#3: Groundwater Nitrate
Nitrate distribution in groundwater / spatial and temporal trends

#4: Groundwater Remediation
Remediation of groundwater

#5: Drinking Water Treatment
N treatment options

#6: Alternative Supplies
Alternative supplies

#7: Costs of Actions
Economic Cost

#8: Funding and Policy
Nitrate Contamination Study Area

Nitrate Source Assessment

Wastewater Treatment Plants and Food Processors

Septic Systems

Total Cropland N Inputs: 380,000 Gg N/yr

Total Cropland N Outputs: 380,000 Gg N/yr
Rosenstock et al., JEQ, 2014

cropland area (without alfalfa)
Assume:

60% Manure Export to County

Assume: All Manure Remains On-Dairy

1 kg N/ha/crop = 0.9 lbs N/ac/crop

Harter, Lund et al, 2012

Increase crop N-use efficiency -- Decrease deep percolation

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

PNB Partial Nutrient Balance

kg N/ha/crop

1 kg N/ha/crop = 0.9 lbs N/ac/crop

Harter, Lund et al, 2012

Agricultural Source Reduction: Improving Farm Technology

Harvested N

Applied N

Management practices bundles are result of capital investments and nitrogen application practices

More efficient and expensive bundles

Bundle 2

Bundle 1

Bundle 0

N

Basic Components Management Measures 50 Practices

Improve irrigation and drainage systems

Perform system evaluation and monitoring

Improve irrigation scheduling

Improve irrigation system design and operation

Other irrigation infrastructure improvements

Improve fertilizer and manure use

Improve rate, timing, and placement

Change crop rotation

Modify crop rotation or grow cover crops

Improve storage and handling

Avoid fertilizer material and manure spills during transport, storage and application
**Economics of Source Reduction**

Percent Reduction in Nitrate Load to Groundwater vs. Percent Reduction in Farm Net Revenue.

- **farm net revenue reduction at constant crop yield rates**
- Salinas Valley
- Tulare Lake Basin

**Focus: Water Quality**

Past and Current: DATA
Dylan Boyle, Aaron King, Giorgos Kourakos, Katherine Lockhart, Megan Mayzelle, Graham E. Fogg and Thomas Harter

**Wells with Known Nitrate Data**

**Lack of Historic Data**
CASTING Database

**Depth of Wells**

**Regionalization & Declustering**
Average Nitrate Concentrations by PLSS Section

Maximum Nitrate Concentrations by Section

Semi-Cofined vs. Confined Aquifer

Spatial Context: Streams?

Depth to Water Table & Soil Type

Depth of Well Screen

Median and exceedance probability obtained from annual well means (2001-2012) temporally clustered, spatially not clustered.

Boyle et al., 2012
Past, Current, and Future: Modeling
Dylan Boyle, Aaron King, Giorgos Kourakos, Katherine Lockhart, Megan Mayzelle, Graham E. Fogg and Thomas Harter
Spatio-temporally distributed sources: loading to water table

Spatially distributed sinks: wells

Adaptive mesh grid refinement

Finite Element Grid

Water Table Distribution
Kourakos et al., WRR, 2012
Matlab code available at: http://groundwater.ucdavis.edu/mSim
(to be updated soon with adaptive mesh refinement code)

Kourakos and Harter, Env. Simulation, 2014
Kourakos and Harter, Comp. Geosciences, 2014

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

Validation

Predictions Using Groundwater Nitrate Loading

Eastern Tulare Lake Basin
Focus: Safe Drinking Water

Vivian Jensen, Kristin Honeycutt, Holly Canada, Aaron King, Anna Fryjoff-Hung, Mimi Jenkins, Katrina Jessoe, Jeannie Darby, Thomas Harter, Jim Quinn, Jay Lund

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

Source: CDPH 2010.

10,000 Affected Private Wells

% of Domestic Wells > 45 mg/L

Total Study Area 2,647,200 people*
401 CPWS/SSWS
74,400 private or local small water systems

High Susceptibility 212,500–250,000 people
212 CPWS/SSWS
10,000 private or local small systems

Low Susceptibility 2,123,000–2,340,200 people
184 CPWS/SSWS
59,800 private or local small systems

Unknown Susceptibility 3,900 people
13 CPWS/SSWS

*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.

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

DACs and Delivered Water Quality

High Susceptibility 212,500–250,000 people
72 Chipping groups
10,000 private or local small systems

Low Susceptibility 2,123,000–2,340,200 people
206 Chipping groups
59,800 private or local small systems

Unknown Susceptibility 3,900 people
13 Chipping groups

*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.
Most cost-effective drinking water supply actions:
- Blending
- Treatment (community, point-of-use)
- Consolidation/regionalization
- Other alternative supplies

Affordability difficult for small communities

Promising revenue sources:
- Fee on nitrogen fertilizer use
- Fee on water use
- Local compensation under Section 13304 of CA Water Code

Focus: Policy Options

Holly Canada, Katrina Jessoe, Thomas Harter, Jay Lund

Funding and Regulatory Framework

The Source Control Challenge

Point Sources of Pollution
Surface Water Quality
- Ground Water Quality
- Nonpoint Sources of Pollution

Challenges to Regulating Nitrate

Point Sources of Pollution
Surface Water Quality
- Ground Water Quality
- Nonpoint Sources of Pollution
Challenges to Regulating Nitrate

- **Point Sources of Pollution**
  - 1980s - now: Superfund, TSCA, RCRA
  - 2000s - now: CA Porter-Cologne: TMDL

- **Surface Water Quality**

- **Ground Water Quality**

- **Nonpoint Sources of Pollution**

Regulatory Approaches to Groundwater Protection and Monitoring

Where does Well Water Come From?
- **Domestic Well**
  - Source area
  - Recharge
  - Regional gradient
  - Effective gw flow direction

Where does Well Water Come From?
- **Irrigation Well / Barn Well**
  - Source area
  - Recharge
  - Regional gradient
  - Effective gw flow direction

Source Area of a Barn / Irrigation Well

- Water flow is horizontal & vertical
- Horizontal travel distances are generally MUCH longer than travel vertical distances
- Different depths of the well screen capture different water!
• Water flow is horizontal & vertical
  Horizontal travel distances are generally MUCH longer than travel vertical distances
  Different depths of the well screen capture different water!

• Scale
  – Millions of acres vs. 1-10 acres

• Intensity
  – Within ~1 order magnitude above MCL vs. many orders of magnitude above MCL

• Hydrologic Function
  – Recharge vs. non-leaky

• Frequency
  – Ongoing/seasonally repeated vs. incidental

• Heterogeneity & Adjacency

Example of Working with a Regulation: Speed Limit

- Responsible Party: Driver
- Feedback: Speedometer
- Management Tool: Brakes
- Enforcement: Radar Controls
Applying Point Source Approach to Nonpoint Source:

- Responsible Party: Landowner
- Feedback: Missing
- Management Tool: $$$ "agronomic"
- Enforcement: Monitoring Wells

Alternative Monitoring Approach to Nonpoint Source:

- Responsible Party: Landowner
- Feedback: Nutrient/Water Monitoring & Assessment
- Management Tool: Water and Nutrient Management
- Enforcement: Annual Nitrogen Budget

Key Elements to Future "Groundwater" Monitoring of NPS

- Three-track monitoring:
  - Enforcement: Monitor/report key outcomes of farm management practices, e.g., annual nitrogen budgets – "proxy" for measuring "groundwater discharge"
  - Research: link "proxy monitoring" to actual groundwater discharge at intensely monitored sites & using models (mgmt practice evaluation)
  - Assurance: Regional trend monitoring network (e.g., GAMA)

STEP 1: GROUNDWATER ASSESSMENT
High Vulnerability Areas: Key Criteria (E&JV Coalition)

- Hydrogeologically high vulnerability
  - Statistical analysis of groundwater nitrate occurrence based on hydrogeology, soils, depth to groundwater, landscape slope, recharge

- Further prioritization (high – 1, medium – 2, low – 3):
  - Exceedances of water quality objectives,
  - Proximity to areas contributing recharge to urban and rural communities that rely on groundwater as a source of supply,
  - Existing field and operational practices that are possibly the cause or source of groundwater quality degradation,
  - The largest acreage commodity types comprising up to at least 80 percent of irrigated agriculture in the high vulnerability areas,
  - Legacy or ambient groundwater conditions,

Eastern San Joaquin Valley Coalition: High Vulnerability Area

Based on:
- Soil
- Crop
- Irrigation

Another Vulnerability Scheme: Nitrate Hazard Index

Based on:
- Soil
- Crop
- Irrigation

Dzurella, Pettygrove et al., Journal Soil Water Conservation, 2015

Soil Crop Irrigation

Based on:
- Soil
- Crop
- Irrigation

Dzurella, Pettygrove et al., Journal Soil Water Conservation, 2015
### Costs of Alternatives

- **No action:** $6 - $10 billion annually
  - Direct costs: $1 - 1.5 billion/a
  - Production in goods and services reduced by $5 - $9 billion/a (27,000 - 53,000 jobs)

- **Alternatives**
  - Wells, desalners, brine line for 1.2 MAF/a of salty gw
  - Brine disposal:
    - Treatment in EBMUD WWTP or others
    - New ocean outfall
  - Deep injection / hydraulic fracturing
  - Salt accumulation areas (TLB)
  - Source control

- **Net cost:** $1.7 billion annually
  - Actual cost: $1,400 - $2,200 / af of product water
  - Potential revenue: $ 650 / af of product water
  - Net cost, capital, O&M: $50 billion / 30 years

---

### Sustainable Groundwater Management Act of 2014

**SEC. 2.** Section 113 is added to the Water Code, to read:

It is the policy of the state that groundwater resources be managed sustainably for long-term reliability and multiple economic, social, and environmental benefits for current and future beneficial uses. Sustainable groundwater management is best achieved locally through the development, implementation, and updating of plans and programs based on the best available science.

- **Implementation of SGMA**
  - Establishment of local Groundwater Sustainability Agencies (GSAs)
    - by June 2017
  - Preparation of Groundwater Sustainability Plan (GSP)
    - by June 2022 (critically overdrafted basins: 2020)
  - Implementation of GSP
    - reach goals by 2042
  - Review, technical assistance, and funding by DWR (5 yearly)
  - Enforcement by SWRCB

---

### Example: Agricultural Landuse Buffers

- **Efficiency of GSA**
  - Water utilization: 207 GSA
  - Water savings: 13,471 MAF
  - Water cost savings: $1.89 billion
  - Total revenue: $2.36 billion

---

### Sustainability = No “Undesirable Results”

- **Sustainable groundwater management** means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.

- **Undesirable result** means one or more of the following effects caused by groundwater conditions:
  1. **Chronic lowering of groundwater levels**
     - Including a significant and unreasonable duration of supply cutbacks or water use restrictions, a substantial level of groundwater storage depletion, and significant and unreasonable subsidence.
  2. **Reduction of groundwater storage**
  3. **Seawater intrusion**
  4. **Degraded water quality**
  5. **Surface water depletions**

- **Implementation**
  - Establishment of local Groundwater Sustainability Agencies (GSAs)
    - by June 2017
  - Preparation of Groundwater Sustainability Plan (GSP)
    - by June 2022 (critically overdrafted basins: 2020)
  - Implementation of GSP
    - reach goals by 2042
  - Review, technical assistance, and funding by DWR (5 yearly)
  - Enforcement by SWRCB
• Data collection, monitoring, modeling, assessment
• Supply management
• Demand management
• Stakeholder management

SCIENCE NEEDS
– NPS source control methods
– NPS pollution soil/groundwater fate, transport
– NPS pollution assessment, monitoring tools

REGULATORY FRAMEWORK
– Enforcement: Paradigm shift in monitoring approaches

AGRICULTURE (largest NPS)
– Socio-cultural change needed to work within new regulatory framework

http://groundwater.ucdavis.edu
http://groundwater.ucdavis.edu/SGMA
http://groundwaternitrate.ucdavis.edu