A RAPID REVIEW OF ENVIRONMENTAL FLOW ASSESSMENT

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Engineering with Nature

Water Operations Workshop

What are "environmental flows"?

Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.

-Brisbane Declaration (2007)

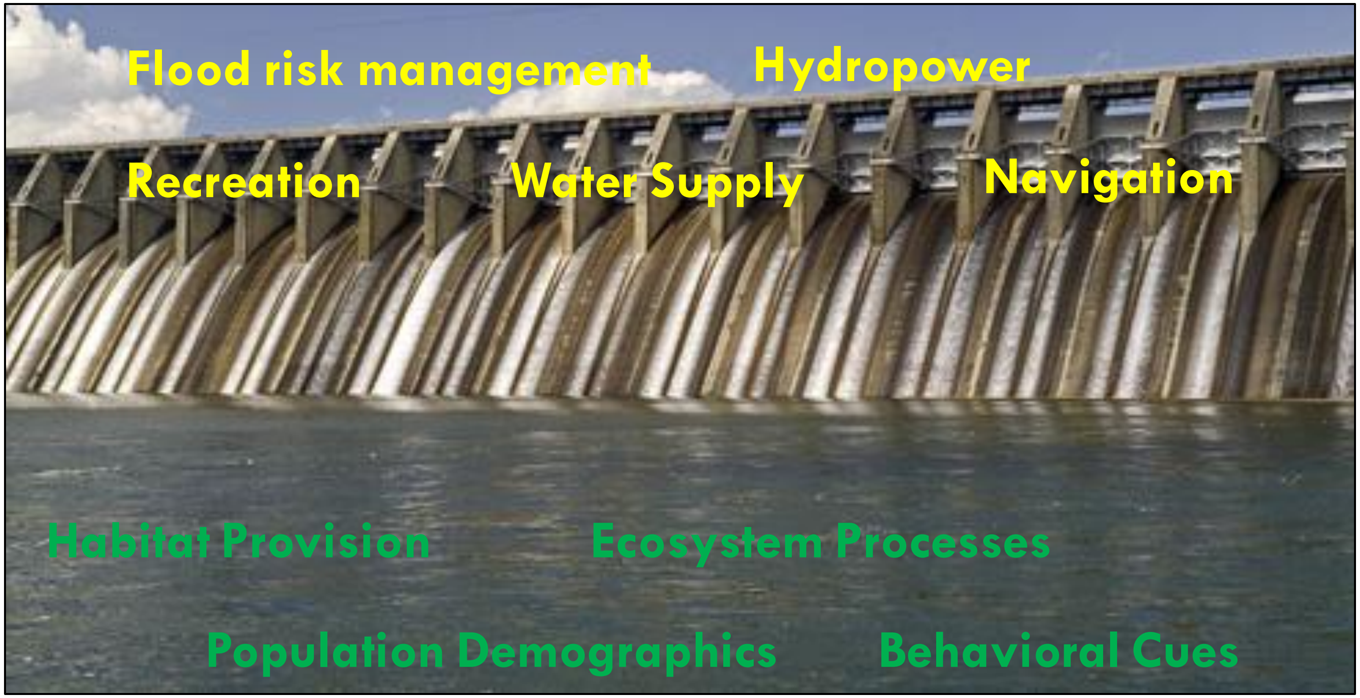


Figure: USACE Savannah

Challenges in eflow assessment

- What alternative flow regimes are available?
- What analytical methods can be used to compare those alternatives?
- How do we choose the “best” alternative?

Alternative Environment Flow Regimes

The "Natural Flow Regime" Paradigm

- **Magnitude**: How big (or small) is an event?
- **Frequency**: How often does an event occur?
- **Timing**: Does the time of the flow event matter?
- **Duration**: How long is the event?
- **Rate-of-change**: How quickly does the event change?

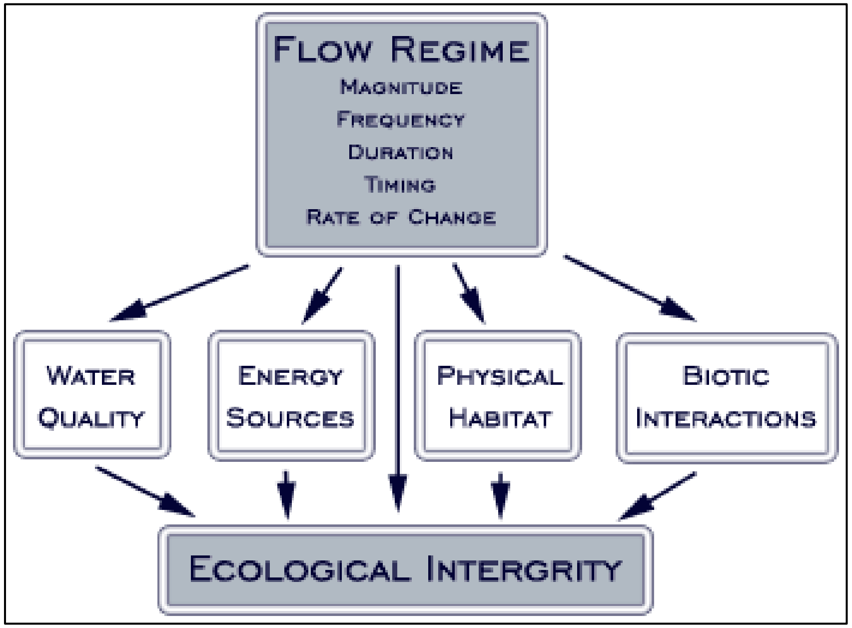


Figure: Poff et al. (1997)

"Environmental Flow Components"

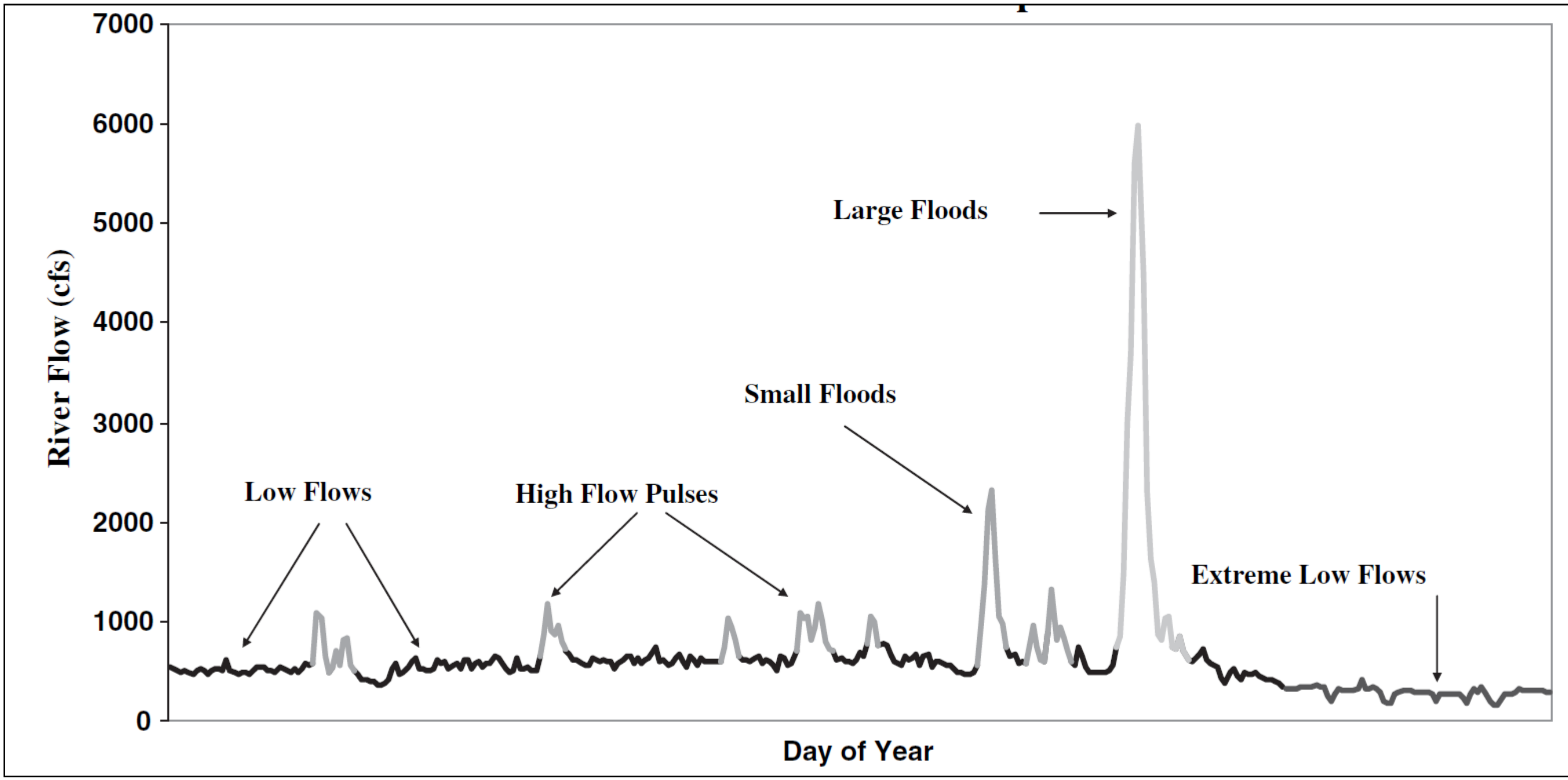
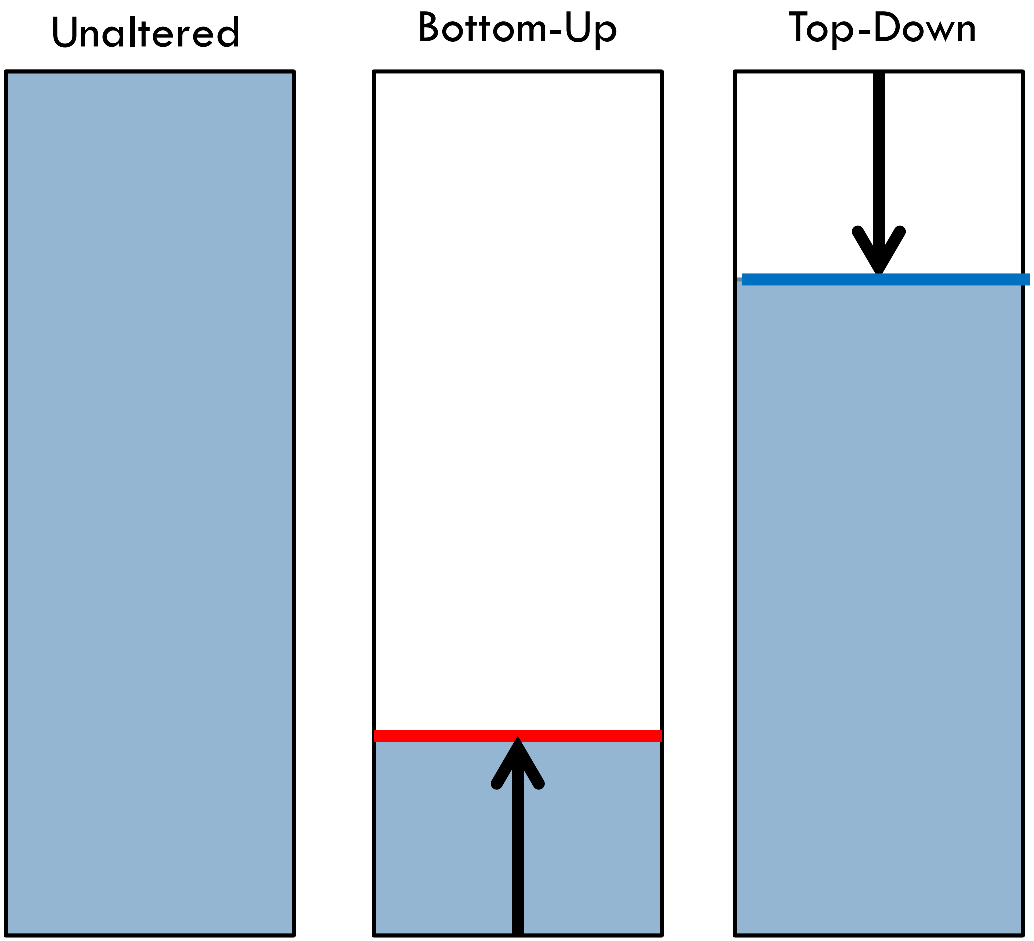


Figure: Matthews and Richter (2007)

Two fundamental eflow approaches



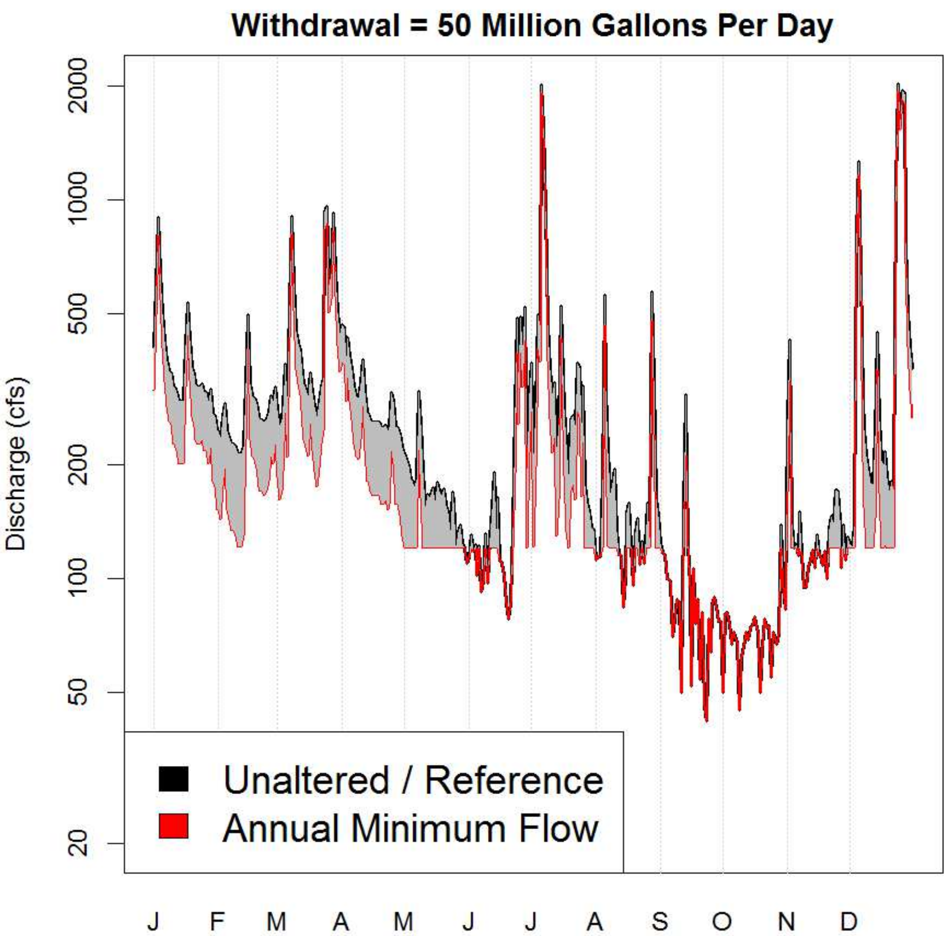
Six families of environmental flows

Method	Description / Premise	Examples
Hydrologic	Simple, desktop analysis based on (sometimes arbitrary) hydrologic statistics	Minimum flows Sustainability boundaries
Hydraulic	Thresholds in channel geometry	Wetted perimeter
Habitat	Habitat provision for a taxa or guild (tools: HEC-EFM, PHabSIM, SEFA,…)	Instream flow incremental method (IFIM)
Holistic	Multi-disciplinary, multi-objective expert panel approach emphasizing flow regime	"Savannah Process" Building Block Method
Optimization	Specify flow regime based on objective, constraint, and penalty functions	Classic economically driven reservoir modeling
Regionalization	Holistic method of addressing eflows for an entire region, which emphasizes scientific and social processes	Ecological Limits of Hydrologic Alteration (ELOHA)

McKay (2013, EMRRP-SR-46)

Alternative Analytical Approaches

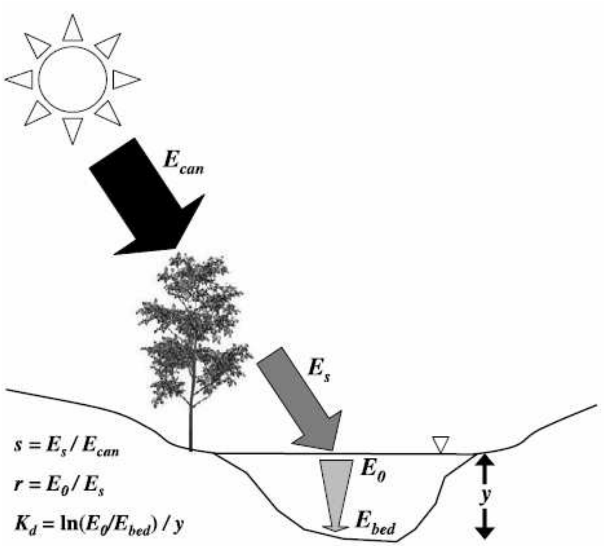
Hydrologic Alteration

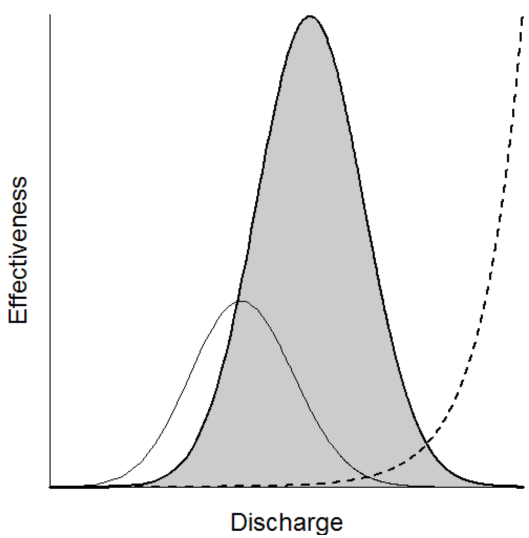


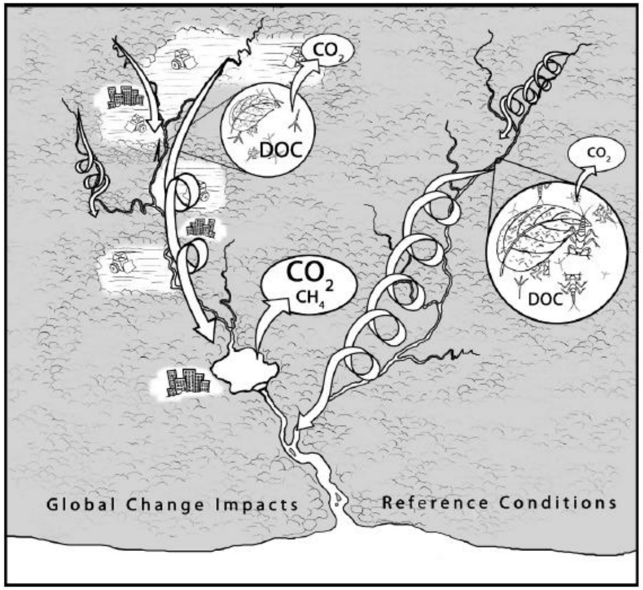
- Hydrologic Statistics
  - Mean
  - Coefficient of variation
  - Skewness
  - Kurtosis
  - Seasonal amplitude
  - Seasonal phase shift
  - …
- Common analytical platforms
  - Indicators of Hydrologic Alteration (IHA)
  - R-package for eflows
  - Ad hoc models

Water Quality and Sediment Transport

- Dissolved Oxygen
- Nutrients (N, P)
- Light
- Sediment
- Carbon (!!)
  - Base of the food web
  - Biotic (fish, plankton, etc)
  - Abiotic (dissolved, particulate, large wood)



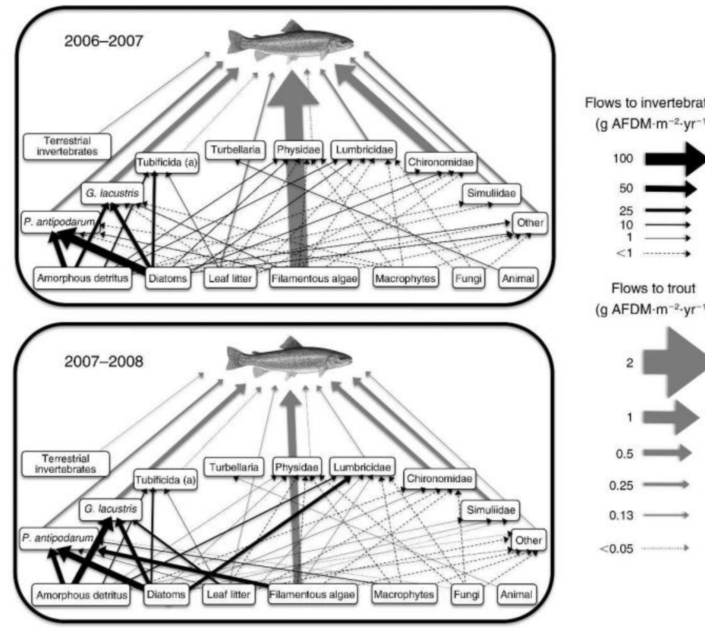


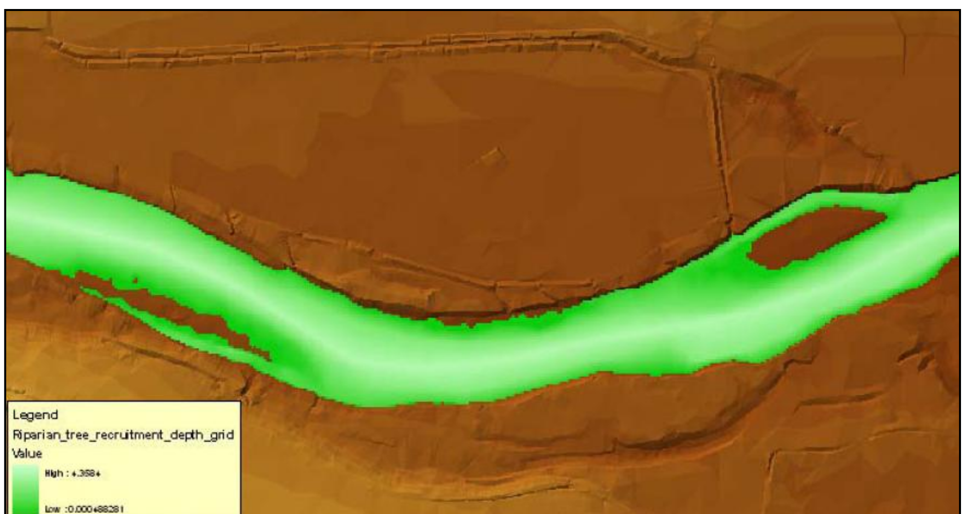


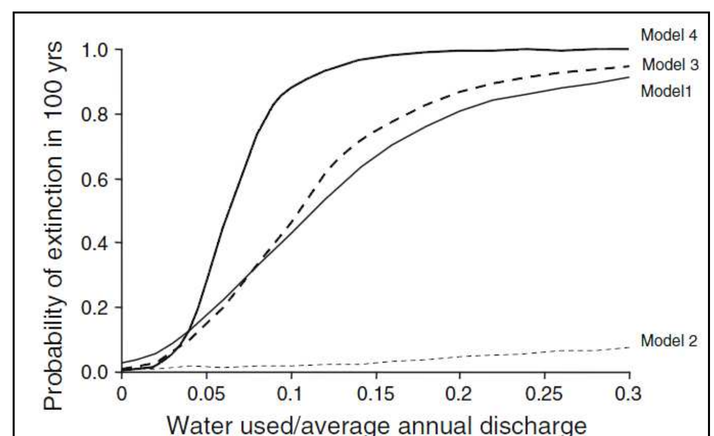
Figures: Julian et al. (2008), McKay et al. (In prep), Kominoski and Rosemond (2012)

Flow-Ecology Relationships

- Habitat Provision: species, guilds
- Population Demography: abundance, survival, recruitment, movement,…
- Ecosystem Processes: decomposition, nutrient uptake, metabolism,…
- Ecosystem energetics: food web stability



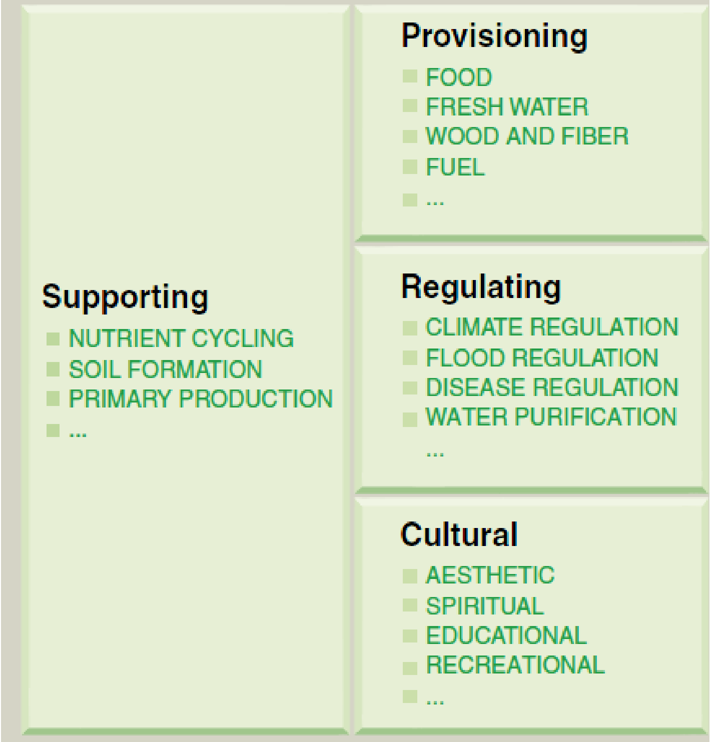




Figures: Hickey and Fields (2009), Peterson et al. (2011), Cross et al. (2011)

Socio-Economic Outcomes

- Ecosystem Services
  - Not new to USACE (flood, nav, rec, etc.)
  - New endpoints for USACE planning
- Cultural and personal dimensions of water management are growing

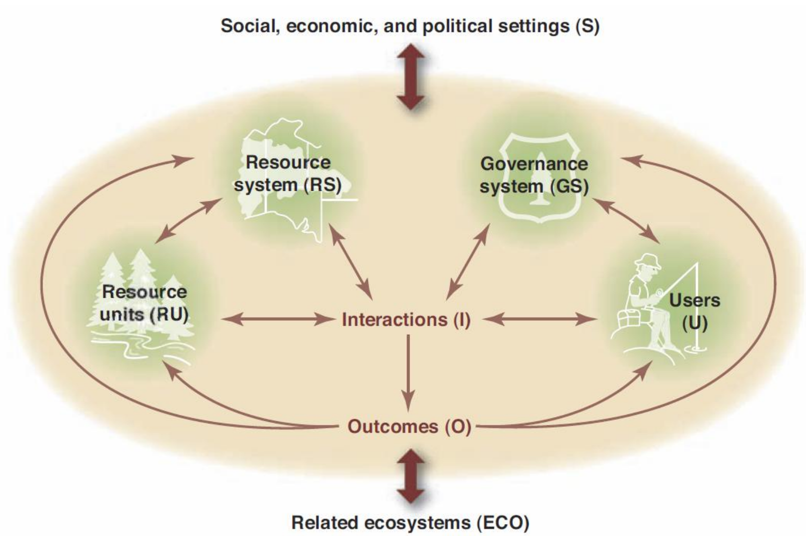


Figures: MEA (2005)

Informing Eflow Decision-Making

Governance in water management

- What is the decision making environment?
- Equity: Who's at the table? Who wins and loses? Distribution
- Decision authority: Funding, Power



Social, economic, and political settings (S)
S1 Economic development. S2 Demographic trends. S3 Political stability.
S4 Government resource policies. S5 Market incentives. S6 Media organization.

Resource systems (RS)
RS1 Sector (e.g., water, forests, pasture, fish)
RS2 Clarity of system boundaries
RS3 Size of resource system*
RS4 Human-constructed facilities
RS5 Productivity of system*
RS6 Equilibrium properties
RS7 Predictability of system dynamics*
RS8 Storage characteristics
RS9 Location

Resource units (RU)
RU1 Resource unit mobility*
RU2 Growth or replacement rate
RU3 Interaction among resource units
RU4 Economic value
RU5 Number of units
RU6 Distinctive markings
RU7 Spatial and temporal distribution

Governance systems (GS)
GS1 Government organizations
GS2 Nongovernment organizations
GS3 Network structure
GS4 Property-rights systems
GS5 Operational rules
GS6 Collective-choice rules*
GS7 Constitutional rules
GS8 Monitoring and sanctioning processes

Users (U)
U1 Number of users*
U2 Socioeconomic attributes of users
U3 History of use
U4 Location
U5 Leadership/entrepreneurship*
U6 Norms/social capital*
U7 Knowledge of SES/mental models*
U8 Importance of resource*
U9 Technology used

Ostrom (2009, Science)

Decision Analysis

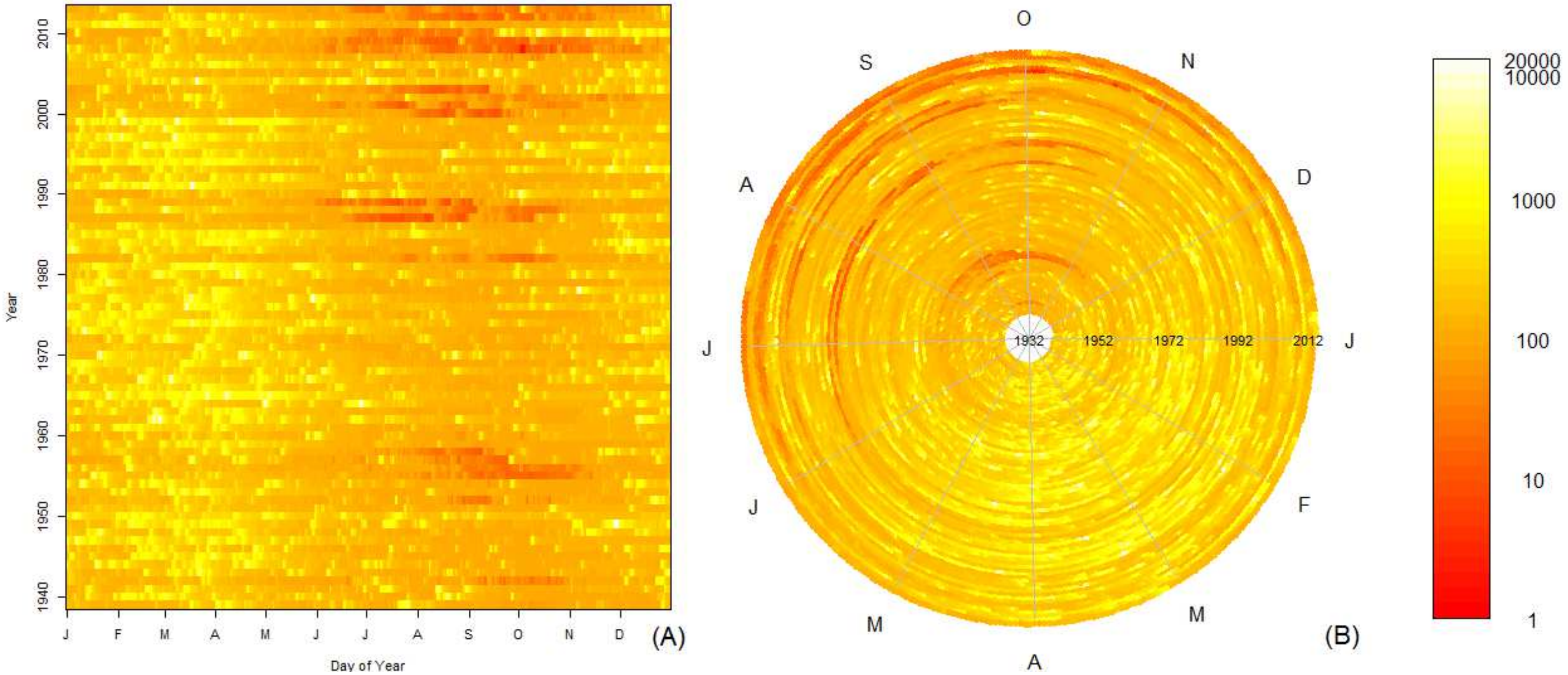
- Objective setting and metric development
- Metric comparison and making trade-offs
- Sequential decisions and adaptive management

General Goals	Specific Objectives	Metrics
Provide for municipal water supply	Maximize water withdrawal	Average annual withdrawal rate
Maintain a healthy river ecosystem	Minimize difference between unaltered and altered hydrographs	7 Discharge metrics normalized from 0 to 1 and averaged

Managing a "Noisy" Hydrograph

- Predictable Variability
- Unpredictable Stochasticity

- Daily
- Seasonal
- Multi-annual: drought, ENSO, AMO
- Multi-decadal: land use, climate



McKay (In press)

USACE Environmental Flow Opportunity

- Restoration via Operations
- USACE owns & operates 692 dams
  - < 40 in Sustainable Rivers Program
  - Volunteers for SRP round 2?
  - Could we develop an “SRP-lite” process?

Could environmental flows be our largest environmental benefit to the nation (80,000 km)?

Could these analyses be conducted under existing authorities?

Contact Information

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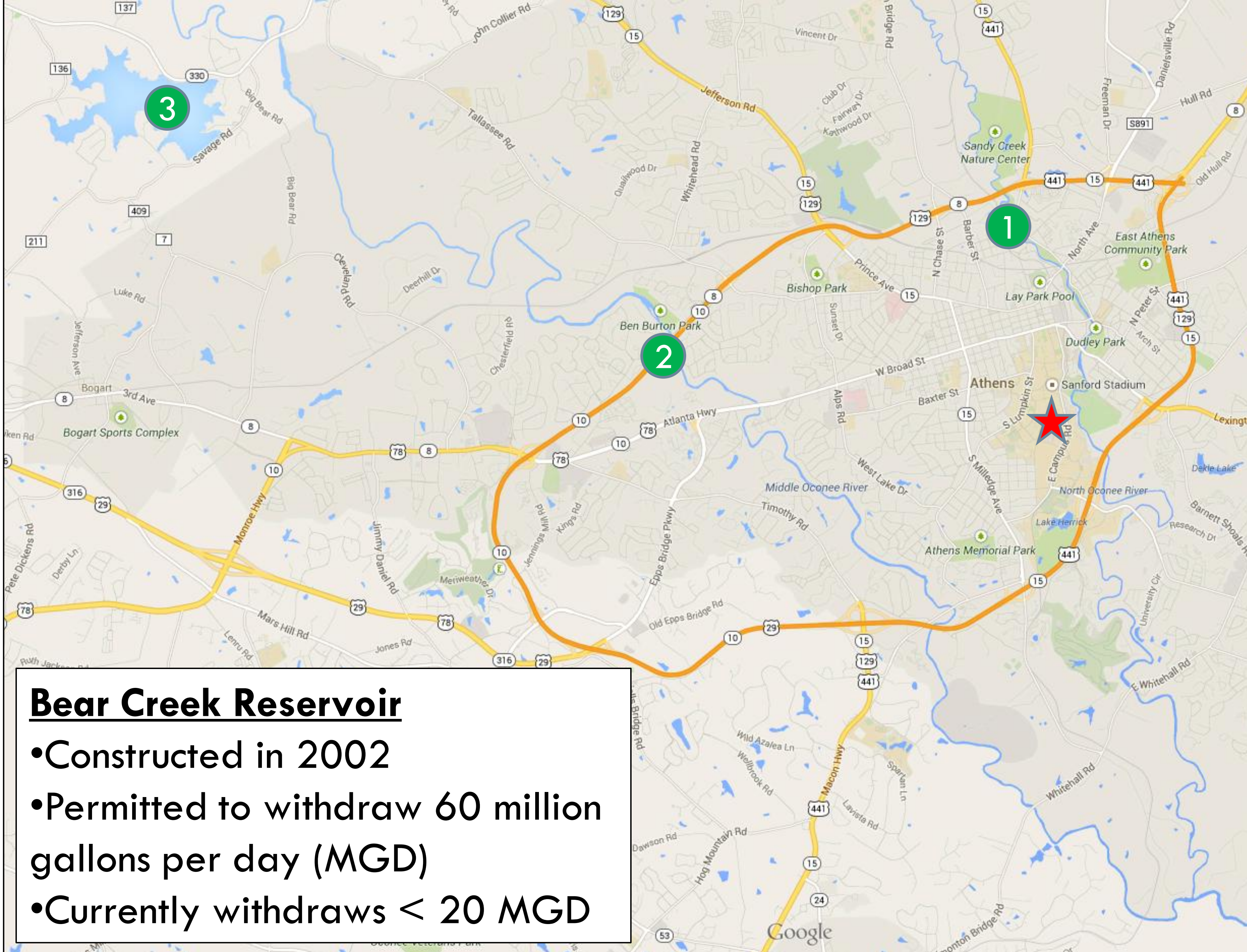
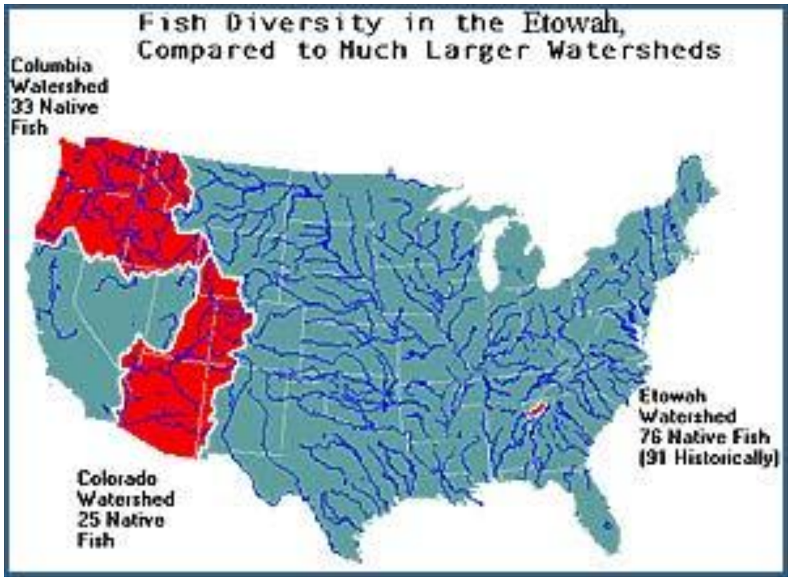
THE MIDDLE OCONEE RIVER



Bear Creek Reservoir

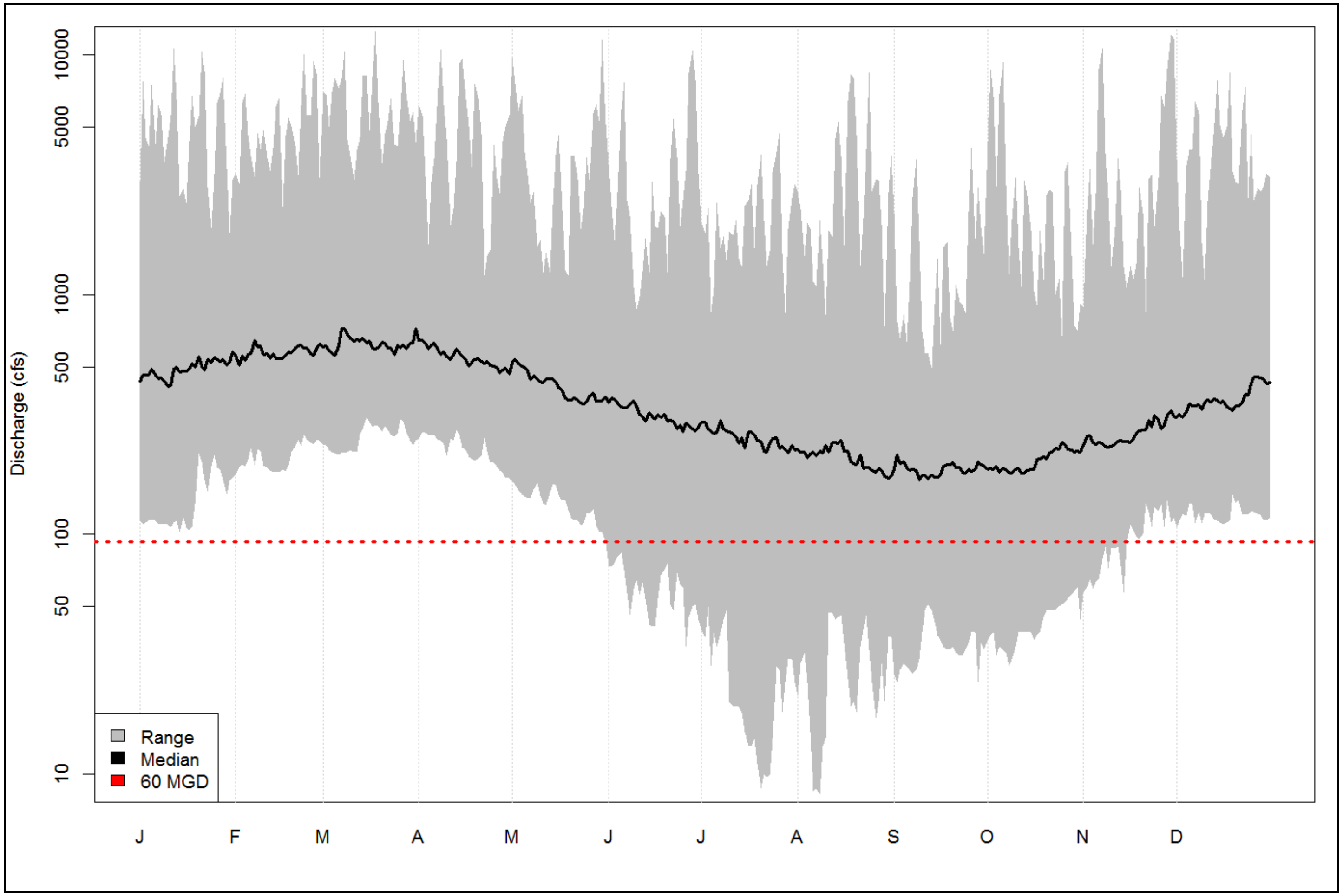
- Constructed in 2002
- Permitted to withdraw 60 million gallons per day (MGD)
- Currently withdraws < 20 MGD

An incredible ecosystem!

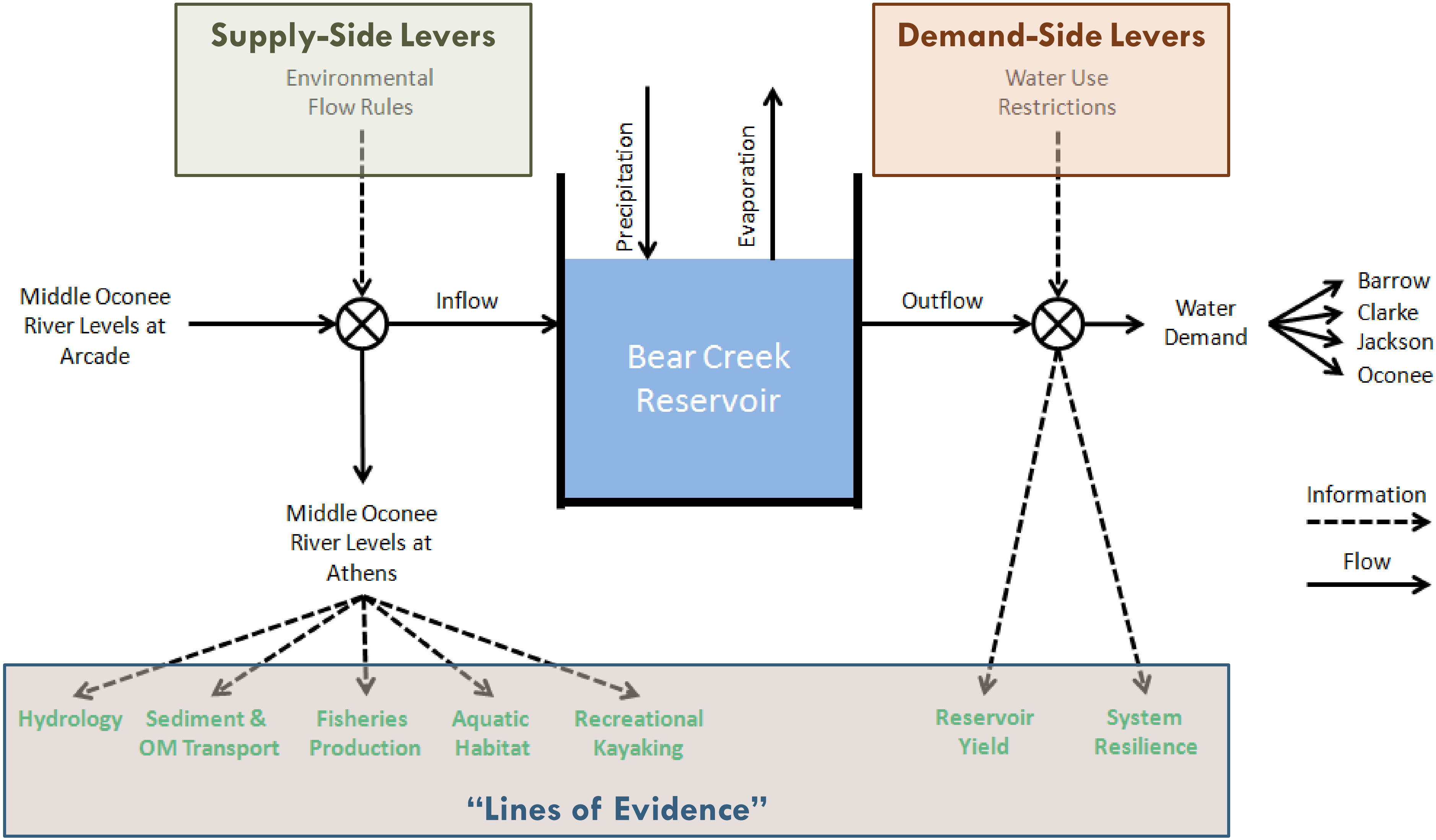


River Basin	Fish Species Richness
Colorado	25
Columbia	33
Etowah	76
Middle Oconee (Ben Burton Park only)	>20

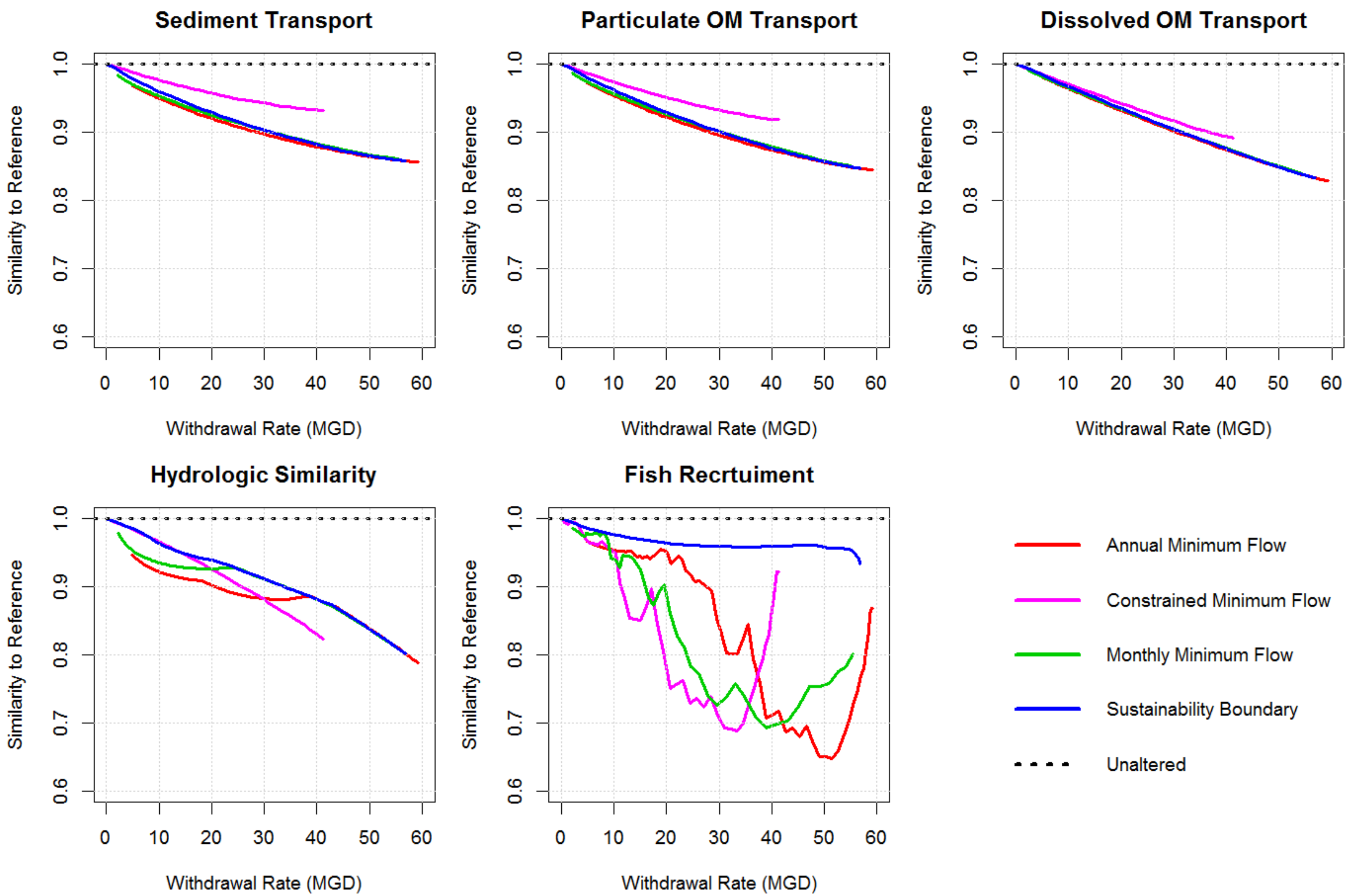
Do withdrawals have a substantial hydrologic effect?



Can we meet municipal water demand with less environmental impact?

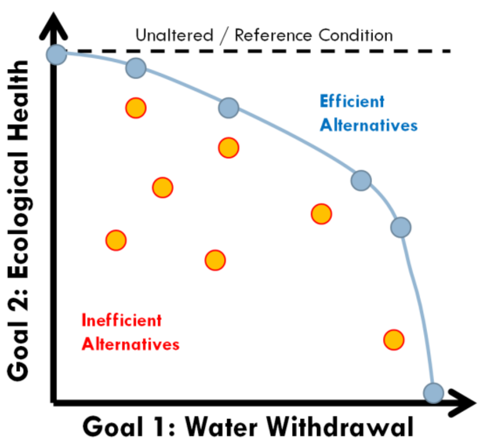


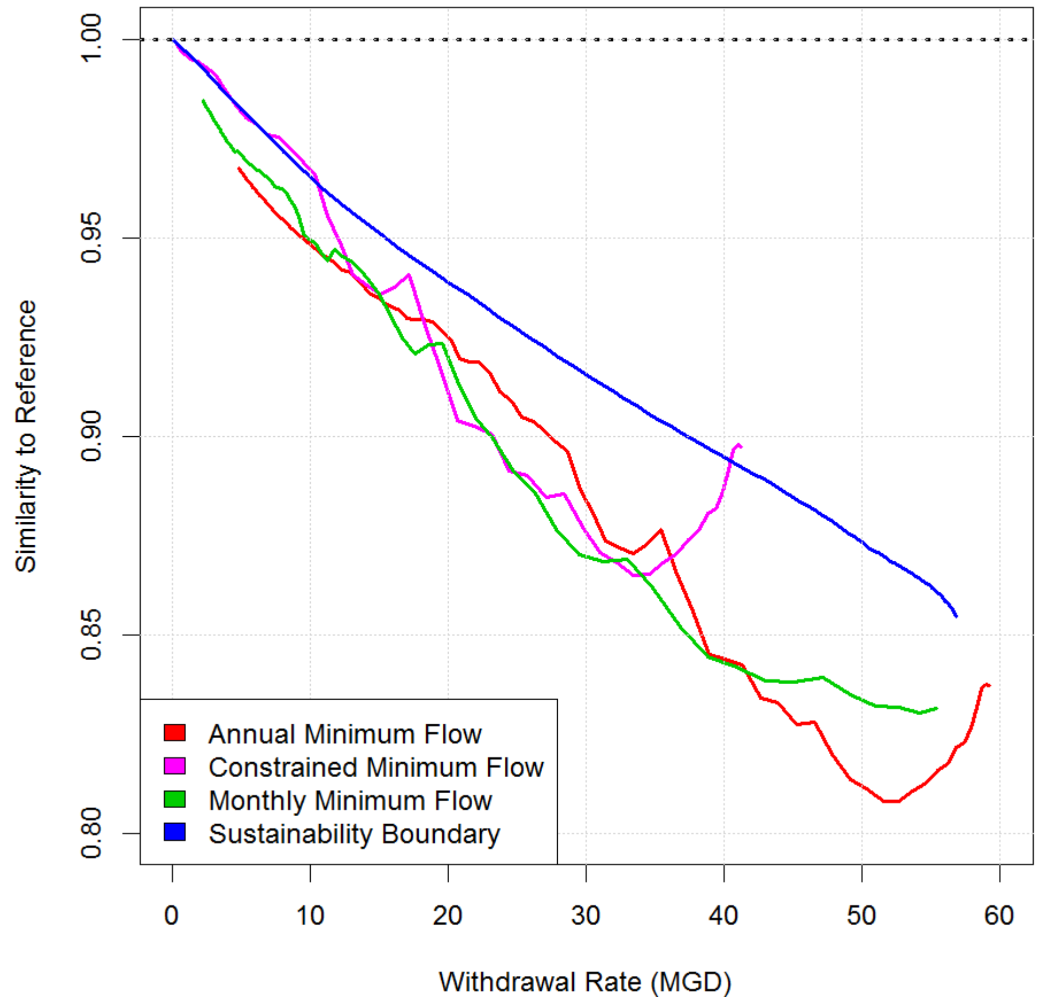
Trade-offs in the Middle Oconee



Trade-offs in the Middle Oconee

- Sustainability boundaries are consistently better relative to BOTH objectives
- Constrained minimum flows cannot obtain more than ~40 MGD
- Annual and monthly minimum flows perform similarly

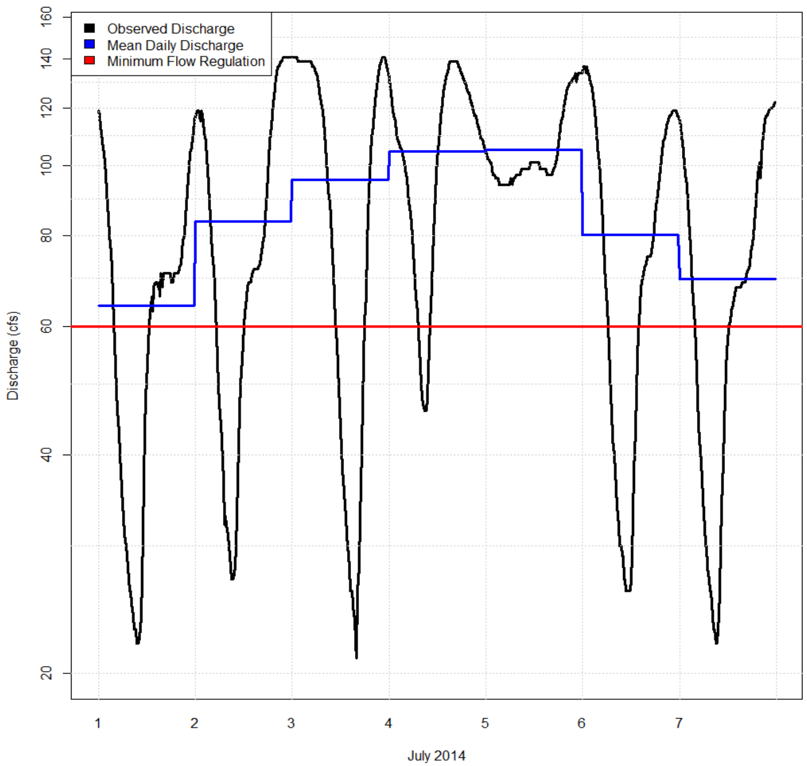




BURNING EFLOW CHALLENGES

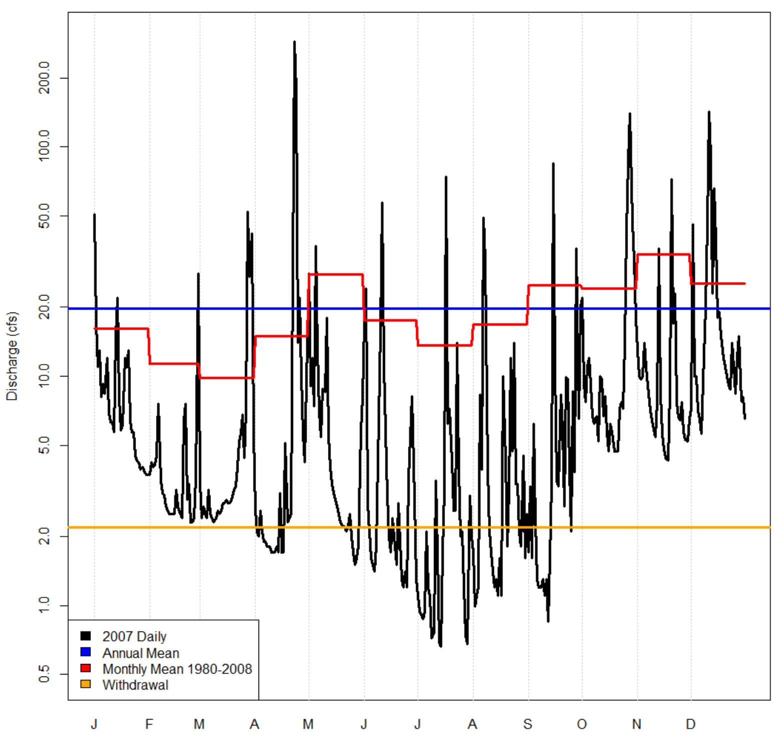
1 – Meaningless mean discharge

Within a Day



Oconee River near Penfield, Georgia

Within a Year



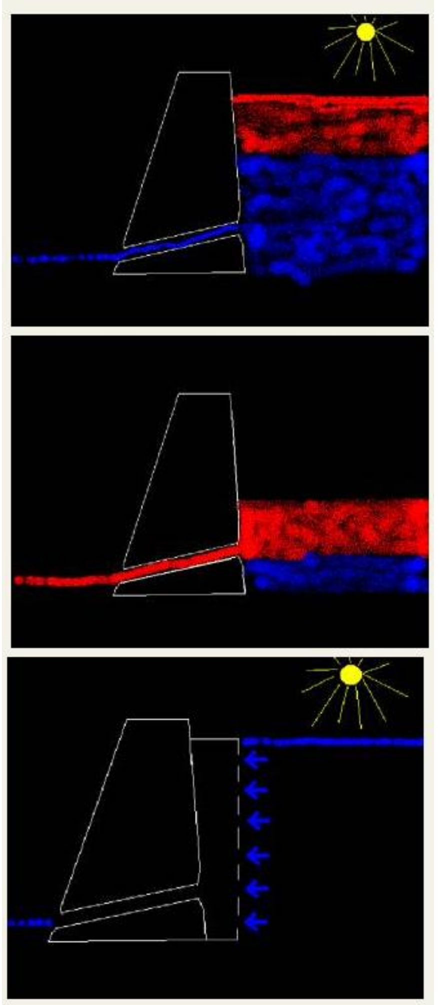
Rio Sabana near Sabana, Puerto Rico

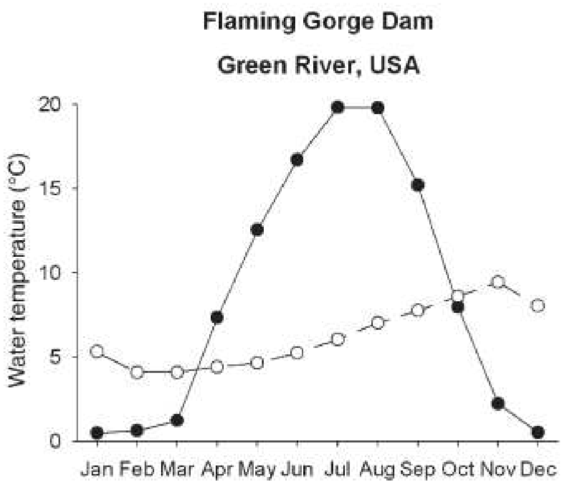
McKay (Submitted)

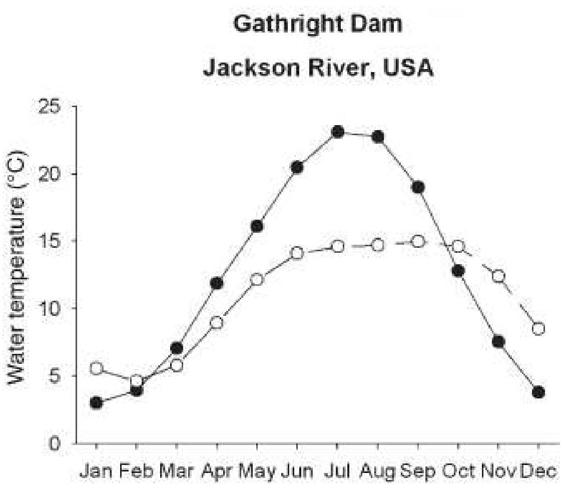
2 – Discharge is a lumped parameter

- We don't just manage flow!
  - Temperature, turbidity, carbon, wood, sediment,…
  - Structural options: Multi-level intakes, Reservoir warming towers, bypasses,…
  - Operational options: Sluicing, flow management…

USACE Cougar Reservoir, Oregon



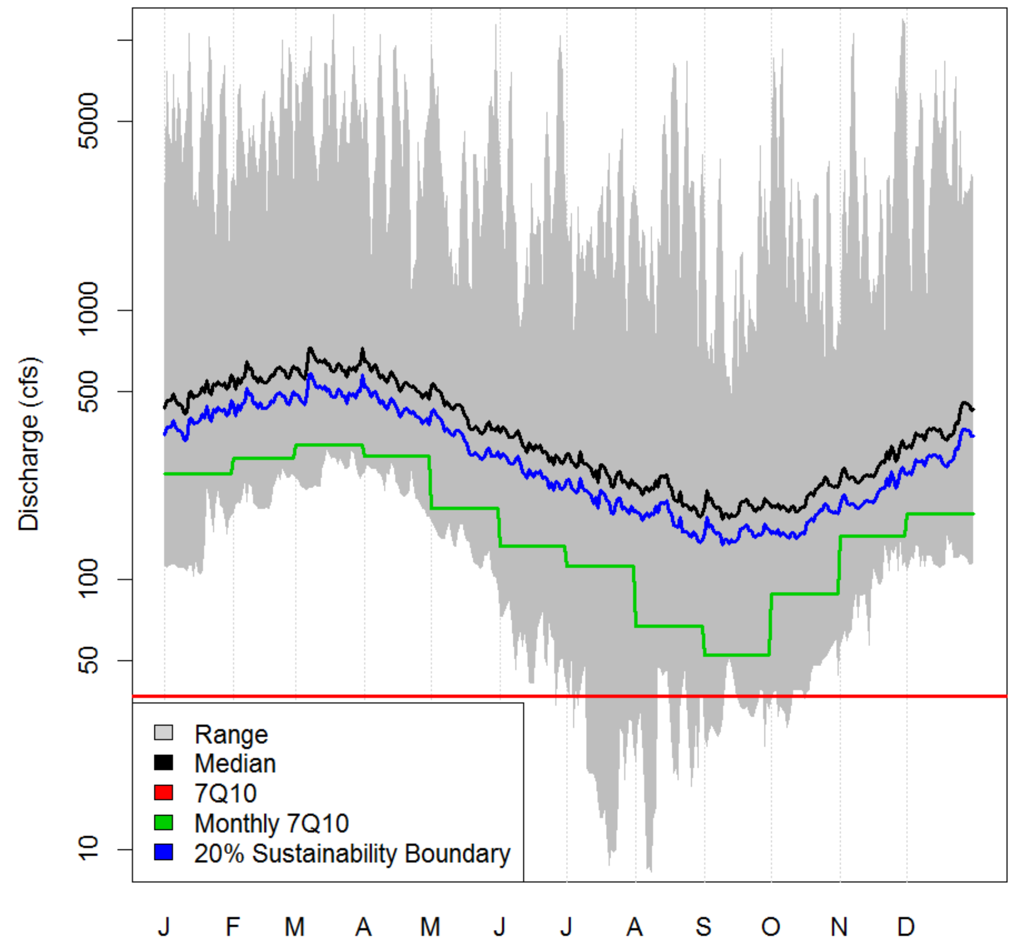




Olden and Naiman (2010)

3 – Minimum flows are minimal

- Do we want minimal ecosystems?
- Moving out quickly with incremental decision-making
  - Eflow analyses can take significant amounts of time
  - Need better "default" options
    - 7Q10 was design flow for wastewater!
  - "Sustainability boundary" provides a strong starting point



4 – More creative alternatives

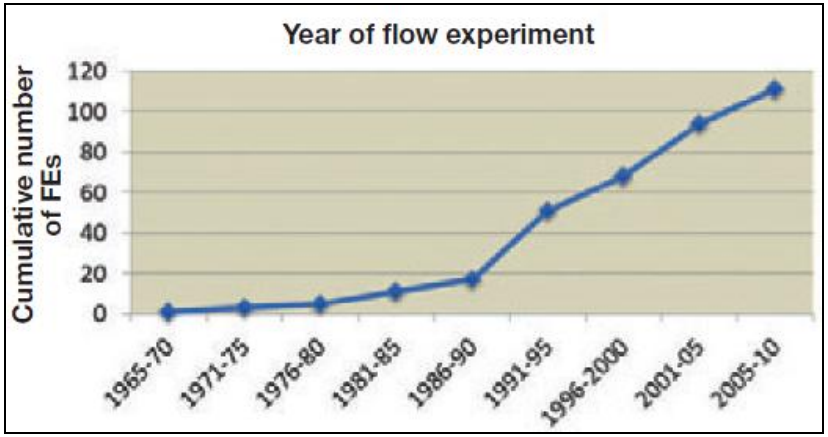
- Using storage for environmental purposes
  - TNC Green River approach
- Re-examining other reservoir purposes
- Creative structural alternatives
- Demand-side management
  - No demand, no need for supply.
  - Replacement of reservoir functions elsewhere?

5 – Governance & Decision Making

- Equity: Who's at the table? Who wins and loses?
- Decision authority: Legal, Funding, Power
- Trust: Communication, Buy-in
- How are objectives chosen, measured, weighted, and combined?
- How are trade-offs presented? When, where, and how much are you gaining (or losing)?

6 – Overcoming administrative hurdles

- Initiating environmental flow studies within a limited budget
  - National and regional prioritization of studies
  - Regional environmental flow assessments (e.g., ELOHA, HGM guidebooks)
- Water control manual updates
  - What can be done within the existing manuals?
  - Can we make manual update easier and more frequent?
- Instituting strong monitoring and adaptive management
  - Fostering an experimental attitude at USACE's "Living Laboratories" complete with hypothesis testing, monitoring, and adaptive management



Olden et al. (2014)