



Shallow Groundwater Quality in the Canadian and Red River Basins

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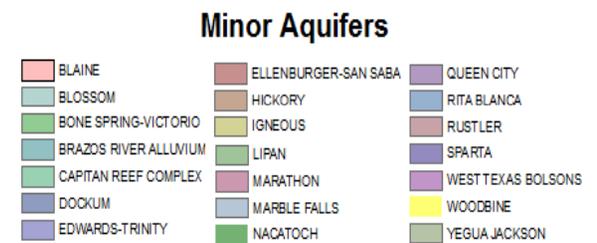
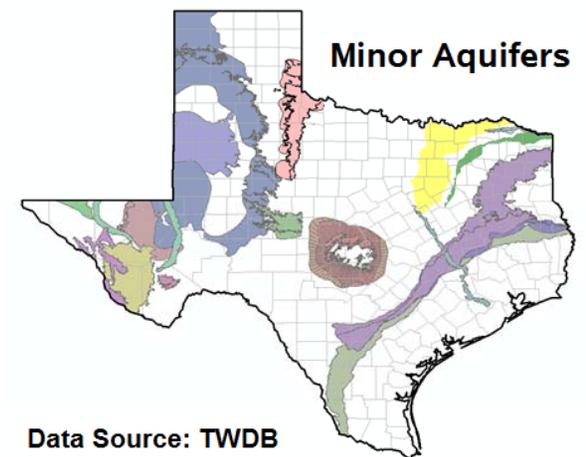
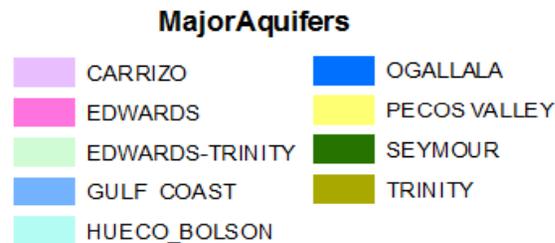
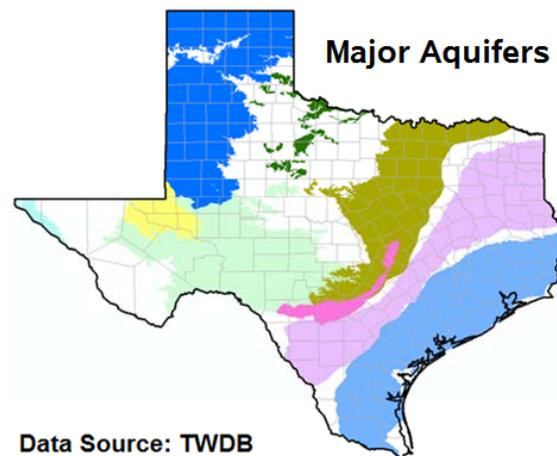


Presentation Outline

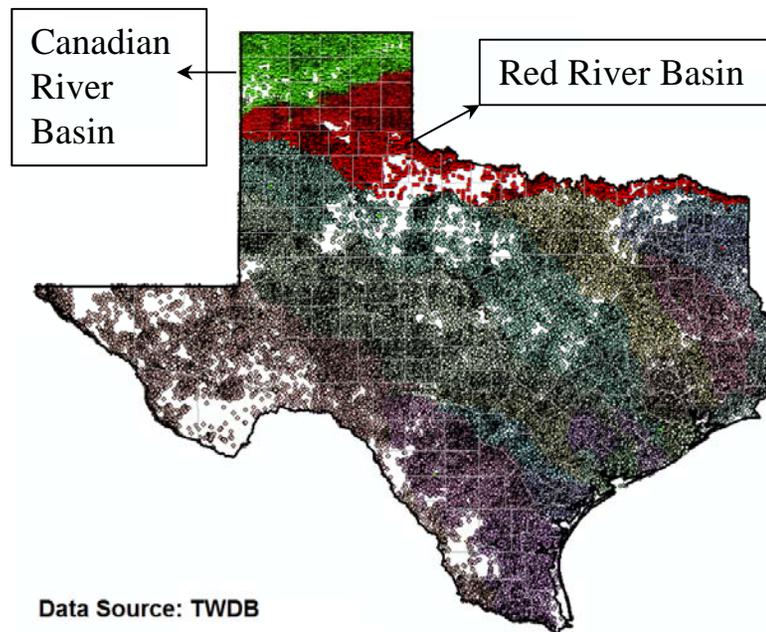
- ❑ Groundwater quality monitoring in Texas.
- ❑ Spatio-temporal variability of nitrate concentration in groundwater in Texas.
- ❑ Groundwater quality in the Canadian and Red River Basins.
 - ❑ Nitrate (NO_3).
 - ❑ Total Dissolved Solids (TDS).
 - ❑ Sodium Absorption Ratio (SAR).
 - ❑ Residual Sodium Carbonate (RSC).

Aquifers of Texas

- ❑ 9 major and 21 minor aquifers.
- ❑ ~ 60% of the total water use supplied from groundwater.
- ❑ > 75% of extracted groundwater used for irrigation.
- ❑ > 95% of rural households rely on groundwater.



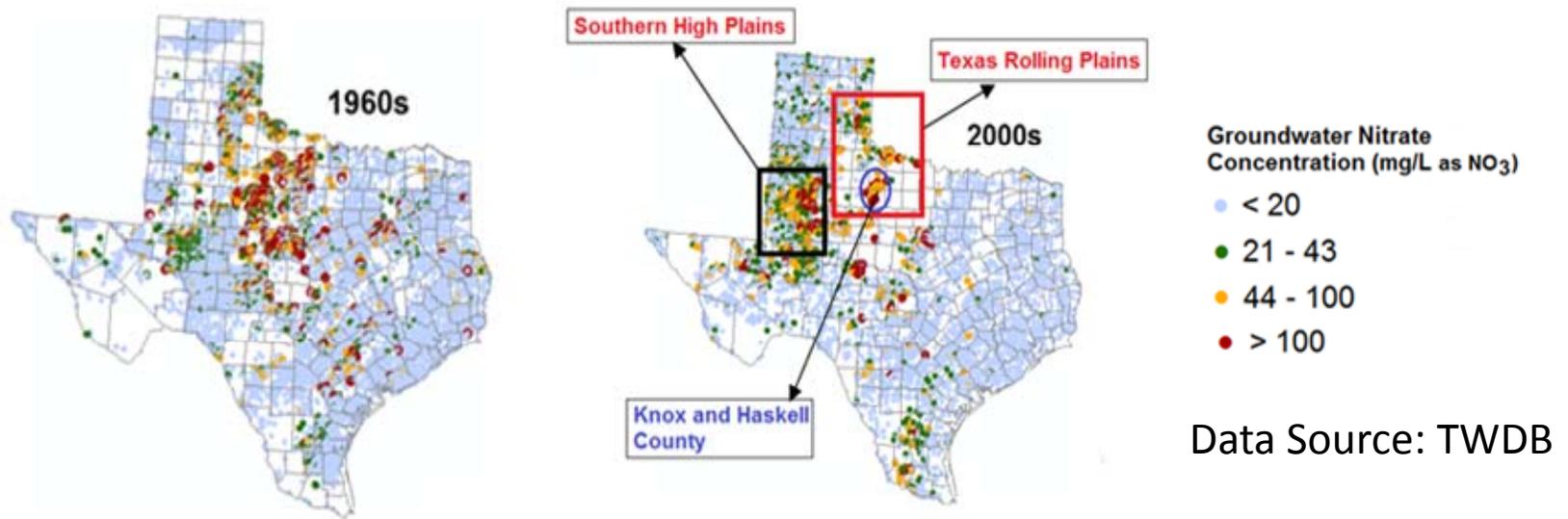
Groundwater Quality Monitoring



Monitored by the
Texas Water
Development Board
(TWDB).

- >120,000 groundwater wells and spring locations.
- Historical information from 1896.
- 33 different water quality parameters.
- Lack of adequate spatial coverage recently.

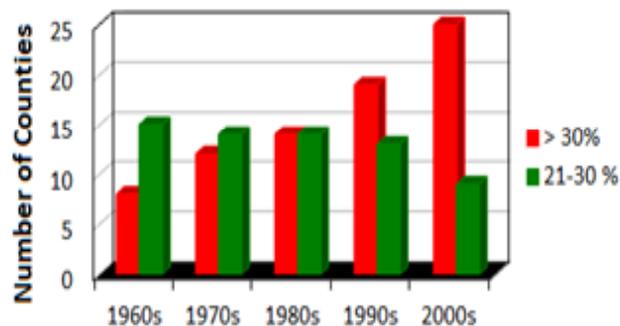
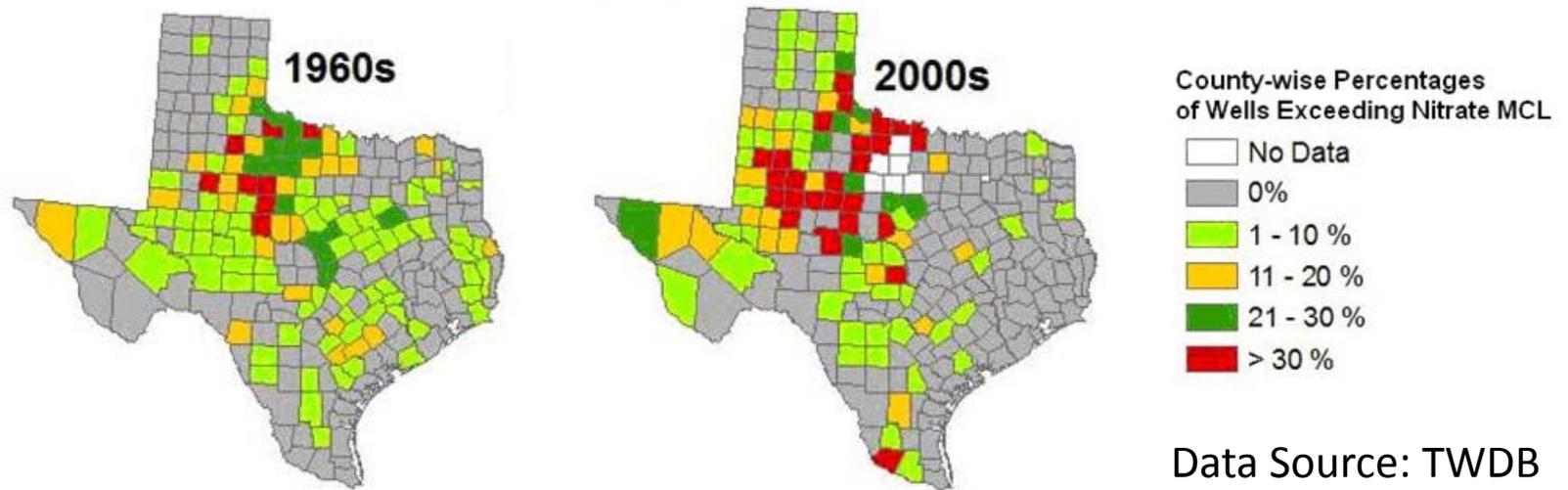
Nitrate Concentration in Groundwater



- ❑ Exceeds the EPA maximum contaminant level (MCL) of 44 mg/L NO₃ (10 mg/L as NO₃-N) at several locations.
- ❑ Distinctly increasing trend since the 1960s.
- ❑ High NO₃ concentrations in the Southern High Plains and the Texas Rolling Plains.

Chaudhuri et al., 2012. *Journal of Environmental Quality*, In Review

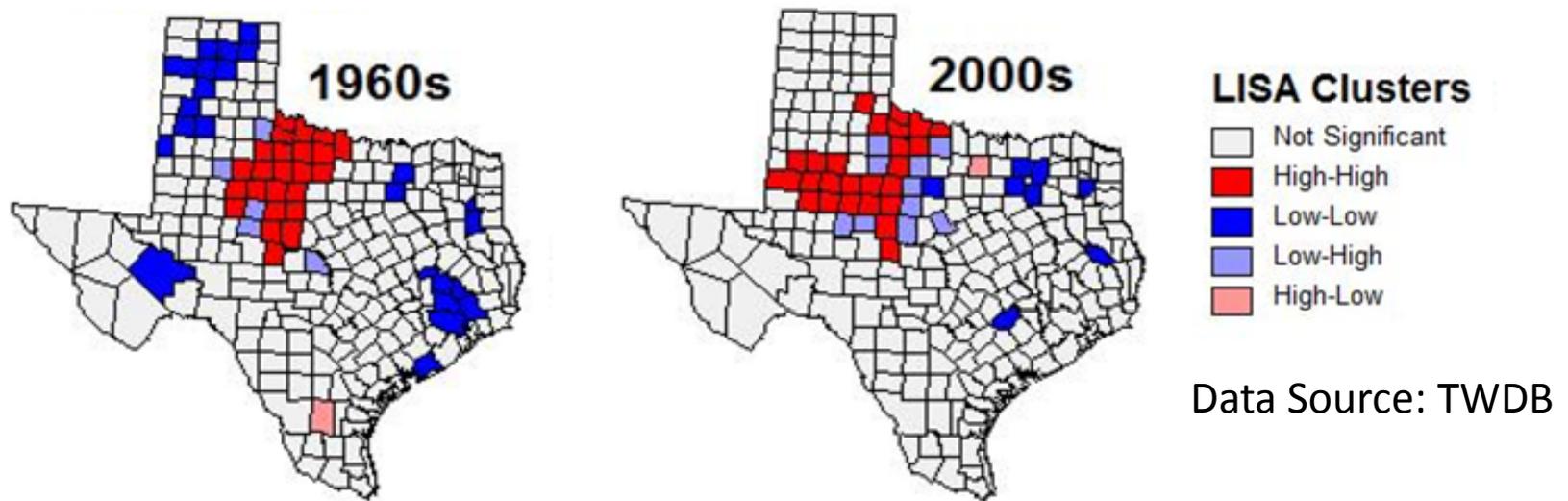
County-wise Groundwater Nitrate Concentration



☐ Counties with > 30% observations exceeding the nitrate MCL increased from 8 to 25.

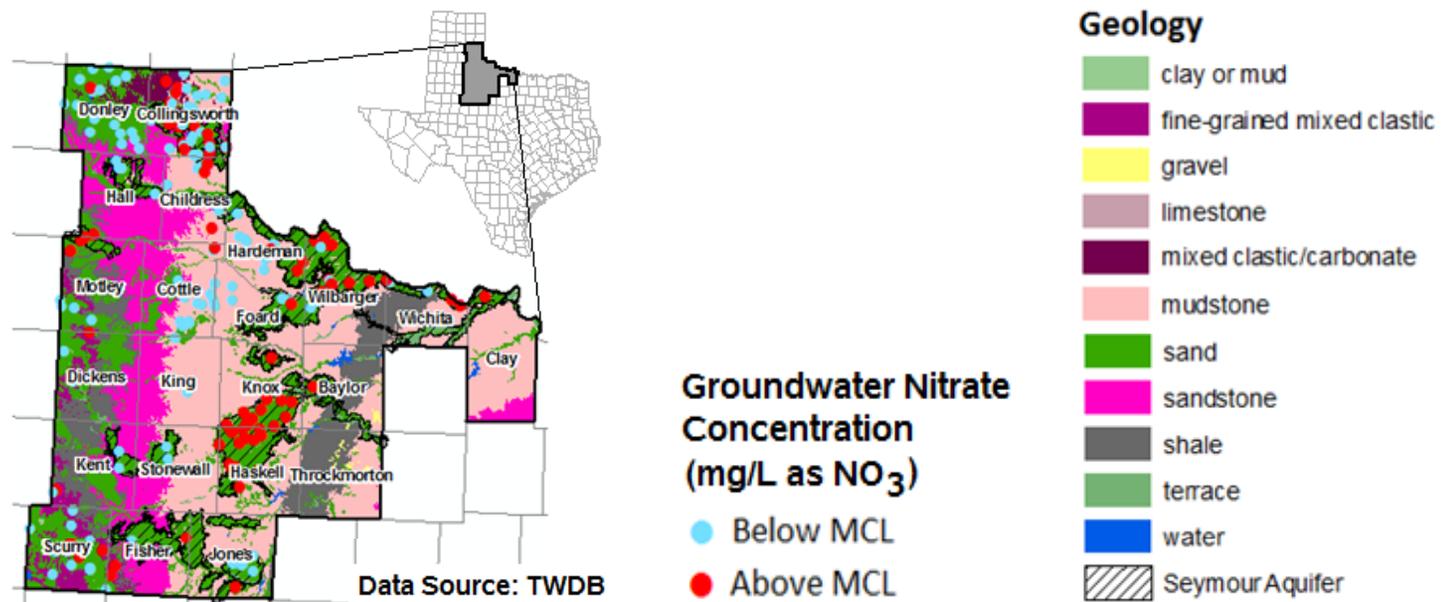
☐ Is there a spatial pattern?

Spatial Pattern in Nitrate Concentration



- ❑ Local Indicators of Spatial Association (LISA).
- ❑ Spatial clusters of counties with high/low NO_3 (> MCL) concentrations since the 1960s.
- ❑ Clustering in the TRP in both decades.

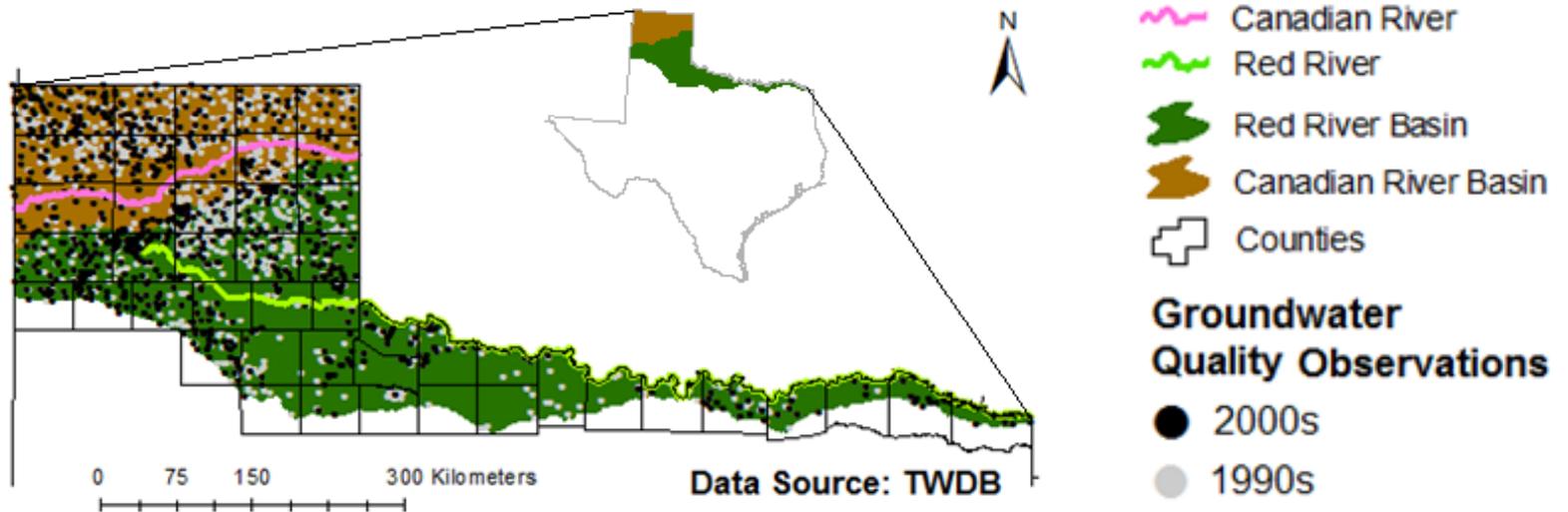
Groundwater Nitrate Concentration in the Texas Rolling Plains



- High concentrations in the Knox and Haskell counties.
- Highly transmissive geologic formation of the Seymour aquifer.
- Close association with agricultural activities.
- Evaporative processes?

Chaudhuri et al., 2012. *Journal of Environmental Quality*, In Review

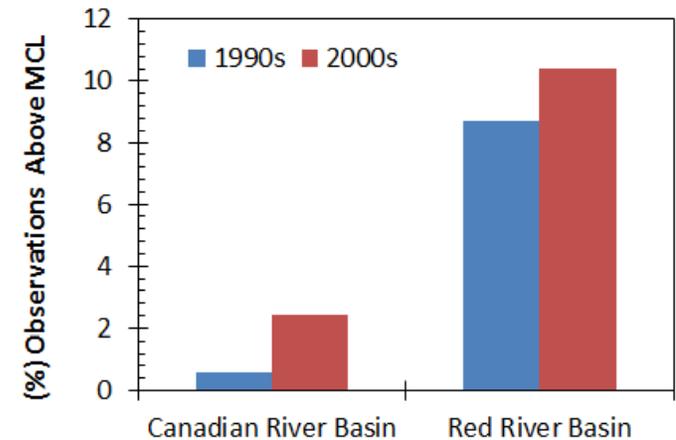
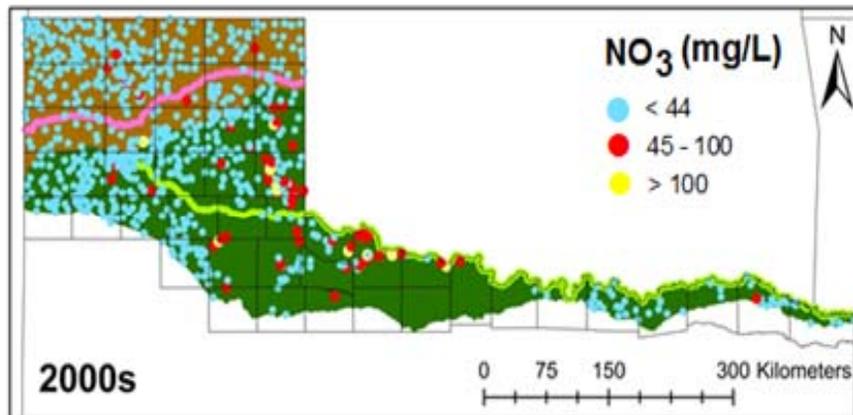
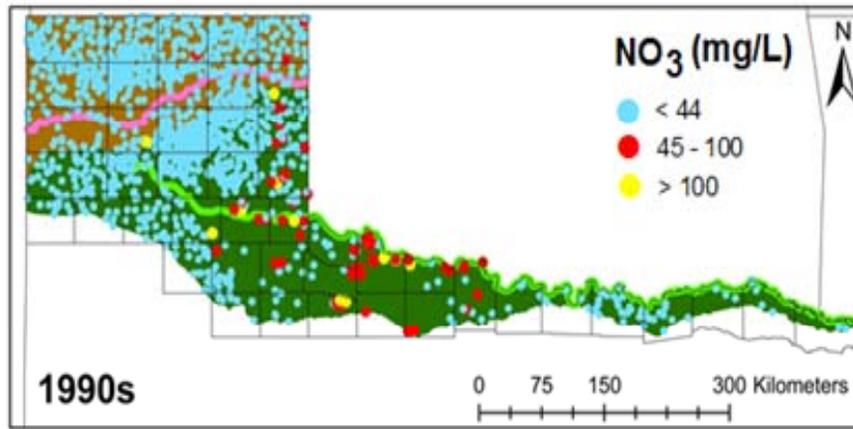
Groundwater Quality in the Canadian and Red River Basins



Number of Groundwater Quality Observations

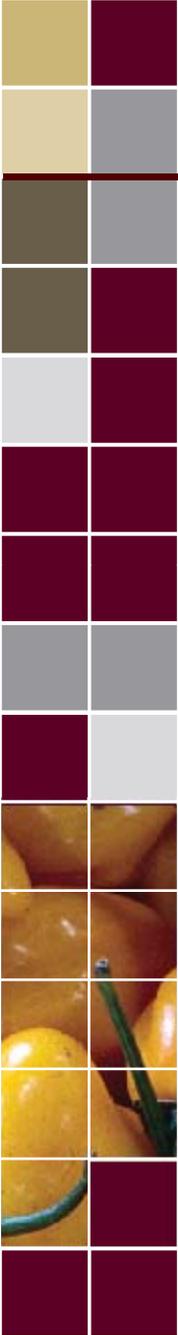
Decade	Canadian River Basin	Red River Basin
1990s	683	835
2000s	371	577

Groundwater Nitrate Concentration in the Canadian and Red River Basins



- ☐ Significantly higher NO₃ in the Red River Basin.
- ☐ Increasing trend in both river basins.

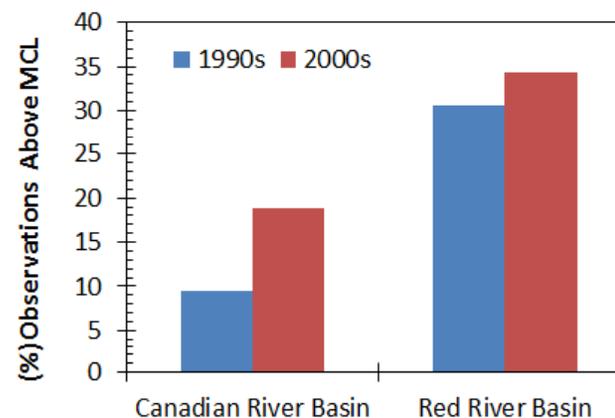
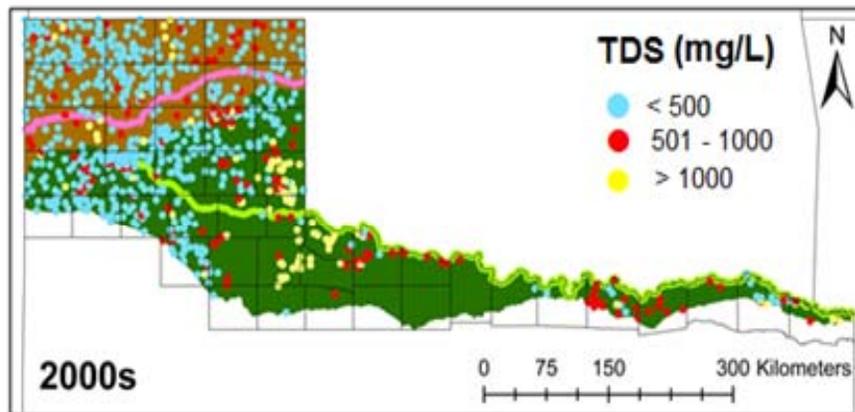
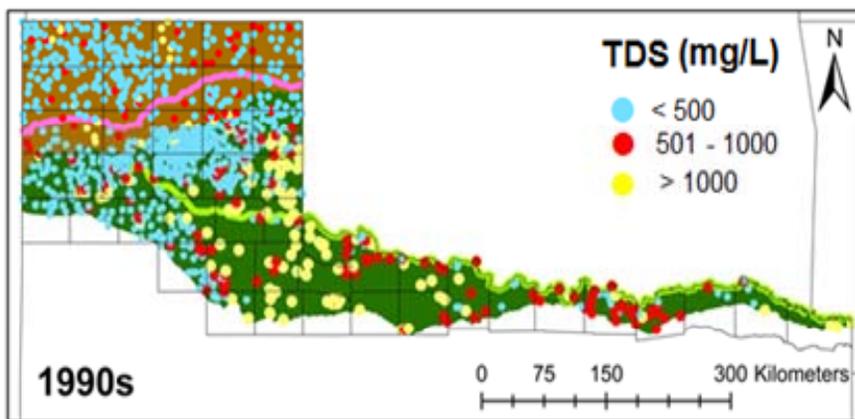
Data Source: TWDB



Total Dissolved Solids (TDS)

- TDS is a qualitative measure of the amount of dissolved ions such as Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Cl^- , SO_4^{2-} , NO_3^- .
- TDS is an indicator of aesthetics.
- US EPA secondary MCL for TDS: **500 mg/L**.
- Secondary MCLs are only guidelines and are not enforced.
- Electrical conductivity (EC) is a measure of TDS.
- High TDS increases water's salinity, reduces clarity, suitability to drinking and disrupts osmotic conditions in the cells of aquatic organisms.
- High TDS is also undesirable for industrial purposes.

TDS in Groundwater in the Canadian and Red River Basins



- ❑ Higher TDS in Red River Basin (especially north of Dallas).
- ❑ Increasing trend between the 1990s and 2000s.

Data Source: TWDB

Measures to reduce TDS Concentrations in Water

Affecting factors

- Urban runoff
- Fertilizer runoff
- Soil erosion
- Rock weathering

Measures for reduction

- Storm water management
- Fertilizer recommendations
- Reduce surface runoff

If TDS of water are high, specific analysis should be conducted to determine major contaminant(s) and then appropriate measures should be adopted.

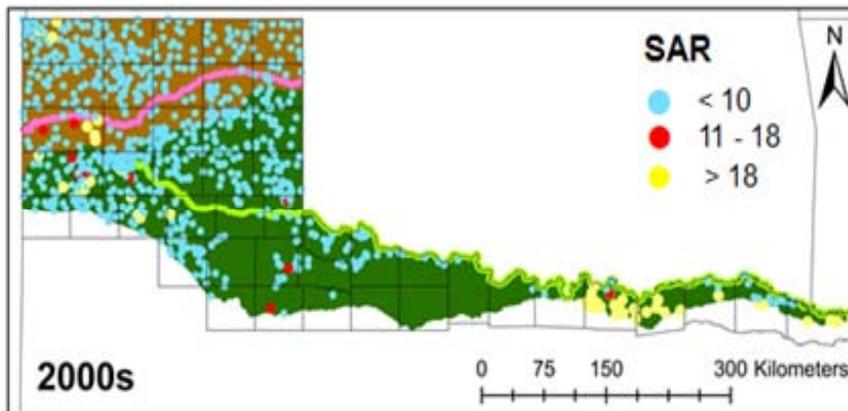
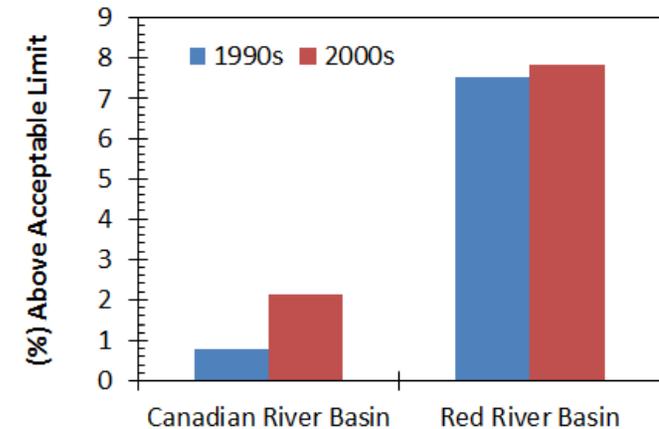
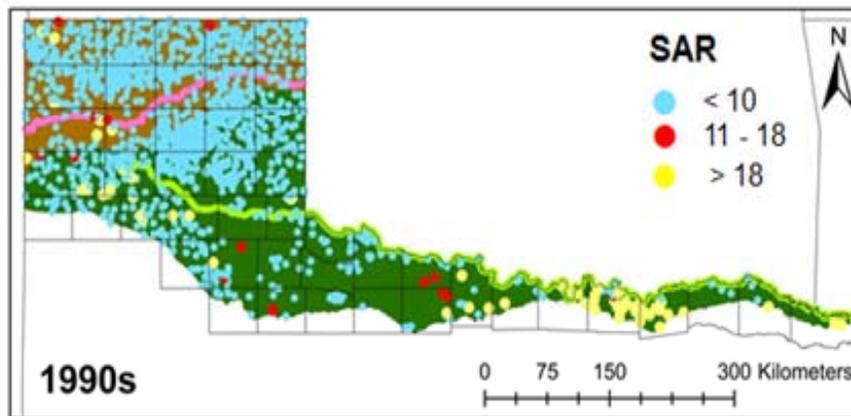
Sodium Absorption Ratio (SAR)

- ❑ Irrigation water quality (sodium hazard) indicator.
- ❑ High Na^+ concentrations in irrigation water are toxic to plants and raise the SAR.
- ❑ High SAR destroys soil structure by dispersing the soil grains and forming soil crusts on the surface.
- ❑ Soil dispersion leads to reduced infiltration and air, water, and nutrient movement.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{1}{2}([Ca^{2+}] + [Mg^{2+}])}}$$

SAR range	Suitability for irrigation
10	Safe
10 - 18	Marginally safe
> 18	Unsuitable

SAR in Groundwater in the Canadian and Red River Basins



- ❑ Higher SAR in Red River Basin (especially north of Dallas).
- ❑ Increasing trend between the 1990s and 2000s.

Data Source: TWDB

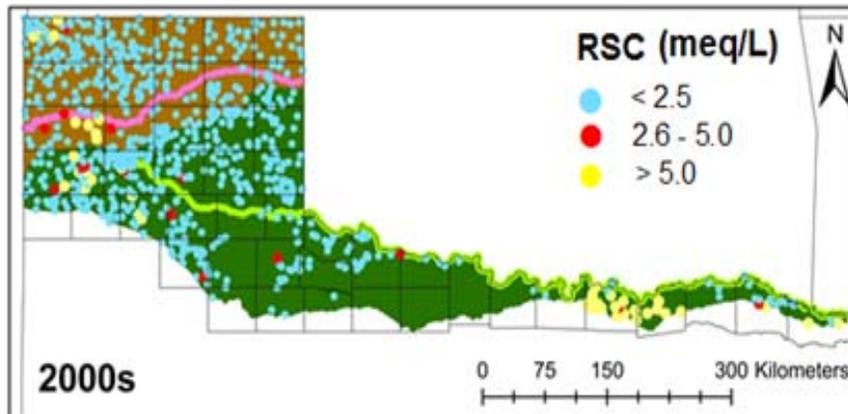
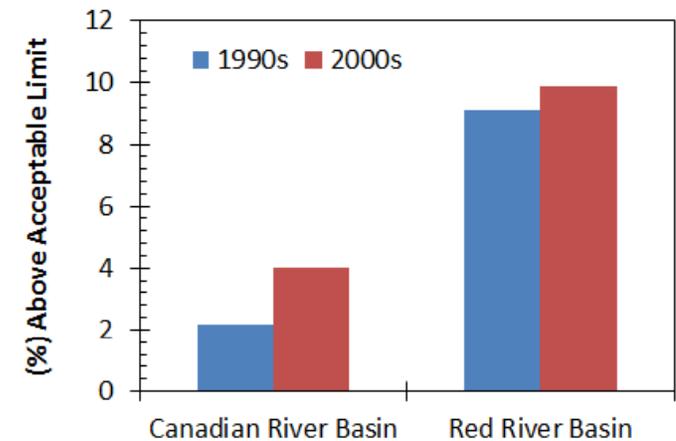
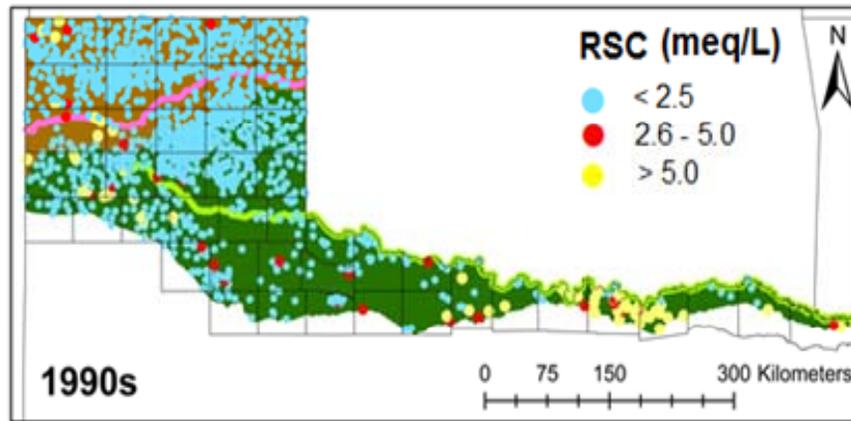
Residual Sodium Carbonate (RSC)

$$\text{RSC} = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

- Irrigation water quality (sodium hazard) indicator.
- “Excess” CO_3^{2-} and HCO_3^- reduce concentrations of Ca^{2+} and Mg^{2+} and increase the effective concentration of Na^+ .
- Excess Na^+ and less Ca^{2+} , Mg^{2+} increases the RSC.
- This causes permeability and infiltration problems.
- Less problem in a coarse-textured (sandy), well-drained soils.

RSC (meq/L) range	Suitability for irrigation
< 1.25	Safe
1.25 – 2.5	Marginally safe
> 2.5	Unsuitable

RSC in Groundwater in the Canadian and Red River Basins

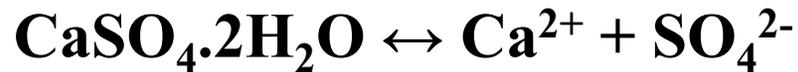


Data Source: TWDB

- Closely follows the spatial pattern of SAR.
- Higher SAR in Red River Basin (more than 9% observations > 2.5 in the 2000s).

Measures to Combat High SAR and RSC in Groundwater

Add Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to soil



- Dissolution of gypsum releases Ca^{2+} .
- Ca^{2+} combines with CO_3^{2-} and HCO_3^- thus reducing RSC.
- Ca^{2+} also acts as a “glue” that binds the soil particles together forming stable aggregates, thus restoring soil structure.
- Restored soil structure creates porosity and aids in air, nutrient and water movement.

How much gypsum?

- Testing is necessary to determine if there is a deficiency.
- Gypsum requirement depends on soil type and chemical properties, rainfall patterns, regional water table, and existing irrigation water characteristics.



Summary

- Groundwater nitrate concentrations in Texas have been increasing over time.
- Highest groundwater nitrate concentrations in the State have been recorded in the Texas Rolling Plains and the Southern High Plains.
- Groundwater nitrate concentration, Total Dissolved Salts, Sodium Absorption Ratio and the Residual Sodium Carbonate are higher in the Red River Basin than in the Canadian River Basin.
- All of the above four groundwater quality indicators in the Canadian and Red River Basins are increasing over time.