Q1: Geography and Hydrology of Each Basin are Comparable and Establish their Water Stressed Nature

- Largely comparable basins and hydrology
  - RG – 870,000 km^2
  - CO – 640,000 km^2
  - Both are pulse flow dominant
  - Arid to semi-arid landscape (some sub-tropical for RG)
  - Reliant on upstream stored water (snowpack, mountain precipitation, etc.)
  - Pre- and Post-Dam discharge (m^3/s)
    - RG - 225 to 40 (often less)
    - CO - 570 to 25 (often near zero)

Colorado River Basin

Rio Grande / Rio Bravo River Basin

Image / Map Credits: American Rivers, Inc.

Q1: Geography and Hydrology (Continued)

- Reduced instream flows and freshwater inflows
  - An uncertain and largely unknown impact on groundwater availability and vice-versa
- Huge potential for adaptive management strategies and data collection / analysis to address this data gap and resulting sustainability concerns

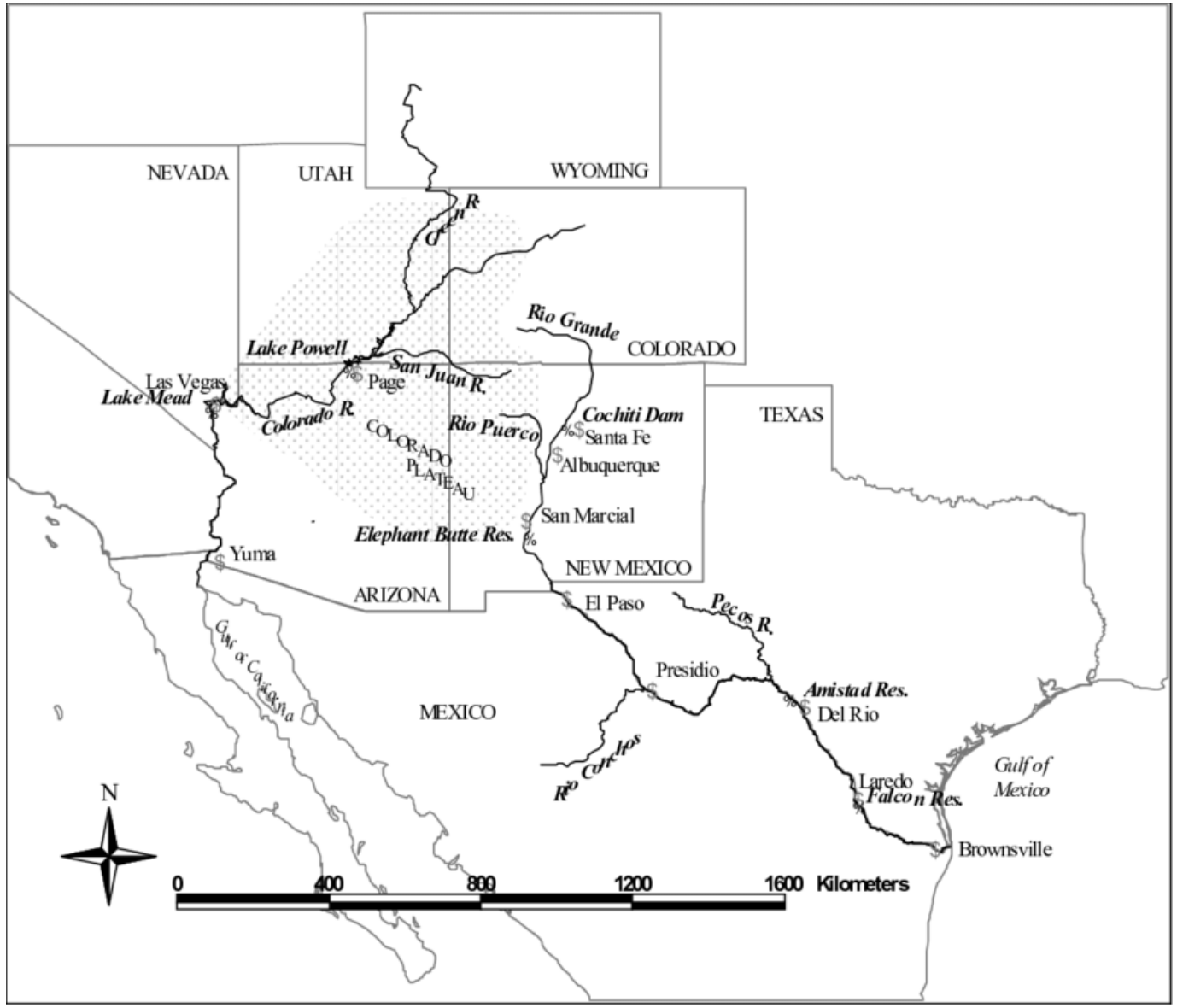

Image / Map Credits: Osterkamp and Gray, 2003

Q1: Deltas of each River are Indicative of even Larger Scale Problems

- Both rivers have deltas that are highly impacted by reduced environmental / instream flows
  - Dams – Irrigation and Municipal Withdrawals
- Pulse flows (even flood pulses) that shaped each delta are now heavily curtailed
  - Massive hydrographic and ecological changes
  - Low to often zero freshwater inflow to estuaries
  - Large scale emphasis (dominant?) on flood control

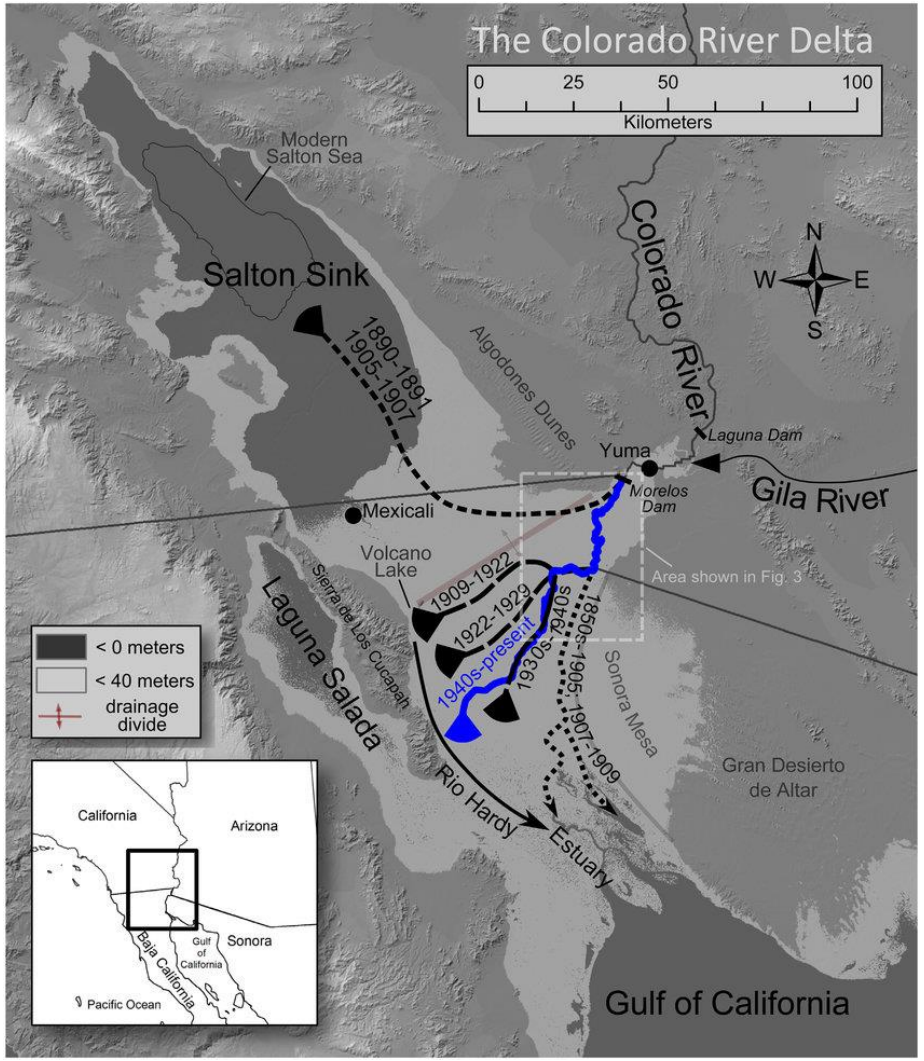

Image / Map Credits: Mueller, E.R. et al., 2016

Q1: Deltas (Continued)

- Impact on SW-GW interactions in and around the deltas are not well-understood
  - Lateral as well as longitudinal impacts
- Issue is compounded by a greater need for international cooperation on research, studies with local participation and input
  - Recent efforts to manage pulse flows and increase base flow along with how this impacts GW sustainability and SW-GW interactions need are encouraging.

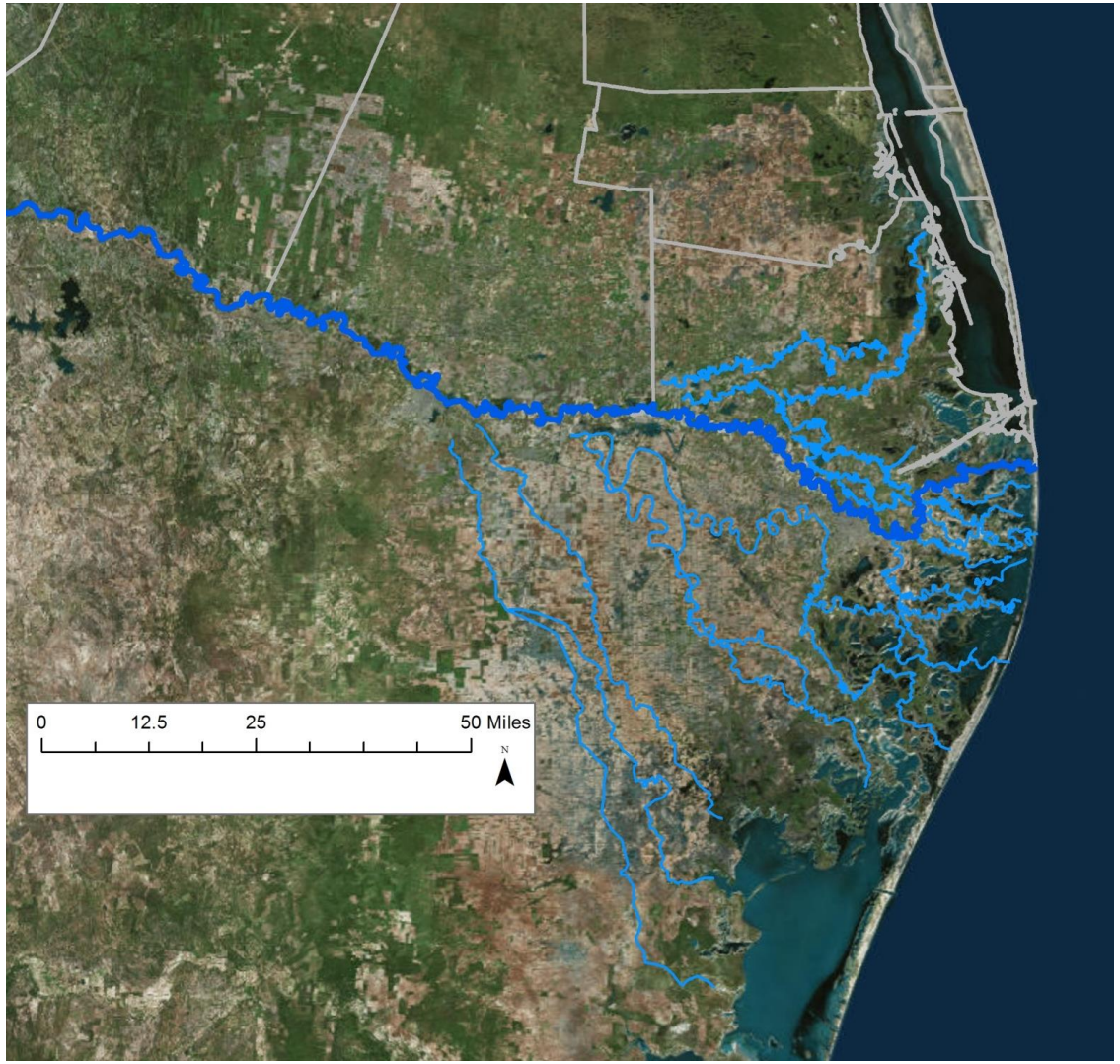

Image / Map Credits: Benavides, J.A.

Q2: Plugging up the Rivers

- Dams and Reservoirs
  - Located throughout both river networks
- Withdrawals and Diversions
  - Large Consumptive Use - Irrigation
- Greatly alter the natural hydrologic processes in each basin
  - Regulating and reducing mean and peak streamflows
  - Reducing pulse flows (volume and frequency)
  - Results in reduced baseflows
- While there is some (adequate?) research on the impact of this flow alteration in the surface water world….
  - Impacts to GW and SW/GW interaction are far less understood
    - Both for quantity and quality (salinity)
  - Local scale impacts are of growing concern in urbanizing areas
  - Ecological impacts are not studied enough

Colorado River Delta Reaching the Gulf of California

Rio Grande / Rio Bravo Fails to Reach the Gulf of Mexico (2001)

Image / Map Credits: Francisco Zamora, Sonoran Institute (above). TPWD (below)

Q2: Gravity Recovery and Climate Experiment (GRACE) – “Scale in the Sky”

- 14 years worth of satellite data (2003-2017)
- Measured tiny space-time variations in Earth’s gravity field
- Effectively weighing changes in water mass over both:
  - River basins and
  - Groundwater aquifers
- GRACE has revealed significant changes in terrestrial water storage across the globe
  - Quantified at regional scales
  - Unimpeded by sparse measurements or restrictive data access policies

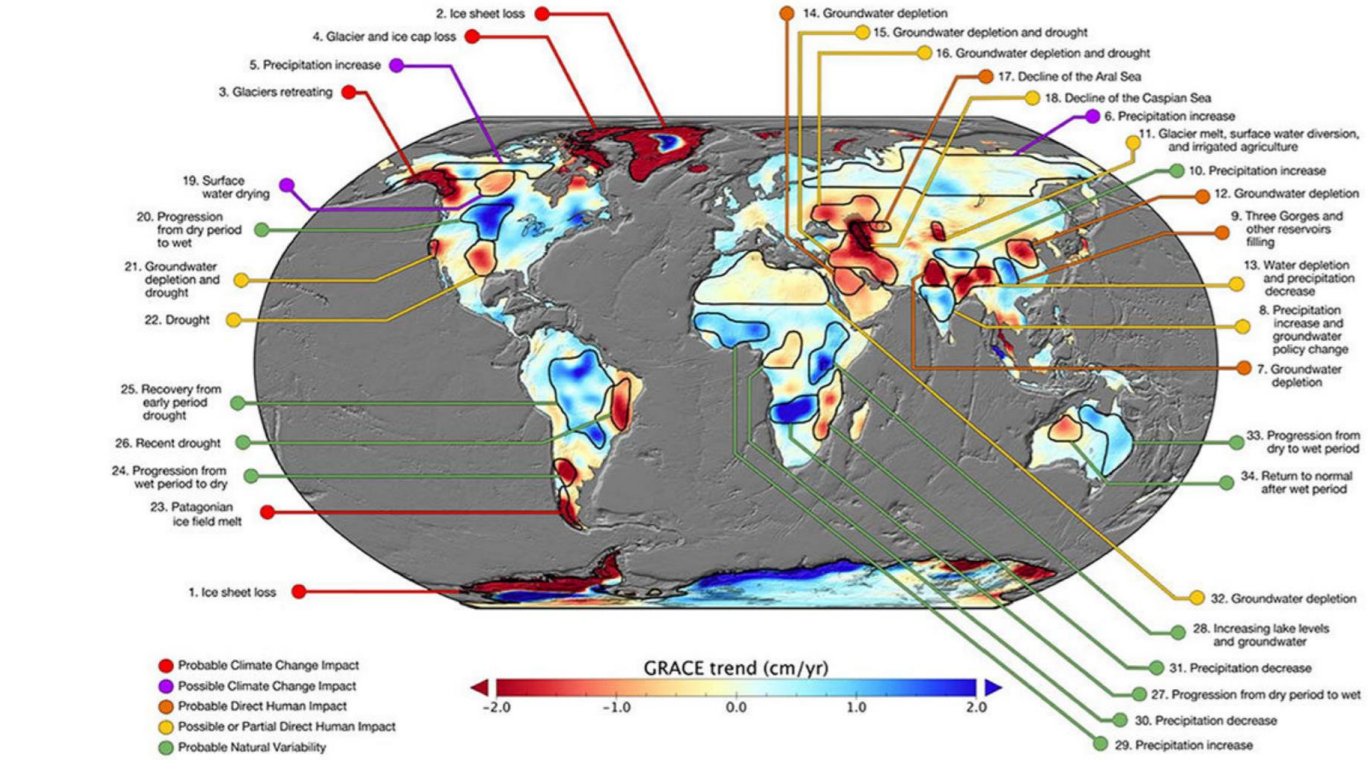

Figure 1. Annotated map of terrestrial water storage trends
. Trends in TWS (cm/yr) based on GRACE observations from April 2002 to March 2016. The cause of the trend in each outlined study region is briefly explained and color coded by category. The trend map was smoothed with a 150 km radius Gaussian filter for the purpose of visualization, however, all calculations were performed at the native 3° resolution of the data product.

Image / Map Credits: Rodell, M. et al. (2019). *Nature.*

Q3: Bringing the River Back to the Sea (and to its groundwater connections)

- Lack of real emphasis on instream, environmental, and freshwater inflows to estuaries, delta regions, and downstream region water rights has had detrimental impacts on these regions
  - Low to often zero freshwater inflow to estuaries
  - Large scale, greater emphasis on water availability in upstream reservoirs and flood control
  - Drought planning is long-term but often secondary to flood control concerns
- Despite decades of growing emphasis on drought impacts in national water planning and management significant problems remain
  - Emphasis tends to remain on post-drought economic loss compensation
  - Less emphasis on reduction of impact / damage susceptibility of droughts
- Downstream adaptations to reduced inflows and potential groundwater recharge / storage
  - Ecosystem
  - Infrastructure – urbanization and development
- Environmental Justice Issue – both longitudinally and laterally
  - Insufficient baseflow and pulse flows for sustained ecology and livability
  - How does this relate to GW/SW interactions and vice-versa?

On May 15, 2014, the Colorado River reunited with the sea. Photos by Francisco Zamora, with aerial support provided by LightHawk.

"Rivers affect the health of our seas, wildlife, communities and economies. Restoring freshwater habitats is no longer optional; it's imperative."

- Osvel Hinojosa Huerta, director of the Water and Wetlands Program at Pronatura Noroeste

Image / Map Credits: Environmental Defense Fund.

Q4: Holistic and Equitable Approach

- Greater emphasis on a holistic approach to binational management of river water
  - Increased emphasis on recoupling SW/GW connectivity
  - Adaptive management of both resources

Environmental Flows Recommendations Report

Final Submission to the
Environmental Flows Advisory Group,
Rio Grande Estuary and Lower Laguna Madre
Basin and Bay Area Stakeholders Committee, and
Texas Commission on Environmental Quality

Texas Commission on Environmental Quality | Texas Parks & Wildlife | Texas Water Development Board

Rio Grande, Rio Grande Estuary, and Lower Laguna Madre
Basin and Bay Expert Science Team

July 2012

Q4: Data Collection at the Local Level

- Enhanced data collection on SW/ GW interactions
  - Particularly in the lower reaches of rivers
  - Increased monitoring (SW and GW), water quality stations (salinity), and addressing downstream needs binationally as a whole

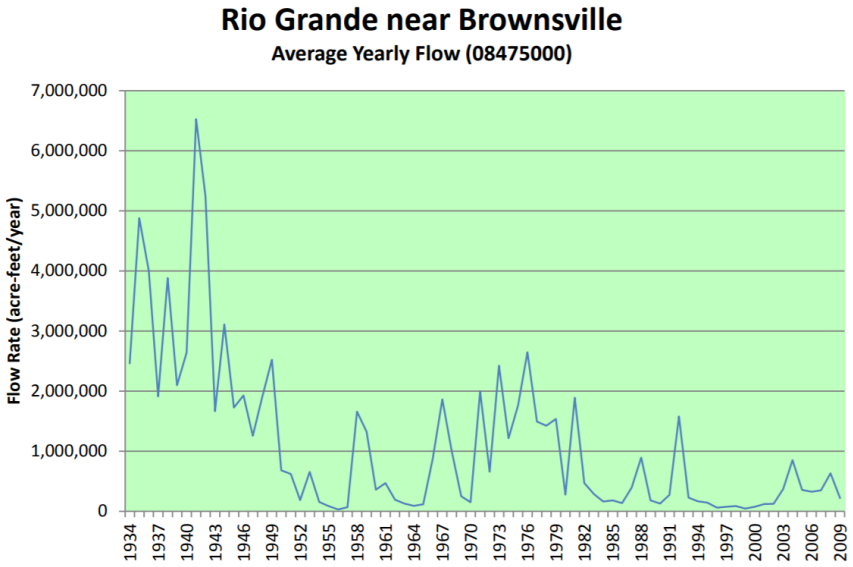

Figure 2.2.7. Average yearly flows as recorded by the IBWC gage #08475000 near Brownsville, TX.

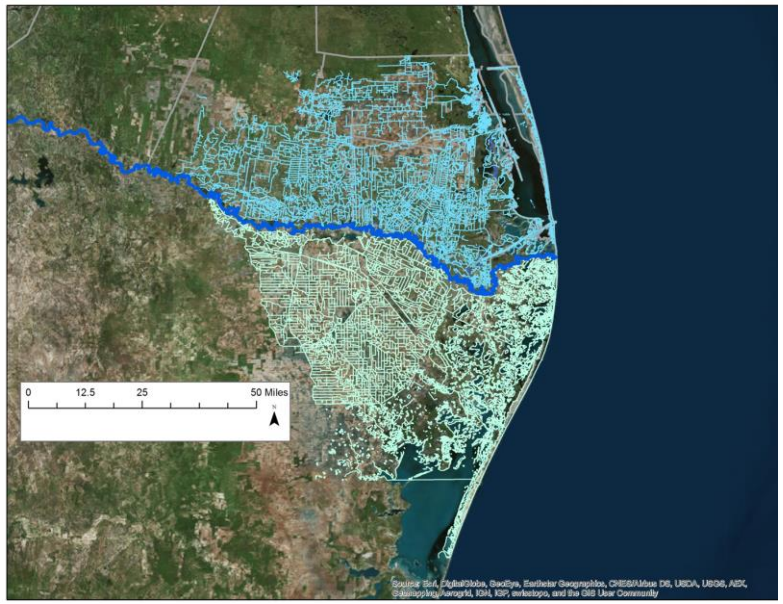

Image / Map Credits: Benavides, J. A. BBEST Report Lower Laguna Madre