A Mass Balance Approach to Evaluate Salinity Sources in the Turlock Groundwater Sub-basin

Toward Sustainable Groundwater in Agriculture
June 15, 2010

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Presentation Outline

- Central Valley Salinity Issues
- Turlock Groundwater Sub-basin
- Salt Balance Methodology
- Results
- Conclusions and Policy Implications

Central Valley Salinity Issues

- Partially Closed Basin
- Salinity / Drainage Issues Not New
- Need for Drainage Recognized Since Late 1800's
- Groundwater TDS Concentration Increasing

Major Salinity Sources

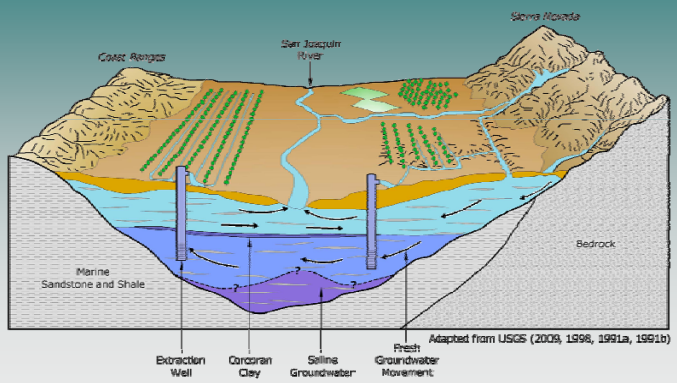
- Irrigated Agriculture (Food and Fiber Crops)
- Confined Animals Feeding Operations (CAFOs) including Forage Crops, e.g., Dairies
- Municipalities & Publically Owned Treatment Works (POTWs)
- Food Processors
- Mineral Dissolution
- Others:
  - septic tanks
  - landfills
  - upwelling of deep saline groundwater

Turlock Groundwater Sub-basin

- Groundwater Sub-basin of Central Valley
- 347,000 acres or 542 square miles
- Groundwater volume of 13 to 23 million AF

Turlock Groundwater Sub-basin

Schematic of Sub-basin



Basic Concepts of Mass Balance Approach

Recharge
Flow: Qr
Concentration: Cr
Mass: Mr = Qr x Cr

GW Flow In
Flow: Qo
Concentration: Co
Mass: Mo = Qo x Co

Groundwater System

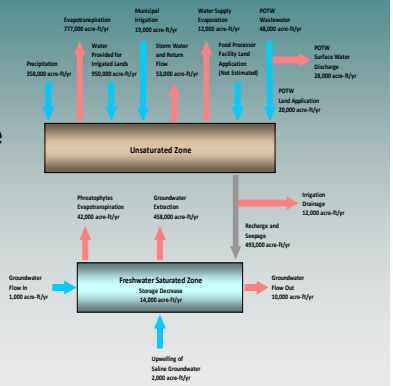
GW Flow In
Flow: Qi
Concentration: Ci
Mass: Mi = Qi x Ci

$\sum$ Flow In - $\sum$ Flow Out = Change in Water Storage Volume

$\sum$ Mass In - $\sum$ Mass Out = Change in Mass

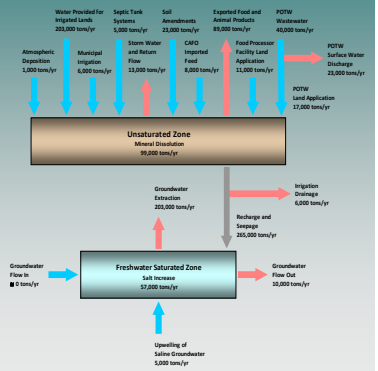
Water Balance

- Publically Available Data From 1997 – 2006
- Representing Average Conditions
- Data Quality and Limitations



Salt Balance

- Salt Balances for Each Potential Source:
  - CAFOs (Dairies)
  - Irrigated Food Crops
  - Municipalities
  - Food Processors
  - Septic Tanks
  - Mineral Dissolution



Example: Irrigated Food Crop Salt Balance

Mif
(Imported Fertilizers)

Mfc
(Harvested Food Crops)

Msw = Qsw x Csw
(Applied Surface Water)

Msa
(Soil Amendments)

Food Crops

Mgw = Qgw x Cgw
(Applied Groundwater)

Mrf = Qrf x Crf
(Return Flow)

Mmd
(Mineral Dissolution)

Mid = Qid x Cid
(Irrigation Drainage)

Mir = Qir x Cir
(Irrigation Recharge To Groundwater)

Example: Irrigated Food Crop Salt Balance

~0 tons/yr
(Imported Fertilizers)

70,000 tons/yr
(Harvested Food Crops)

Msw = Qsw x Csw
(Applied Surface Water)

7,000 tons/yr
(Soil Amendments)

Food Crops

Mgw = Qgw x Cgw
(Applied Groundwater)

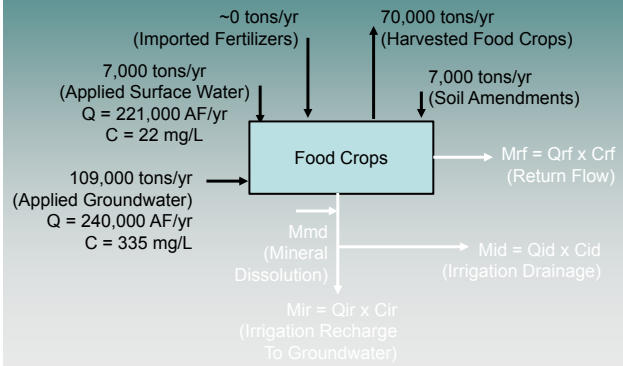
Mrf = Qrf x Crf
(Return Flow)

Mmd
(Mineral Dissolution)

Mid = Qid x Cid
(Irrigation Drainage)

Mir = Qir x Cir
(Irrigation Recharge To Groundwater)

Example: Irrigated Food Crop Salt Balance



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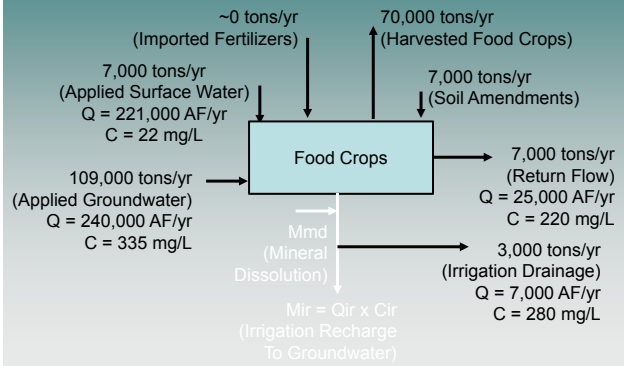

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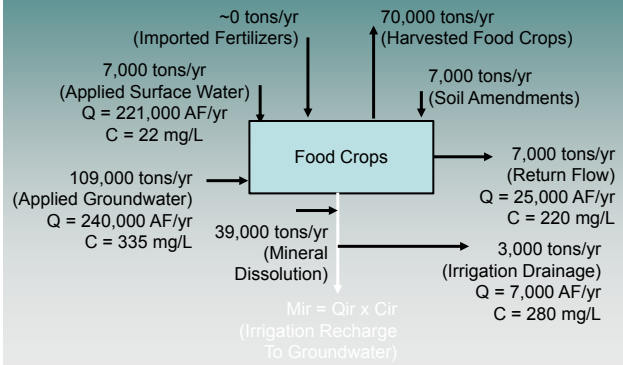
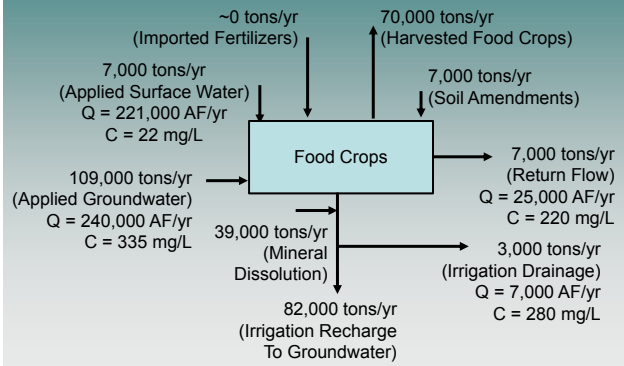
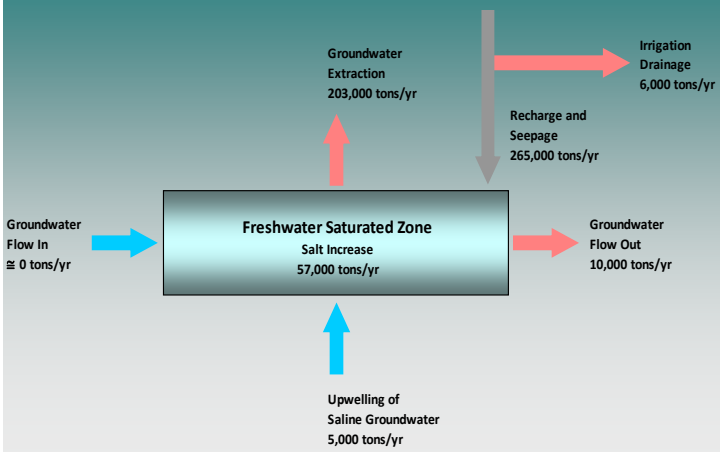


Example: Irrigated Food Crop Salt Balance



Groundwater Salt Balance



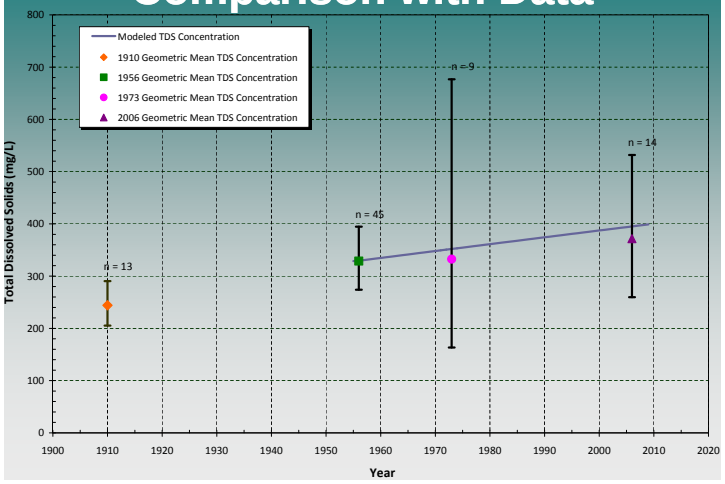
Salt Source Contributions

Sector or Source	Surface Water (tons/yr)	Groundwater (tons/yr)
CAFOs & Forage Crops	9,000	111,000
Irrigated Agriculture	10,000	82,000
Municipalities	16,000	21,000
Food Processors	7,000	16,000
Septic Tank Systems	--	5,000
Water Supply Seepage (Mineral Dissolution)	--	23,000
Precipitation (Mineral Dissolution)	~0	6,000
Atmospheric Deposition	~0	1,000
Upwelling of Saline Groundwater	--	5,000
TOTALS	42,000	270,000

Salt Source Contributions

Sector or Source	Surface Water	Groundwater
CAFOs & Forage Crops	21%	41%
Irrigated Agriculture	24%	30%
Municipalities	38%	8%
Food Processors	17%	6%
Septic Tank Systems	--	2%
Water Supply Seepage (Mineral Dissolution)	--	9%
Precipitation (Mineral Dissolution)	~0	2%
Atmospheric Deposition	~0	0.4%
Upwelling of Saline Groundwater	--	2%

Comparison with Data



Conclusions

- A Reasonable Salt Source Evaluation Was Achieved Using Publically-Available Data and a Salt Mass Balance Approach
- Mass Balance Approach Provides a Sensible Framework for Salt Management:
  - Cost Effective and Simple
  - Quantifies Individual Salt Inputs
  - Identifies Areas for Further Work

Areas for Further Work

- Detailed Salt and Water Balances at Representative CAFOs, Food Processors, and Municipalities
- Mineral Dissolution Studies on Effects of Soil and Water Types
- Evaluation of Local Estimated Salt Contributions of Fertilizers and Soil Amendments

Potential Policy Implications

- Regional Salt Management Should Include Source Control, Focusing on “Low-Hanging Fruit”, Identified Through Mass Balances and Feasibility Studies
- Facilitates Coordination Among Stakeholders for Developing Regulatory Approved Salinity Management Plans
- Promotes Regulatory Efforts Without Prolonged Additional Study or Detailed Groundwater Flow and Solute Transport Modeling