorgos Kourakos,
Holly Canada, Josue Medellin-Azuara, Kristin Dzurella,
Kristin Honeycutt, Megan Mayzelle, Mimi Jenkins, Nicole
de la Mora, Todd Rosenstock, Vivian Jensen,
Researchers

<http://groundwaternitrate.ucdavis.edu>

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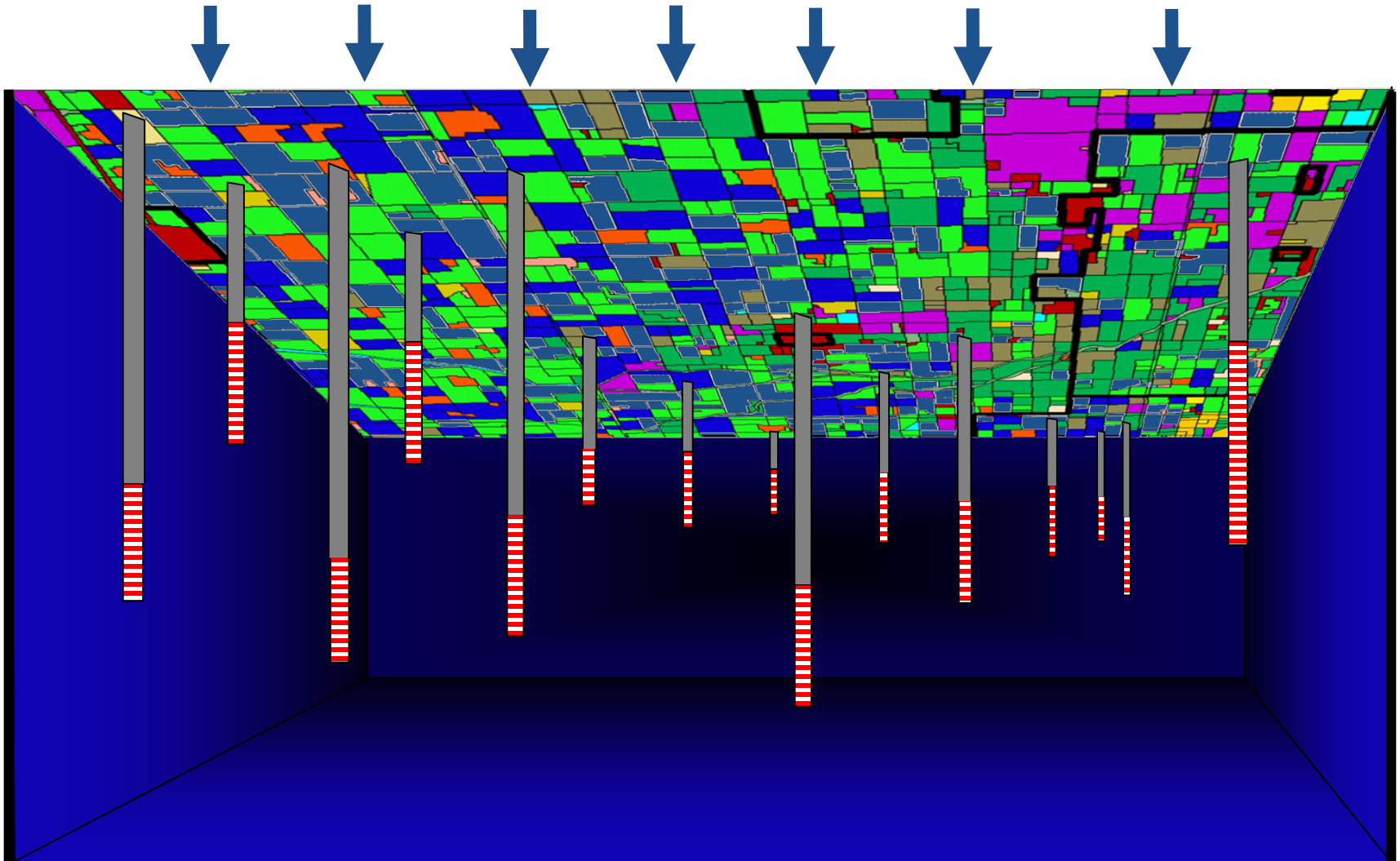
#1: Sources of Nitrate





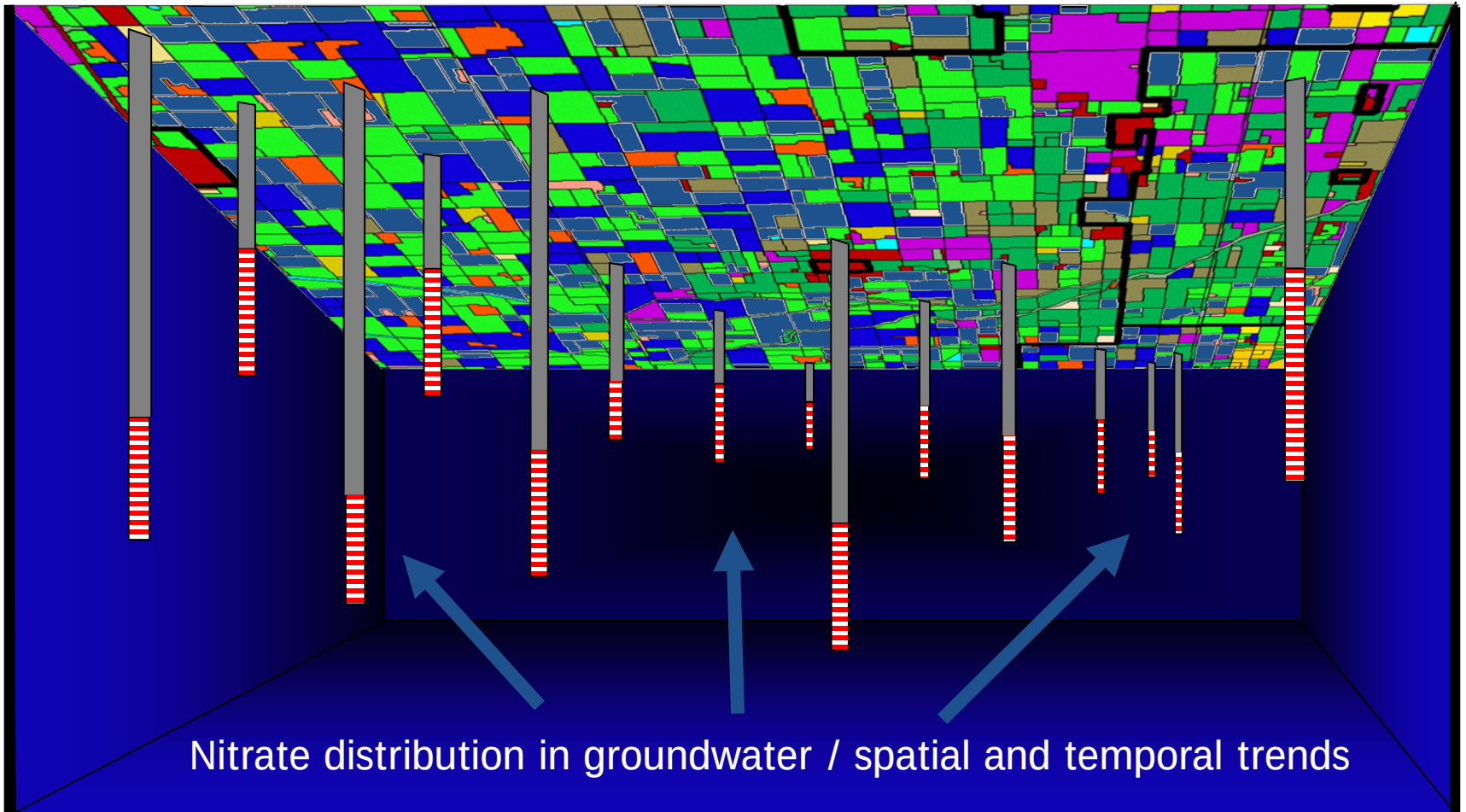
#2: Nitrate Source Reduction

N Loading Reduction Options / Source Control



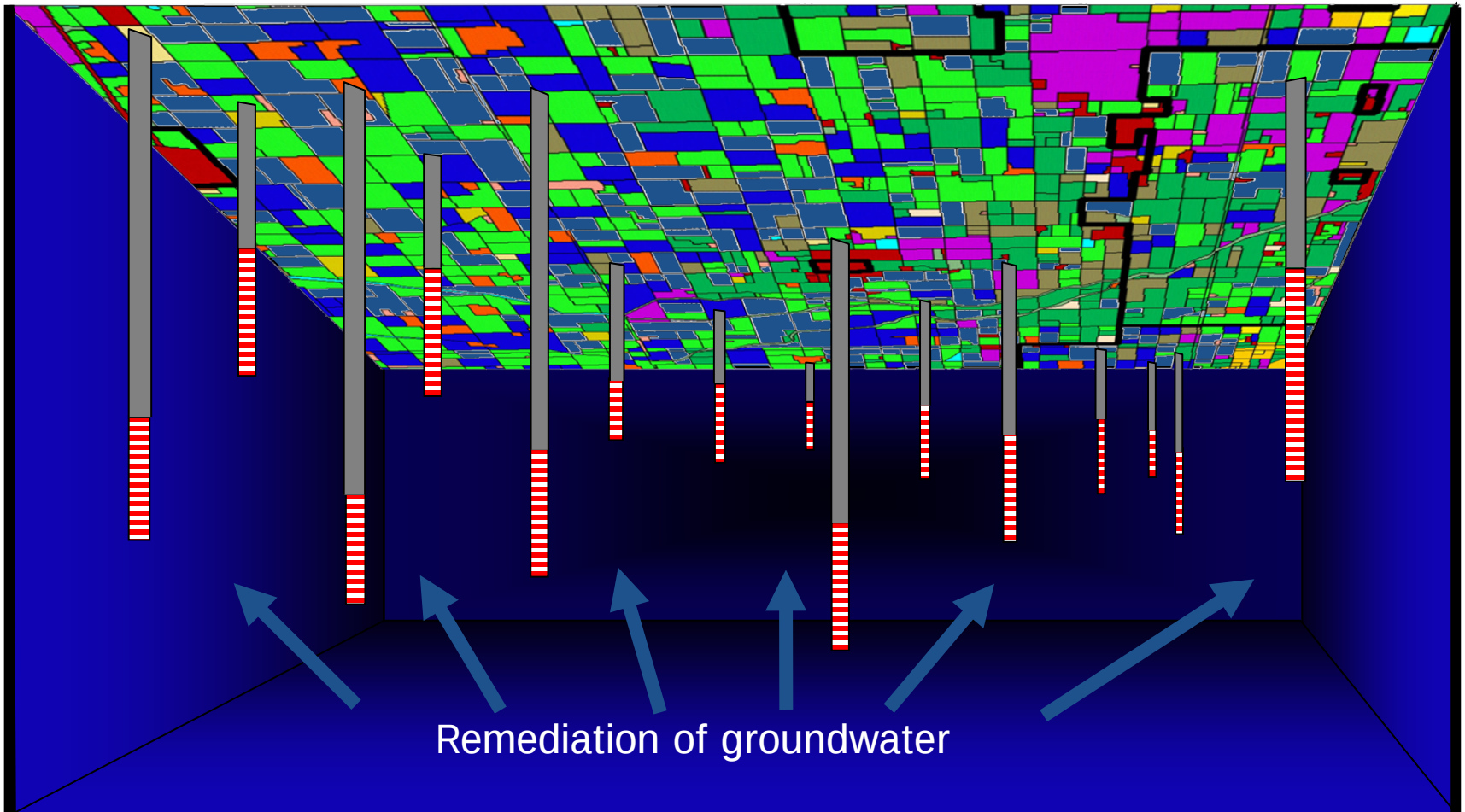


#3: Groundwater Nitrate





#4: Groundwater Remediation

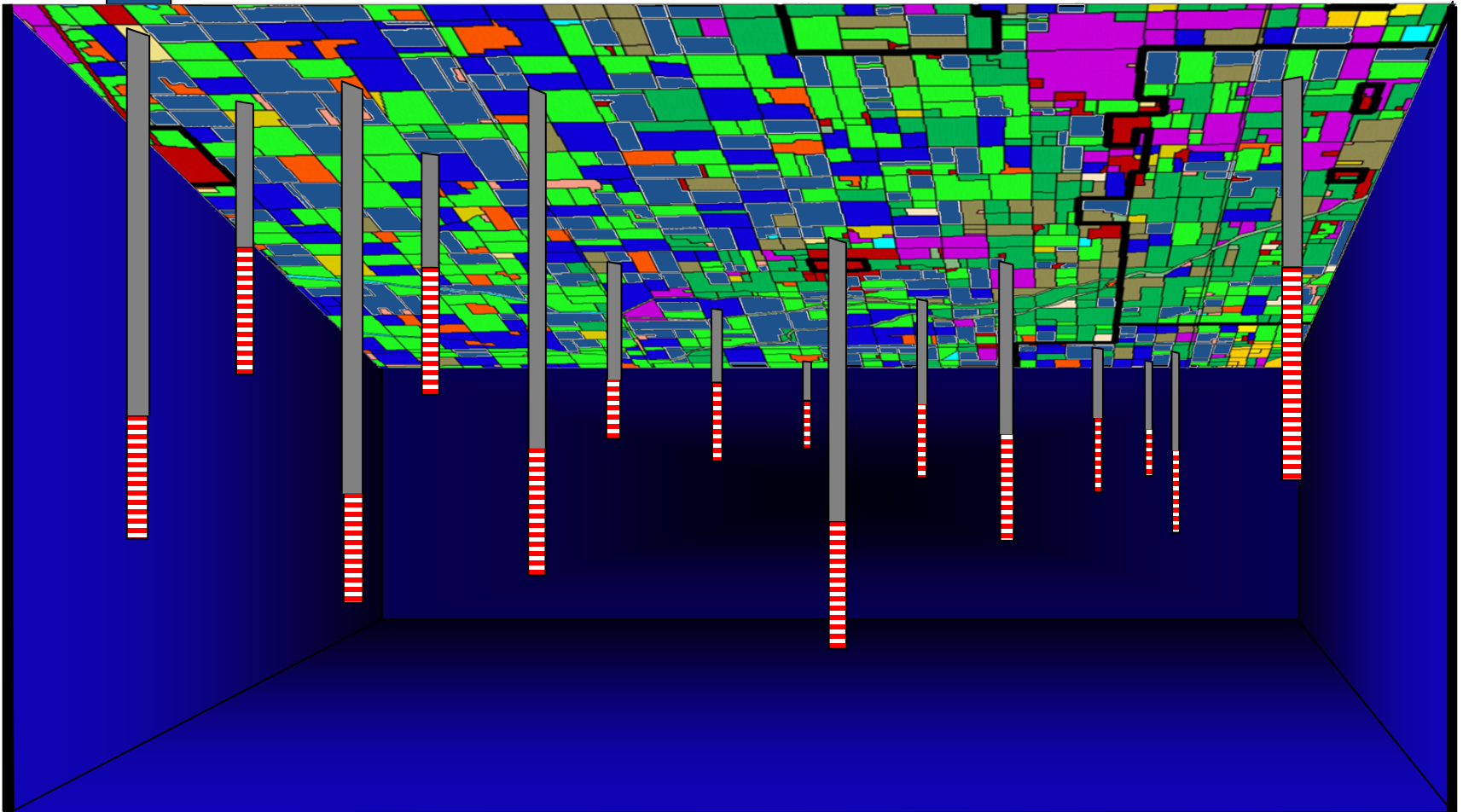




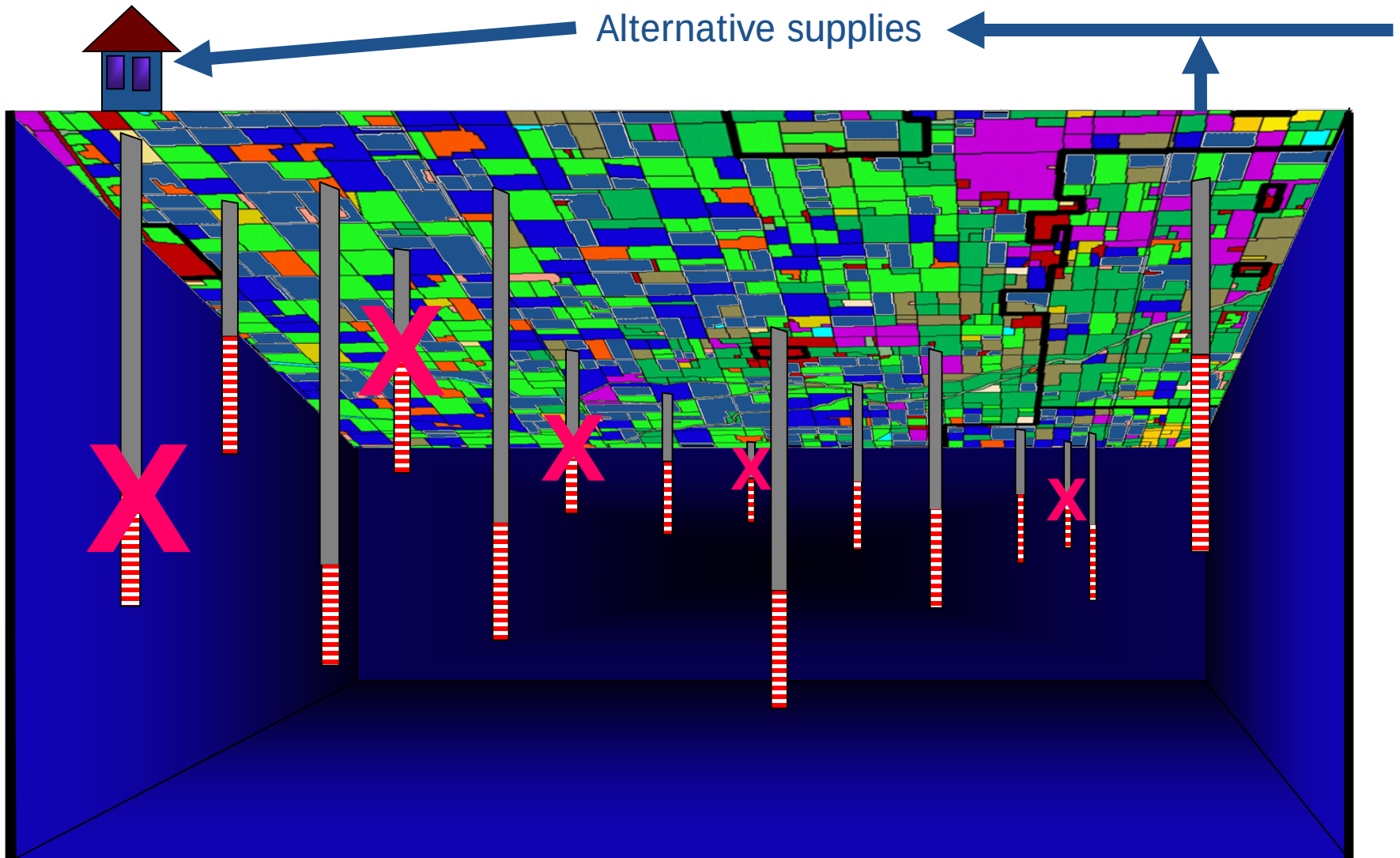
#5: Drinking Water Treatment



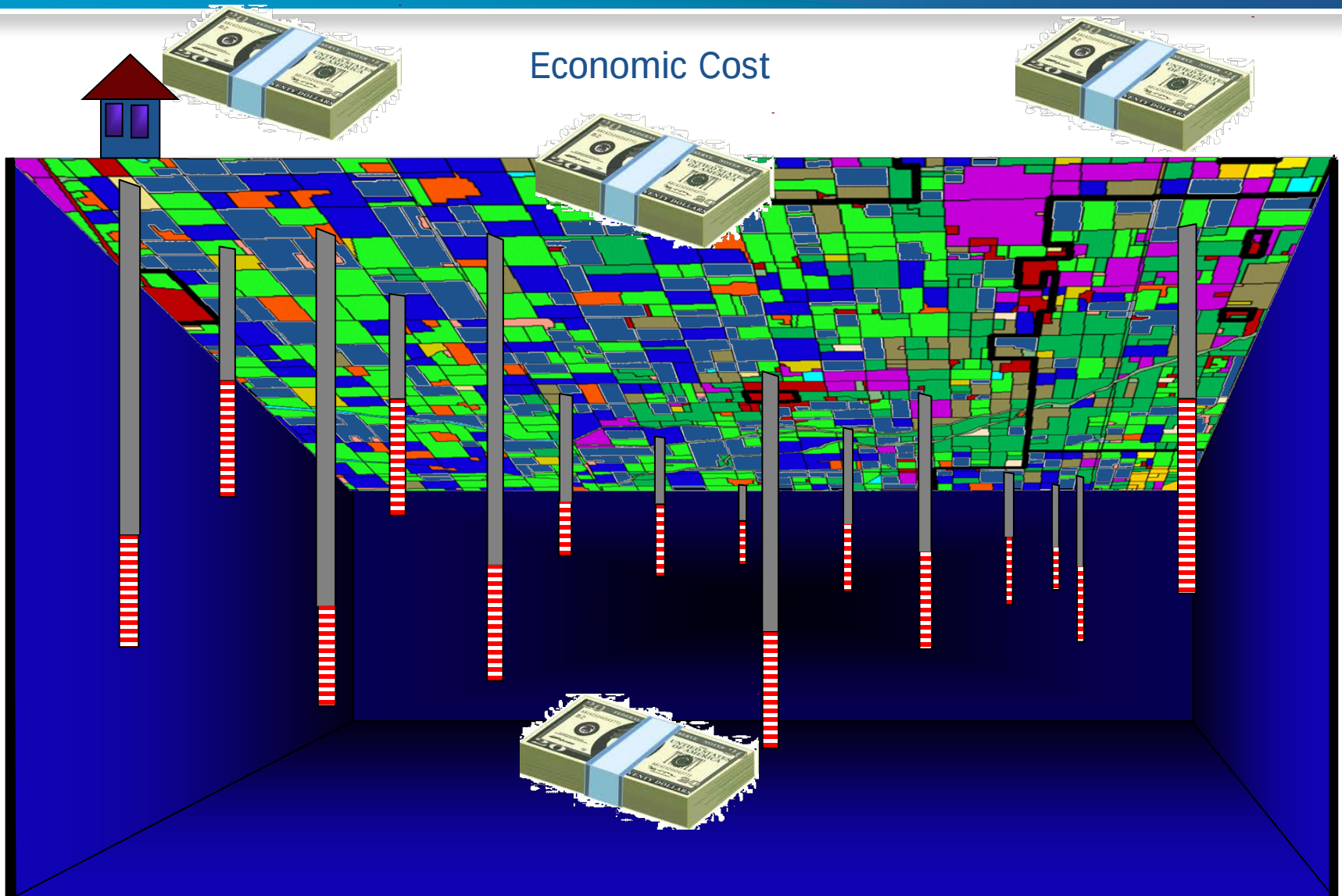
N treatment options



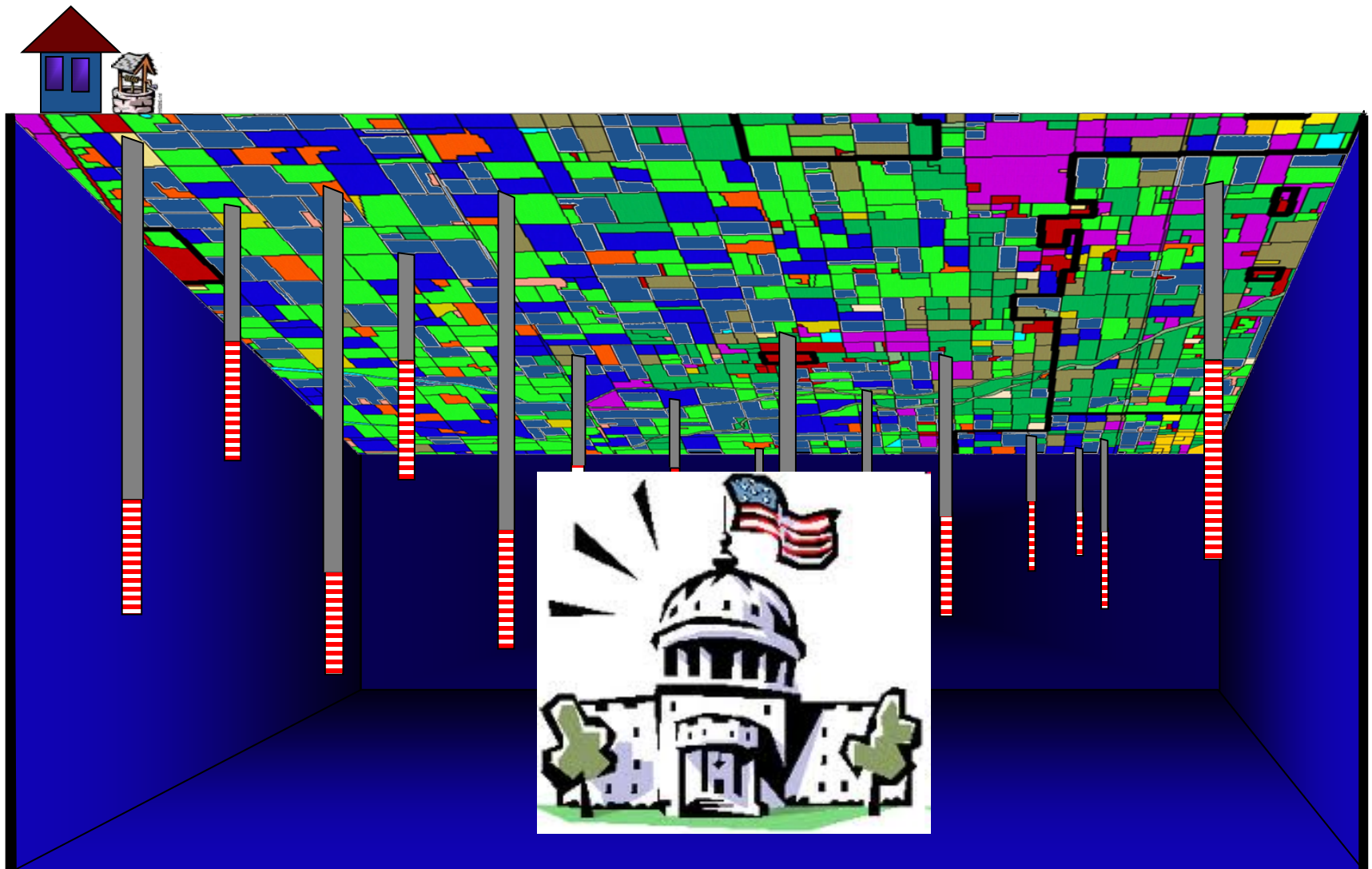
#6: Alternative Supplies



#7: Costs of Actions

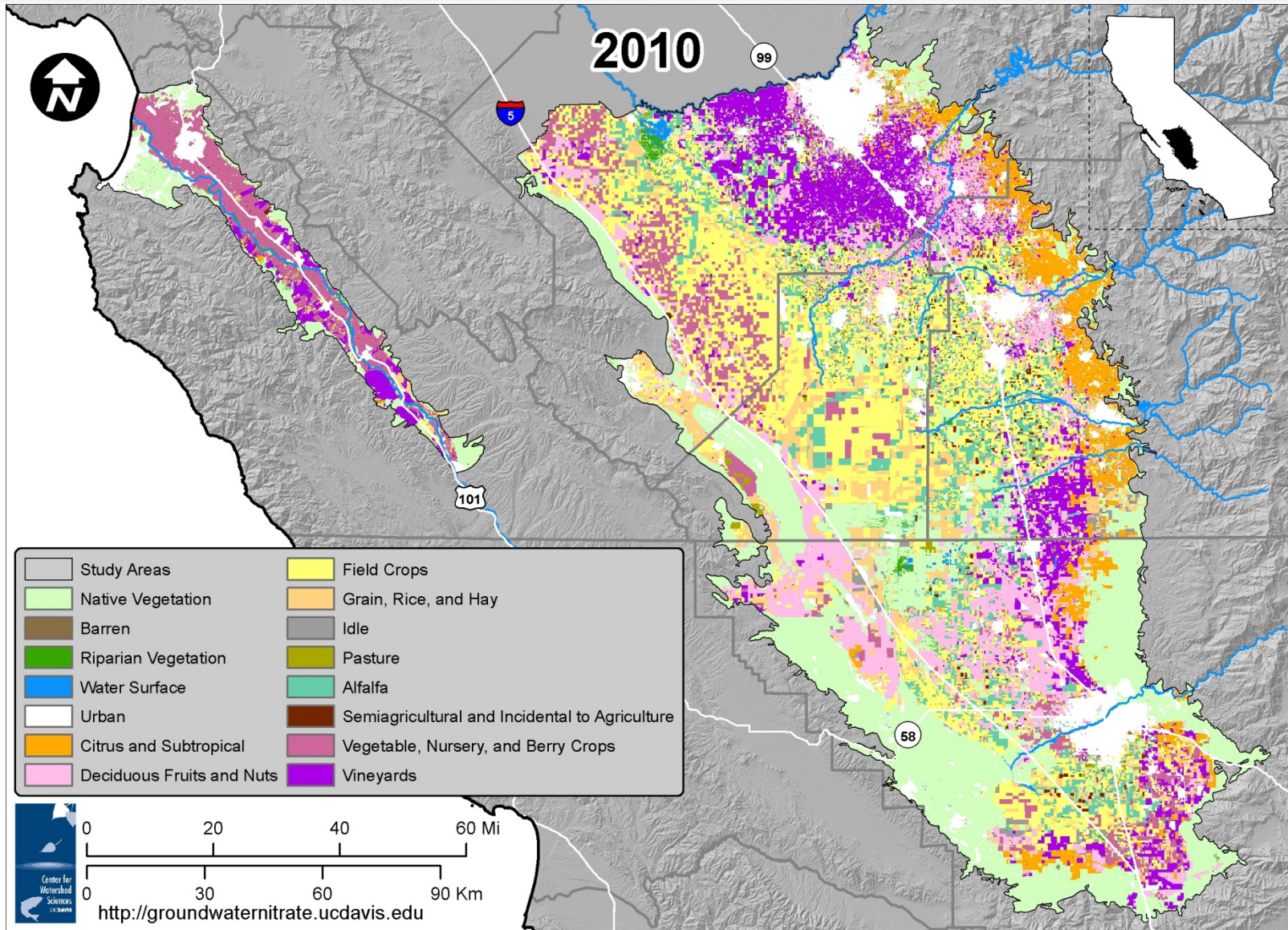


#8: Funding and Policy





Nitrate Contamination Study Area



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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 2: LANDUSE & POTENTIAL GROUNDWATER LOADING

Tulare Lake Basin Meeting
May 3, 2012

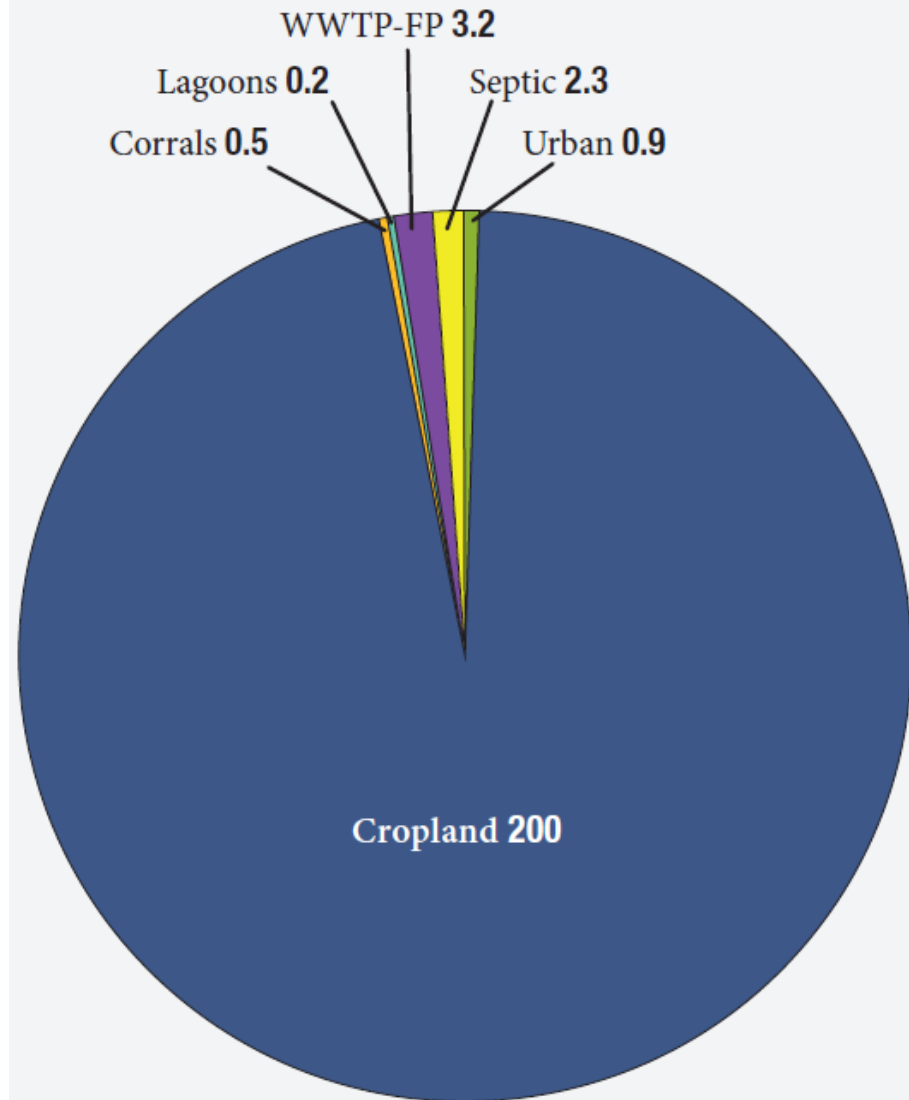


Thomas Harter, Anna Fryjoff-Hung, Allan Hollander,
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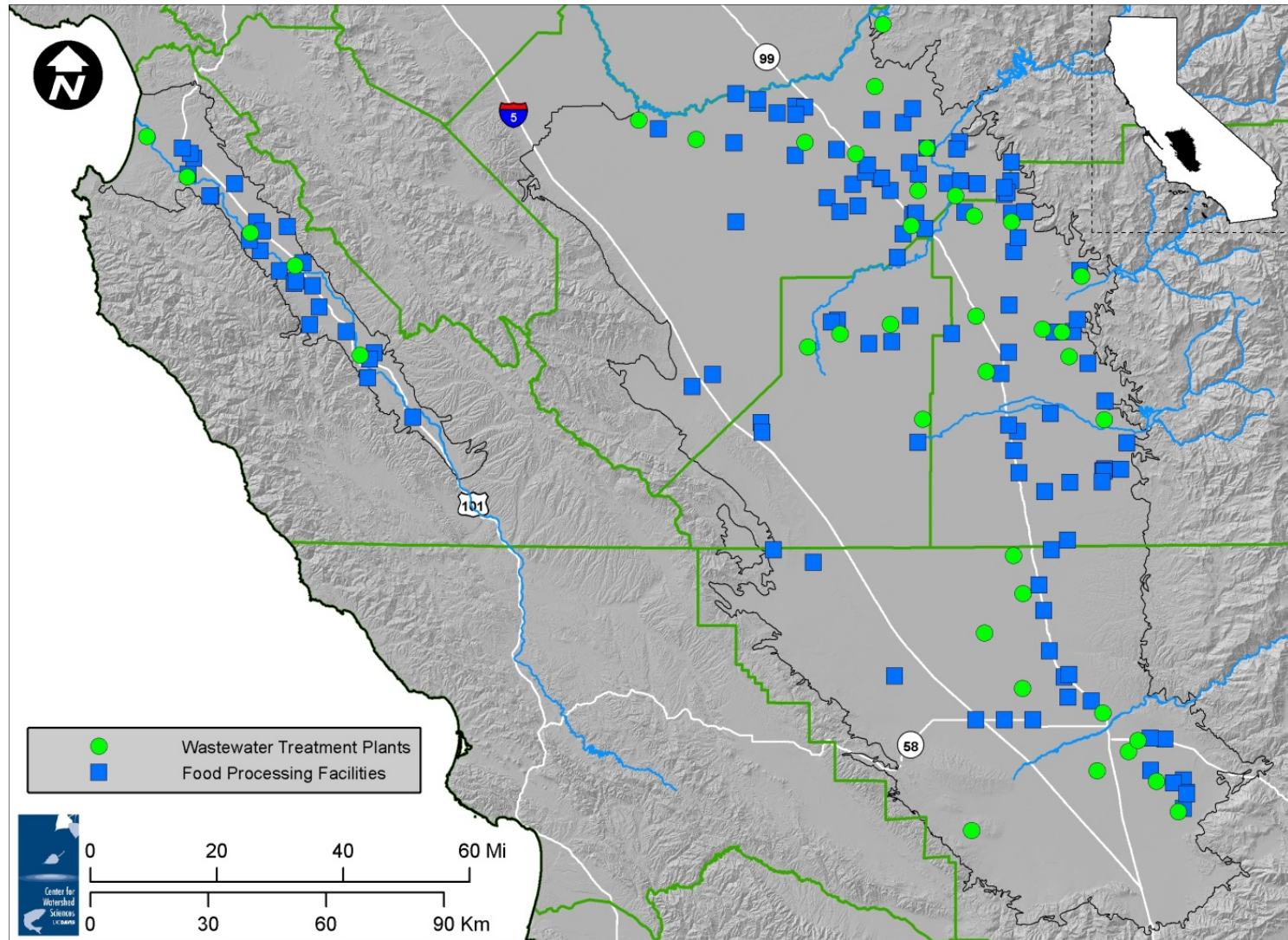


Sources of Groundwater Nitrate



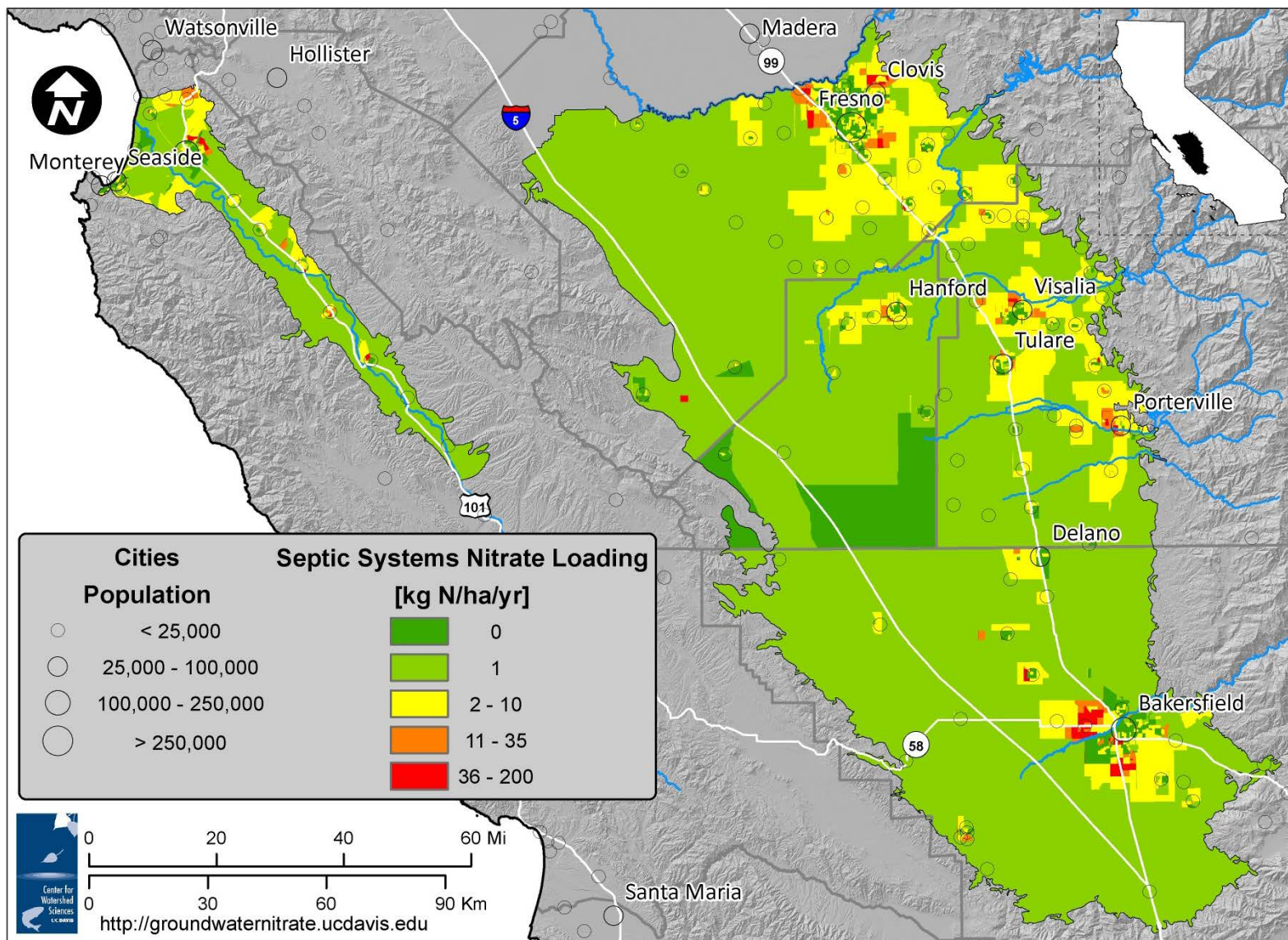
Gg N/yr

Wastewater Treatment Plants and Food Processors

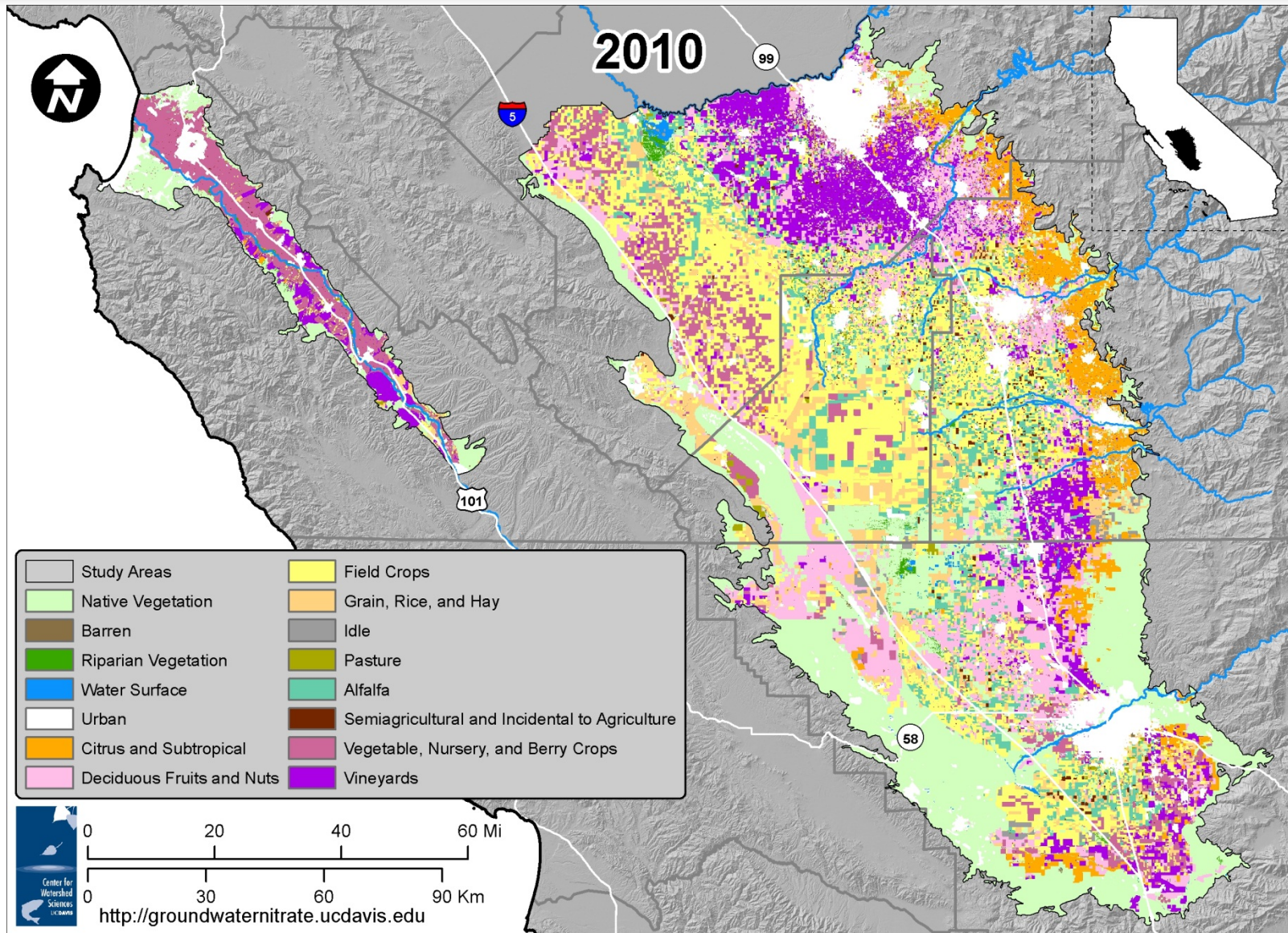




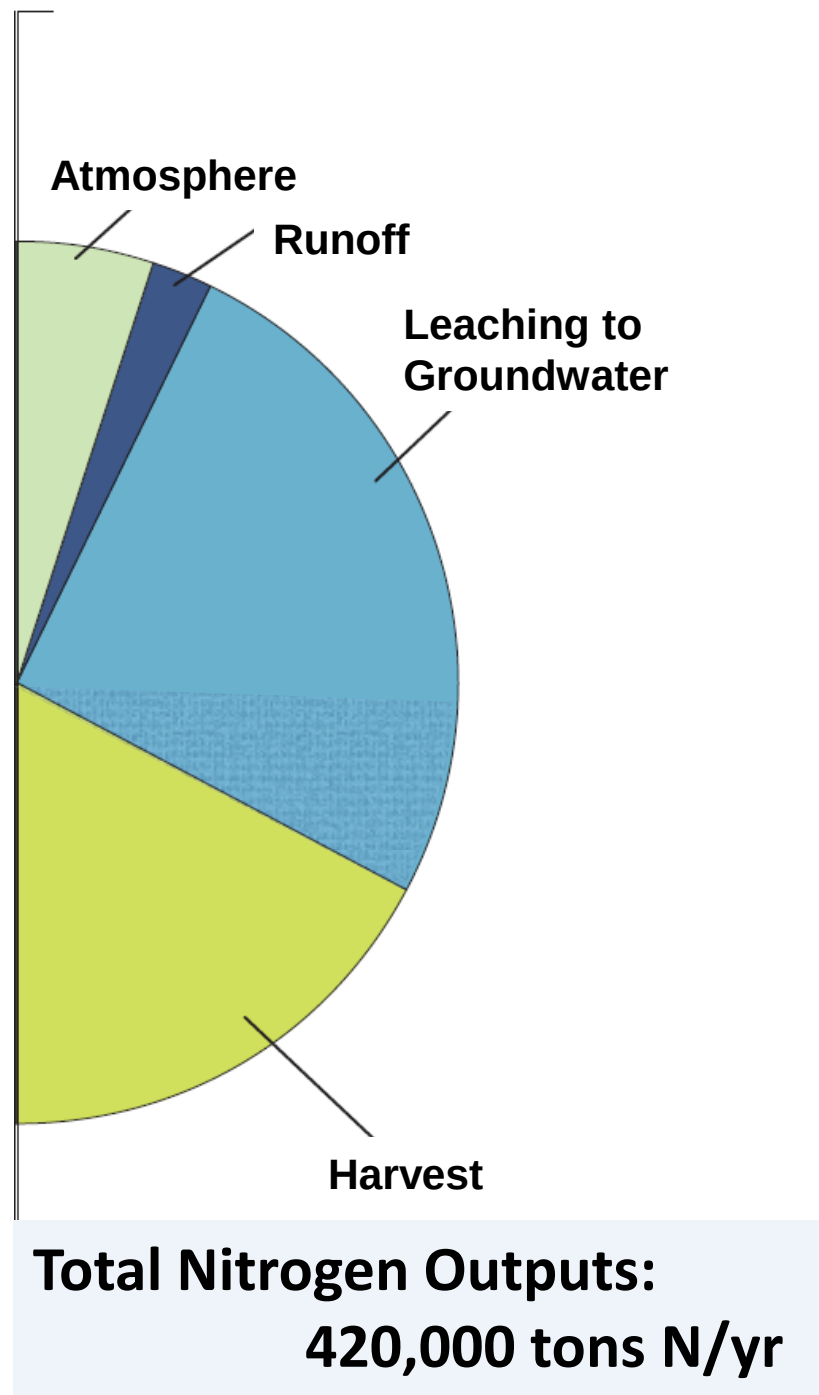
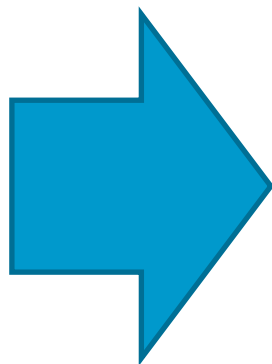
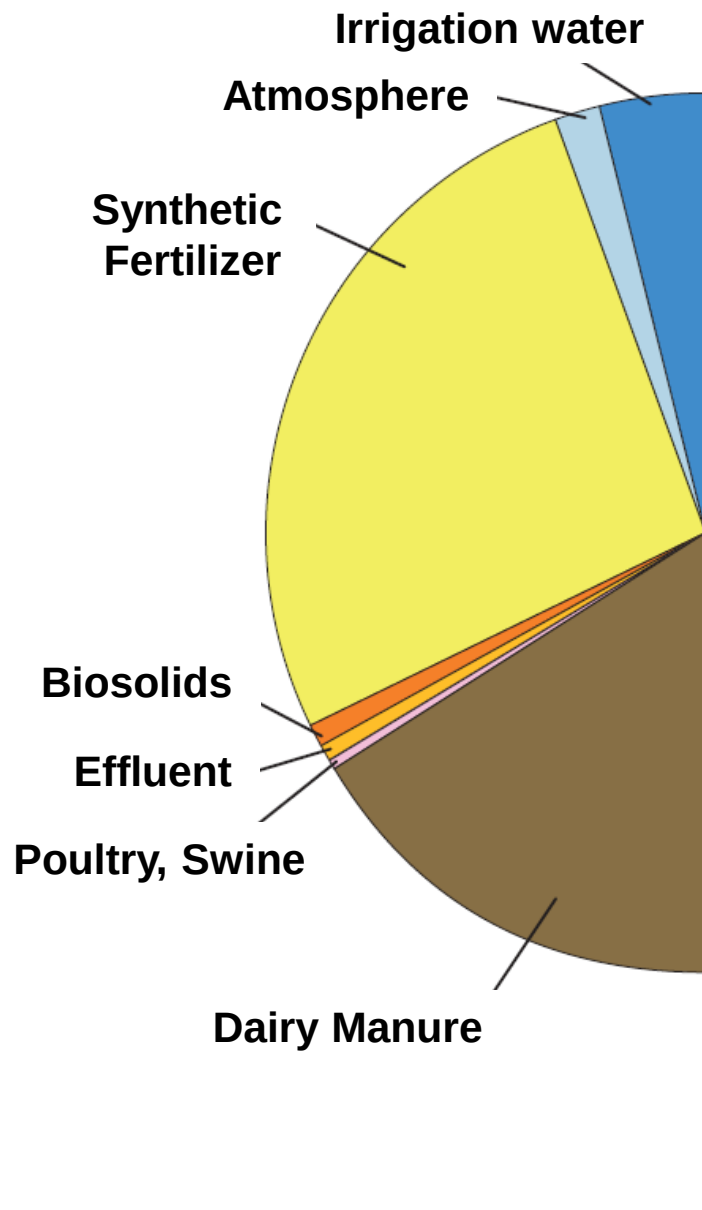
Septic Systems



Agricultural Sources



**Total Nitrogen Inputs:
420,000 tons N/yr**

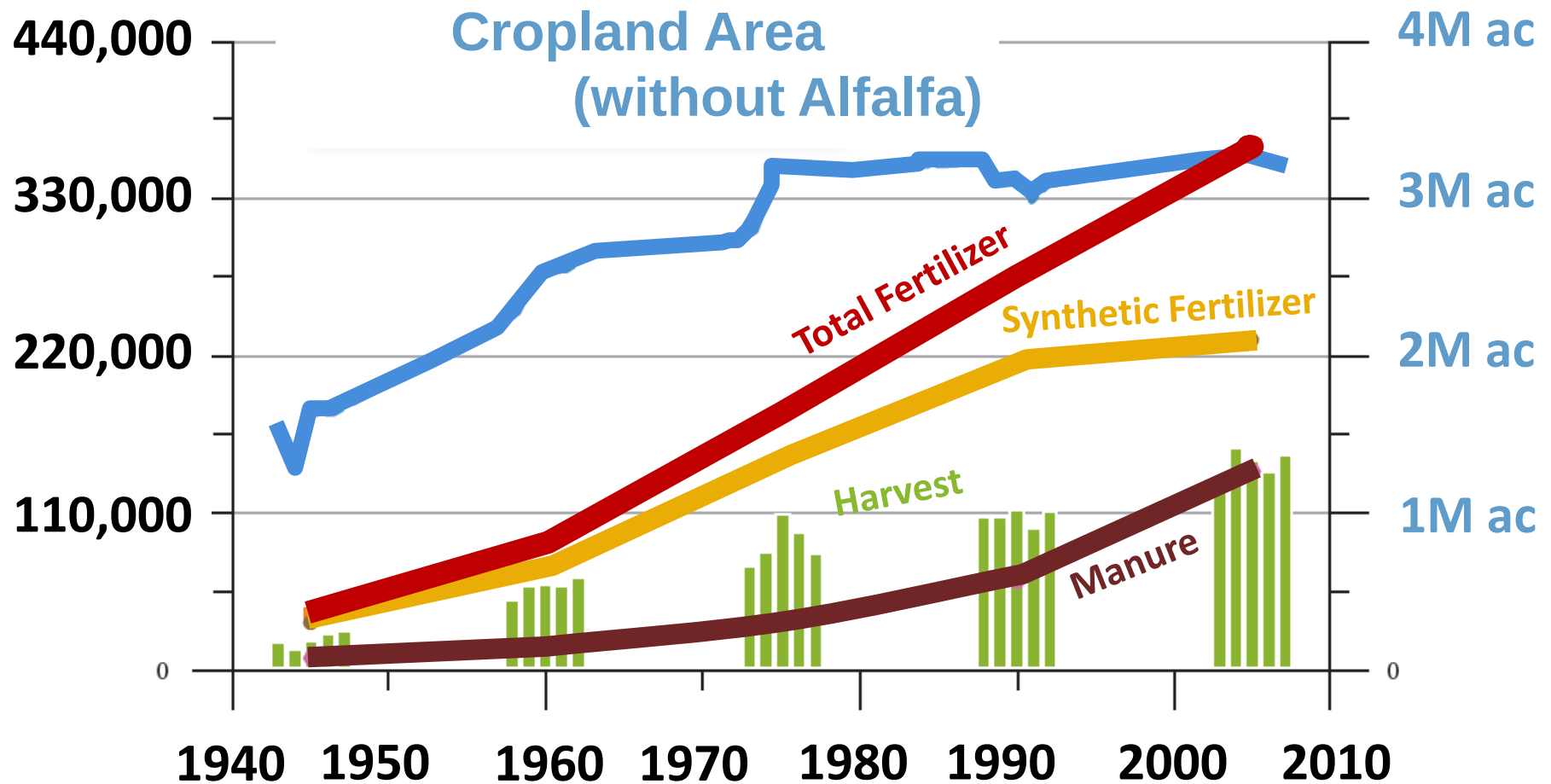




Historic Nitrogen Fluxes

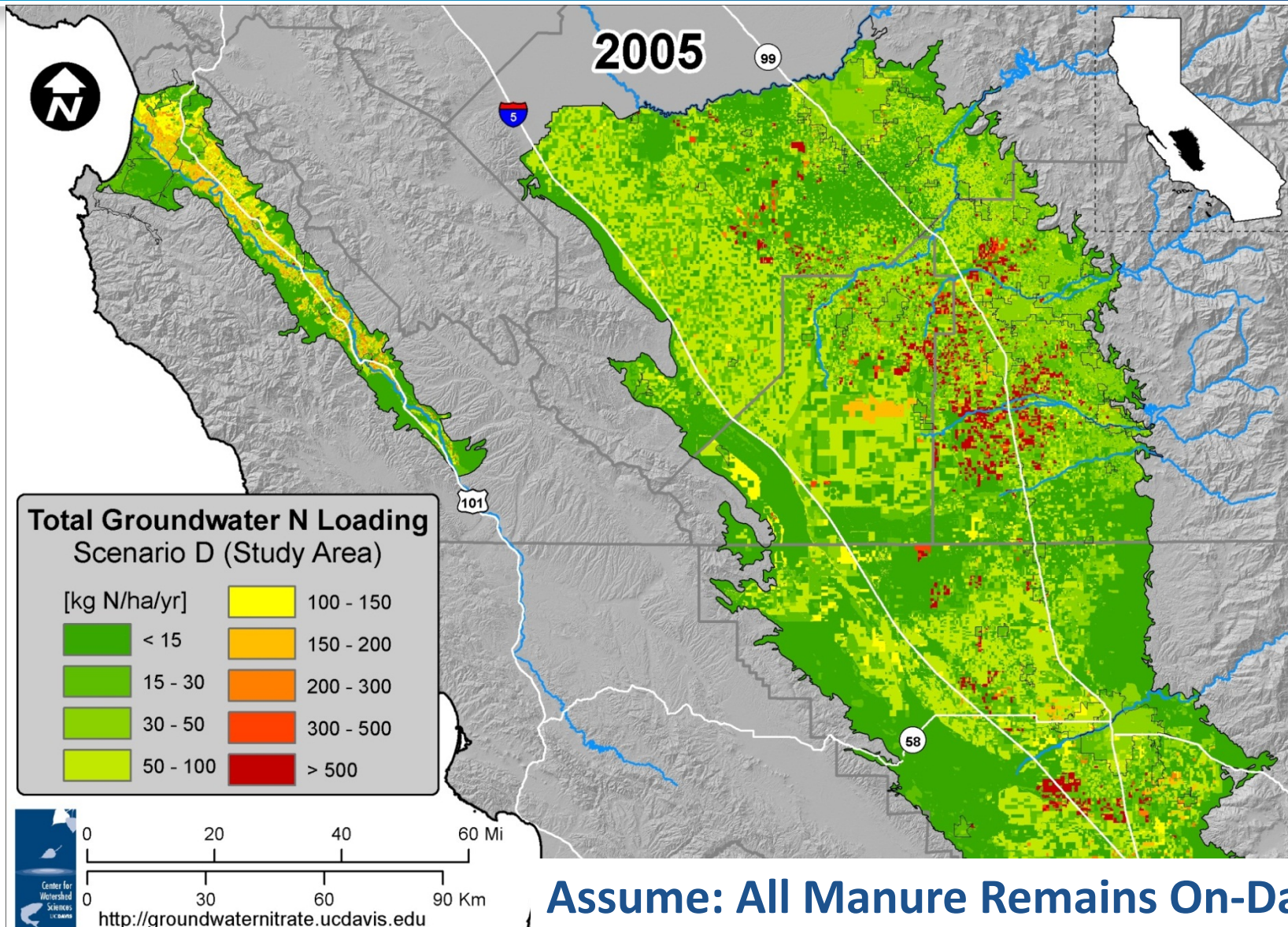
tons N/yr

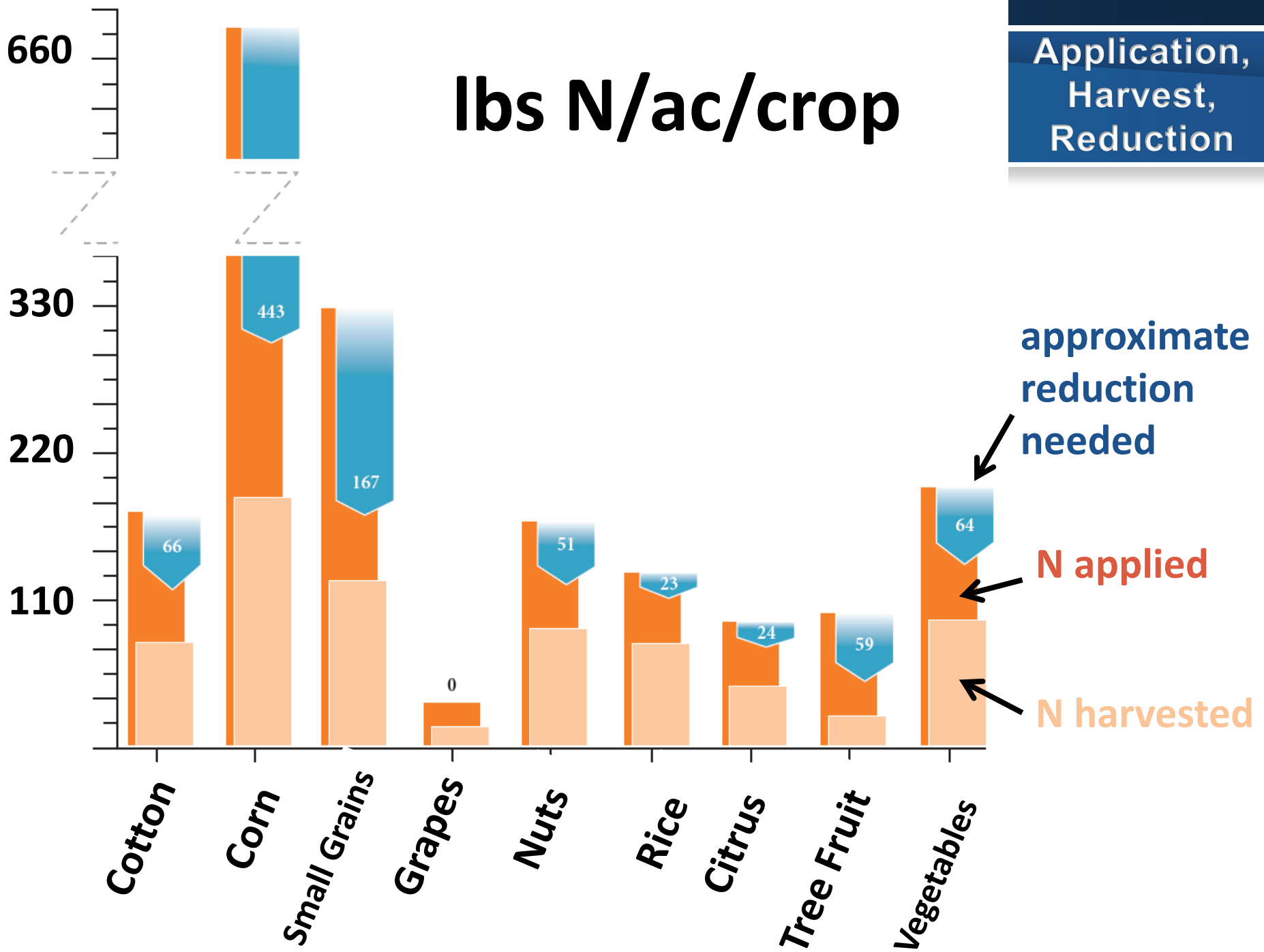
Cropland Area





Estimated Groundwater Nitrate Loading





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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 3: NITRATE SOURCE REDUCTION

Tulare Lake Basin Meeting
May 3, 2012



Kristin Dzurella, Thomas Harter, Vivian Jensen, Aaron King, Josue Medellin-Azuara, Stuart Pettygrove

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Agricultural Source Reduction

Increase crop N-use efficiency -- Decrease deep percolation

Basic Components	Management Measures	50 Practices
Improve irrigation and drainage systems	✓ Perform system evaluation and monitoring	3
	✓ Improve Irrigation scheduling	4
	✓ Improve irrigation system design and operation	13
	✓ Other irrigation infrastructure improvements	2
Improve fertilizer and manure use	✓ Improve rate, timing, and placement	15
Change crop rotation	✓ Modify crop rotation or grow cover crops	4
Improve storage and handling	✓ Avoid fertilizer material and manure spills during transport, storage and application	9



FINDINGS: Cropland Source Reduction

- Recommended practices can increase N in the harvested crop to ~**60-80%** of N inputs
 - Current averages as low as ~30-40%
- Some practices are already in use:
 - Rate of adoption, regional impact unknown
- Suite of practices will be the most effective:
 - Tailored to specific soils and crops
- Barriers to expanded adoption:
 - Logistics, education, costs





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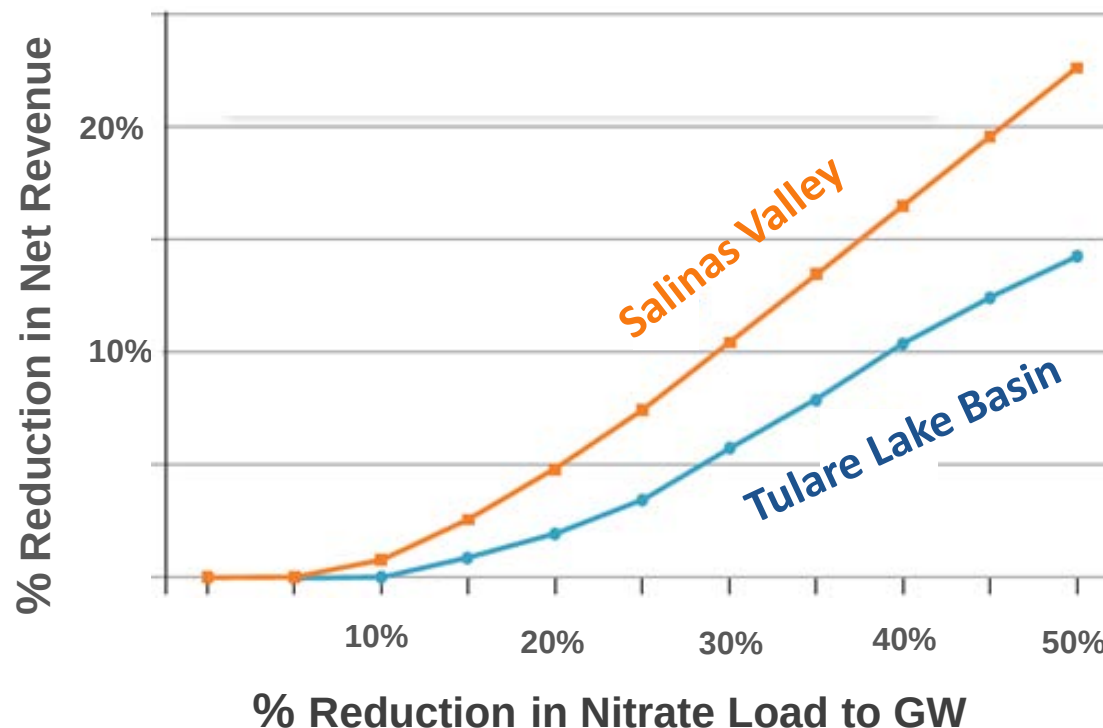
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Economics of Source Reduction

- Cost of improving crop N use efficiency is uncertain but likely low for small improvements.
- Load reductions of half or more may come at a significant cost, potential reduction in irrigated crop area.





Cropland Source Reduction

PROMISING ACTIONS

- Expand efforts to promote adoption of N-efficient practices:
 - Grower education
 - Adaptive research
- Support development of N accounting methods:
 - Grower evaluation of improvements in crop N-use efficiency
- Fine-tune nitrate leaching risk assessment methods:
 - Identify associated monitoring requirements





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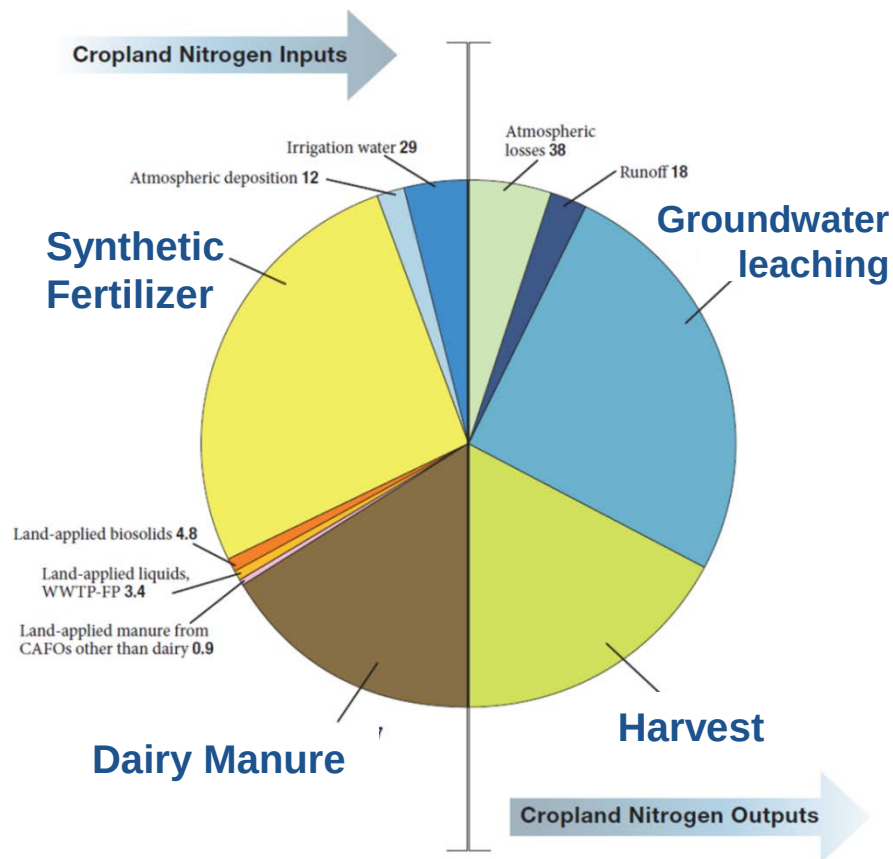




Livestock Operations

Dairy manure now regulated...to comply:

- Exporting excess manure off-farm
- Receiving farms not reducing synthetic N enough
 - Improve methods for determining fertilizer value
 - Alternative Forms
- Guidance in co-managing organic and conventional N



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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 4: GROUNDWATER QUALITY

Tulare Lake Basin Meeting
May 3, 2012



Dylan Boyle, Aaron King, Giorgos Kourakos, Graham Fogg, Thomas Harter

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thharter@ucdavis.edu

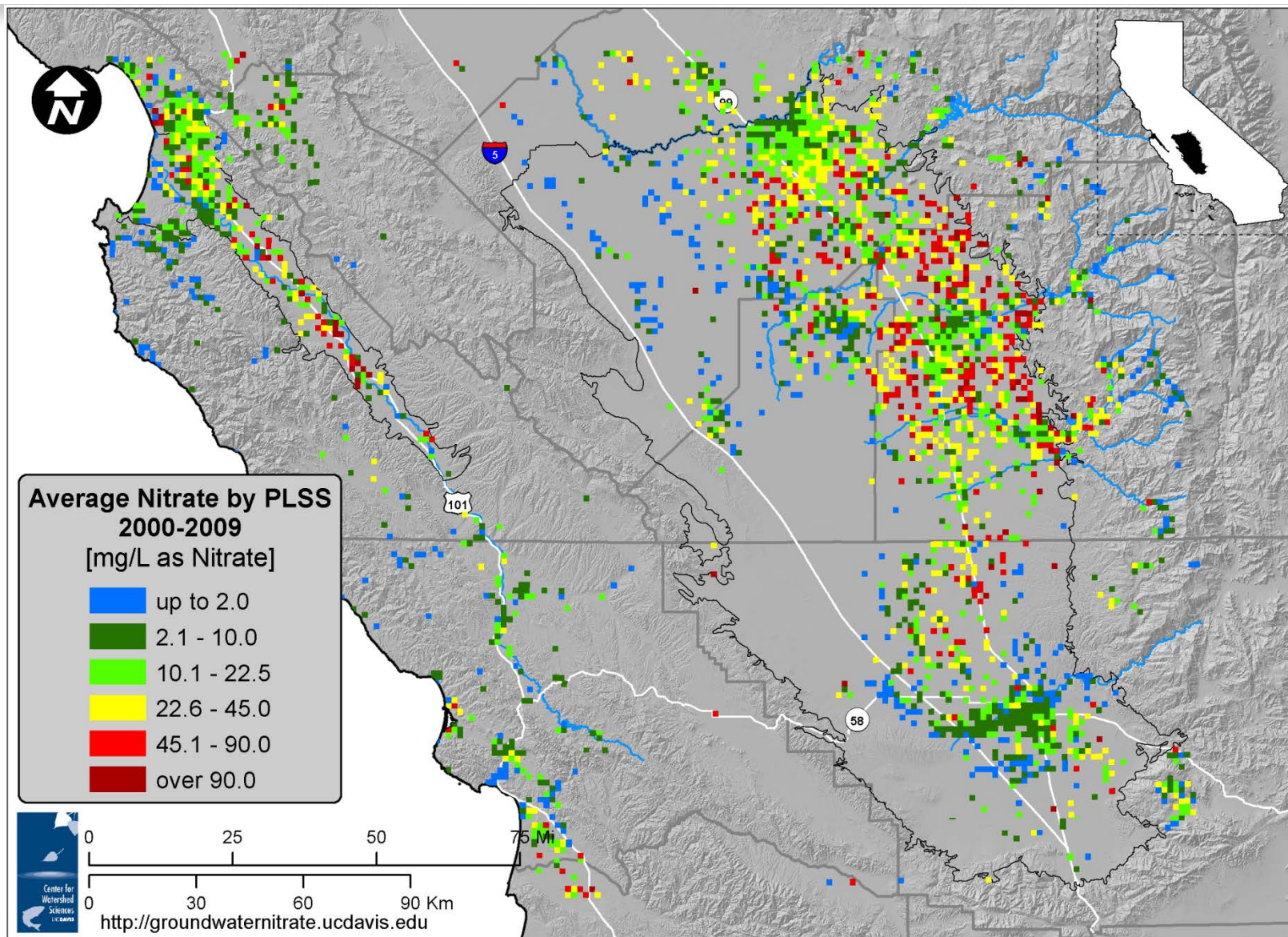


Key Findings

- Widespread nitrate contamination
 - Eastern TLB and Salinas Valley most affected
- Lack of long-term historic water quality datasets
 - Majority of data 2000→present.
- Future: nitrate expected to increase in many areas

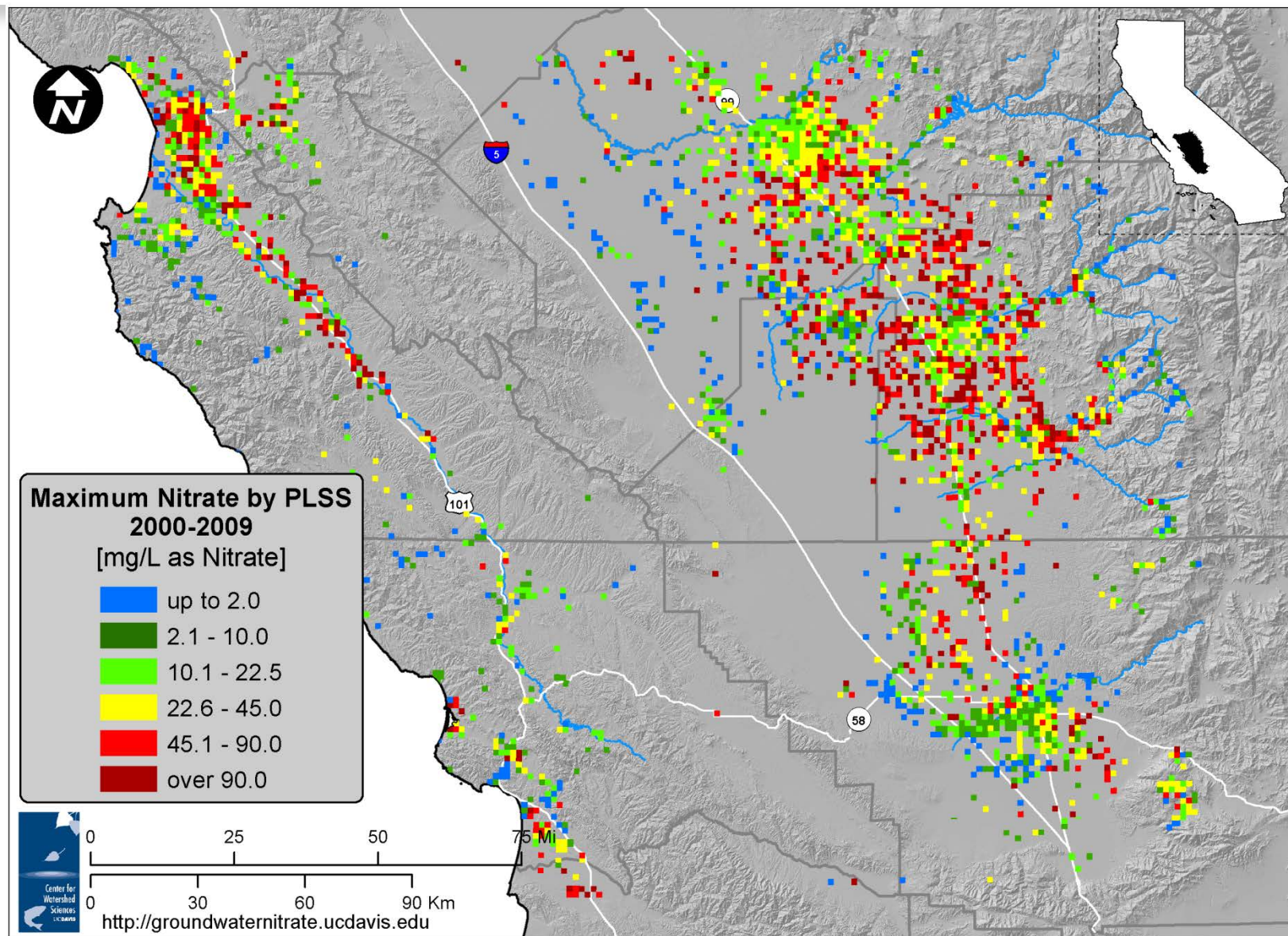


Average Nitrate Concentrations by Section





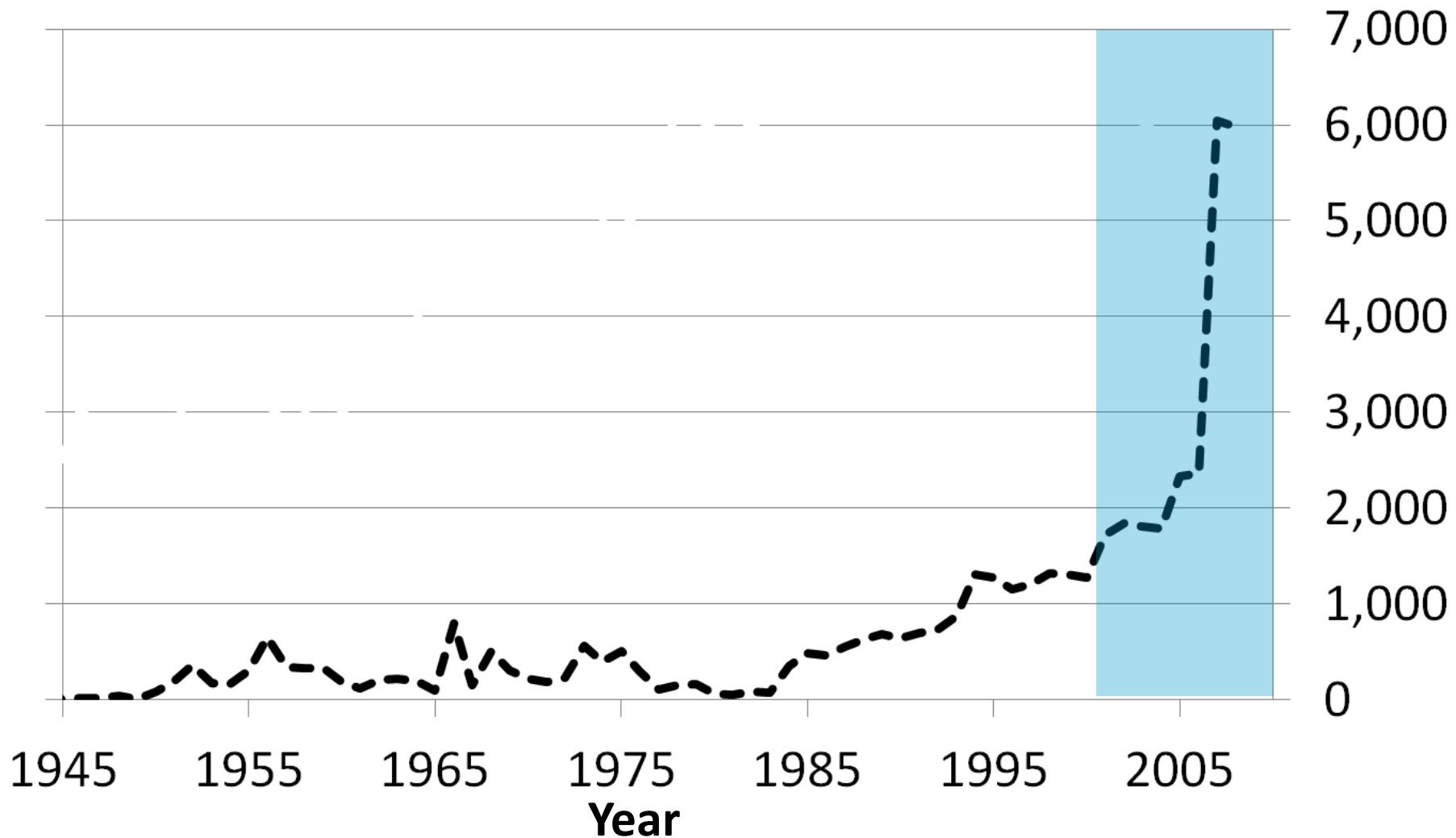
Maximum Nitrate Concentrations by Section





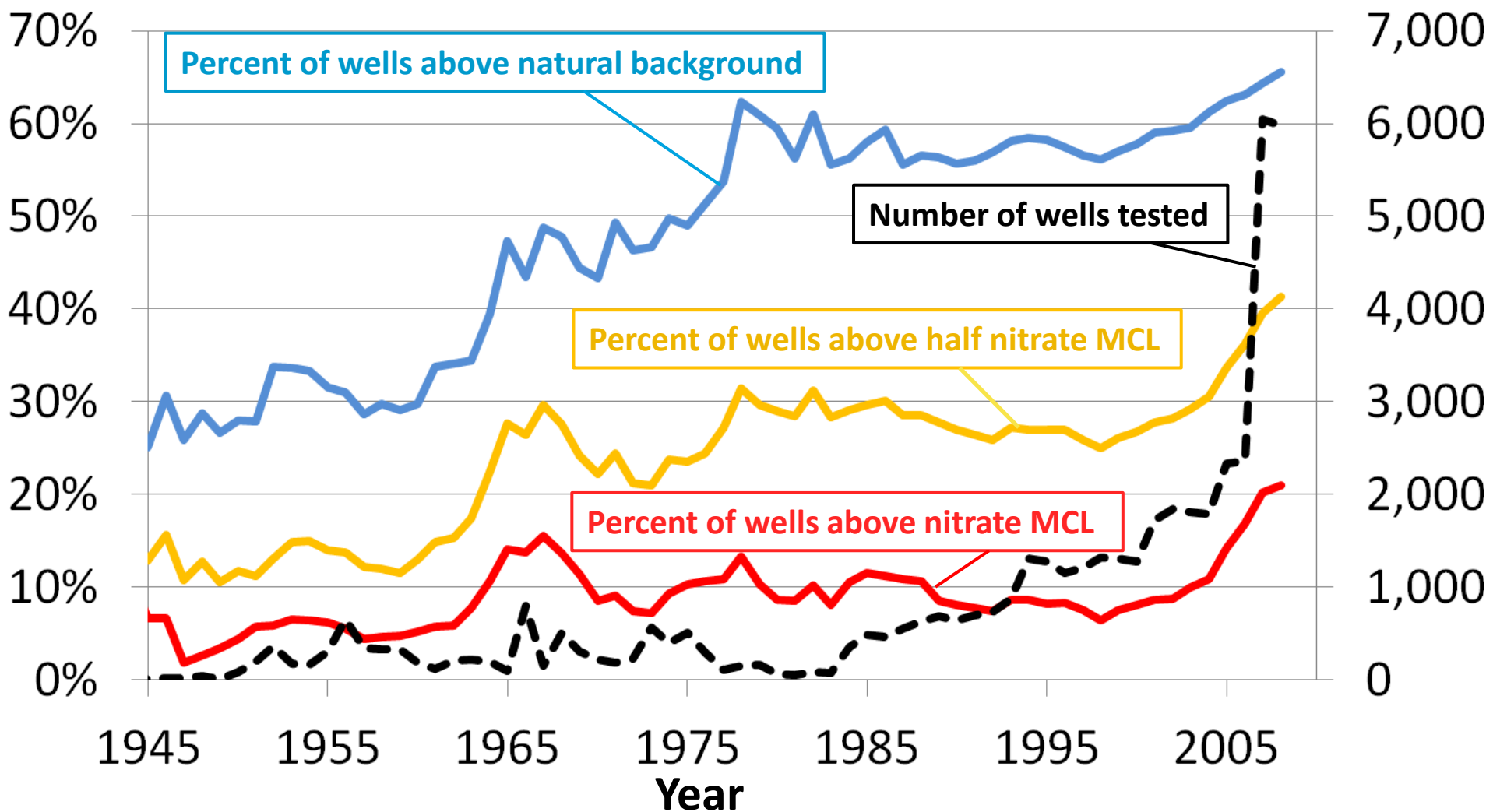
Number of Wells Sampled

CASTING Database





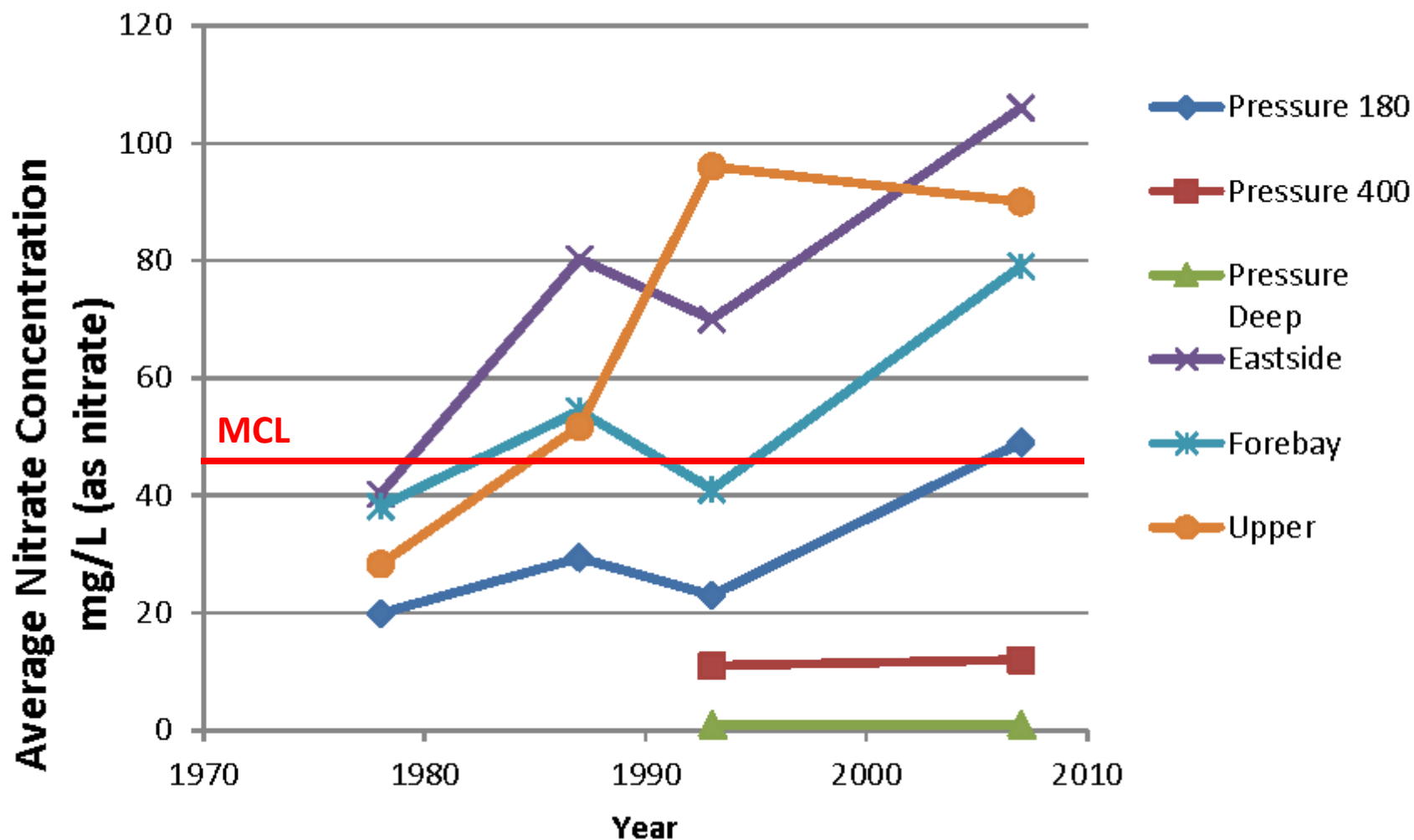
Historic Nitrate Trends, TLB: Exceedance Rate





Nitrate Trends, Salinas Valley

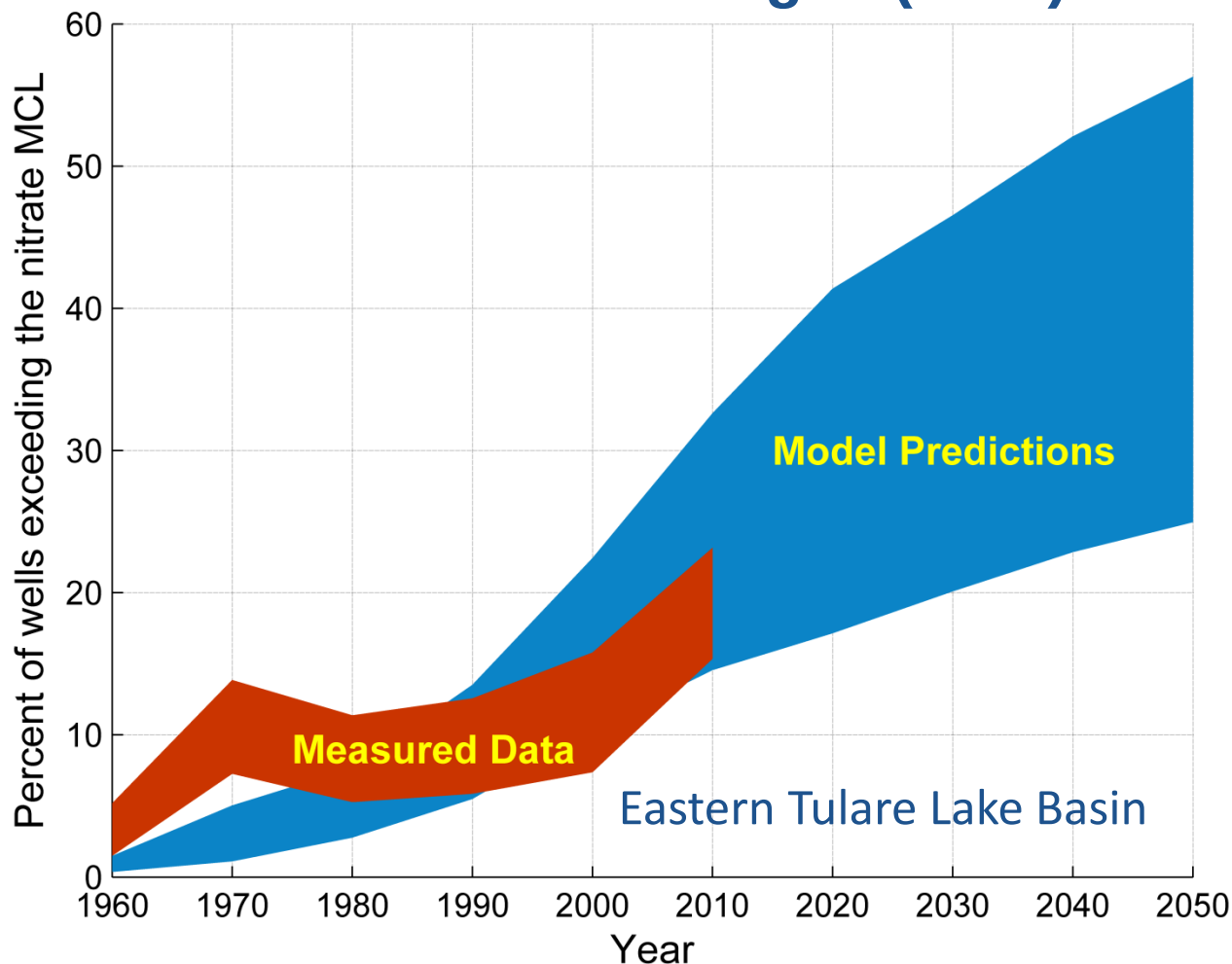
(MCWRA Published Regional Well Network Data)





Predictions Using Groundwater Nitrate Loading

**Exceedance Probability,
Nitrate above 45 mg/L (MCL)**



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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 5: GROUNDWATER REMEDIATION

Tulare Lake Basin Meeting
May 3, 2012



Aaron King, Graham Fogg, Vivian Jensen, Thomas Harter

Center for Watershed Sciences
University of California, Davis
Contact: amking@ucdavis.edu
thharter@ucdavis.edu



Key Findings

- Basin-wide conventional remediation is not feasible
 - Expensive (>\$14-30 billion) (volume: 35-88 million acre feet)
 - Technically infeasible – time, inefficiency
- Local remediation is appropriate
 - Clean up of nitrate hot spots with plume-scale remediation methods
 - In situ (e.g. Permeable Reactive Barriers)
 - Ex situ (e.g. Pump and Treat)
- Basin-wide groundwater quality management needed
 - Source reduction
 - Regional adoption of Pump and Fertilize
 - Recharge with higher quality water



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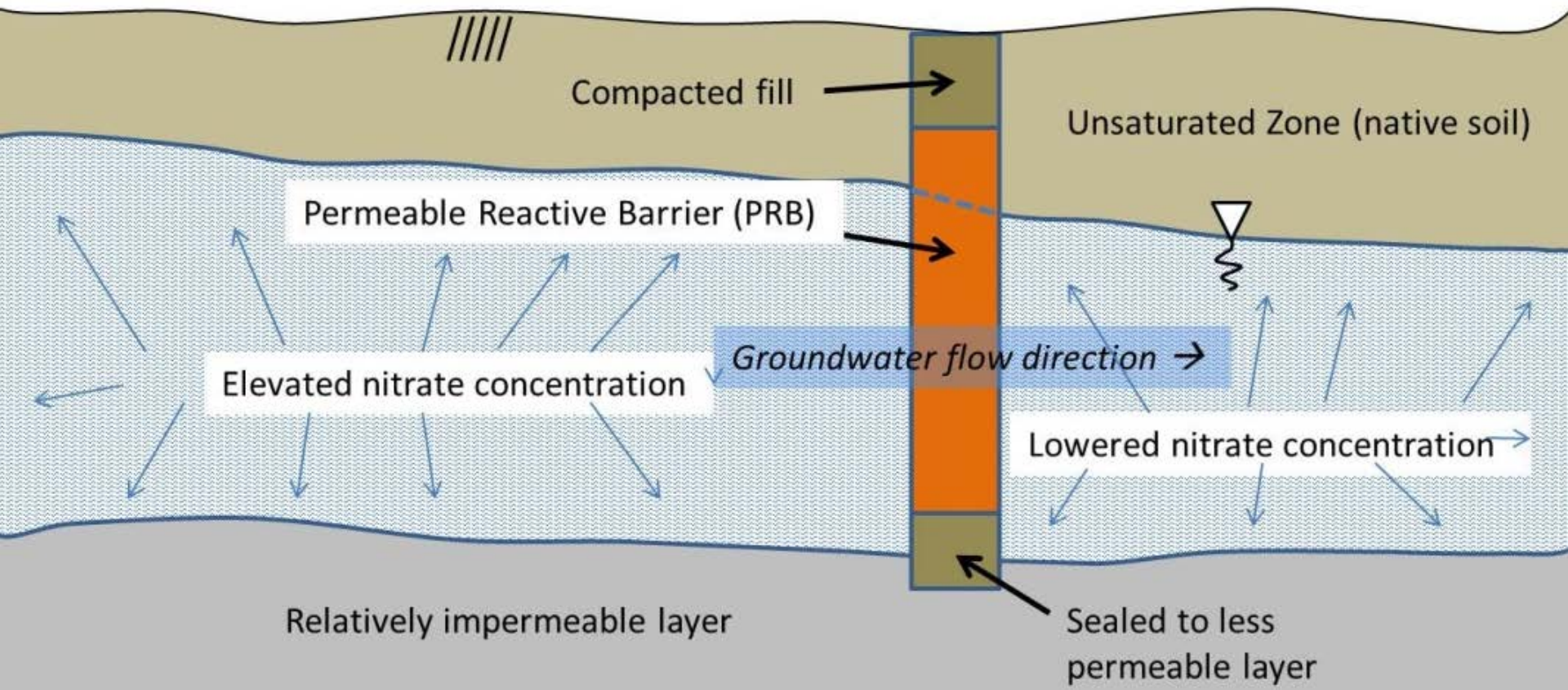
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Local-Scale Remediation Options

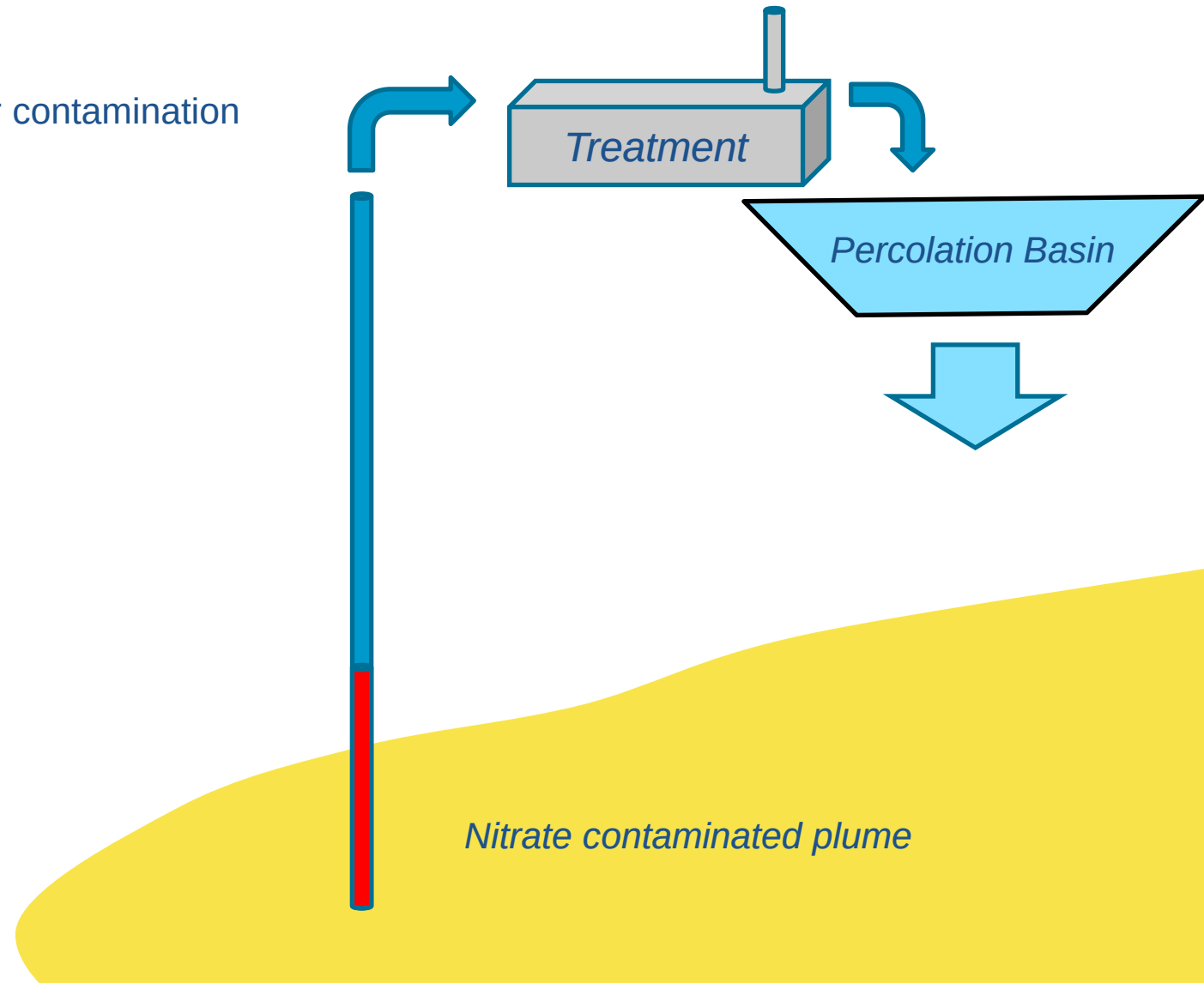
- Permeable Reactive Barriers
 - Maximum cost-effective depth 50-100 feet
 - Enhance denitrification to protect specific wells
 - Intercept high nitrate subsurface flows
 - High capital cost, very low O&M cost





Local-Scale Remediation Options

- Pump and Treat
 - Can target deeper contamination
 - High Capital cost
 - High O&M cost





Pump and Fertilize (PAF)

- Current irrigation pumping captures more than current recharge
- Crops remove nitrogen from irrigation water
- N in irrigation water
 - Consider in fertilizer calculations
 - 32,000 short tons (\$30 M fertilizer value)
 - Potential for 15% reduction in applied synthetic fertilizer
- Implementation
 1. Education and outreach
 - Monitoring of well nitrate costs \$150 per well per year
 2. Regional groundwater quality management modeling
 3. Redistribution of irrigation pumping to shallower depths



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Groundwater Quality Management

- Any remediation requires source reduction
- Increase fraction of high quality recharge
 - Groundwater banking
 - River recharge management
- Preferential pumping
 - High N → irrigation (pump and fertilize)
 - Low N → drinking water
- New groundwater management paradigms
 - Basin-wide strategies
 - Joint management water quantity and quality



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 - Joint management water quantity and quality
- Near-term solutions to supply safe water now

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Addressing Nitrate in California's Drinking Water

TECHNICAL REPORTS 6 & 7: DRINKING WATER TREATMENT & ALTERNATIVE WATER SUPPLY

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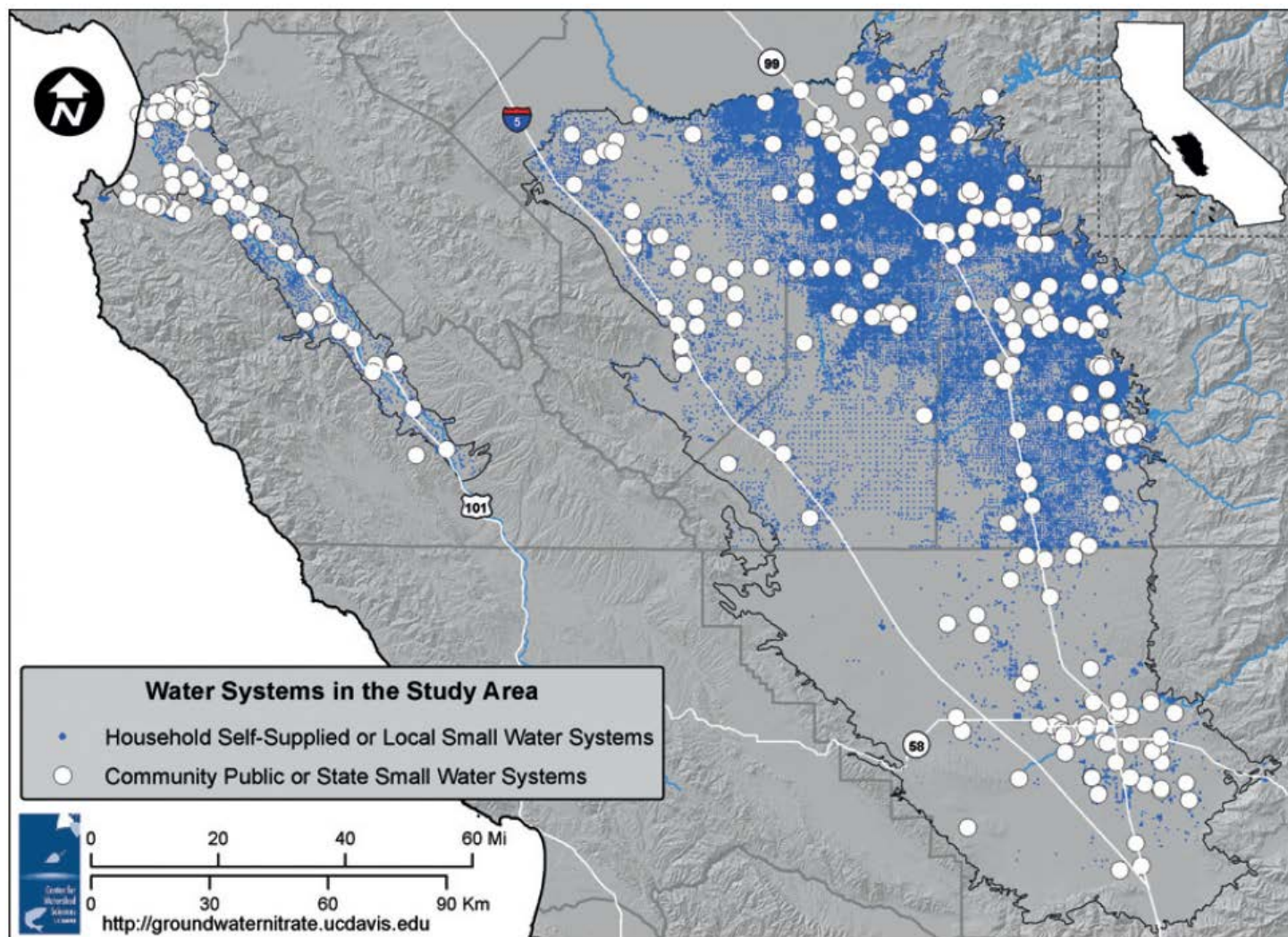
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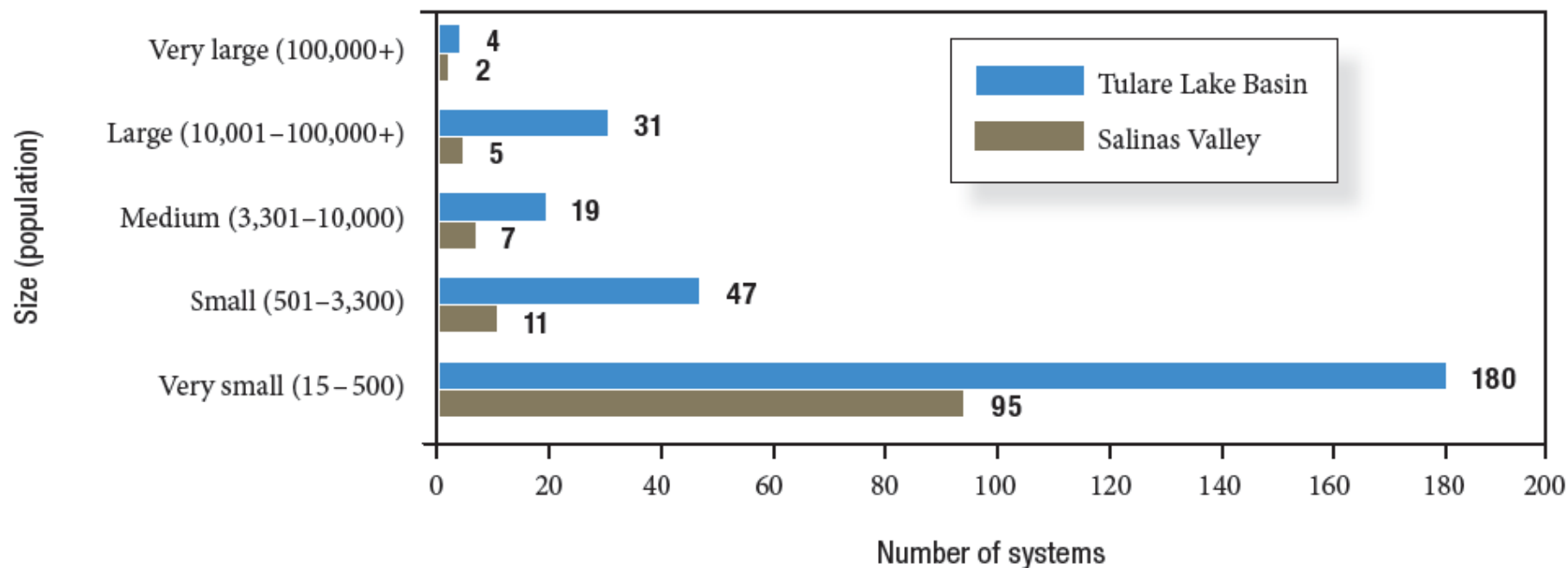
All Water Systems



Estimated locations of the area's roughly 400 regulated community public and state-documented state small water systems and of 74,000 unregulated self-supplied water systems. Source: Honeycutt et al. 2012; CDPH PICME 2010.



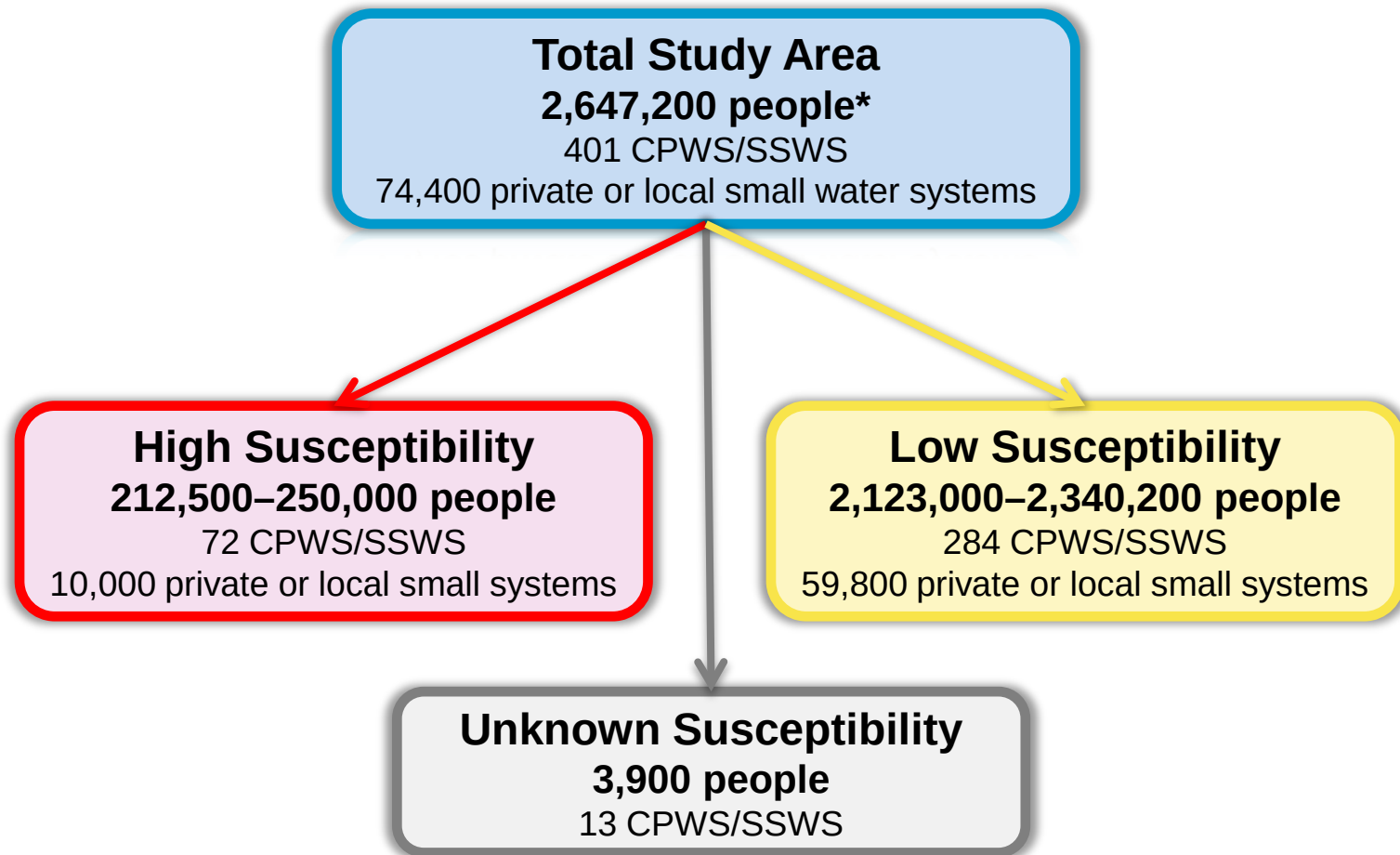
Community Public & State Small Water Systems



*Community public and state-documented state small water systems of the Tulare Lake Basin and Salinas Valley.
Source: CDPH 2010.*



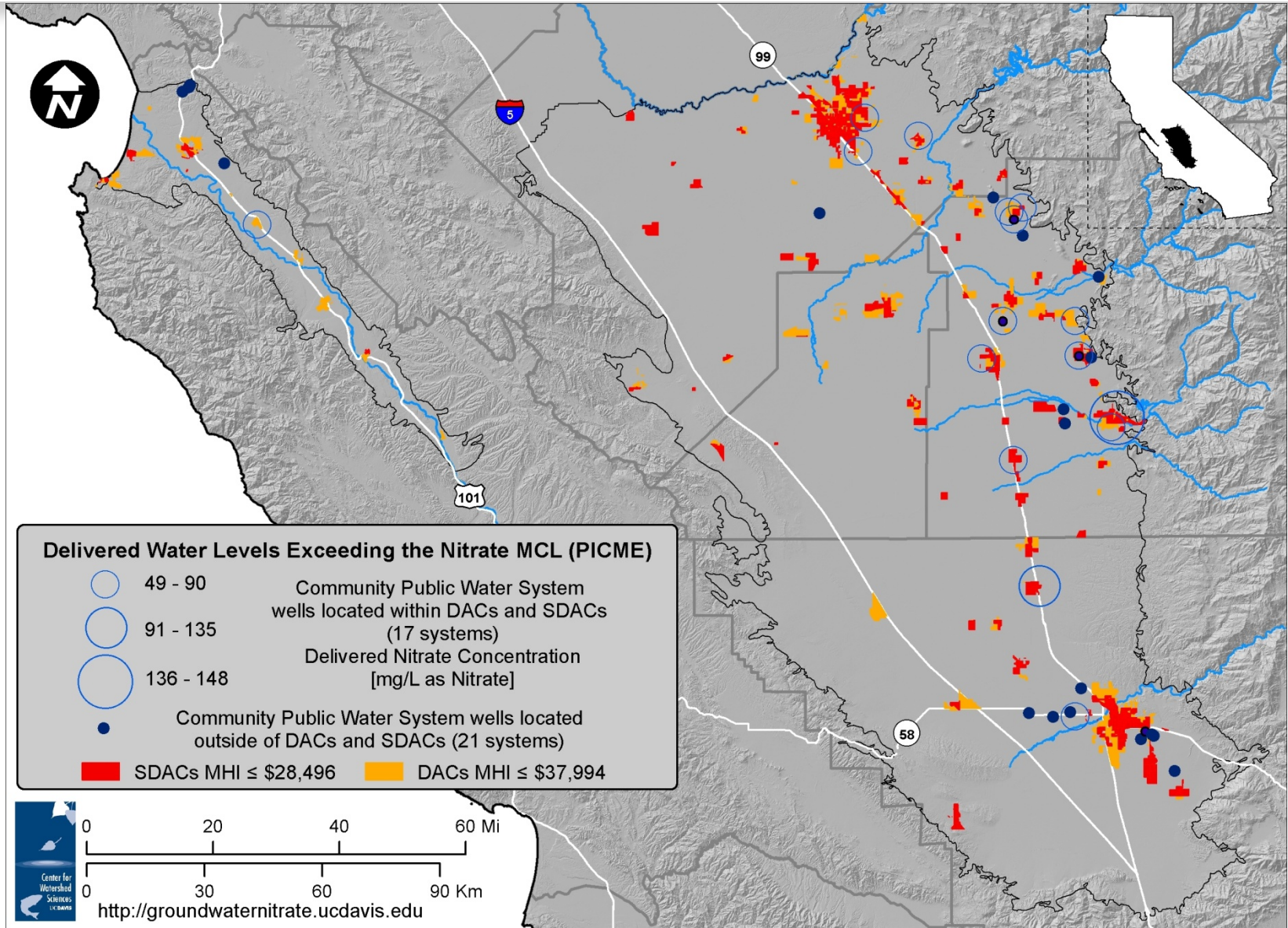
Susceptible Population



**Total study area population includes population served by surface water systems which is not susceptible to groundwater nitrate contamination and is not included in the subsequent susceptibility classifications.*



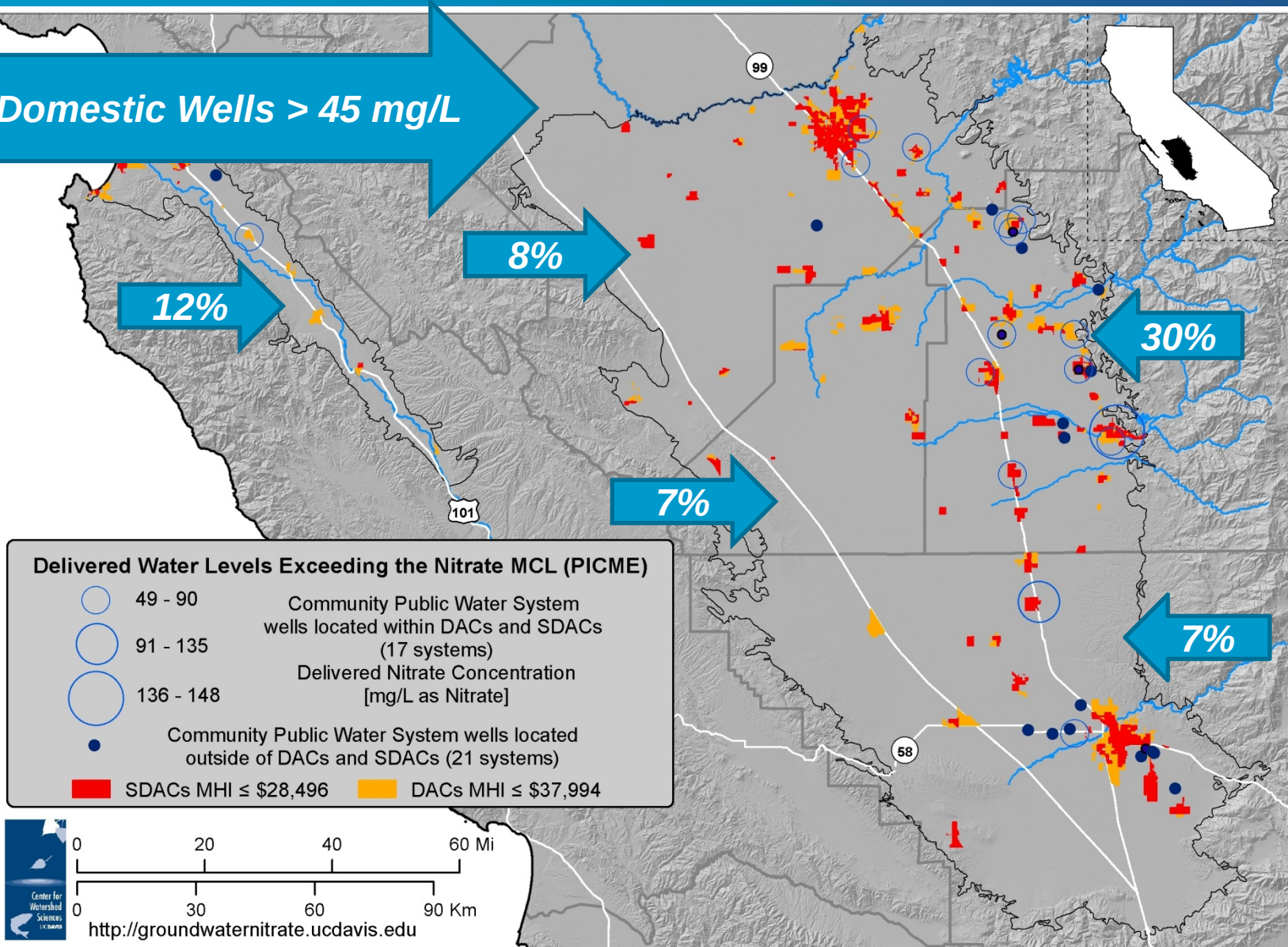
DACs and Delivered Water Quality





DACs and Delivered Water Quality

% of Domestic Wells > 45 mg/L





Alternative Water Supply Options

**Improve
Existing
Source**



Deeper Well or New Well
Blending
Treatment

**Use
Alternative
Supply**



Surface Water
Connection to Another System
Regionalization and Consolidation
Trucked Water and Bottled Water



Treatment Options

REMOVAL TECHNOLOGIES – Disposal concern



Source: Siemens



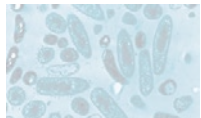
Source: Dow Chemical



Source: PC Cell

- Ion Exchange
 - Nitrate displaces chloride on resin, resin recharge with brine solution.
- Reverse Osmosis
 - Water molecules pushed through membrane, contaminants left behind.
- Electrodialysis
 - Electric current governs ion movement through membranes.

REDUCTION TECHNOLOGIES – Limited full-scale application to date



Source: AnoxKaldnes



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- Biological Denitrification
 - Bacteria transform nitrate to nitrogen gas.
- Chemical Denitrification
 - Metals reduce nitrate to ammonia (typically).



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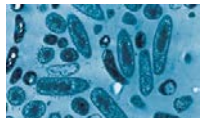
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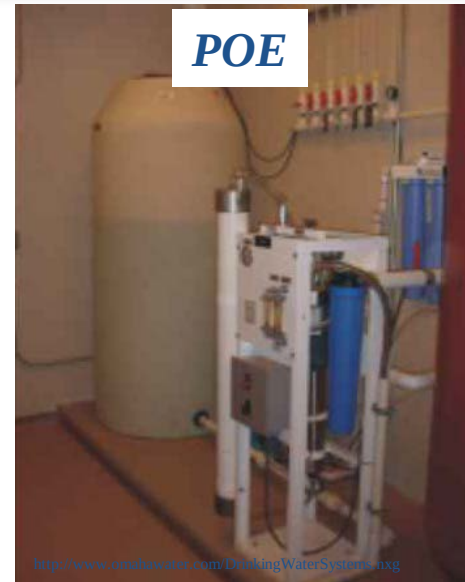


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POU/POE



- Point-of-Use (POU)
 - Under the sink, treatment of only potable water
- Point-of-Entry (POE)
 - Household treatment, treatment of all water
- CDPH regulations limit POU treatment for water systems
- Primary option for household self-supply treatment



Costs for Alternative Supply Options

Option	Estimated Annual Cost Range (\$/year)	
	Self-Supplied Household	Small Water System (1,000 households)
Improve Existing Water Source		
Blending	N/A	\$85,000–\$150,000
Drill deeper well	\$860–\$3,300	\$80,000–\$100,000
Drill a new well	\$2,100–\$3,100	\$40,000–\$290,000
Community supply treatment	N/A	\$135,000–\$1,090,000
Household supply treatment (POU)	\$250–\$360	\$223,000
Alternative Supplies		
Piped connection to an existing system	\$52,400–\$185,500	\$59,700–\$192,800
Trucked water	\$950	\$350,000
Bottled water	\$1,339	\$1.34 M
Relocate households	\$15,090	\$15.1 M
Ancillary Activities		
Well water quality testing	\$15–\$50	N/A
Dual distribution system	\$575–\$1,580	\$260,000–\$900,000



Estimated Annualized Basin Wide Costs

Alternative Supply Costs for CPWS/SSWS (220,000 people)

- Short-term Solutions: **\$13 - \$17 million/year** (includes POU and new well)
- Long-term Solutions: **\$34 million/year** (excludes POU and new well)

Alternative Supply Costs for Households (34,000 people)

- POU: \$2.5 million/year

Alternative Supply Costs for TOTAL Susceptible Population (254,000)

- Short-term Solutions: \$20 million/year
- Long-term Solutions: \$36 million/year



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Major Findings

- 254,000 people susceptible or potentially susceptible.
- Individual engineering and financial analyses for each system.
 - Not one solution for all, but necessary technology is available.
- Significant potential for consolidating small systems.
- Multiple contaminant removal technologies promising.
- Obstacles and hurdles do exist.
 - Small systems, unincorporated regions, lack of local water board
 - Technical, Managerial & Financial capacity, O&M costs.



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- 254,000 people susceptible or potentially susceptible.
- Individual engineering and financial analyses for each system.
 - Not one solution for all, but necessary technology is available.
- Significant potential for consolidating small systems.
- Multiple contaminant removal technologies promising.
- Obstacles and hurdles do exist.
 - Small systems, unincorporated regions, lack of local water board
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- **Promising Options for Community Public Water Systems**
 - Consolidate
 - Ion exchange
 - New well
 - Blending
- **Promising Options for Self-Supplied Households**
 - Point-of-Use
 - New well
- **Overall Cost = \$20 - \$36 million/year**
 - \$80 - \$142 / year per SUSCEPTIBLE PERSON
 - \$5 - \$9 / year per IRRIGATED ACRE
 - \$100 - \$180 / year per TON OF FERTILIZER NITROGEN
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SBX2 1

Addressing Nitrate in California's Drinking Water

TECHNICAL REPORT 8: REGULATORY & FUNDING OPTIONS

Tulare Lake Basin Meeting
May 3, 2012



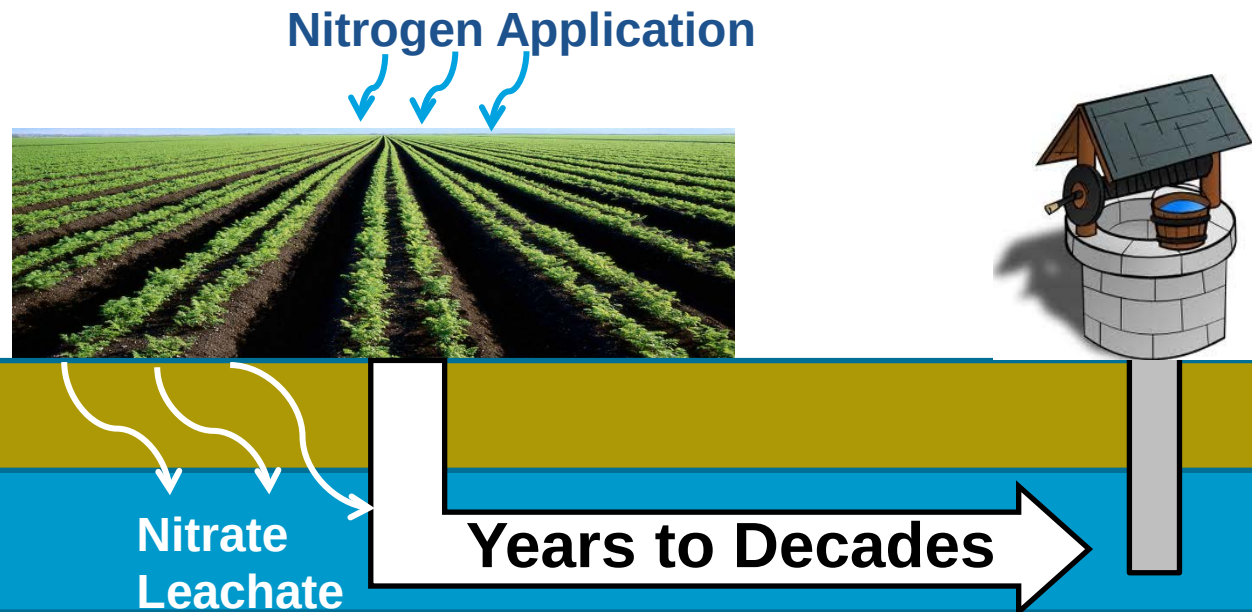
Holly Canada, Thomas Harter, Kristin Honeycutt,
Katrina Jessoe, Mimi Jenkins, Jay Lund

Center for Watershed Sciences
University of California, Davis
Contact: hecanada@ucdavis.edu
kkjessoe@ucdavis.edu
thharter@ucdavis.edu



Major Findings: Current Regulatory Programs

- Drinking water problem is most urgent
- Regulations have been insufficient to control groundwater nitrate contamination
- Drinking water source quality will improve only after many years of nitrate source reductions





Regulatory Options Considered

- Technology Mandate
- Performance Standard
- Fee
- Cap and Trade
- Information Disclosure
- Liability Rules
- Negotiation or Payment for Service
- De-designation of Beneficial Use



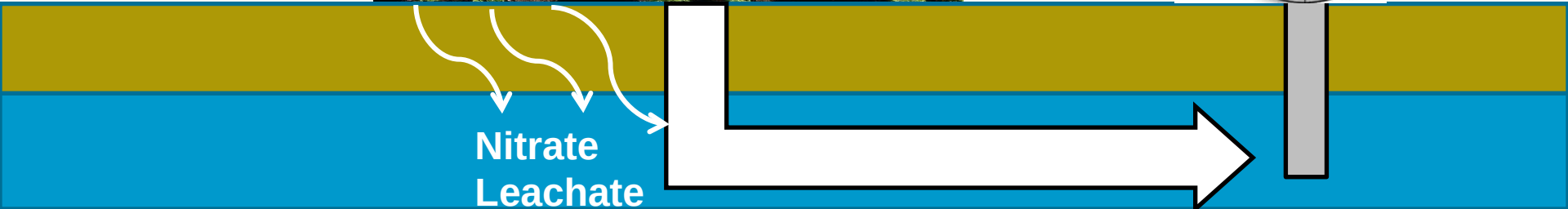
Ways to regulate nitrate?

- Technology Mandate
- Performance Standard
- Fee
- Cap and Trade

Nitrogen Application



Nitrate
Leachate





Regulating Nitrogen Application Preferred

Regulated Entity	Abatement Costs (costs to reduce loading to achieve a nitrate standard)	Monitoring / Enforcement Costs	Information Requirements	Revenue Raising
Nitrate Leachate	Lower – regulate pollutant	High	High	Maybe
Nitrogen Application	Higher – regulate input	Low	Low	Maybe

Nitrogen Application



Nitrate
Leachate





Promising Regulatory Options

- 1. Nitrate dischargers pay for the additional drinking water costs - authorized under Section 13304 of CA Water Code.**
- 2. Regulate nitrogen use rather than nitrate leachate.**
- 3. Consider market-based instruments for long-term regulation.**
- 4. Learn from successful Department of Pesticide Regulation programs.**



Chronic Funding Problems

1. Small, rural communities
2. Communities are spread-out

**higher infrastructure costs
= higher household costs**

3. Lack economies of scale
4. Less Technical, Managerial, Financial (TMF) resources

**difficulty with:
loans
funding applications
operation & maintenance**



Funding Options



**Cap and Trade
with Auctioned
Permits**

**Fee on
Bottled Water**



Food Tax

**Fixed or
Volumetric
Fee on
Agricultural
Water**



Nitrogen Fee

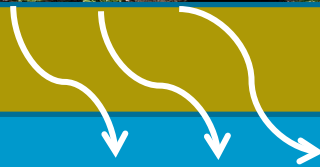


**Agricultural
Property Tax**

**Fixed or
Volumetric
Fee on
Drinking
Water**



Nitrate Leachate Fee



**Groundwater
Pumping Fee**





Promising Funding Options for Affected Communities

- 1. Where appropriate, combine funding programs.**
- 2. Fund long-term drinking water solutions, particularly regionalization of small systems.**
- 3. Increase financial assistance to small systems.**
- 4. Create state funding programs for domestic well owners and for small water systems.**



Promising Statewide Funding Options

- 1. Increase CDFA's mill assessment rate on nitrogen fertilizer sales to its full authorized amount.**
 - Raises additional \$1 Million / year statewide.
- 2. Introduce a statewide nitrogen fertilizer sales fee, perhaps equivalent to sales tax**
 - Could generate \$28 Million / year in study area.
- 3. Section 13304 of CA Water Code, compensation**
- 4. Consider a more comprehensive statewide water use fee**



Key Take Home Messages

- Safe drinking water is the most pressing issue
 - Challenges: organization and funding
- Nitrate loading can be reduced, long-term
 - Challenges: training, research, investment, compliance, and funding
- State needs to collect and organize data to allow for better assessment
 - Challenges: institutional silos, organization, privacy issues/data security, and funding



Promising Actions

- See back page of the “Executive Summary”

Addressing Nitrate in California's Drinking Water
With a Focus on Tulare Lake Basin and Salinas Valley

Report for the State Water Resources Control Board to the Legislature

EXECUTIVE SUMMARY

This Report and its associated eight Technical Reports were prepared by
Thomas Harter and Jay R. Lund
(Principal Investigators)
Katharine Darby, Graham E. Fogg, Richard Howitt,
James E. Quins, G. Stuart Pettygrove,
(Co-Investigators)

Maximum Nitrate in Water
2000-2009
(mg/L as Nitrate)
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10 to 20
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Action	Safe Drinking Water	Groundwater Degradation	Economic Cost
No Legislation Required			
Safe Drinking Water Actions			
D1: Point-of-Use Treatment Option for Small Systems +	♦♦		low
D2: Small Water Systems Task Force +	♦		low
D3: Regionalization and Consolidation of Small Systems +	♦♦		low
Source Reduction Actions			
S1: Nitrogen/Nitrate Education and Research +		♦♦♦	low-moderate
S2: Nitrogen Accounting Task Force +		♦♦	low
Monitoring and Assessment			
M1: Regional Boards Define Areas at Risk +	♦♦♦	♦♦♦	low
M2: CDPH Monitors At-Risk Population +	♦	♦	low
M3: Implement Nitrogen Use Reporting +		♦♦	low
M4: Groundwater Data Task Force +	♦	♦	low
M5: Groundwater Task Force +	♦	♦	low
Funding			
F1: Nitrogen Fertilizer Mill Fee		♦♦♦	low
F2: Local Compensation Agreements for Water +	♦♦	♦	moderate
New Legislation Required			
D4: Domestic Well Testing *	♦♦		low
D6: Stable Small System Funds	♦		moderate
Non-tax legislation could also strengthen and augment existing authority.			
Fiscal Legislation Required			
Source Reduction			
S3: Fertilizer Excise Fee	♦♦	♦	moderate
S4: Higher Fertilizer Fee In Areas at Risk	♦	♦	moderate
Funding Options			
F3: Fertilizer Excise Fee	♦♦	♦♦	moderate
F4: Water Use Fee	♦♦	♦♦	moderate



Key Take Home Messages

- Safe drinking water is the most pressing issue
 - Challenges: organization and funding
- Nitrate loading can be reduced, long-term
 - Challenges: training, research, investment, compliance, and funding
- State needs to collect and organize data to allow for better assessment
 - Challenges: institutional silos, organization, privacy issues/data security, and funding

SBX2 1 (2008, Perata)

**UC Davis Report to State Water Board
for its Report to the Legislature**

**ADDRESSING NITRATE IN
CALIFORNIA'S DRINKING WATER,
TULARE LAKE BASIN AND SALINAS VALLEY**

Tulare Lake Basin Meeting
May 3, 2012

Thomas Harter & Jay Lund, *Principal Investigators*

Jeannie Darby, Graham Fogg, Richard Howitt, Katrina Jessoe, Jim Quinn, Stu Pettygrove, Joshua Viers,
Co-Investigators



Aaron King, Allan Hollander, Alison McNally, Anna Fryjoff-Hung, Cathryn Lawrence, Daniel Liptzin, Danielle Dolan, Dylan Boyle, Elena Lopez, Giorgos Kourakos, Holly Canada, Josue Medellin-Azuara, Kristin Dzurella, Kristin Honeycutt, Megan Mayzelle, Mimi Jenkins, Nicole de la Mora, Todd Rosenstock, Vivian Jensen,
Researchers

<http://groundwaternitrate.ucdavis.edu>

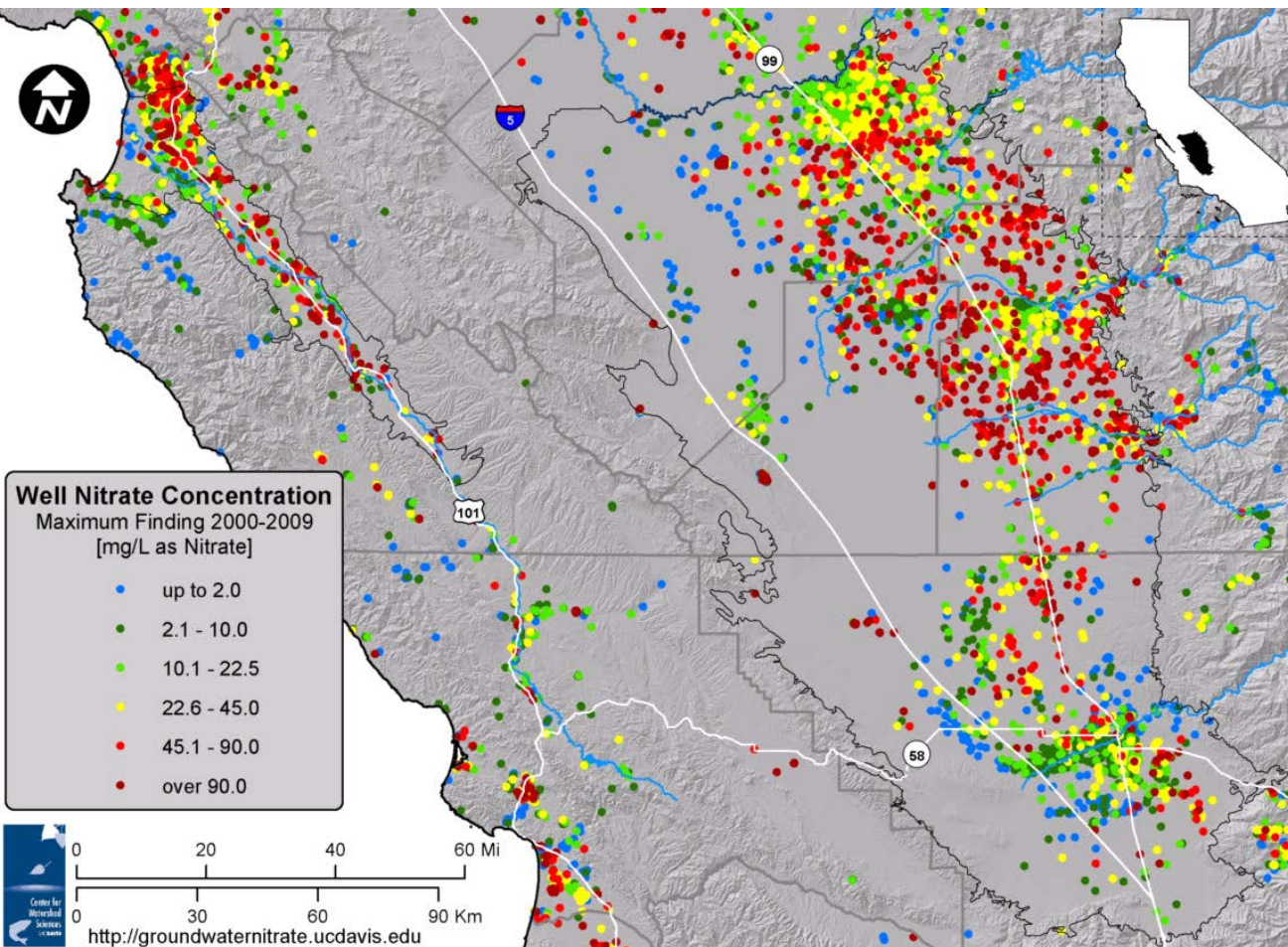
Center for Watershed Sciences
University of California, Davis
Contact: ThHarter@ucdavis.edu



KEY FINDINGS



Nitrate Contamination Will Persist



- Nitrate contamination will worsen for years/decades
- Direct remediation of groundwater is extremely costly

RED: ABOVE THE NITRATE MCL (45 mg/L)

DARK RED: ABOVE TWICE THE NITRATE MCL (90 mg/L)



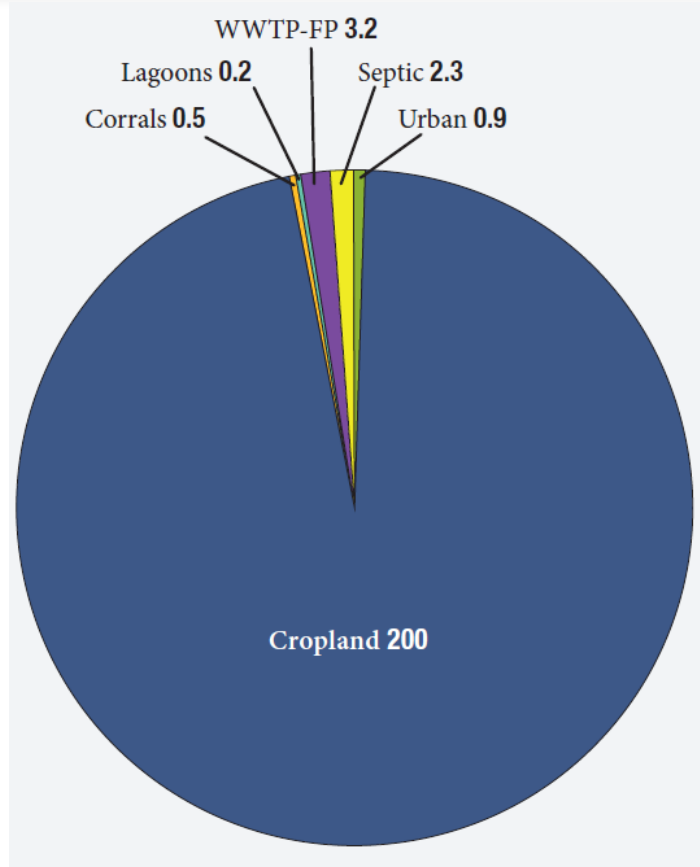
Cost of Safe Drinking Water: \$20 - \$36 Million / Year (Study Area)

- **Most cost-effective drinking water supply actions:**
 - Blending
 - Treatment (community, point-of-use)
 - Consolidation/regionalization
 - Other alternative supplies
- **Affordability difficult for small communities**
- **Most promising revenue source:**
 - Fee on nitrogen fertilizer use
 - Fee on water use
 - Local compensation under Section 13304 of CA Water Code





Largest Nitrate Source: Cropland



- Nitrate loading reductions are possible

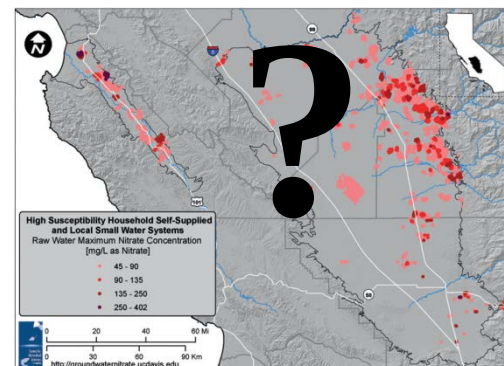
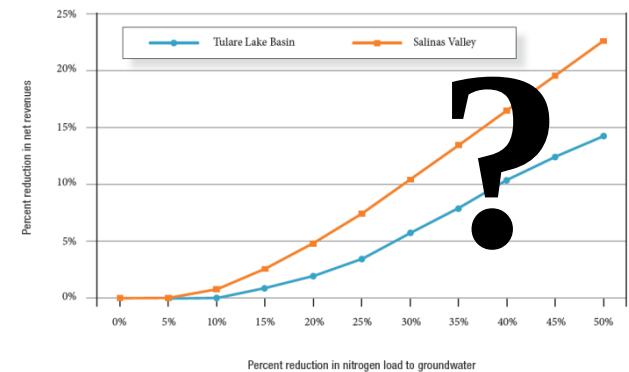
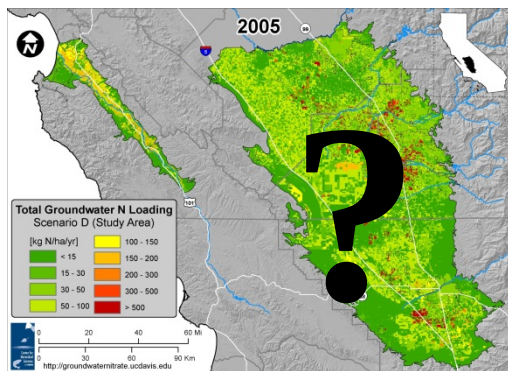
- Largest cropland nitrogen sources:
 - Synthetic fertilizer
 - Animal manure





Data for Assessing Public Exposure and Nitrate Sources

- More consistent, accessible data needed for efficient implementation
- Agencies not organized to gather data or make effective use of data





Funding Options

Nitrogen Fee



Nitrate Leachate Fee



Funding Options

**Fixed or
Volumetric
Fee on
Agricultural
Water**



Nitrogen Fee



Nitrate Leachate Fee





Funding Options

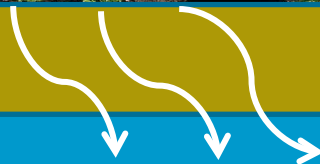
**Fixed or
Volumetric
Fee on
Agricultural
Water**



Nitrogen Fee



Nitrate Leachate Fee



**Fixed or
Volumetric
Fee on
Drinking
Water**





Funding Options

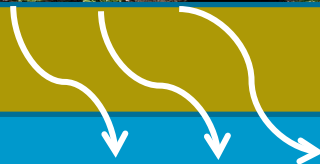
**Fixed or
Volumetric
Fee on
Agricultural
Water**



Nitrogen Fee



Nitrate Leachate Fee



**Fixed or
Volumetric
Fee on
Drinking
Water**



**Groundwater
Pumping Fee**





Funding Options

**Fixed or
Volumetric
Fee on
Agricultural
Water**



Nitrogen Fee

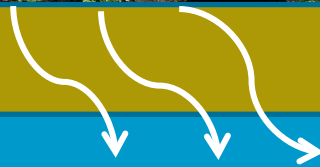


**Agricultural
Property Tax**

**Fixed or
Volumetric
Fee on
Drinking
Water**



Nitrate Leachate Fee



**Groundwater
Pumping Fee**





Funding Options

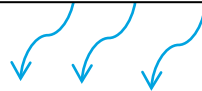


**Cap and Trade
with Auctioned
Permits**

**Fixed or
Volumetric
Fee on
Agricultural
Water**



Nitrogen Fee

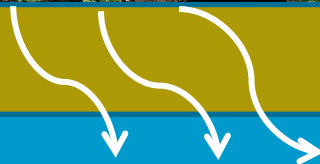


**Agricultural
Property Tax**

**Fixed or
Volumetric
Fee on
Drinking
Water**



Nitrate Leachate Fee



**Groundwater
Pumping Fee**

