Monitoring Flow Alteration & Ecological Response to Inform Management

Potomac Large River Environmental Flow Needs Expert Workshop

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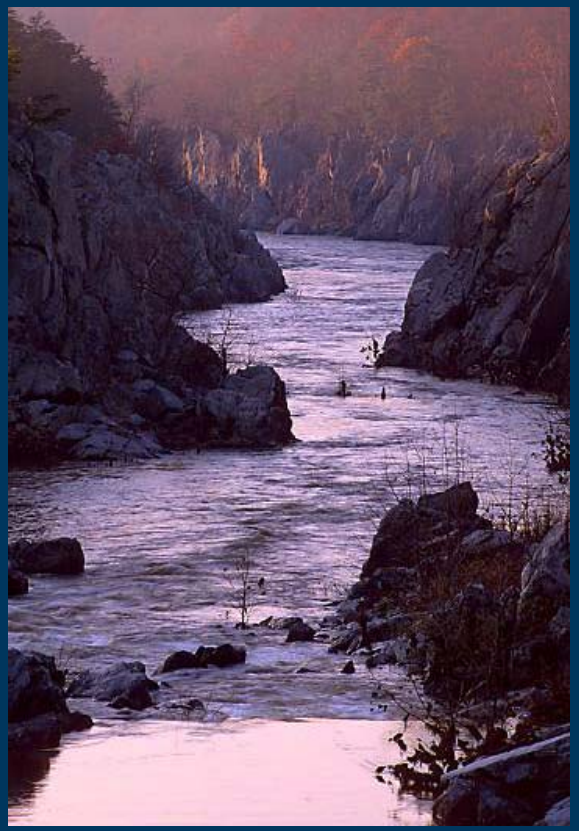
Monitoring for What?

- To fill an information gap on the relationships between flow alteration and ecological response, especially at low flows:
  - so that flow-ecology relationships and protective hydrologic ranges can be revised; and
  - to influence management actions

Challenge: to develop a ***hydroecological monitoring & research program*** that produces scientifically ***rigorous results*** that can be meaningfully interpreted and used to ***influence management decisions***

Potomac Context: Direct Management of Extreme Low Flows

Results of this workshop, and subsequent monitoring, can influence directly managed flows

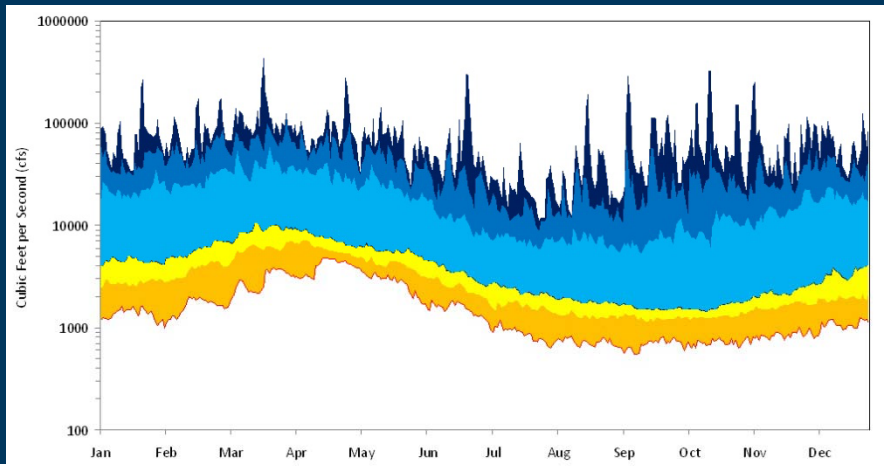


- **Extreme low flows** – infrequent & a result of complex balancing of demands from utilities, runoff, and storage in 5 reservoirs to meet two flow targets;
- 1999 & 2002 extreme low flow events with no obvious ecological stresses where sampling was done
- Earlier workshops noted a research need & desire to set aside resources to monitor short-term impacts
- Controlled experiment may be unrealistic, given travel time and limited storage in reservoirs
- Targeted research/assessment would be valuable
- "Learning by doing" through monitoring is possible
- Funding is a continuing concern

Potomac Context: Largely Intact Flows, Diffusely Managed

Much of the flow regime is intact and diffusely managed

- Future flow changes due to additional surface & groundwater water withdrawals on tributaries, land use change, etc
- Monitoring to detect future ecological impacts of flow changes
  - Requires monitoring of other stressors (e.g., water quality, sedimentation)
  - Could be equivalent to a water quality monitoring framework for flow-influencing stormwater management, withdrawal permitting, etc.



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Sustainable Rivers Project

Current Sites

US Army Corps of Engineers

Legend

- Sustainable Rivers Project sites
- ACOE Divisions
- ACOE Districts

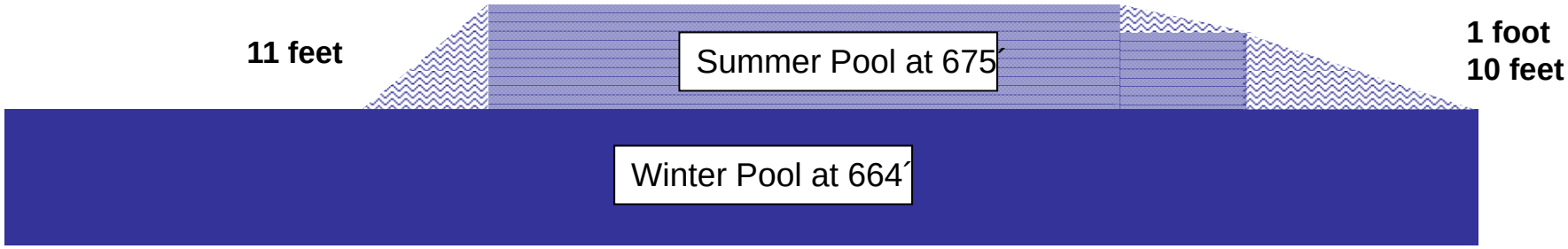
Re-Operation of the Green River Dam

A Collaborative Project between the Louisville District and TNC

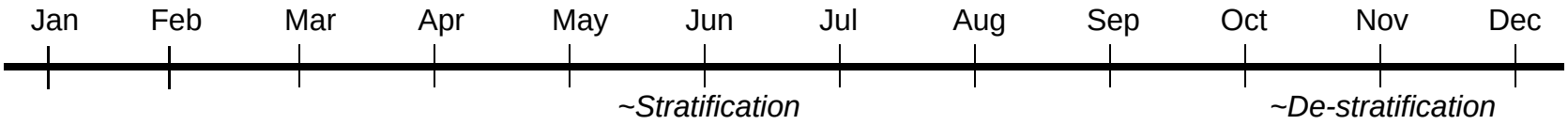
Green River, Kentucky

- 60 species of freshwater mussels
  - 21 imperiled
  - 7 endangered (federal)
- 151 fish species
  - 7 endemic
  - 12 globally rare
- Mammoth Cave Complex

Green River Dam



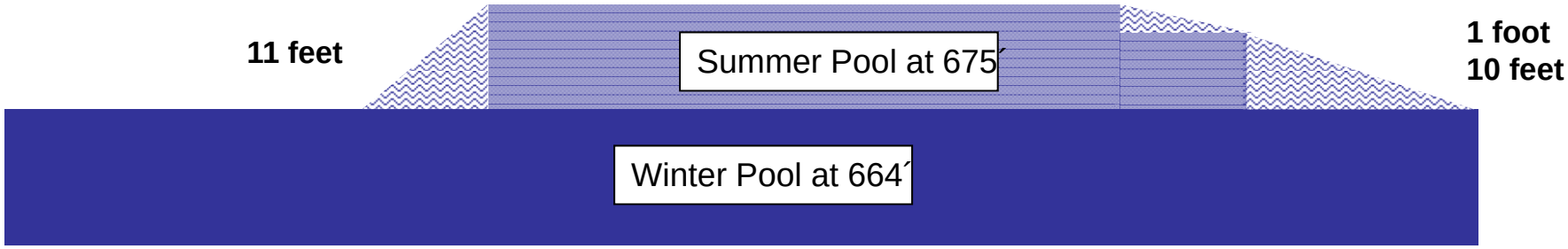
Historic Operation



- Spring spawning (fish and mussel)
- emergence of flying adult aquatic insects
- channel structure and substrate

- Fall spawning (fish and mussel)
- concentration of prey species

Green River Dam



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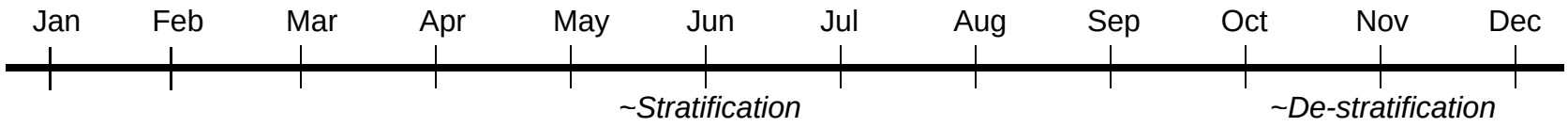

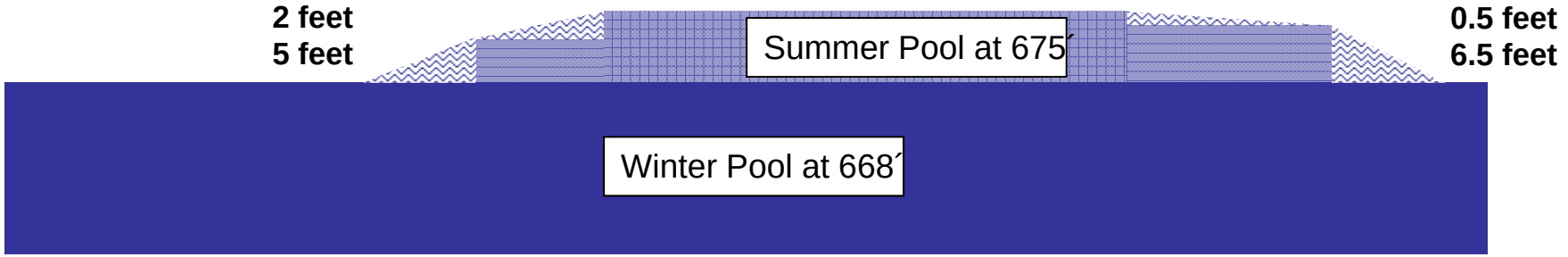

Re- Operation

Varied release rates

E-flow Monitoring on the Green River

Release	Dates implemented	Monitoring targets	Results
Green River			
Delayed reservoir drawdown Increased flood pool elevation Increased maximum release rate Extended refill period	Water years 2002-through 2008	Mussel recruitment and brooding	Rates of gravidity, fecundity, and fertilization increases downstream with distance from dam and are generally lower than in other rivers (Moles and Layzer, 2008)
		Invertebrate diversity	Invertebrate diversity increases downstream with distance from dam but did not change between 2000 and 2002 (McMurray and Schuster, undated)
		Invertebrate production	Invertebrate production increases downstream with distance from dam but did not change consistently between 2000 and 2002 (Summers, 2004)
		Fish diversity	Fish diversity and abundance decreased from 2000 to 2004 (Thomas et al., 2004; Lienesch, 2008) likely due to naturally higher flows; fish diversity decreased longitudinally downstream of the dam in 2000 but not in 2004 when diversity was lower at all sites.

E-flow Monitoring on the Green River

Release	Dates implemented	Monitoring targets	Results
Green River			
Delayed reservoir drawdown Increased flood pool elevation Increased maximum release rate Extended refill period	Water years 2002-through 2008	Mussel recruitment and brooding	**Increase in recruitment of 2- year old mussels: Rates of gravidity, fecundity, and fertilization increases downstream with distance from dam and are generally lower than in other rivers (Moles and Layzer, 2008)**
		Invertebrate diversity	Invertebrate diversity increases downstream with distance from dam but did not change between 2000 and 2002 (McMurray and Schuster, undated)
		Invertebrate production	**Invertebrate production increases downstream with distance from dam but did not change consistently between 2000 and 2002 (Summers, 2004)**
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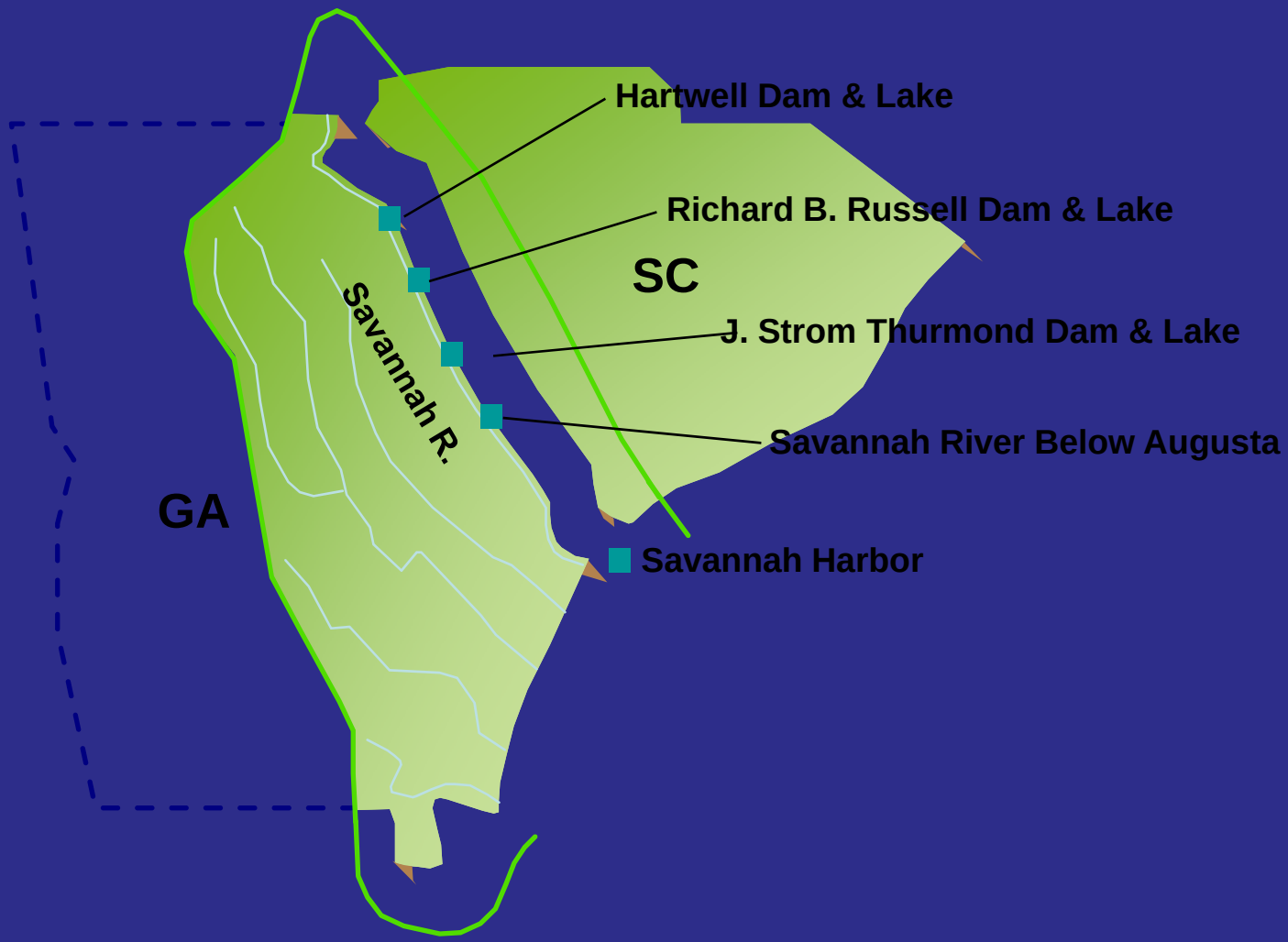
Savannah River Basin



Measuring impacts at SRP sites: A Synthesis (Konrad et al, in review)

Release	Dates implemented	Monitoring targets	Results
Savannah River			
High flow pulse with maximum daily streamflow 419 cms[1]	15-19 March 2004		None
High flow pulse with maximum daily streamflow of 544 cms[1]	16-20 March 2005	Fish and invertebrate use of floodplain	Mosquitofish, sunfish, and bullheads used floodplain and feed on invertebrates commonly inhabitating the floodplain (Wrona et al., 2007)
High flow pulse with maximum daily streamflow of 765 cms[1]	**20-25 March 2006**	Floodplain inundation**; fish and invertebrate use of floodplain; short nosed sturgeon movement; salinity gradient in estuary**	See above for results on floodplain use**; short nosed sturgeon migrated out of river during pulse; interface between freshwater and salt water was displaced about 4 km downstream for 10 days beginning about 7 days after the release (Wrona et al., 2007)**
Low flows and high flow pulses	Water year 2005 Water year 2006	Spider Lily flowers and seedlings Water quality parameters, floodplain tree diversity and seedling establishment; groundwater elevations in floodplain	Lilies were inundated during flowering in 2005 (Wrona et al., 2007 Temperature and conductivity generally increase in the downstream direction, water temperatures dropped by about 5 degrees C during the high flow pulse; germination of floodplain tree species; herbivory by deer suppresses spider lily reproduction; (Wrona et al., 2007)


Bill Williams
River, Arizona

Measuring impacts at SRP sites: A Synthesis (Konrad et al, in review)

Release	Dates implemented	Monitoring targets	Results
Bill Williams River			
High flow pulse with maximum daily streamflow of 56 cms[2]	12 March-8 April 2006	Hydraulic conditions, groundwater levels; woody vegetation seedling establishment; beaver dam persistence	High flow pulses increase the relative density of Salix due to selective removal of smaller Tamarix seedings; **50 cms is needed to remove beaver dams** (Shafroth et al., 2009)
High flow pulse with maximum daily streamflow of 14 cms[1]	9-11 April 2007	Hydraulic conditions, groundwater levels; woody vegetation seedling establishment; **beaver dam persistence**; invertebrate assemblage structure	**Lower magnitude high flow pulses can breach beaver dams** (Andersen and Shafroth, 2008); invertebrate taxa responses depend on taxa life history, morphology, and behavioral traits (Shafroth et al., 2009)
High flow pulse with maximum daily streamflow of 27 cms[2]	31 March-1April 2008	Hydraulic conditions; groundwater levels, woody vegetation seedling establishment; beaver dam persistence; invertebrate assemblage structure; fish diversity	Continued monitoring of responses in terms of hydraulic conditions, riparian vegetation, invertebrates, and fishes (A. Hautzinger, per. comm.)

Lessons from the TNC-Army Corps Sustainable Rivers Project

The Sustainable Rivers Project illustrates examples of theoretically sound but pragmatic approaches to measuring impacts of dam re-operation.

Outcomes of flow manipulations can be transient, lagged, and spatially variable because of other factors - when and where you measure matters.

No simple, prescriptive approach to guide how sites should measure impacts because of differences in strategies, objectives, and ecosystems.

Environmental Flows Monitoring & Assessment Framework

Question: How can we structure our thinking about environmental flow monitoring & assessment in the Potomac?

Answer: Borrow from folks much worse off than us

- Cottingham et al (2005) provides a useful framework based on work on Australian e-flows

Environmental Flows Monitoring & Assessment Framework

Step 1: Define the Scope of the Program and its Objectives

- *The summary report and this workshop provide us a strong foundation*

Step 2: Define the conceptual understanding of flow–ecology relationships and the questions (hypotheses) to be tested

- *The environmental flow needs report and Day 1 have advanced this significantly*

Environmental Flows Monitoring & Assessment Framework

Step 3: Select variables to be monitored

- *Requires Workshop input and consideration of current baseline work using selection criteria*

Current Baseline and Monitoring:

- Fish communities-- large river assessment (not yet available), state data, game fish in mainstem
- Riparian plants– NPS-TNC Gorge assessment
- Benthic macroinvertebrates – MD core Hester-Dendy stations
- Mussels-- Lack of coverage & quantitative sampling
- Habitat/Geomorphology– very limited

Monitoring & Assessment Framework: Selecting Variables

Criteria for Variable Selection (Watts et al, 2001 & Cottingham et al 2005)

- responsive to changes in flow at spatial and temporal scales relevant to river management
- responsive within the timeframe of the project funders and managers
- have scientific justification
- represent important structural and/or functional component of the riverine ecosystem
- easily measured and quantitative
- responses easy to interpret
- can determine and measure directions of change
- respond differently to background variability
- cost-effectiveness
- relevant to policy and management needs
- cover a range of habitats and trophic levels, range of organizational levels
- linked to flow-ecology hypotheses

Environmental Flows Monitoring & Assessment Framework

Step 4: Determine the study design, accounting for the specific activities and location

- Should be informed by this Workshop
- Focus on developing causal links between e-flows and ecological response, allowing us to refine (or even reject) hypotheses
- Location = river section relevant to e-flow objective or key taxa
- Consider how monitoring can relate/overlap with other Potomac monitoring needs (water quality, indicators of connectivity, EPA Healthy Watersheds)
- The use of control or reference locations is desirable, but often will not be available

Environmental Flows Monitoring & Assessment Framework

Step 5: Optimize the study design and identify how data are to be analyzed

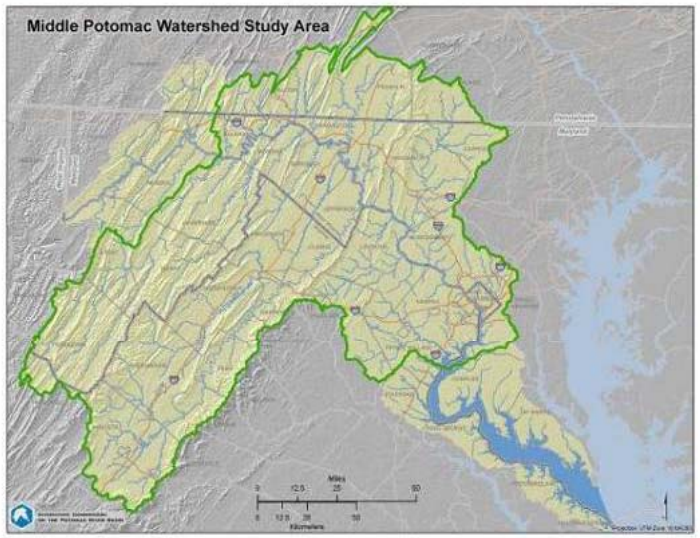
To take place, budget willing, at a follow up stakeholder workshop, considering:

- Natural range of variability of proposed variables & the effect size required
- Whether a pilot study could establish the feasibility of monitoring sites and the variability & suitability of variables to be measured
- Sites, duration, spatial variation, frequency of sampling, etc.
- Funding and potential phasing (a federal-state-NGO collaborative effort seems most likely to have success)

Environmental Flows Monitoring & Assessment Framework

Step 6: Implement the Study Design

- Assess whether environmental flows are meeting ecological objectives (in particular for extreme low flows)
- review the conceptual understanding and hypotheses in an adaptive management context
- inform the definition of quantitative protective hydrologic ranges and any relevant state policy



Monitoring to Refine Flow Recommendations: Breakout Groups

- Flow ecology-relationships emerging from this Workshop are not perfect, due to lack of data that strongly links ecological needs to flow alterations. Monitoring and targeted research can narrow that uncertainty over time

- Opportunity to inform an ecological flow-focused large river monitoring program to serve as an early warning system to support water allocation, dam management, and land management decisions

- May be useful to think of monitoring related to level of management control
  - Directly managed flows
  - Diffusely managed flows

Monitoring to Refine Flow Recommendations: Breakout Groups

You will be divided into two concurrent breakout discussions to discuss monitoring of:

- Flow sensitive taxa, life stages, and habitats; in relation to
- Emerging priority flow statistics

- Use Monitoring variable selection criteria to help prioritize which key taxa, life cycle, or processes should be monitored based on identification of emerging priority flow statistics

- Also consider research or assessment projects that may be critical to inform future management (e.g. habitat assessment in the reach below Little Falls)

Breakout Group Instructions

Season	*Flow Component (prioritize lows for starting the discussion)*	*Emerging Priority Flow Statistic to be monitored (our key outcome from Day 1)*	*Taxa Affected (species or group(s), and associated key flow hypothesis)*	Key taxa, life cycle or process to be monitored [this will be filled in by workshop participants during the breakout discussion]	Priority Locations for Monitoring (reaches or sub-basins)	Other abiotic factors that require monitoring associated with this taxa or flow statistic (e.g., water quality, groundwater withdrawals)	Cost Resource neutral --available through current monitoring Requires 100s, 1000s, 10,000s, or 100,000s to accomplish?

- Are there any "must monitor" species, which people are most concerned with - economic, keystone, or other particularly significant species that society doesn't want to see lost?

- Biota to think about:
  - Mussels – distribution, composition, density, stress
  - Invertebrates – communities using traits or indices that may be sensitive to flow?
  - Fish- communities with focus on habitat guilds (e.g., fluvial specialists)?
  - See page 77 of report

- What are the abiotic factors (or other stressors) that must be monitored to attempt to sort out flow-ecology causal links?