Environmental Flows in River Basin Management: Methodologies for Assessment

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Outline

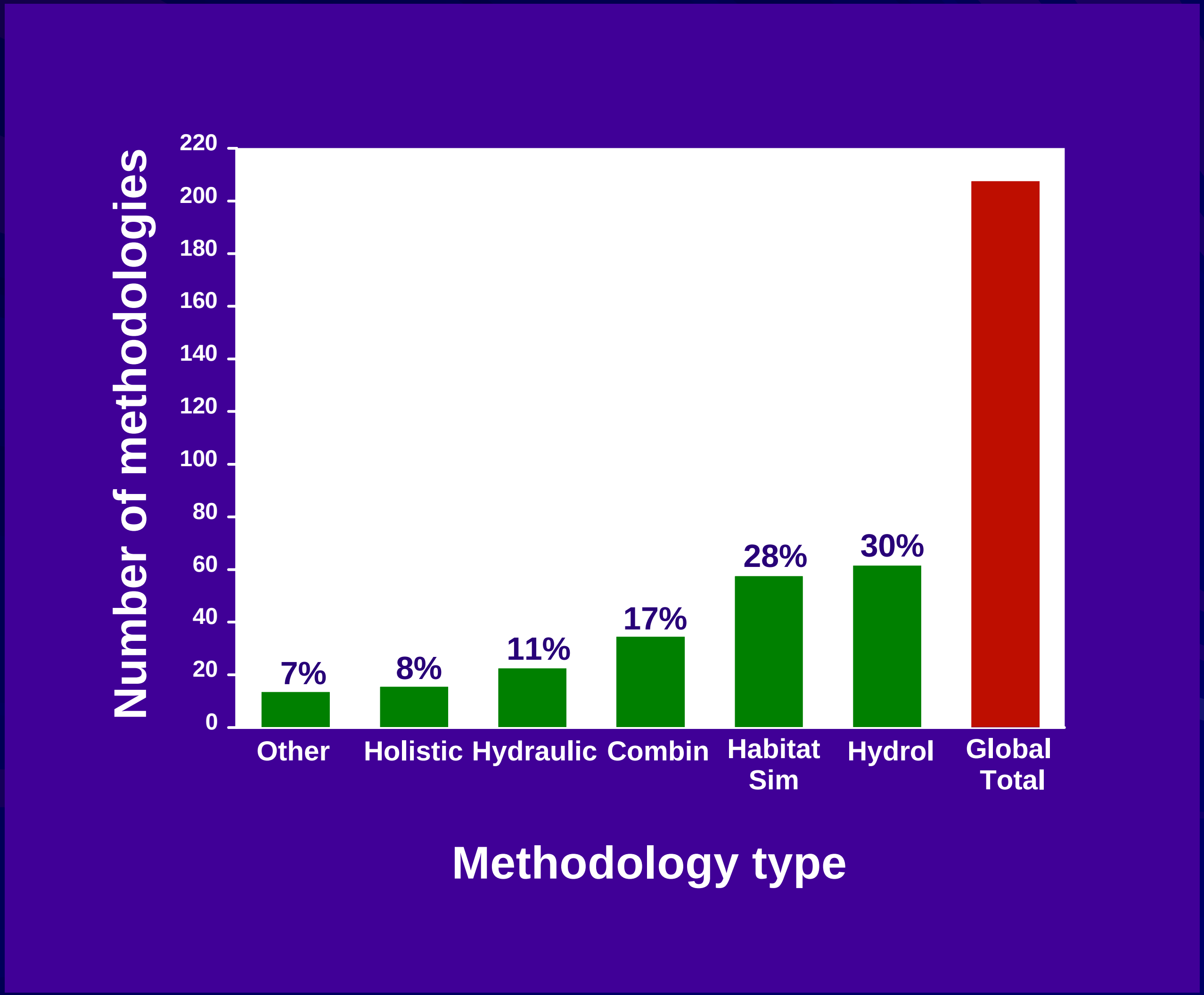
- **Environmental flow determination**
  - ➢ Broad considerations
  - ➢ Hierarchy for methodology application
  - ➢ Examples of types of methodologies
  - ➢ Strengths and limitations

- **Environmental flow implementation**
  - ➢ IWRM and RBM context
  - ➢ Factors for successful strategy
  - ➢ Policy toolbox

Broad considerations

- Societal vision and objectives for region/catchment and future condition of river(s)
- Ecosystem importance (ecological, social), current status, resilience
- Basin flow management – integration with land management
- Social dependencies and value for people - ecosystem services for livelihoods
- Basin context - highly regulated (closed) to undeveloped (open)
- Water governance - national policies provide guiding frameworks - but implementation at catchment level
- Capacity – institutional, technical

Methodologies to support environmental flow management



(Tharme 2003)

Hierarchical application of methodologies

1. **Planning / Reconnaissance Level**
   Hydrology-based
   planning estimates, regional analyses, low priority systems

2. **Intermediate or Comprehensive Level**
   (a) Habitat simulation
   (b) Holistic
   high priority systems, allocation tradeoffs

(1) Planning level hydrological methodologies: strengths and deficiencies

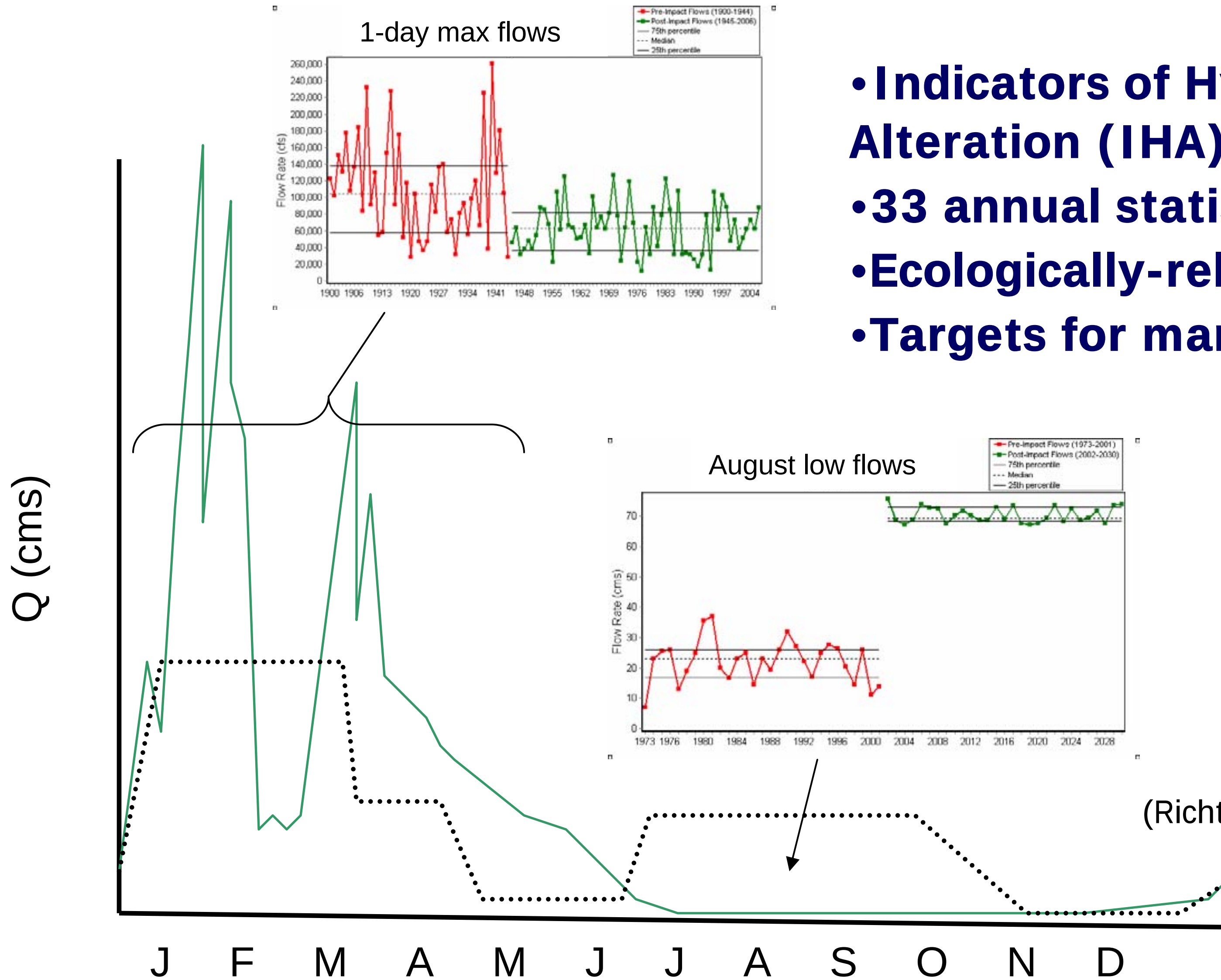
- Simple, rapid, inexpensive
- Low data needs (desktop), primarily flow data
- Suitable for water resource planning
- Potential for regionalization for different river ecotypes
- *Simplistic, inflexible, low confidence and resolution*
- *Dynamic nature of flow regime seldom addressed*
- *Unsuitable for high profile, negotiated cases*
- *Ecological links weak* - recent advances in ecological relevance of flow indices used to set flow targets

Evolution of holistic approach to environmental flows

- Flow as key driver of ecosystem – "natural flow paradigm" (Poff *et al*. 1997)
- Hydrological variability
  - Magnitude
  - Frequency
  - Duration
  - Timing
  - Rate of change

- Shift from *minimum* flow to flow regime

Range of Variability Analysis

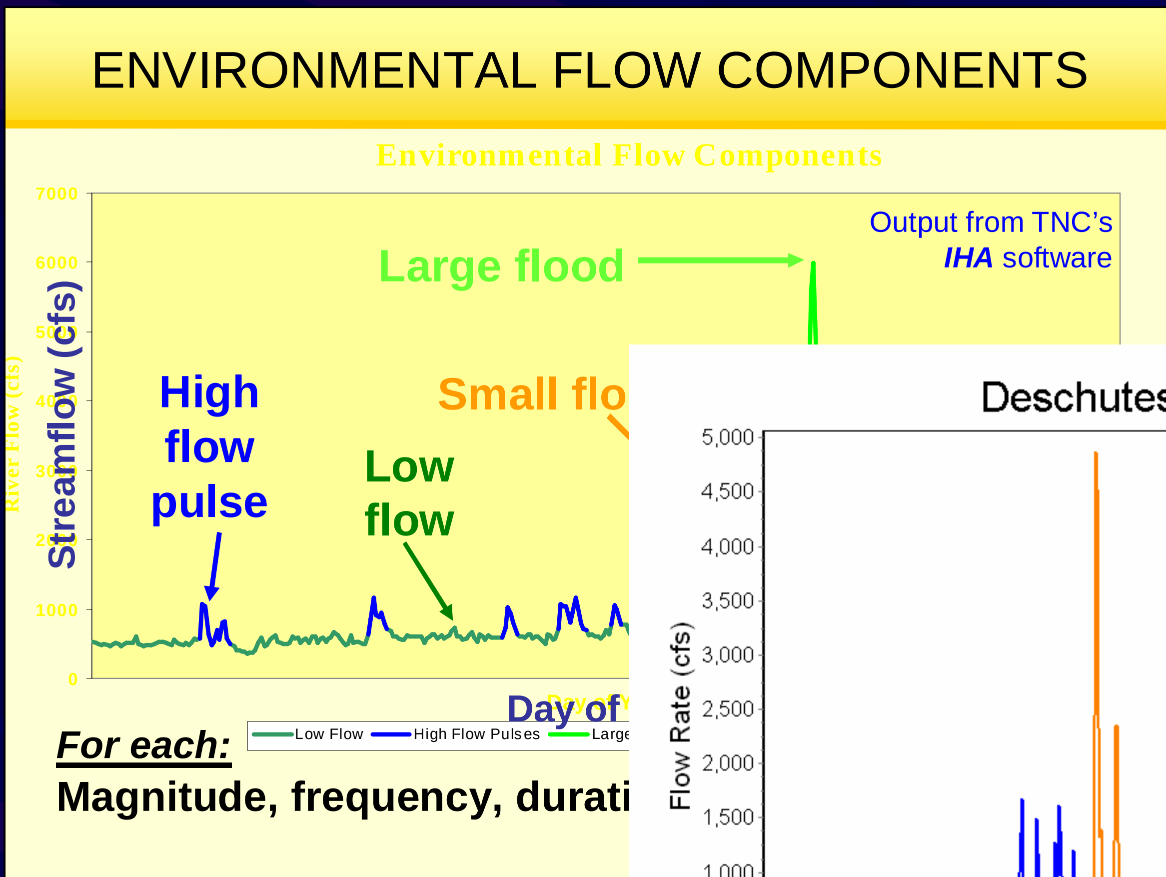


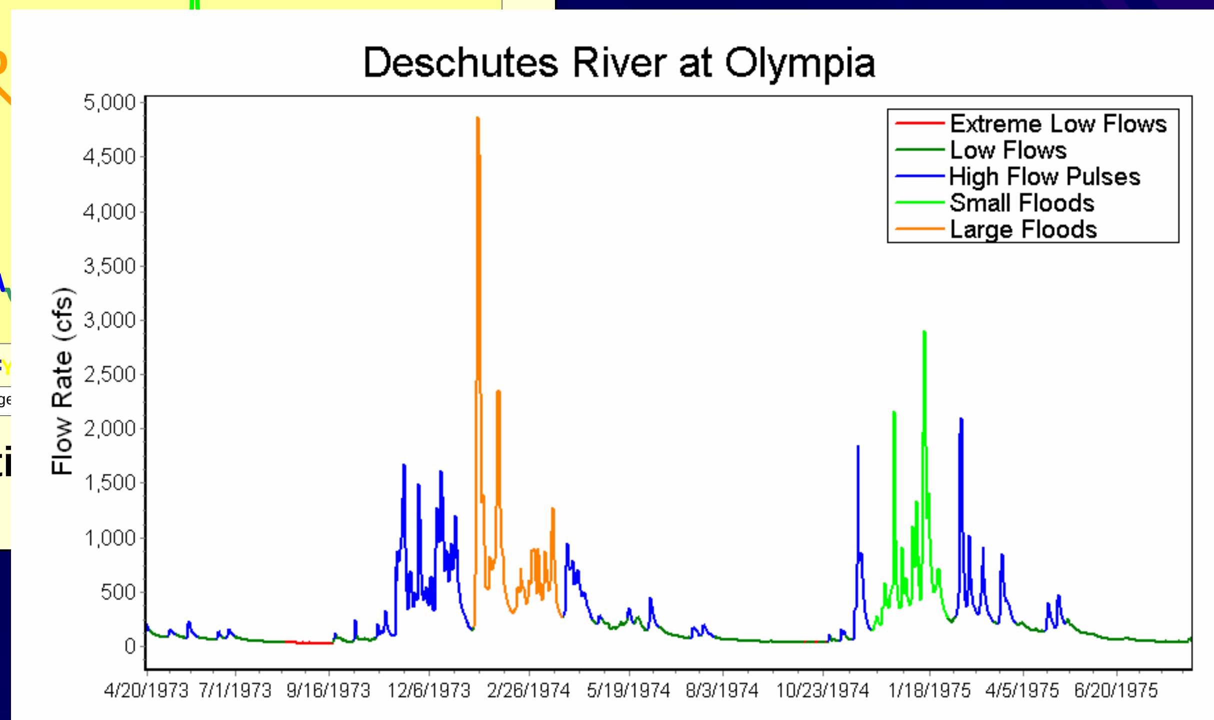
- Indicators of Hydrologic Alteration (IHA) software
- 33 annual statistics
- Ecologically-relevant
- Targets for management

(Richter *et al.* 1996, 1997)

Natural hydrograph ——— **Regulated hydrograph** ....

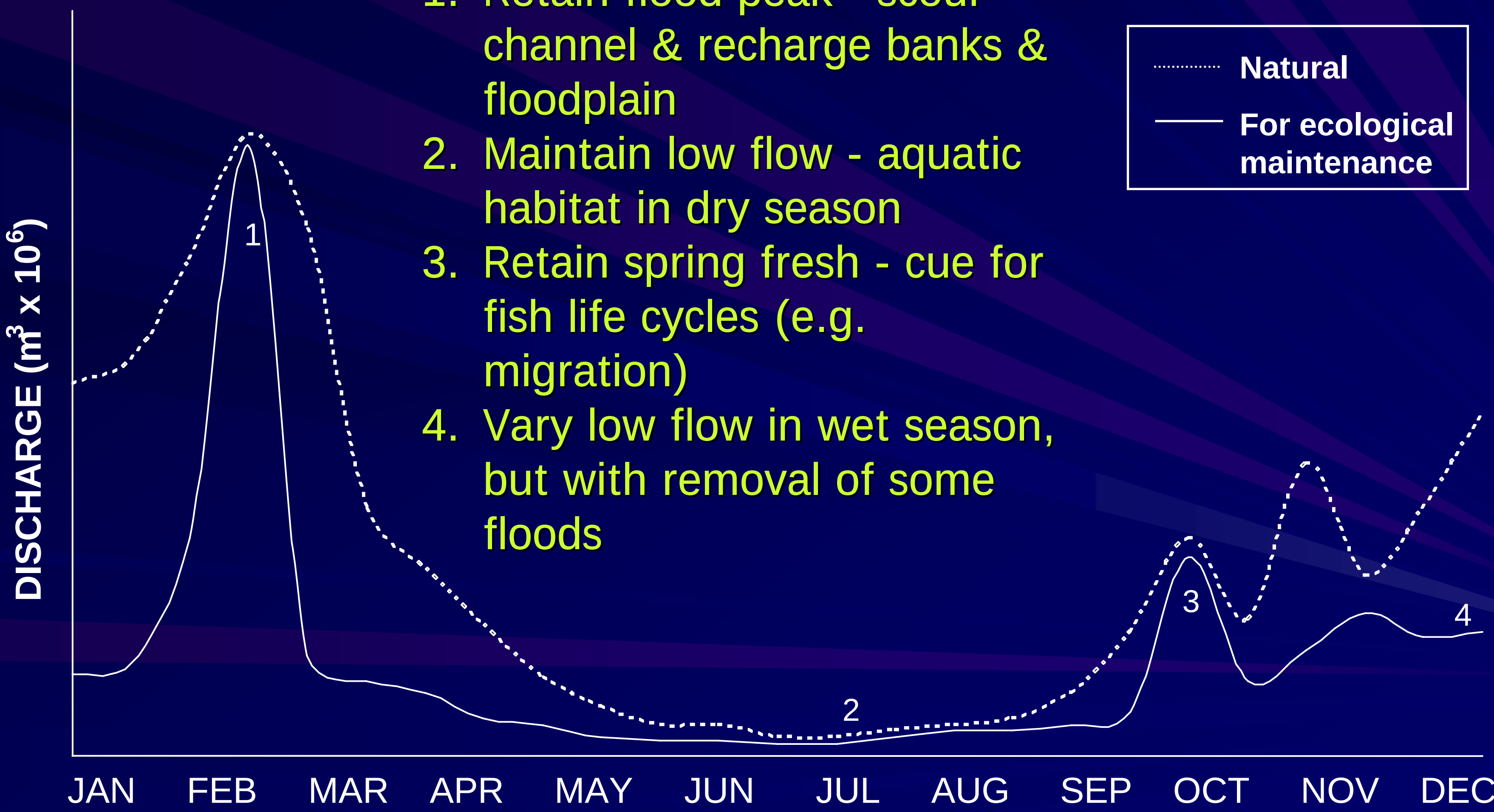
Environmental Flow Components
34 additional flow statistics





(2) Intermediate/Comprehensive level methodologies: Holistic type

1. Retain flood peak - scour channel & recharge banks & floodplain
2. Maintain low flow - aquatic habitat in dry season
3. Retain spring fresh - cue for fish life cycles (e.g. migration)
4. Vary low flow in wet season, but with removal of some floods



Specialists for inter-disciplinary expert panel

River flow	surface & groundwater hydrology, hydraulics, water resources modelling, climate change
Channel form	geomorphology, sedimentology, land use
Biota	vegetation, fish, invertebrates, frogs, reptiles, mammals, birds
Water quality	chemistry, microbiology
Subsistence users	sociology, anthropology, water supply, public health, animal health
Economics	resource economist, macro-economist
Process	co-ordinator, international mentor

Construction of e-flow regime: ecological and social motivations (e.g. BBM)

e.g. BBM site, Sabie River FEBRUARY

LOW FLOW

2.2 $m^3 s^{-1}$; 1.04 m

Geomorph:

- Increase riffle biotopes

Fish:

- Provide access to nursery areas i.e. marginal veg., NB for cyprininds, *Serranochromis*

Inverts:

- Provide natural biotope diversity

HIGHER FLOWS

15.0 $m^3 s^{-1}$; 1.58 m; 10 days; 1:1 ARI

Geomorph:

- Provide scouring of active channel

Rip. Veg.

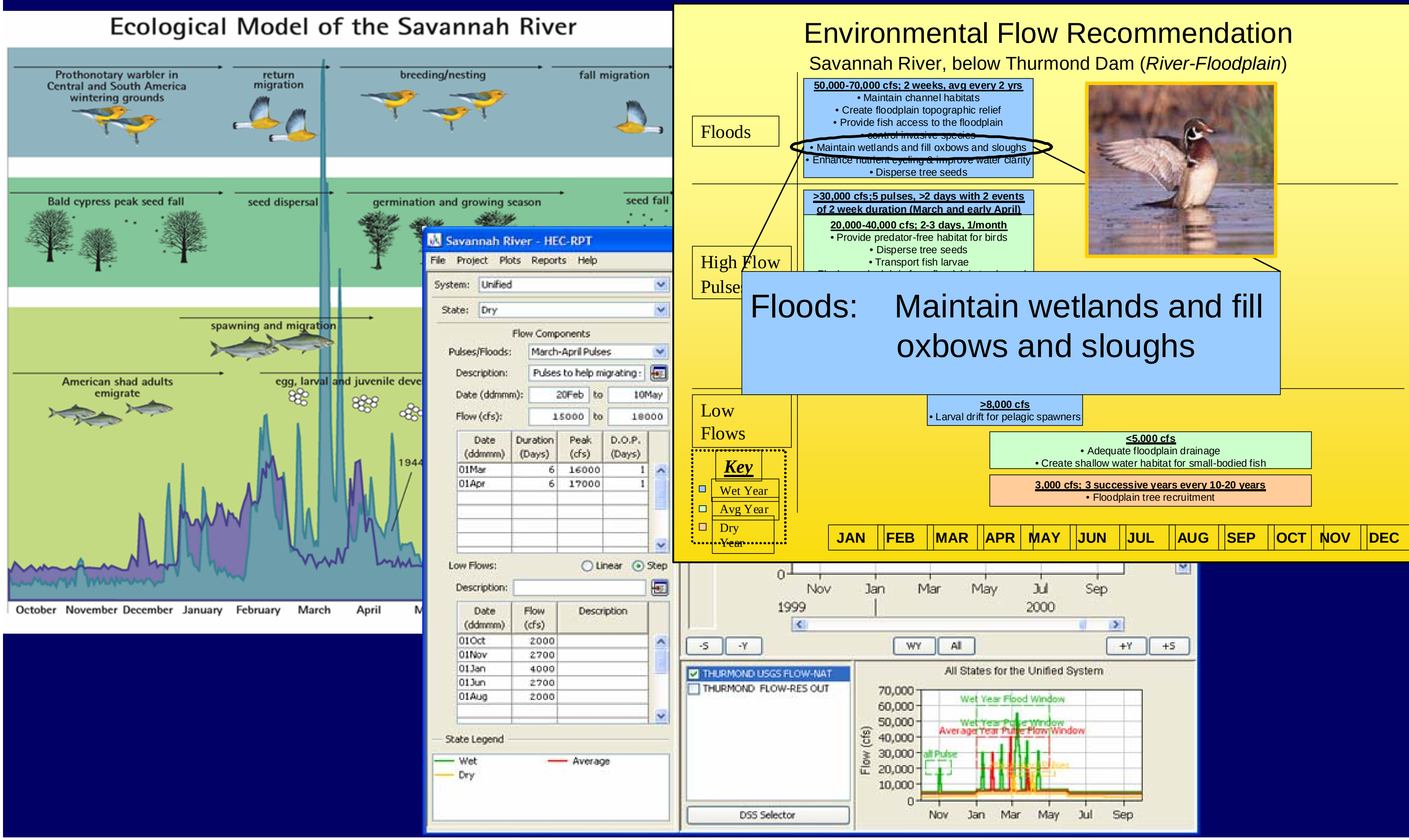
- Activate wide range of seasonal & perennial channels, maintaining all associated veg.

Fish:

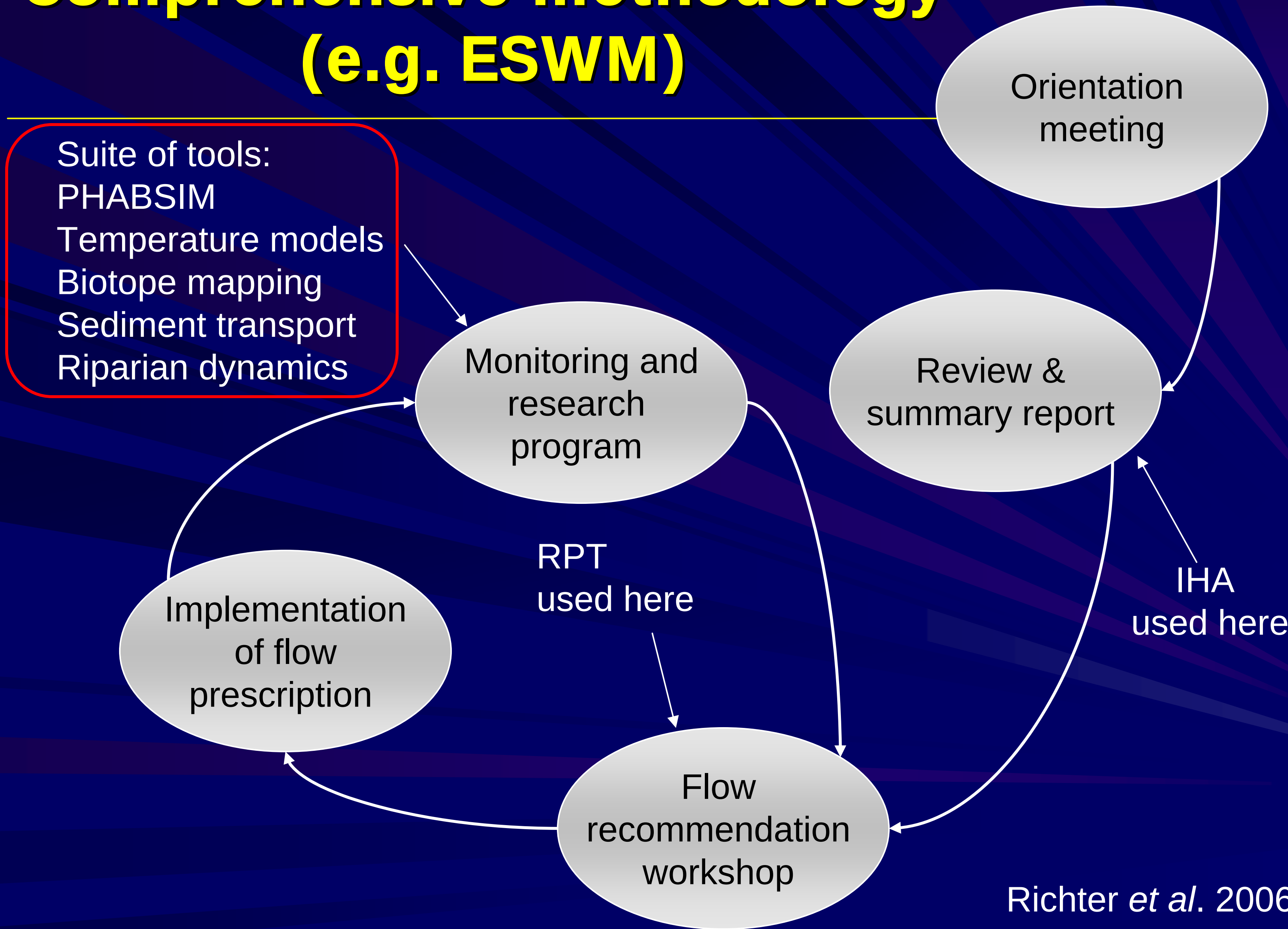
- Provide spawning cues for large *Labeo* spp., provide habitat diversity

*** Subsistence use**

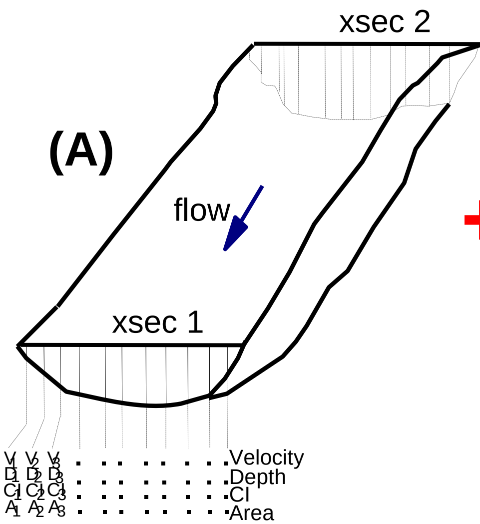
Tools to assist with construction of environmental flow regime



Comprehensive methodology (e.g. ESWM)



Physical habitat modelling for target species (e.g. PHABSIM)



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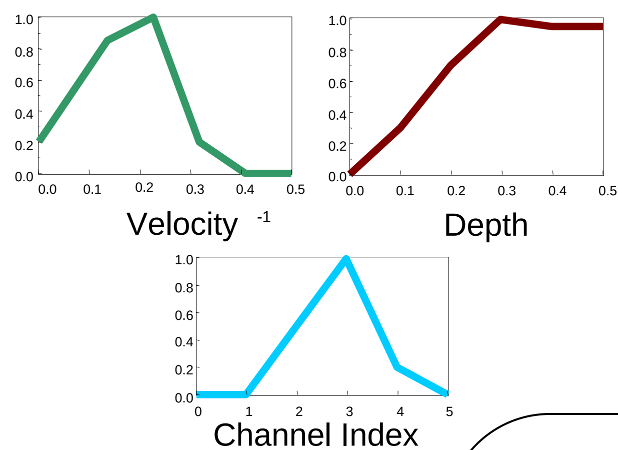
(B) Habitat suitability curves for target sp.



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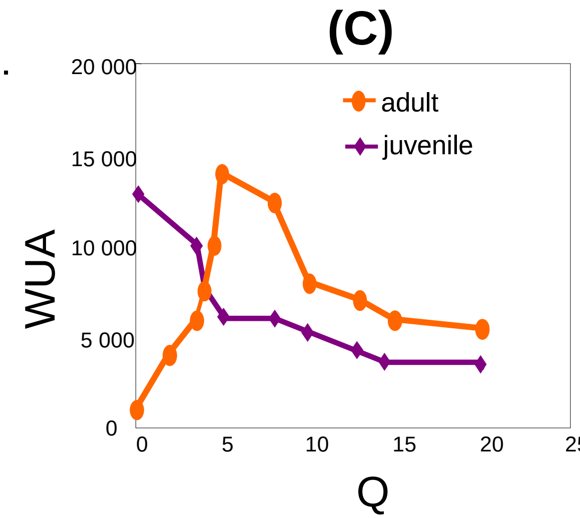
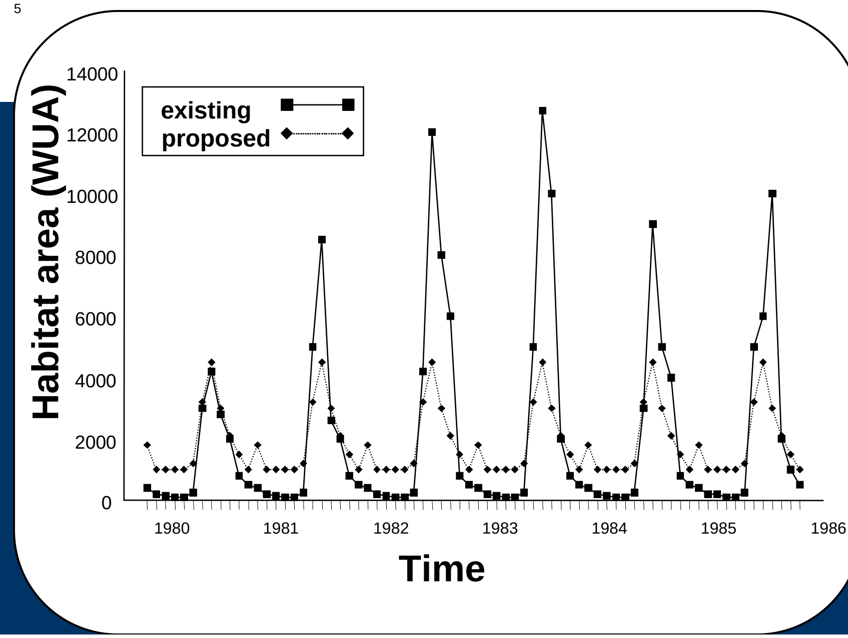
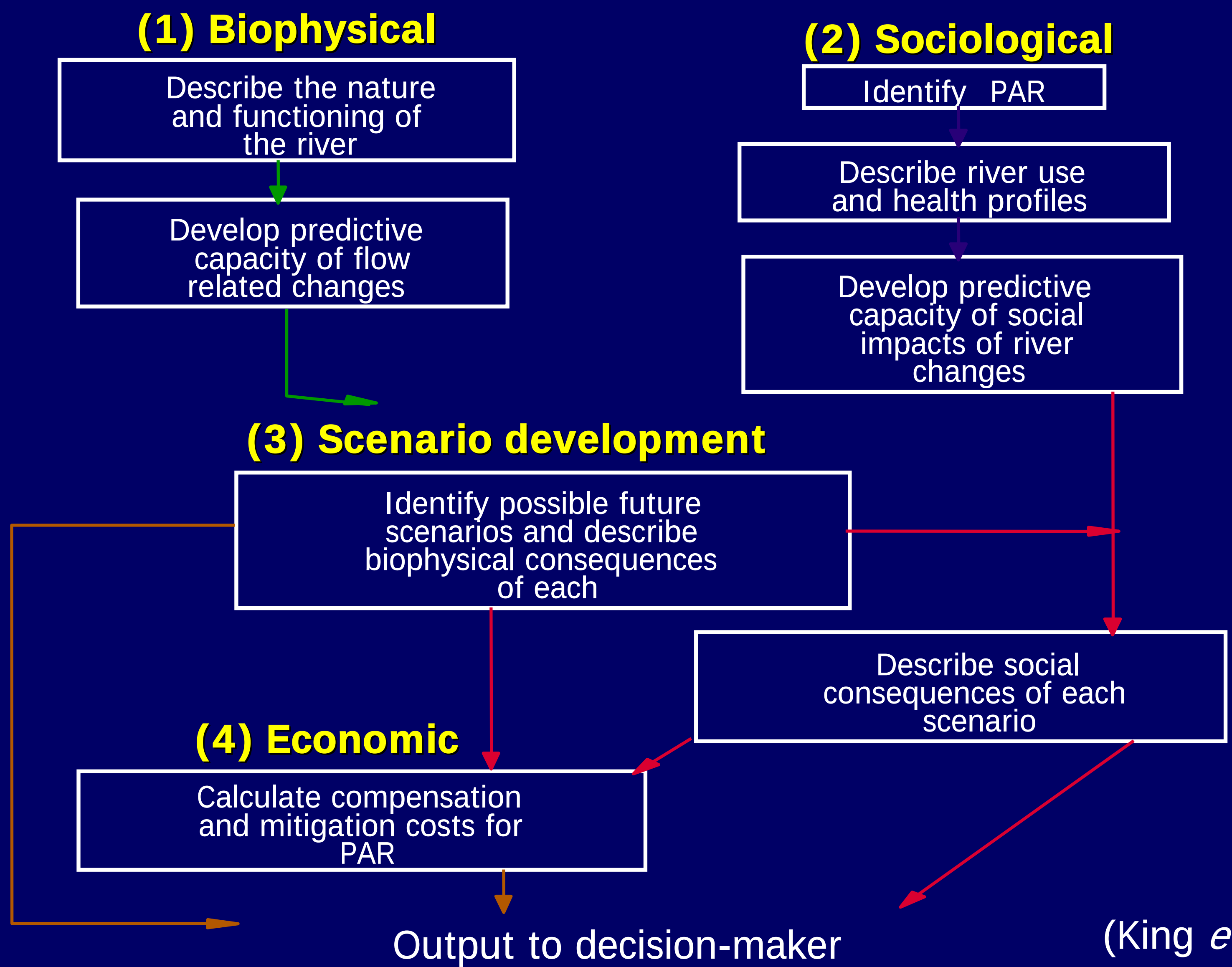




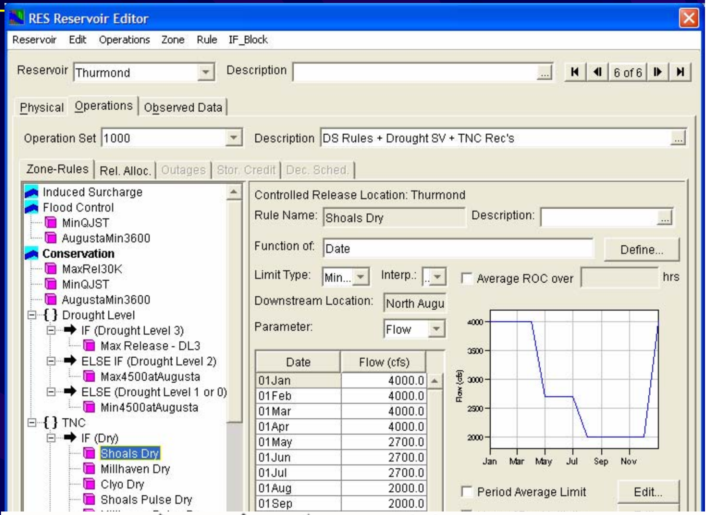
Environmental flow framework (e.g. DRIFT)

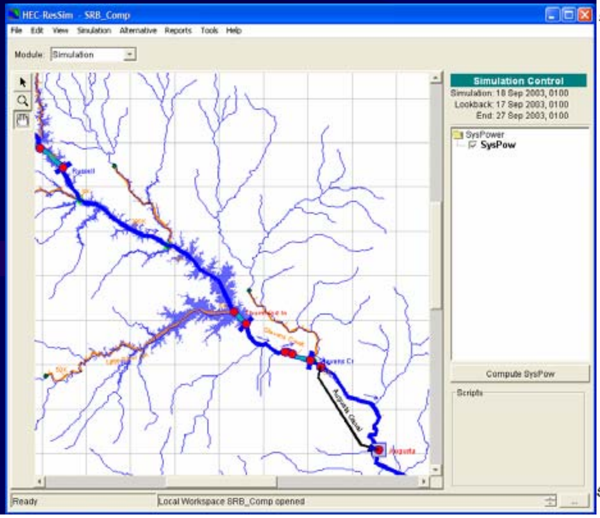


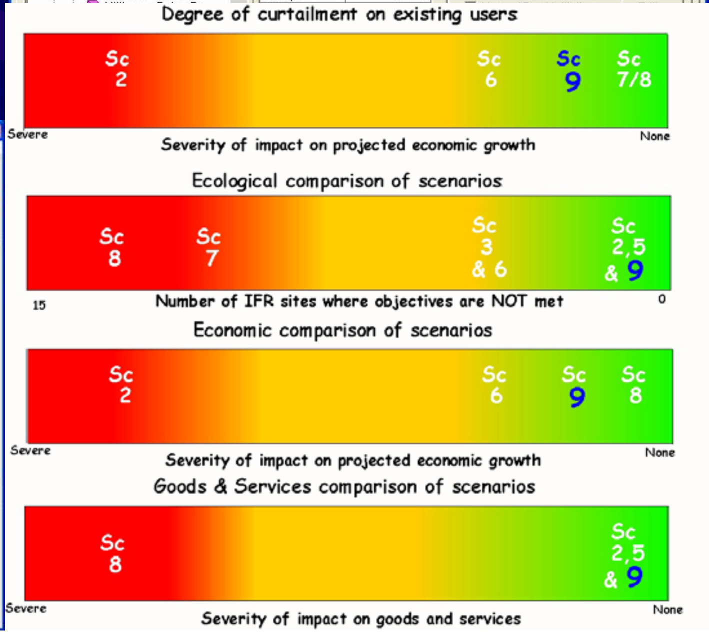
(King *et al.* 2003)

Integration of environmental flows in water resources planning and management

- Implications of alternative scenarios
- Tradeoff analysis for water allocation across sectors
- Operation procedures & reoptimization of water management system
- E-flow standards & rules - supply assurance and risk
- Siting of storage & flow control structures
- Protection of natural flow regimes in key tributaries







Holistic methodologies: strengths and deficiencies

- Whole-ecosystem integrity
- Alternative e-flow regimes / scenarios for different ecological *and social* conditions
- Interdisciplinary team in rigorous science-based process
- Data rich and data poor contexts
- Uses ecologically relevant flow regime characteristics
- Addresses biological and social responses to flow alteration
- *Reliant on expert judgement*
- *Difficult to reconcile opinions of different experts*
- *Moderate to high resource demands*
- *Site specific*





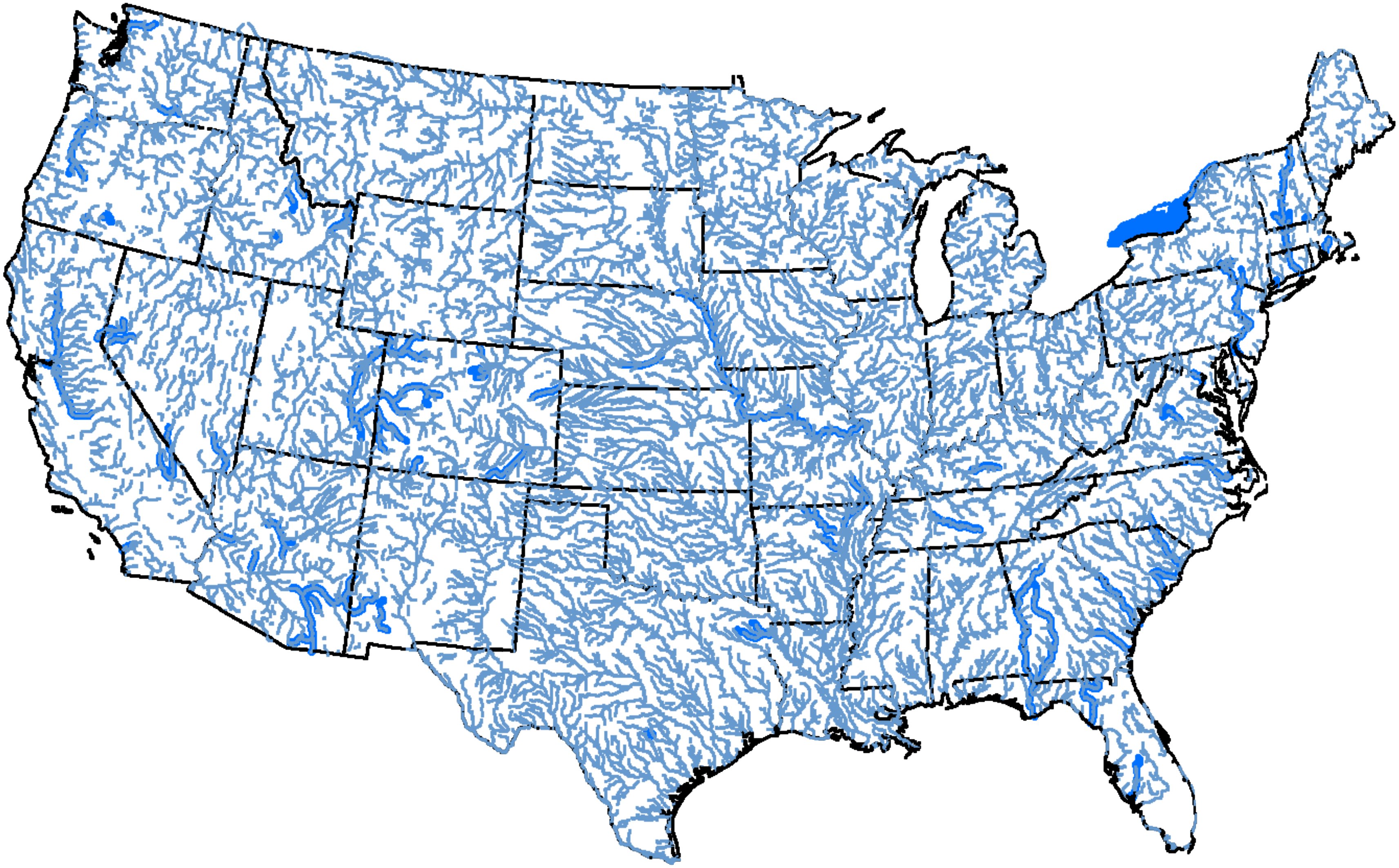


ELOHA

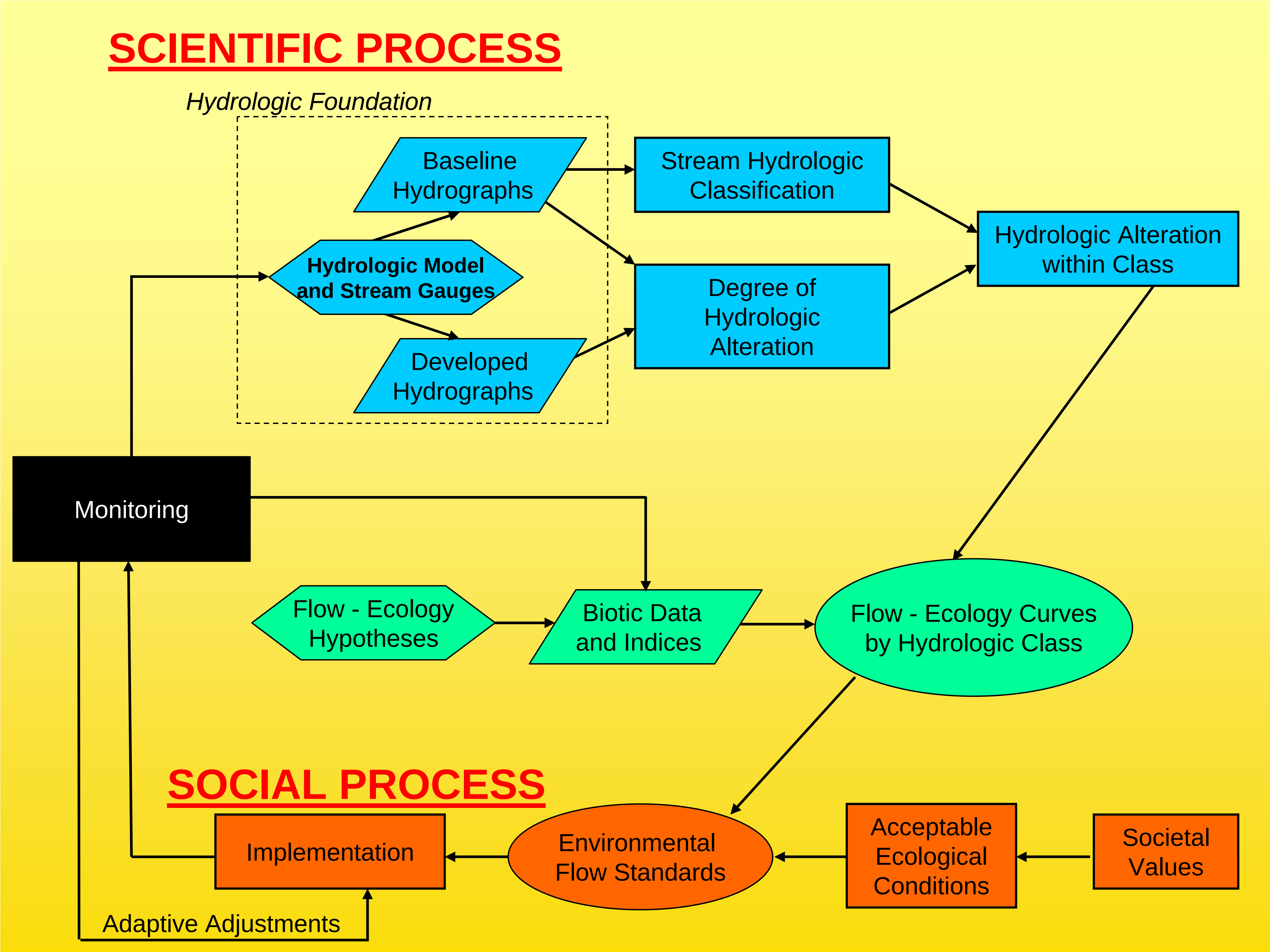
Ecological Limits of Hydrologic Alteration

A new regional desktop method

Environmental Flow Prescriptions by River



Rivers for which environmental flows prescribed


SCIENTIFIC PROCESS
Hydrologic Foundation
Baseline Hydrographs
Hydrologic Model and Stream Gauges
Developed Hydrographs
Stream Hydrologic Classification
Degree of Hydrologic Alteration
Hydrologic Alteration within Class
Monitoring
Flow - Ecology Hypotheses
Biotic Data and Indices
Flow - Ecology Curves by Hydrologic Class
SOCIAL PROCESS
Implementation
Environmental Flow Standards
Acceptable Ecological Conditions
Societal Values
Adaptive Adjustments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Gracias
Thank you
IHA software & resources   www.nature.org/freshwaters
HEC-RPT software   www.hec.usace.army.mil

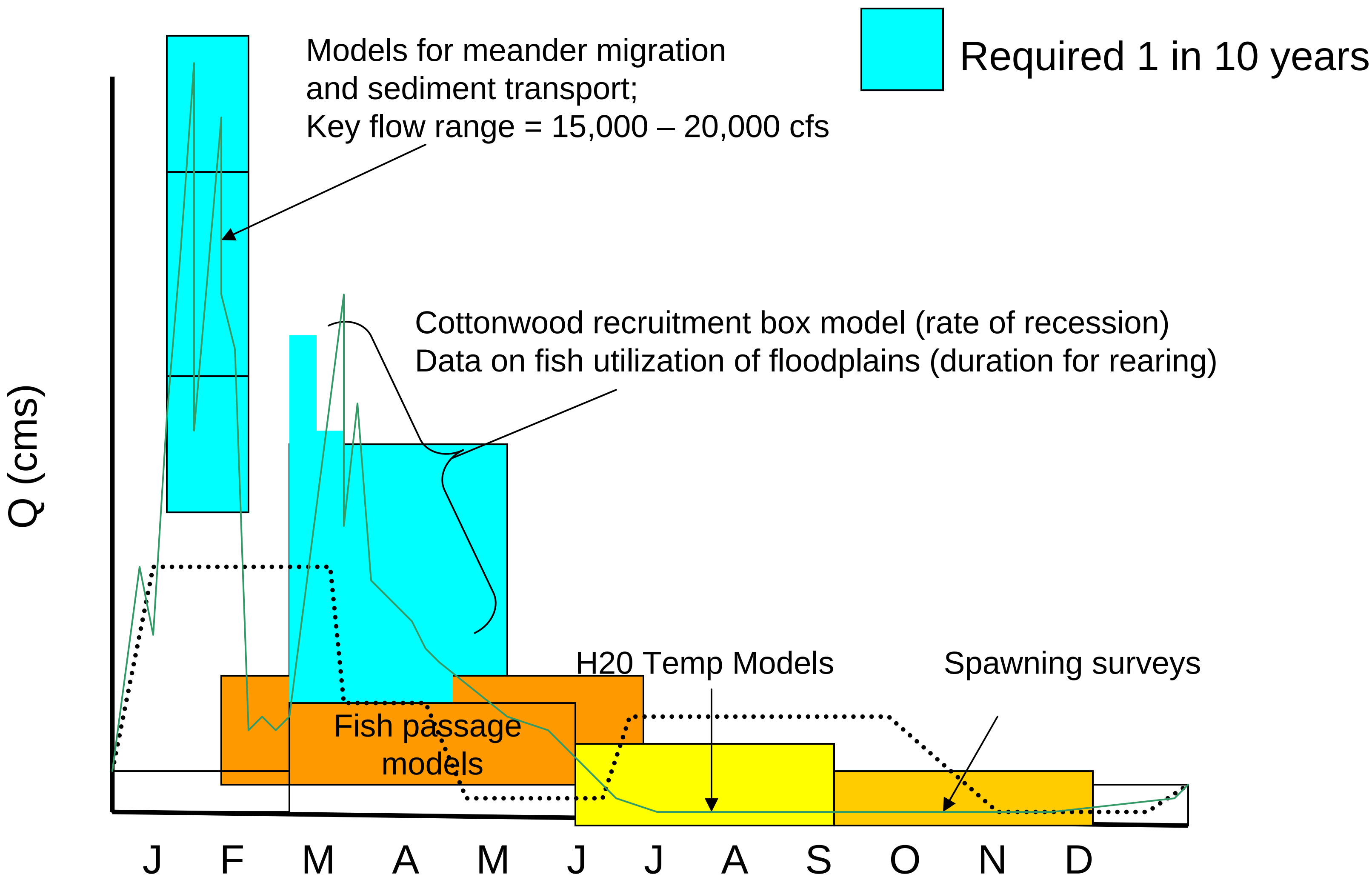
Integration of e-flows in IWRM / RBM: Conditions for success

- Harmonized policy and regulations with explicit recognition of e-flows principles
  - at basin level, preferably also at national/regional level
  - across all sectors - optimization for multiple benefits
- Reliable, credible knowledge base - information systems, monitoring, infrastructure
- Technical expertise and tools
  - e-flows determination (incl. strategic targeting of river systems for protection)
  - yield analyses and water allocation tradeoffs
  - infrastructure operating rules

Conditions for success cont.

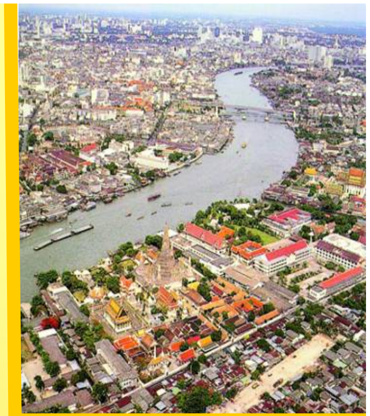
- Transparent, robust decision-making arrangement – stakeholder inclusion
- E-flows integrated in basin management plans and linked to other drivers of change (e.g. land use)
- Institutional capacity for implementation, monitoring, refinement
- E-flows process connected with national plans - IWRM strategy, poverty reduction strategy, MDGs, etc.
- E-flows included in water resource investments and policy reforms

Field sampling, analyses, modeling, experimental flow releases to reduce uncertainties and refine e-flow recommendations



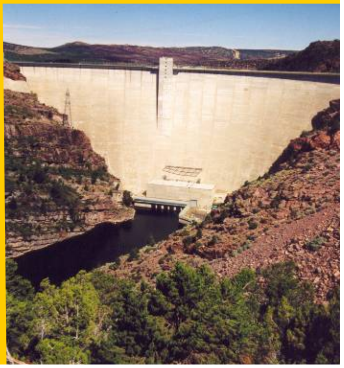
Criteria for Regional Environmental Flow Method

- Addresses many rivers simultaneously
- Explicitly links flow and ecology
- Applies across a spectrum of:
  - Flow alteration types
  - Data availability and scientific capacity
  - Social and political contexts



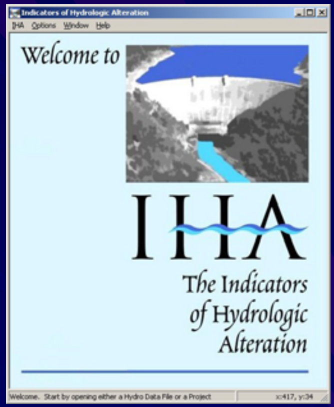




Indicators of Hydrologic Alteration (IHA) 7 software

67 ecologically-relevant flow statistics (daily flow data) used to:



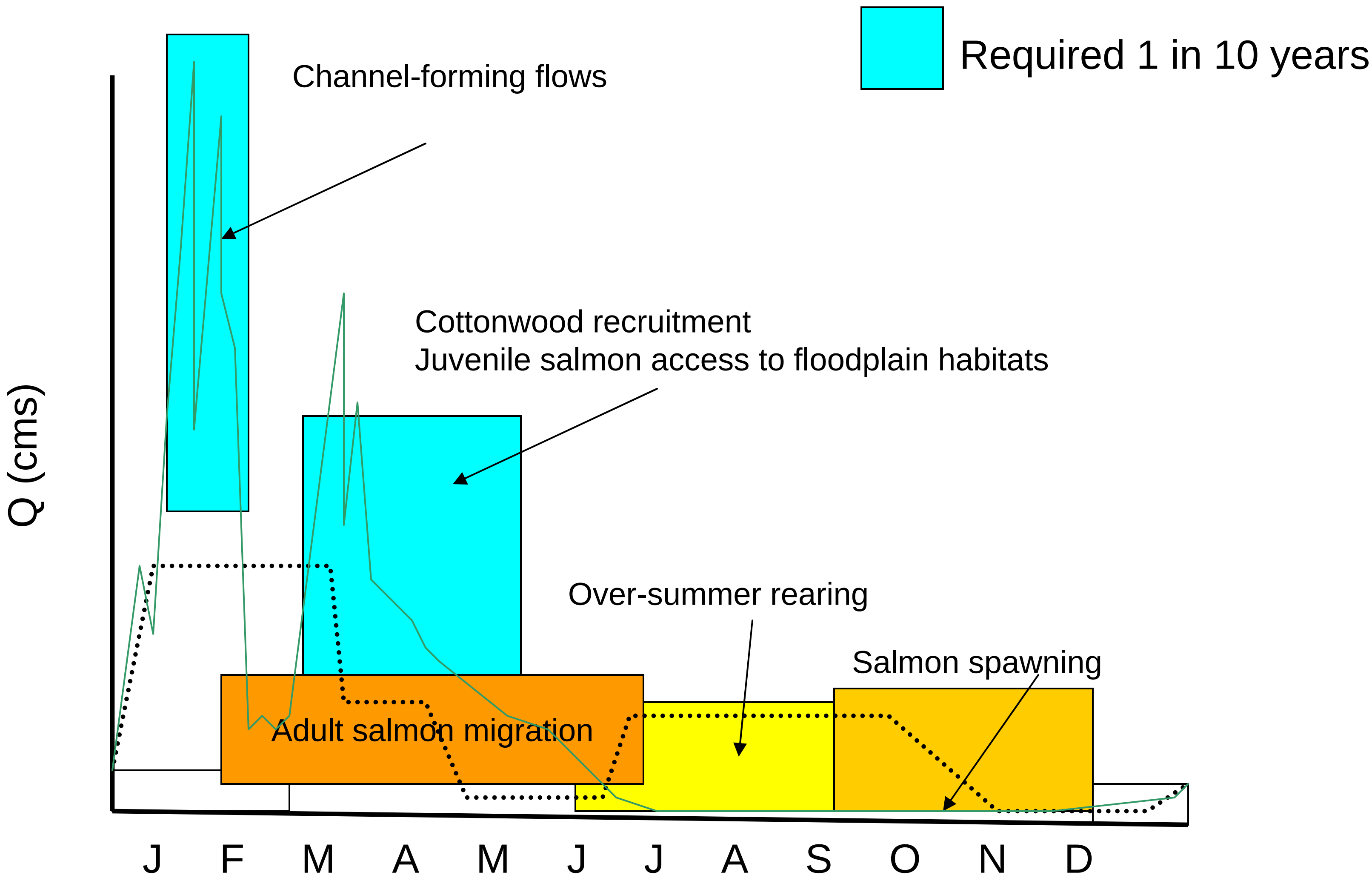
- Characterize the natural flow regime
- Assess how flow regime has changed over time
- Analyze flows provided by different management scenarios
- Aid in developing e-flow recommendations (in conjunction with ecological information)

(Richter *et al*. 1996, 1997)

Indicators of Hydrologic Alteration (IHA) 7 software

IHA Annual Statistics (33 indices)

- Monthly average flows
- Magnitude of annual extremes (1-, 3-, 7-, 30-, and 90-day minimums and maximums)
- Timing of annual extremes (1-day max and min)
- Zero flow days
- Frequency and duration of high and low pulses
- Rates of flow changes and reversals
- Base flow index (7-day minimum flow / mean annual flow)



Expert panel approach to define initial flow recommendations, framed as hypotheses

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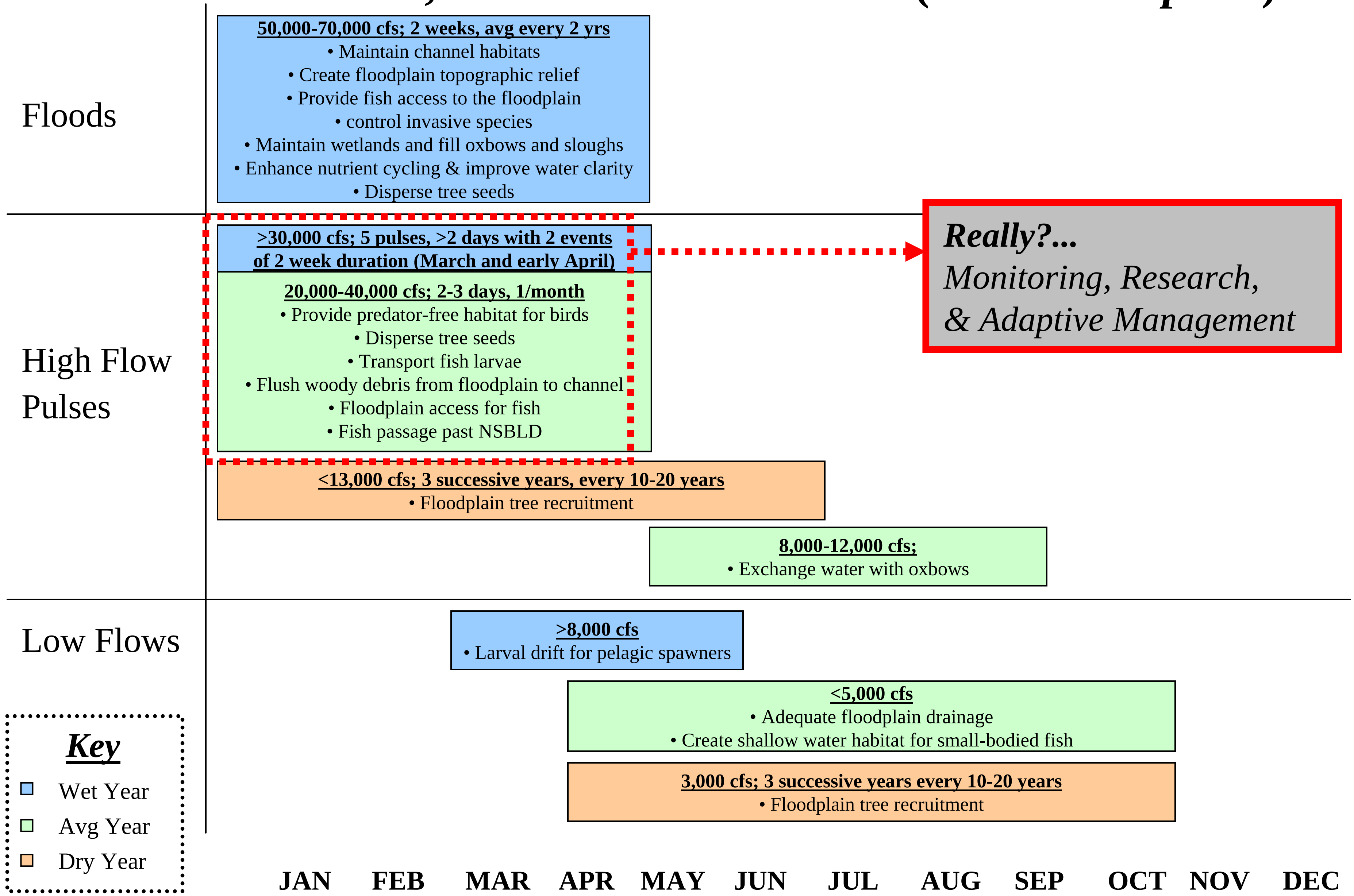
Environmental Flow Recommendations

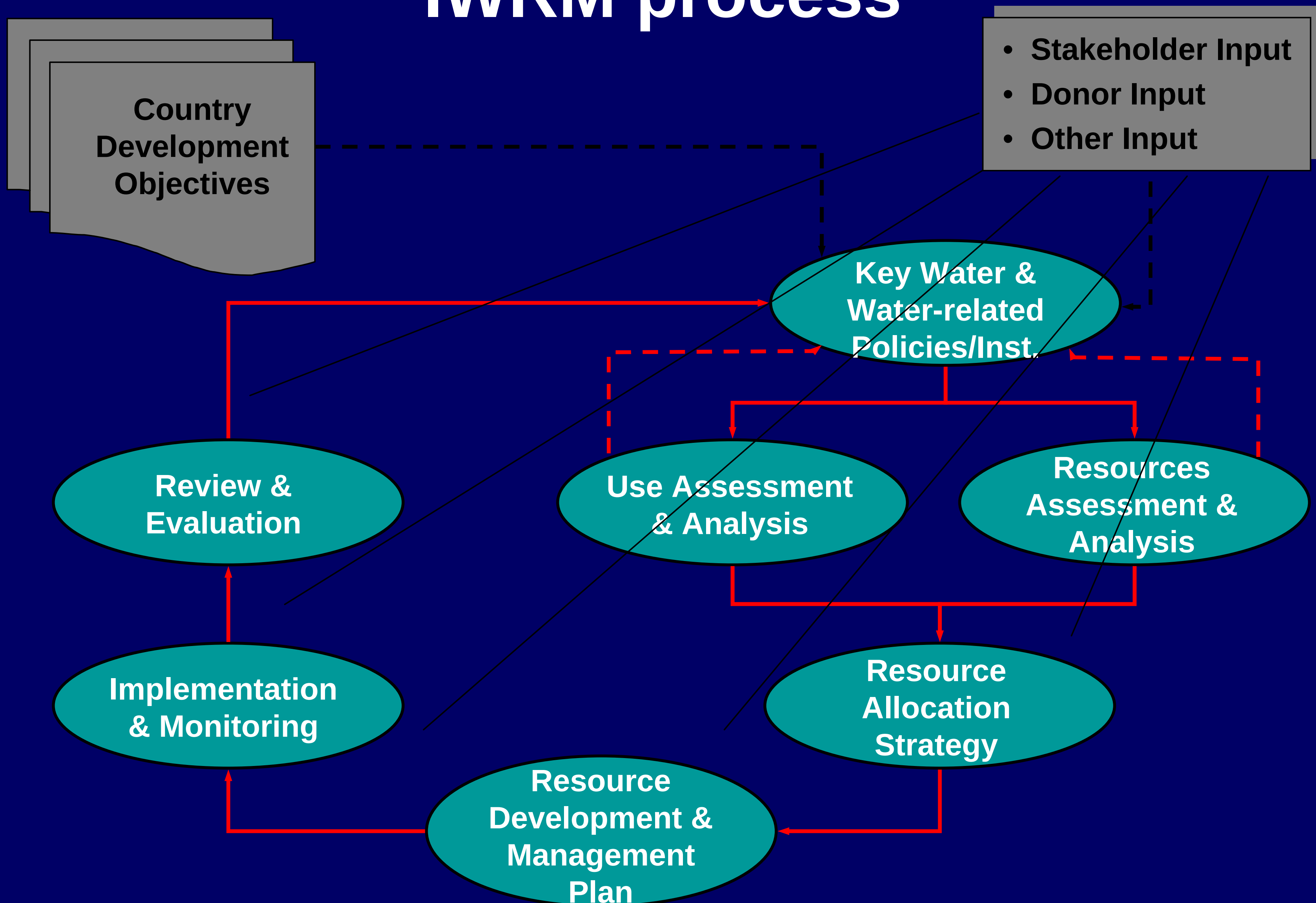
Savannah River, below Thurmond Dam (*River-Floodplain*)



Water and environment sectors

- E-flow provision is a water resources management *and* environmental issue - should be addressed concurrently in
  - environmental sector *and*
  - water sector
- EIAs for water resource development projects - opportunities to introduce e-flows, but insufficient to ensure implementation
- E-flows need to be addressed in strategic water resource planning at basin level
  - Water management options for basin as a whole
  - Siting of storage and flow control structures
  - Protection of natural flow regimes in key tributaries

IWRM process



Implementation strategy

- Allow transitional period –
  - preliminary determinations of e-flows to support evaluation of individual licence applications, updated later
  - range of approaches, from desktop to comprehensive
- Design integrated basin-level plans
  - e.g. protection of natural flows in key tributaries
- In currently over-allocated catchments, develop interim objectives and timeframes – e.g. formalised in Catchment Management Strategies
- Adaptive management approach
  - monitor initial implementation of e-flow allocation and feed back results into
    - ✓ improved ecosystem understanding
    - ✓ better estimates of e-flows

Policy toolbox

- Resource directed measures
  - Classification system, Reserve, resource quality objectives (i.e. quality of all aspects of water resource: flow, water quality, habitat and biota)
- Source directed controls
  - Standards, BMP, licensing, EIA
- Economic instruments
  - Tariffs, charges, penalties
- Information systems
  - National monitoring networks, catchment-level monitoring
- Institutional arrangements
  - New water management institutions at catchment level, central government has policy and regulatory role

A framework for developing environmental flows