Sustainability of Engineered Rivers in Arid Lands: Declining Environmental Flow\textsuperscript{1} and Groundwater\textsuperscript{2}

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Dams and environmental flows regime

- Impact of engineered features on inflows
  - Impacts on quantity, timing and quality of water required to meet ecosystem demands

- Magnitude of flow is reduced by consumption and increased evaporation

- Frequency of high flow pulses, particularly rainy season, are reduced

- Reservoirs tend to support downstream water rights - can reduce frequency of very low flows because water must be released to satisfy downstream water rights
Altered Flows and Biodiversity

- Flow determines physical habitat in a river
- Aquatic species have evolved life history strategies in response to the natural flow regime
- Many species rely on connections between habitats
- Increases stress on native species and facilitates invasion and colonization by exotic species
- Significant but variable ecological responses to all types of flow alteration (Poff and Zimmerman (2010))
Displays modeled Environmental Flows for the current condition of a river system. This is just flow required to maintain the current condition – as the figure shows, some river basins are currently in peril of low flow conditions; future management scenarios need to plan for strategies to increase these inflows.
Surface/groundwater interactions

- Circular connection
  - River withdrawals can deplete groundwater/pumpage can deplete river
  - Pollution of surface water can degrade groundwater/degraded groundwater can impact surface water quality
  - Low flows in river = less recharge = less inflow

- Need to understand (quantitative) linkages between groundwater and surface water

- Rates of aquifer recharge can be impacted by:
  - Precipitation changes
  - Pumping changes
  - Development on recharge zones
  - Changes to soil and lens structures
SERIDAS river basins with current global groundwater basins supplies and areas of low rainfall (data source WHYMAP, 2018)
Need new ways of thinking about arid lands with high evaporation

- **Texas Water Plan**
  - Proposed reservoirs are the most expensive items in the Plan
  - Reservoir permitting and construction are lengthy and contentious

- **2011 drought:**
  - Evaporation loss from Lakes Travis and Buchanan > water used by City of Austin

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**Assisted Groundwater Recharge:**
- $90-$1100 acre-foot

**Reservoir Expansion:**
- $1700-$2700 acre-foot

**Seawater Desalination:**
- $1900-$3000 acre-foot

*(Numbers from Stanford’s Water in the West)*
Environmental Flows Case Study: Rio Grande

- Flows below Elephant Butte dam are low in volume and intermittent (Ward and Schmandt 2013).
- Historically, waters of Rio Grande flowed into the Gulf of Mexico. In recent years reduced flows in the Rio Grande due to water diversions and flow management have resulted in siltation at the mouth.

- Since 1934 when flow gaging began at Brownsville, annual flow has declined from 2.5 million ac-ft to 1.1 million ac-ft.
Reduction in flow and flow variability has resulted in loss of habitat diversity
- Darters are adapted to riffles and shallow runs, but not pools. Bass need deep pools. The Mexican tetra requires deep runs (URGBBEST 2012).

Change in substrate particle size
- Between Cochiti and Elephant Butte there has been a decrease in sand substrate and increase in gravel and cobble substrate (Dahm et. al 2005). Different species are adapted to these substrates for feeding and reproduction. Low flow has increased the area of sand and silt substrate.

Between Big Bend NP and Amistad Reservoir, 8 of 41 native fish species have been extirpated (Hubbs et al. 2008). This was caused by dams, habitat alteration and competition from nonnatives (URGBBEST 2012).
In some recent years there has been no outflow at the mouth of the Rio Grande. If the flow velocity falls below approximately 1 ft/sec at the mouth, then the long shore current will close the mouth with sediments (LRGBBEST 2012). This would eliminate the estuarine function of the lowest section of river and it would no longer be a nursery for marine species, e.g. shrimp, crabs, snapper.
Groundwater Case Study: Rio Grande

- USA and Mexico share the Rio Grande/Bravo watershed of 335,000 sq miles
- Texas, New Mexico and Colorado share US resources
- US – 75% of water is for agriculture
- Ongoing litigation between States over rights and usage
Groundwater Case Study: Rio Grande

Basin/Groundwater Challenges

- Texas, New Mexico, Colorado – *Rio Grand Compact*
  - Established apportionment for some of the water from the Rio Grande for the three states
- Texas claims New Mexico is violating the Compact by increased groundwater pumping, reducing flows in the Rio Grande

*Rio Grande (Nuevo Progresso Bridge, 2007)*
Sustainable Groundwater and Inflows in terms of SERIDAS and Basin Management

- Project trends in groundwater and surface water usage - Will this threaten water quality? Will groundwater and/or basin withdrawal impact inflows?
- Are Aquifer Storage and Recovery projects, conservation principles, agriculture alternatives in place? Planned? How will they supplement current supply?
- Project reservoir storage and construction - How do existing dams or new dams change recharge and inflows?
- Project effects of current and likely water management policies

- Need comprehensive planning tool that visualizes entire set of sustainability and resiliency factors for all of river basin management: surface and groundwater
SERIDAS Inflows and Groundwater

- Watershed sustainability approach needs to be a goal for SERIDAS
  - Ability of entire watershed (surface water, groundwater and interconnections) to recover after slow-burn (drought) and swift (extreme rainfall) impacts

- Groundwater is hydrologically connected to the river – borrowing from future water supply and impacting flows – circular: less flows in river = lower recharge

Sustainability = better human health, resilient environment, and robust economy
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