Selecting Appropriate Methods and Tools for Developing Environmental Flow Recommendations

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nature.org/freshwater

Environmental flow methods

- Broad categories of methods
- Evolution of approaches
- Overview of holistic approaches
- Environmental flow components
- Framework for method selection

Basic categories of environmental flow methods

Tharme (2003);

- Hydrologic
  - Tennant (Montana) method
- Hydraulic
  - Wetted perimeter method
- Habitat simulation
  - PHABSIM (part of IFIM)
- Holistic
  - DRIFT, BBM, TNC's "Savannah Process"

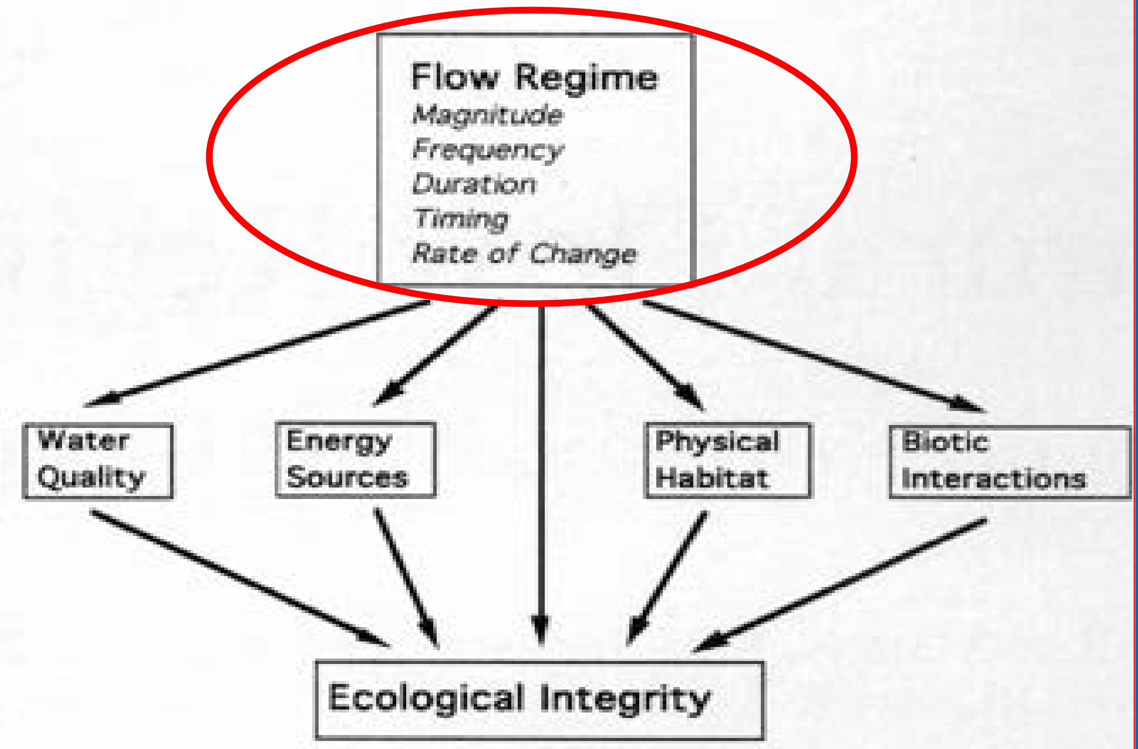
IFC (2004) Uses: Standard Setting, Incremental, and Monitoring/Diagnostic

Limitations of methods

Most commonly used methods:

- Seek a single (or a few) discharge values (inherent in method or how method is generally implemented)
- Are not generally designed to incorporate infrequent events and riverine process needs:
  - Tennant
  - Wetted Perimeter
  - PHABSIM
- Are difficult to reconcile with functional riverine and riparian ecosystems and the need for inter- and intra-annual variability

Evolution of environmental flows



(Poff et al. 1997)

The Natural Flow Regime

A paradigm for river conservation and restoration

N. LeRoy Poff, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg

Evolution of environmental flows

Stable low flows…

Instream flows…

…vs. a range of flows, including floods

…vs. flows above bankfull

People catching trout

Focused on trout

…vs. focused on riparian veg

and sediment transport

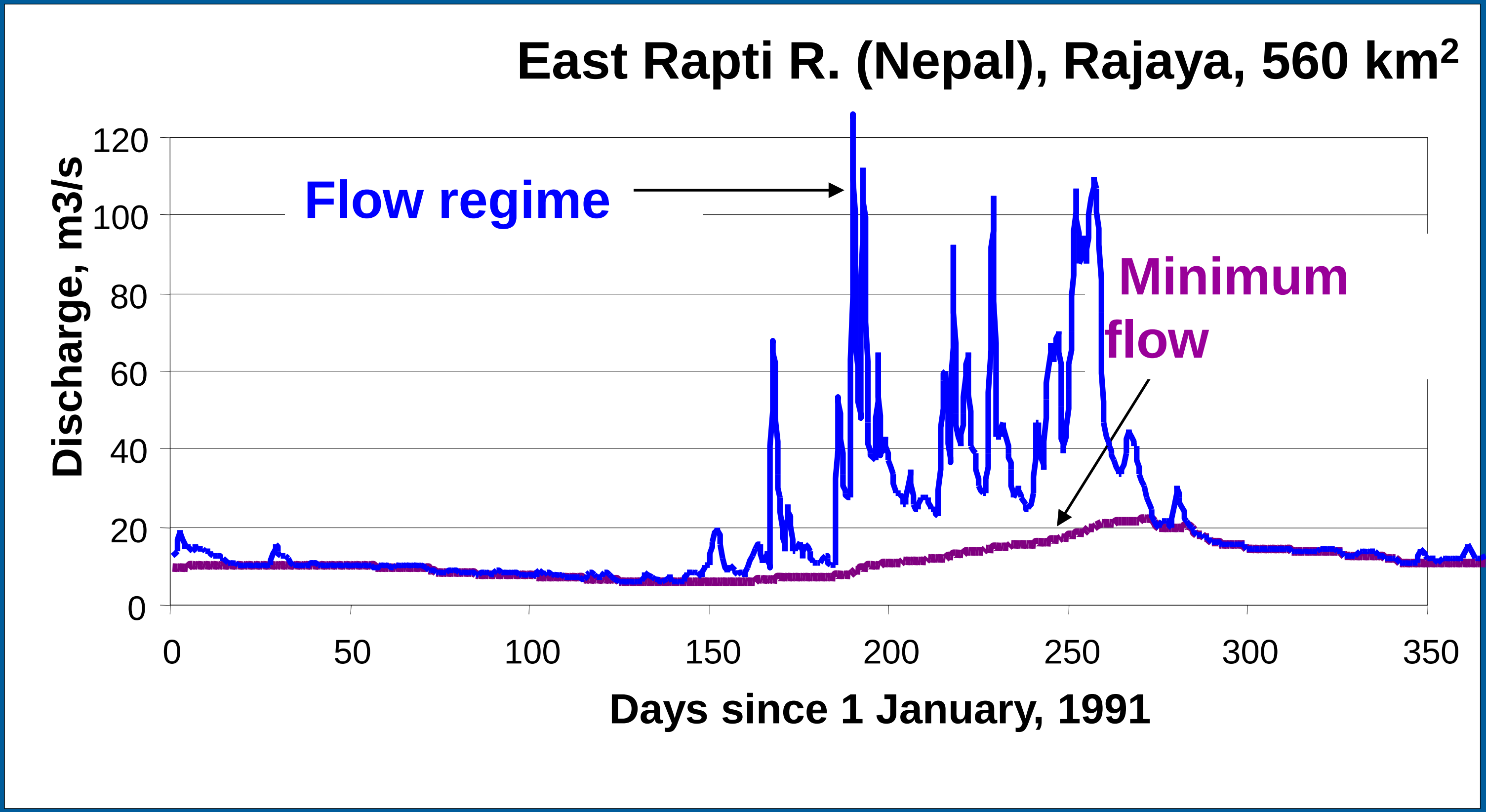
and large wood & channel form

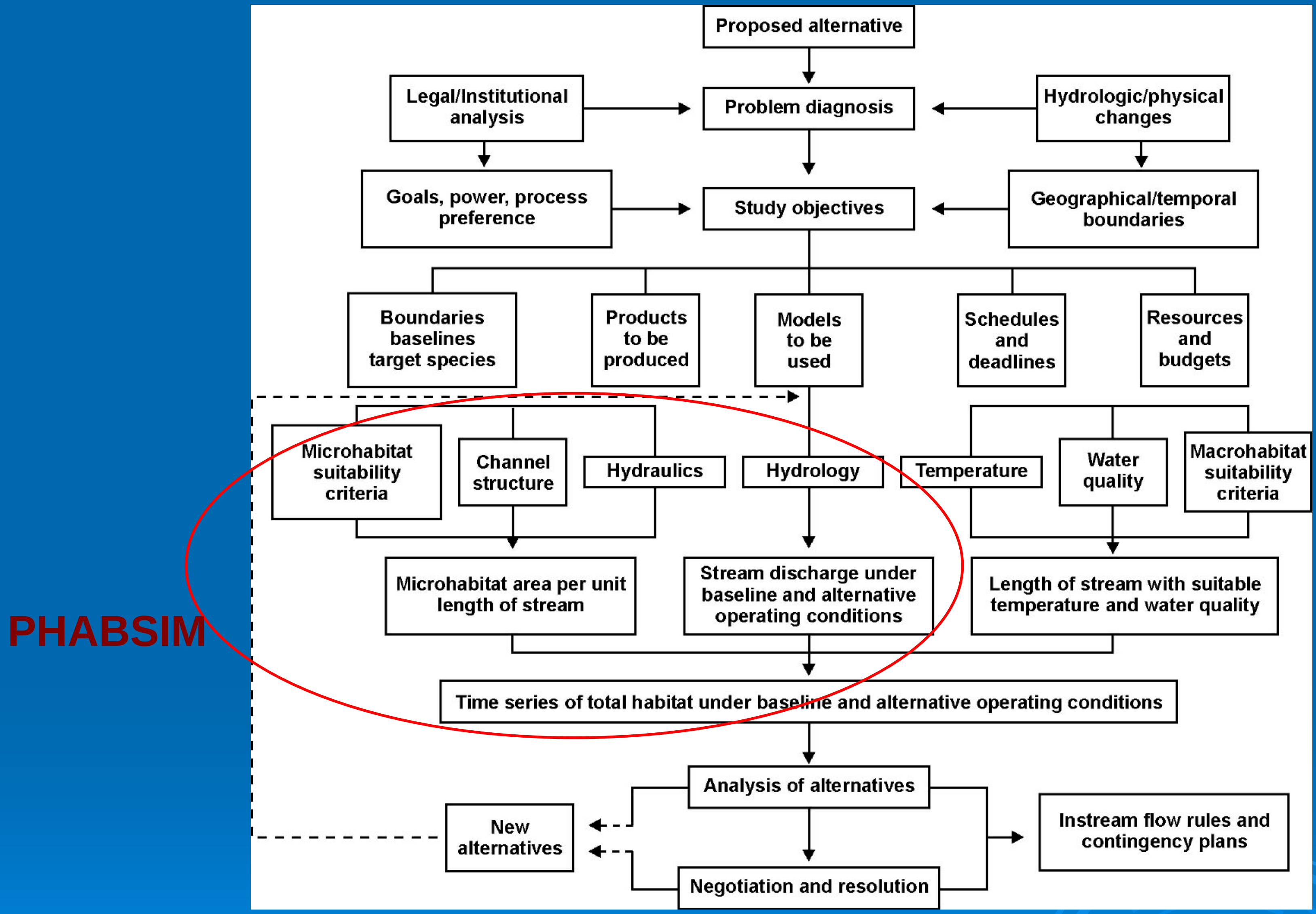
and invertebrates

and people

Shift from minimum flow to *flow regime:

* magnitude, frequency, duration, timing, rate of change
* flow components (low flows, freshes, floods)





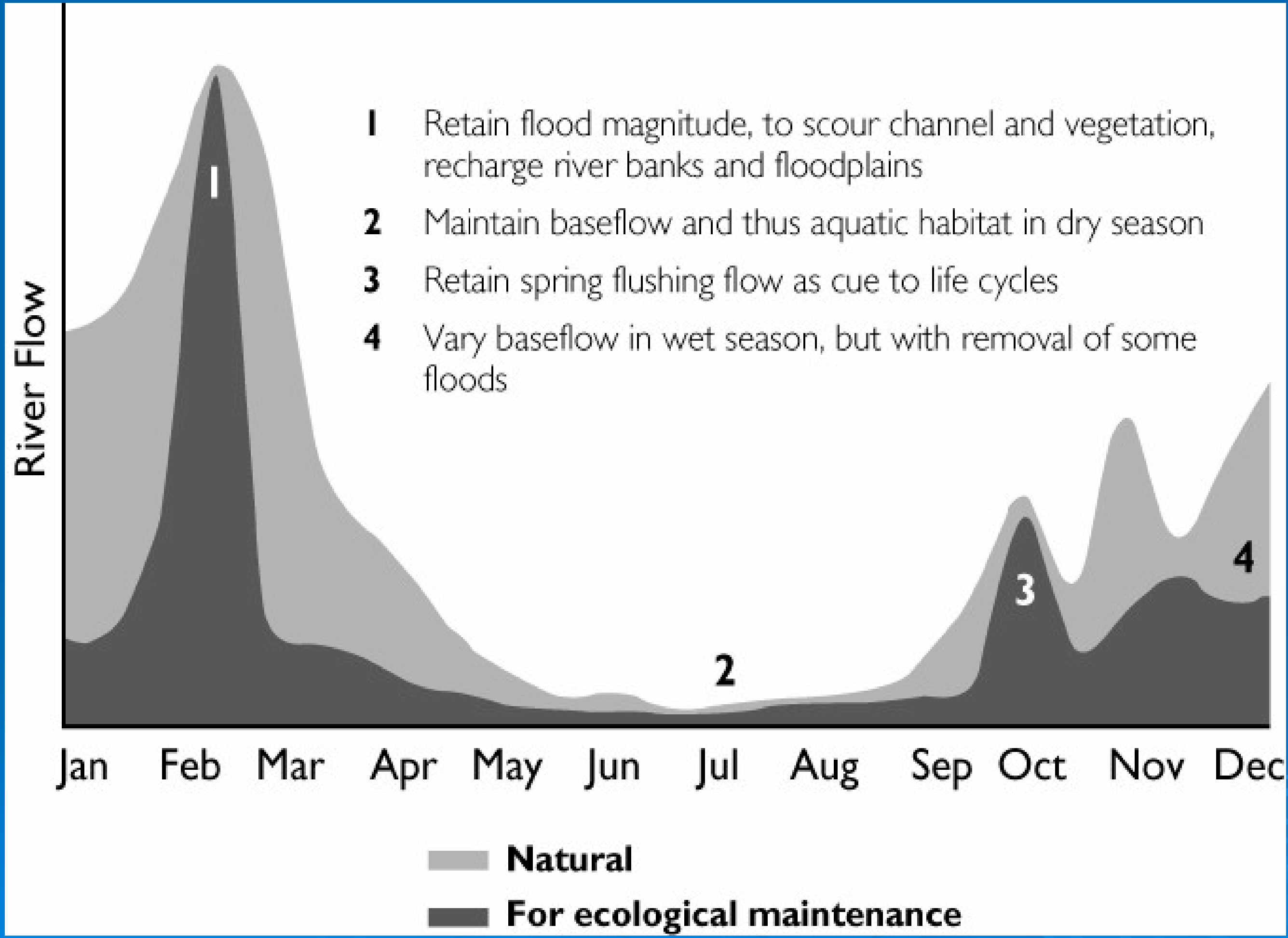
Instream Flow Incremental Methodology

USGS Fort Collins

Holistic Methods Attempt to Better Account for Ecosystem Needs

- Well-developed in South Africa (DRIFT) and Australia (BBM)
- Encompasses variability, a range of flow types, and a range of resources (human & ecological)
- Foundation of The Nature Conservancy's framework for developing environmental flows for situations ranging from resource- and data-poor to extensive resources and/or data

Protecting Ecological Functions with Environmental Flows



From: *Rivers for Life: Managing Water for People and Nature*, Postel and Richter (2003)

Specialists for inter-disciplinary team

River flow	surface & groundwater hydrology, hydraulics, water resources modelling, climate change
Channel form	geomorphology, sedimentology, physical habitat
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

Top-down approach: DRIFT

Downstream Response to Imposed Flow Transformation

(Brown and Joubert 2003, King et al 2003))

Module 1
Biophysical

Module 2
Sociological

Module 3
Scenario development

Module 4
Economics

DRIFT output to decision maker:
Biophysical, sociological, economic consequences of each scenario

DRIFT

Scenario development

Evaluation of biophysical and social consequences

Flow Scenario

- Constant minimum release (0.5 m^3 s^{-1})

Biophysical Component

- *Phragmites australis* (reed)

Severity of Predicted Change

- Negative and severe

Direction and % Change

- Increase (60-80%)

Ecological Reason

- Grows only in wet bank zone

Social links

- **Medicine, fodder, construction**

Bottom-up approach:
Building Block Methodology (BBM) (King and Louw 1998)

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.

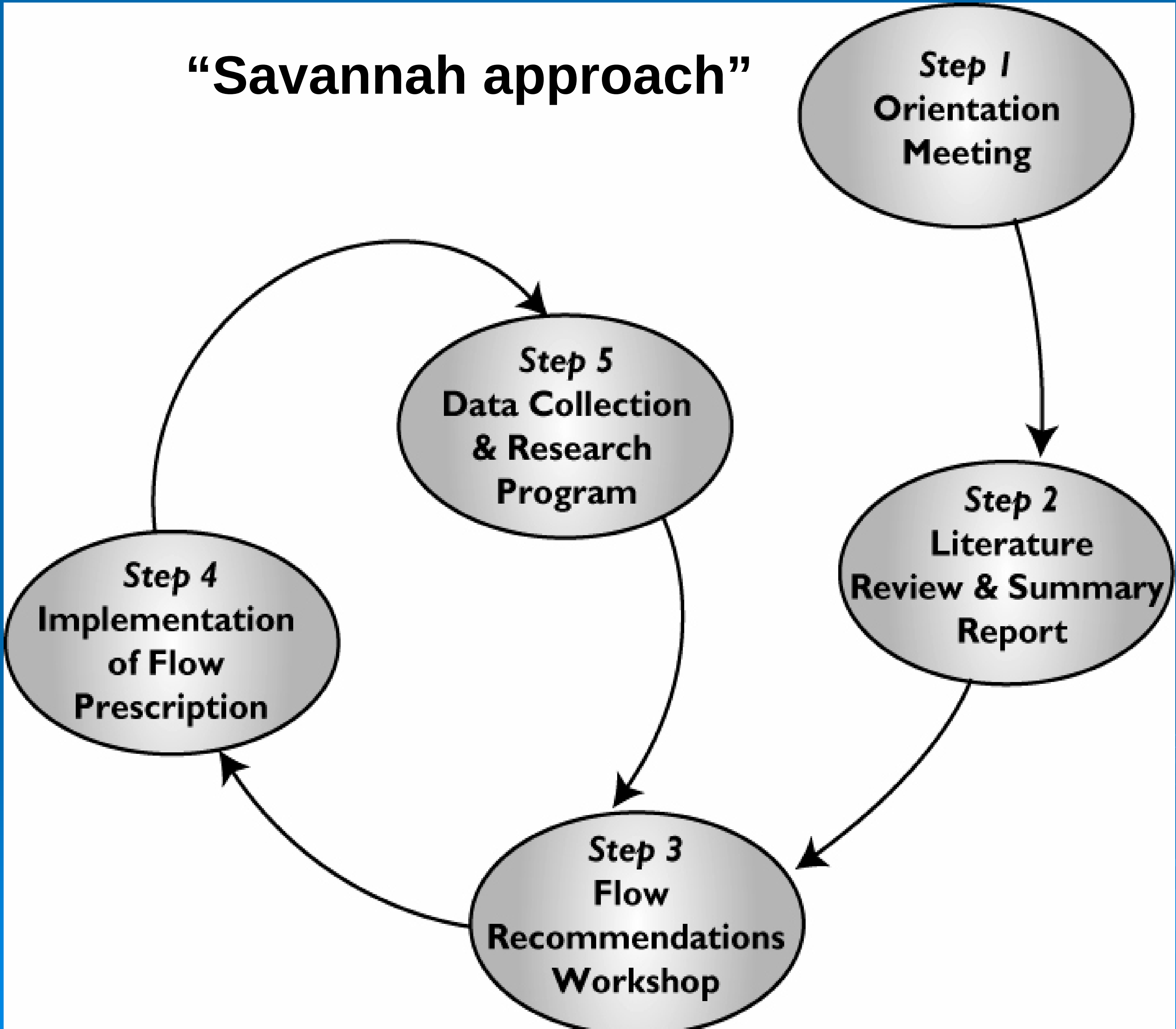
- Activate wide range of seasonal & perennial channels, maintaining all associated veg.

Fish:

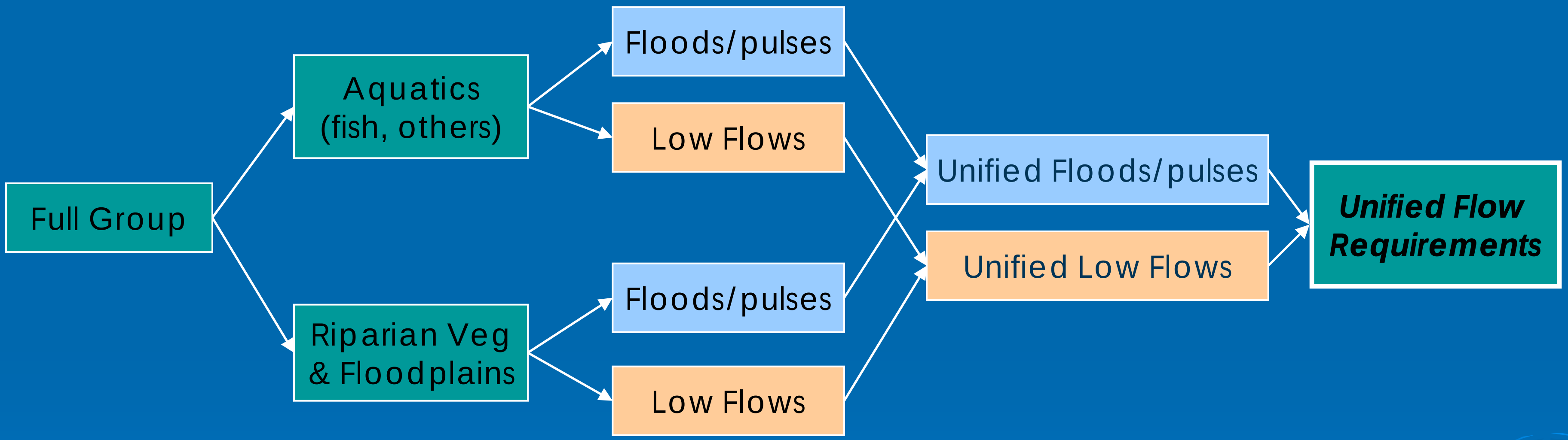
- Provide spawning cues for large *Labeo* spp., provide habitat diversity

*** Subsistence use**

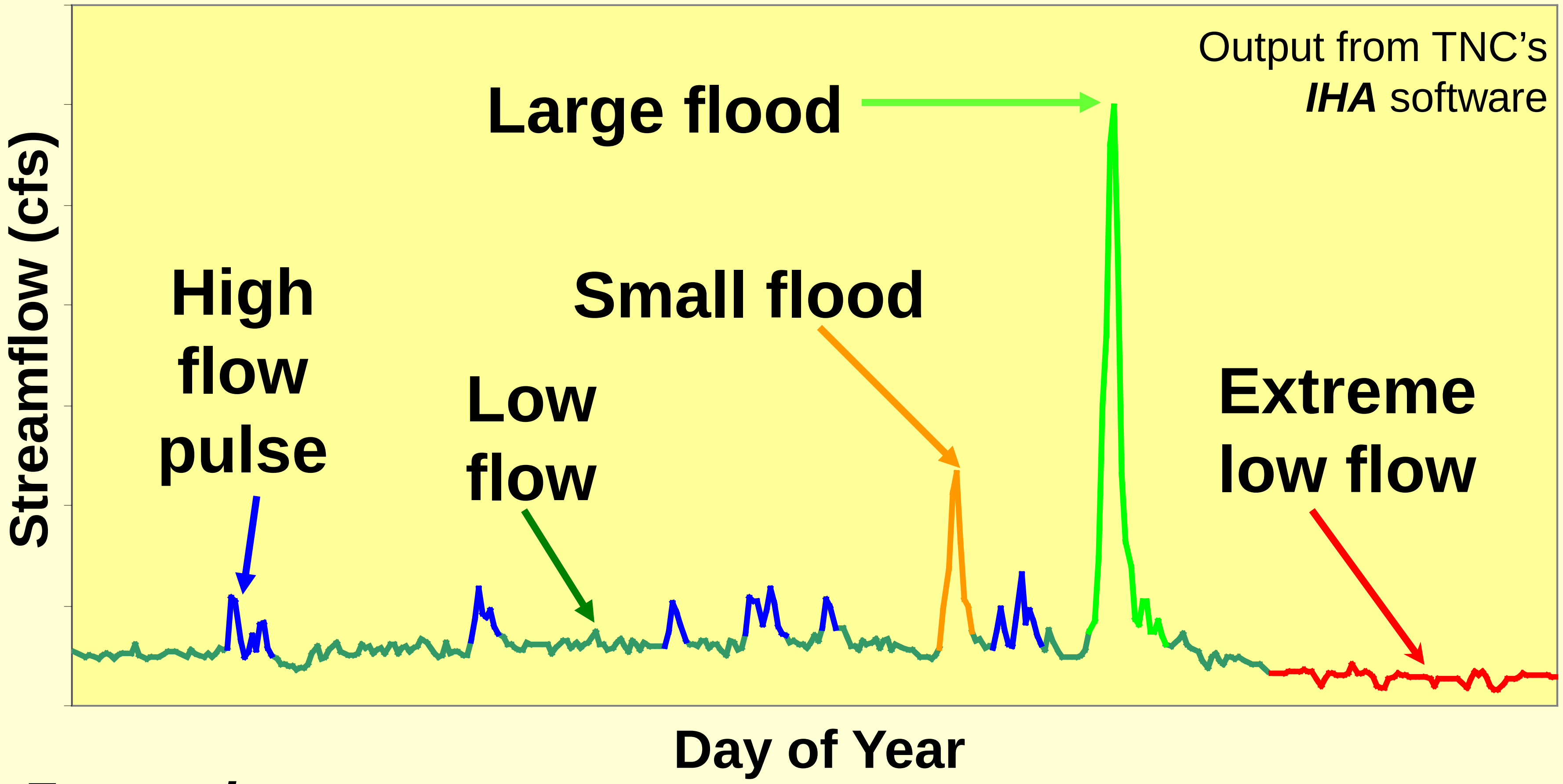
“Savannah approach”



Environmental flow workshop structure, using “Savannah process”



ENVIRONMENTAL FLOW COMPONENTS



For each:

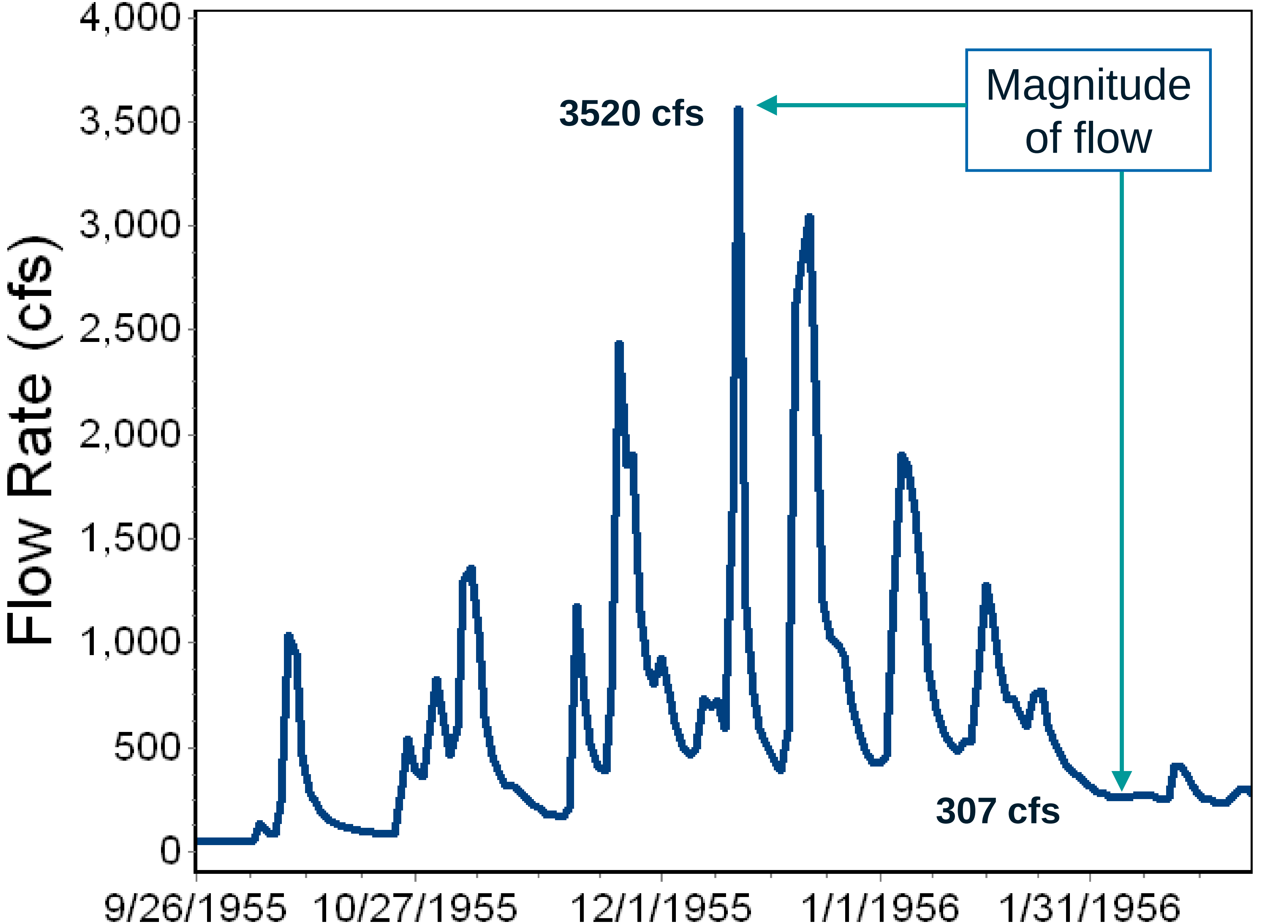
Magnitude, frequency, duration, timing, rate of change

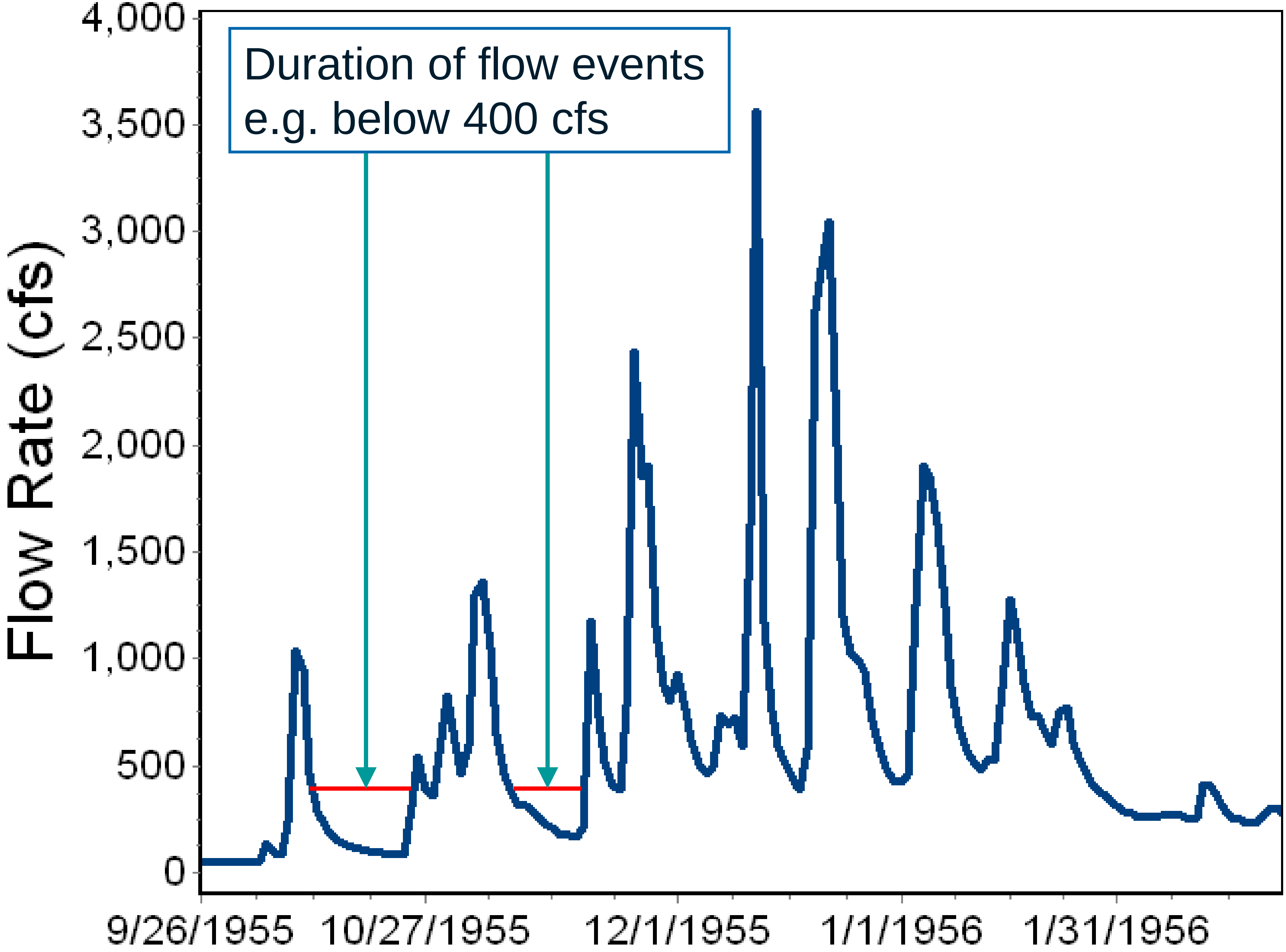
Flow Characteristics

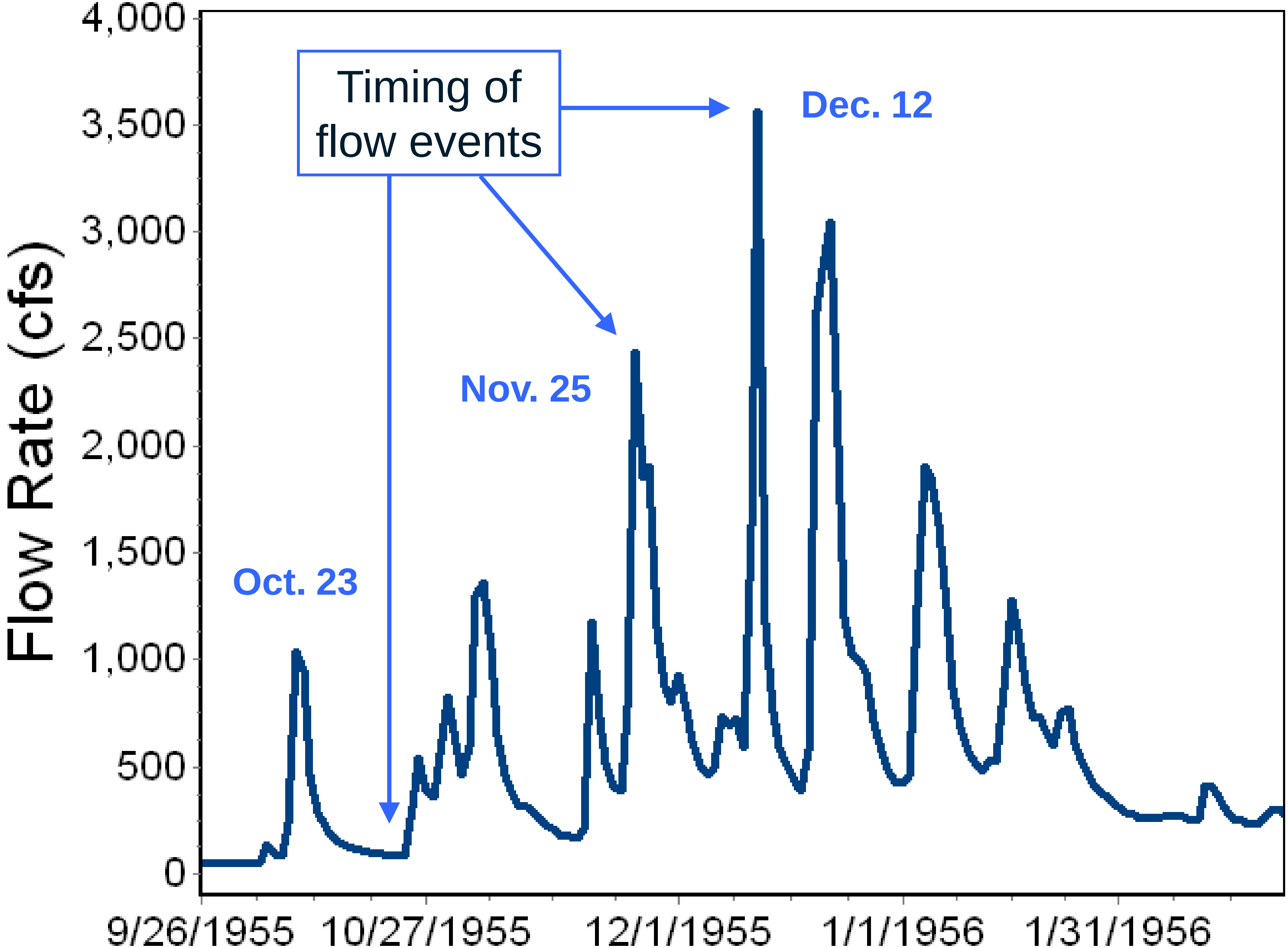
WRITE THESE DOWN:

- **Magnitude** (how much flow or what level?)
- **Duration** (how long do certain flows or levels last?)
- **Timing** (when do certain flows or levels occur?)
- **Frequency** (how often do certain flows or levels occur?)
- **Rate of change** (how fast do flows or levels change from one condition to another?)

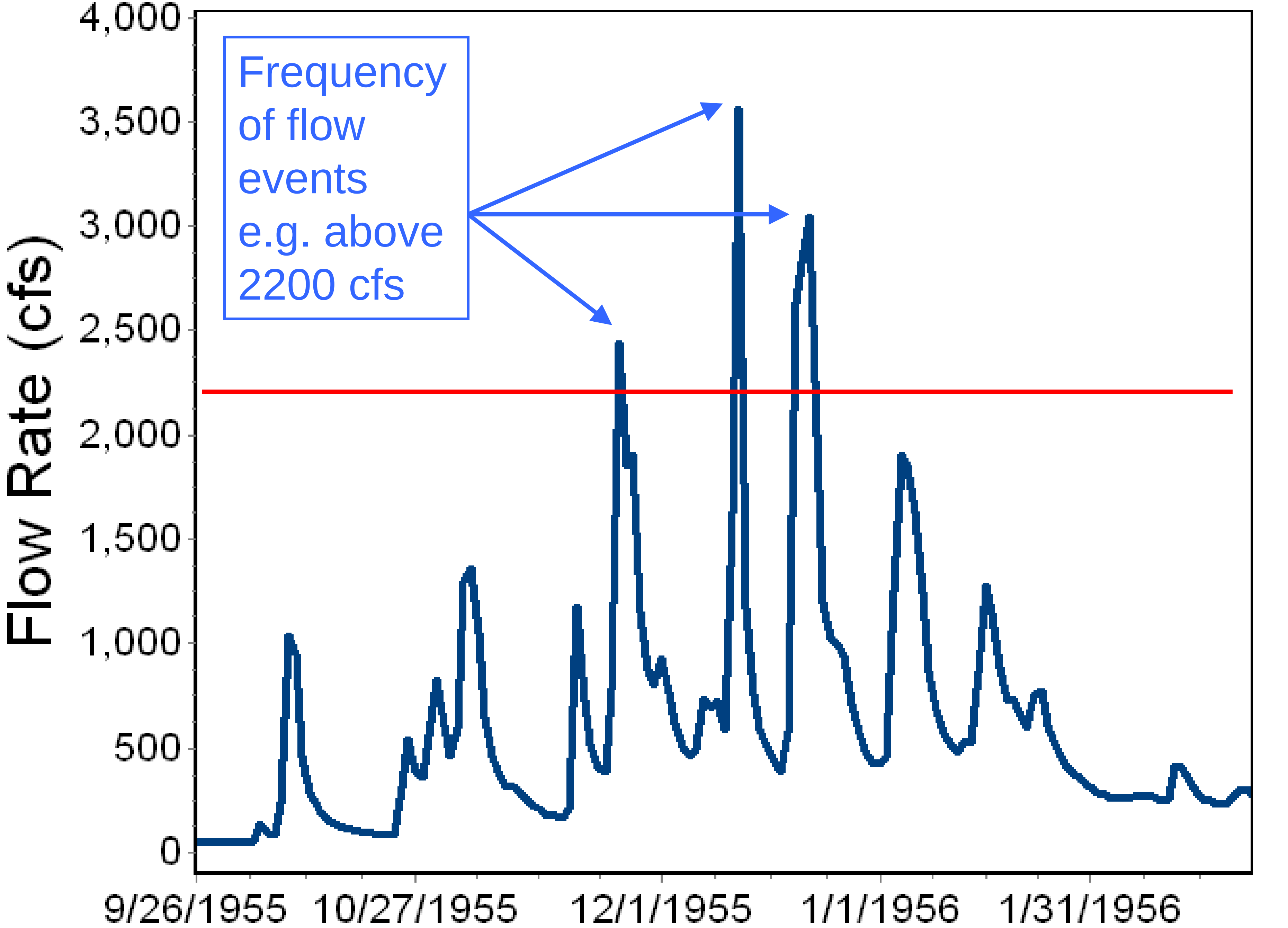
Richter et al. 1996, “A Method for Assessing Hydrologic Alteration Within Ecosystems.”(*Conservation Biology*)


Flow Rate (cfs)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
3520 cfs
Magnitude of flow
307 cfs
9/26/1955
10/27/1955
12/1/1955
1/1/1956
1/31/1956

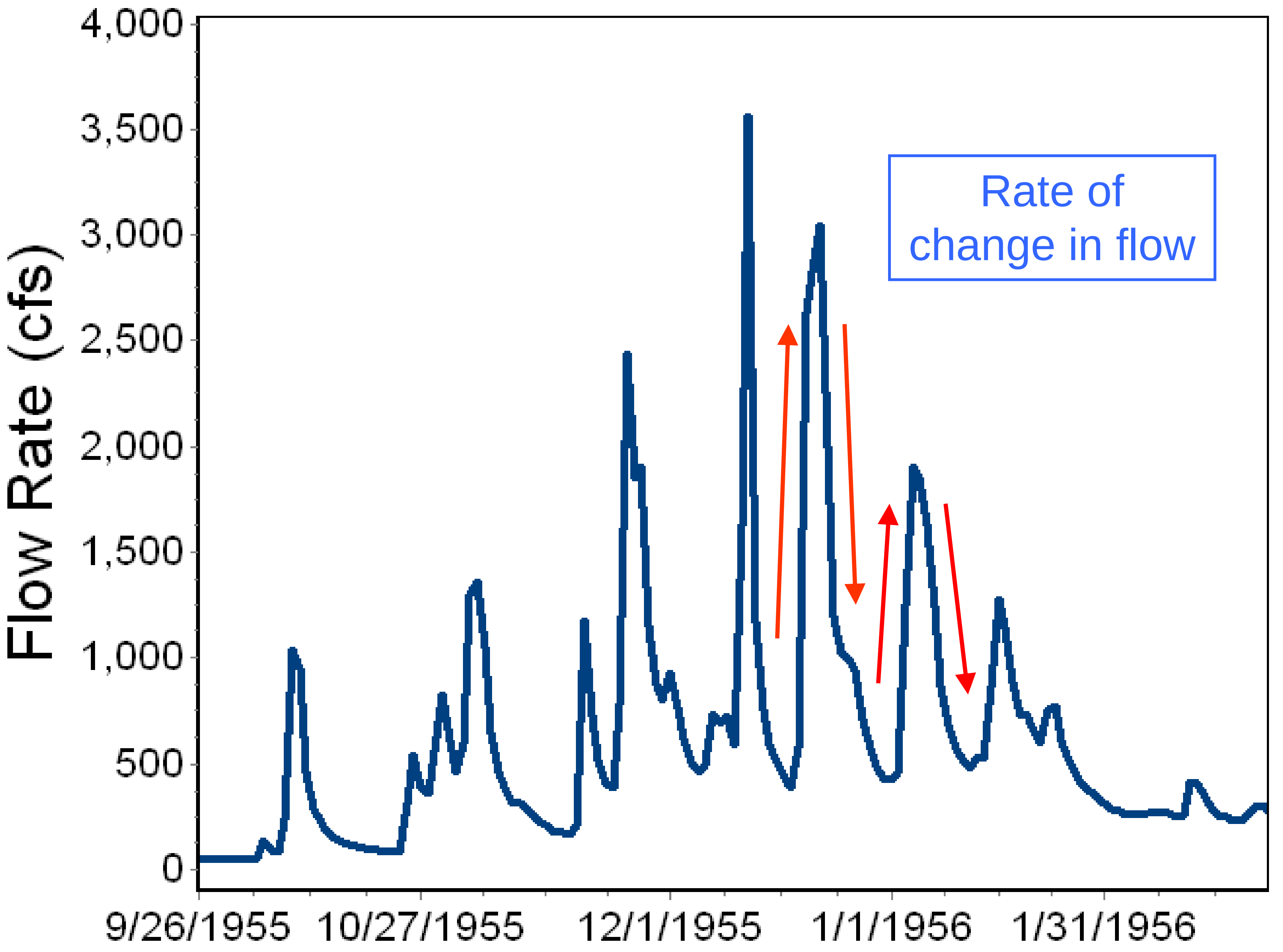

Duration of flow events
e.g. below 400 cfs
Flow Rate (cfs)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
9/26/1955
10/27/1955
12/1/1955
1/1/1956
1/31/1956



Flow Rate (cfs)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Timing of flow events
Oct. 23
Nov. 25
Dec. 12
9/26/1955
10/27/1955
12/1/1955
1/1/1956
1/31/1956



Flow Rate (cfs)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
9/26/1955
10/27/1955
12/1/1955
1/1/1956
1/31/1956
Frequency of flow events e.g. above 2200 cfs



Flow Rate (cfs)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
9/26/1955
10/27/1955
12/1/1955
1/1/1956
1/31/1956
Rate of
change in flow

Environmental Flow Recommendations

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

Floods

50,000-70,000 cfs; 2 weeks, avg every 2 yrs
- Maintain channel habitats
- Create floodplain topographic relief
- Provide fish access to the floodplain
- control invasive species
- Maintain wetlands and fill oxbows and sloughs
- Enhance nutrient cycling & improve water clarity
- Disperse tree seeds

50,000-70,000 cfs; 2 weeks, avg every 2 yrs

High Flow Pulses

>30,000 cfs; 5 pulses, >2 days with 2 events of 2 week duration (March and early April)

>30,000 cfs; 5 pulses, >2 days with 2 events of 2 week duration (March and early April)

20,000-40,000 cfs; 2-3 days, 1/month
- Provide predator-free habitat for birds
- Disperse tree seeds
- Transport fish larvae
- Flush woody debris from floodplain to channel
- Floodplain access for fish
- Fish passage past NSBLD

20,000-40,000 cfs; 2-3 days, 1/month

<13,000 cfs; 3 successive years, every 10-20 years
- Floodplain tree recruitment

8,000-12,000 cfs;
- Exchange water with oxbows

Low Flows

>8,000 cfs
- Larval drift for pelagic spawners

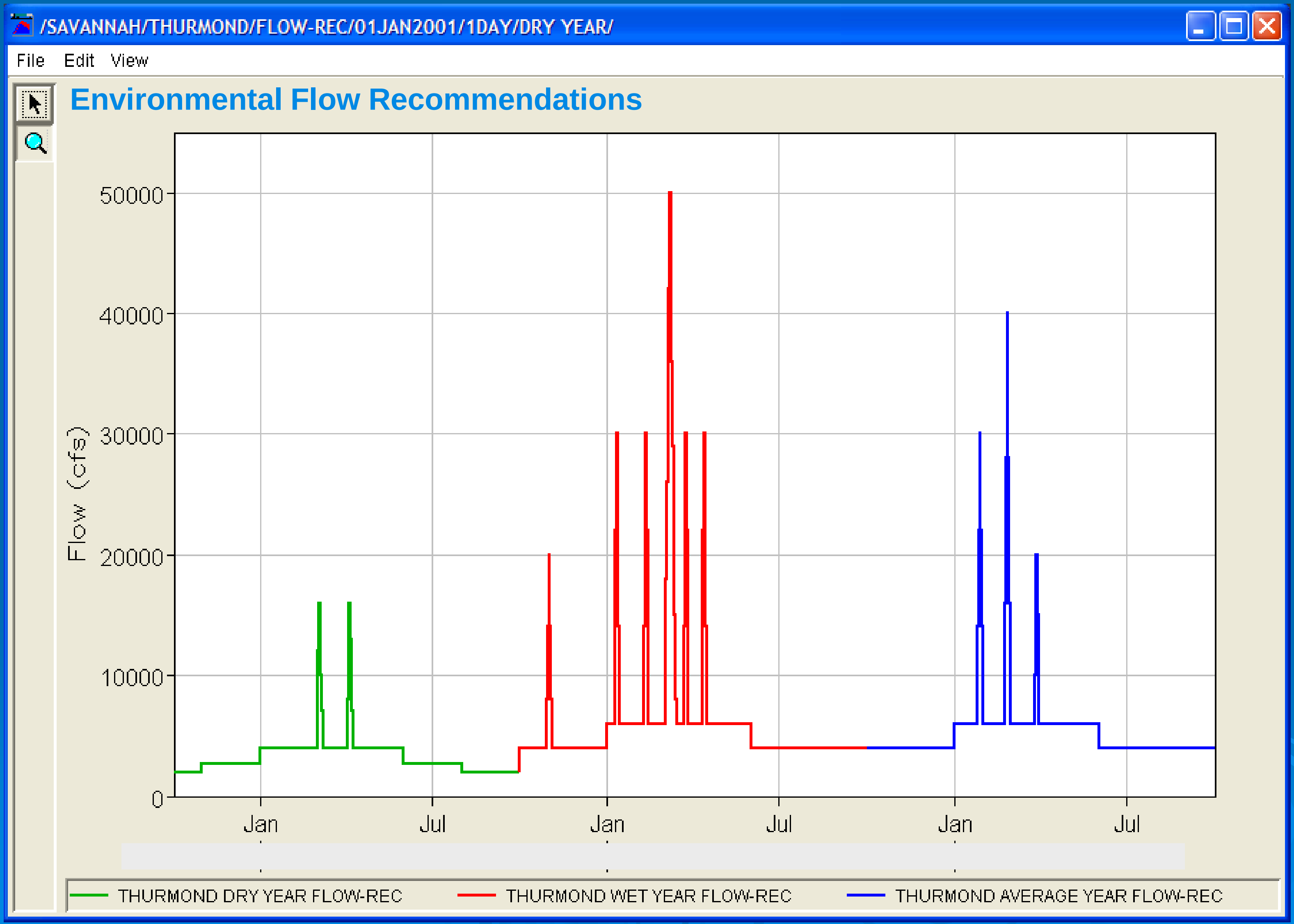
<5,000 cfs
- Adequate floodplain drainage
- Create shallow water habitat for small-bodied fish

3,000 cfs; 3 successive years every 10-20 years
- Floodplain tree recruitment

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Key
- Wet Year
- Avg Year
- Dry Year

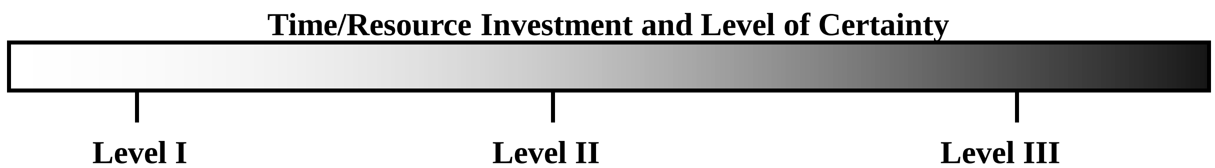
Environmental Flow Prescription



Holistic methodologies: strengths and weaknesses

+ Whole-ecosystem focus
+ Generates alternative environmental flow scenarios for different ecological and social conditions
+ Use of interdisciplinary expert judgment in structured, consistent process
+ Usable in data rich and data poor contexts (use of available techniques and understanding)
+ Explicit links with characteristics of flow regime and with biological and social responses to flow change
- Reliant on expert judgment
- Difficulties in reconciling opinions of different experts
- Moderate to high resource demands

Three Levels of Comprehensive Environmental Flow Assessment



Hydrologic desktop methods consider range of natural variability linked to key ecosystem processes

Expert-panel approaches with little or no modeling

Integrated field studies and modeling encompassing tools such as:

- Riparian recruitment models
- Sediment transport
- Temperature models
- Instream habitat models
- Other environmental flow methodologies (e.g, PHABSIM, IBMs)
- Decision support systems to assist integration

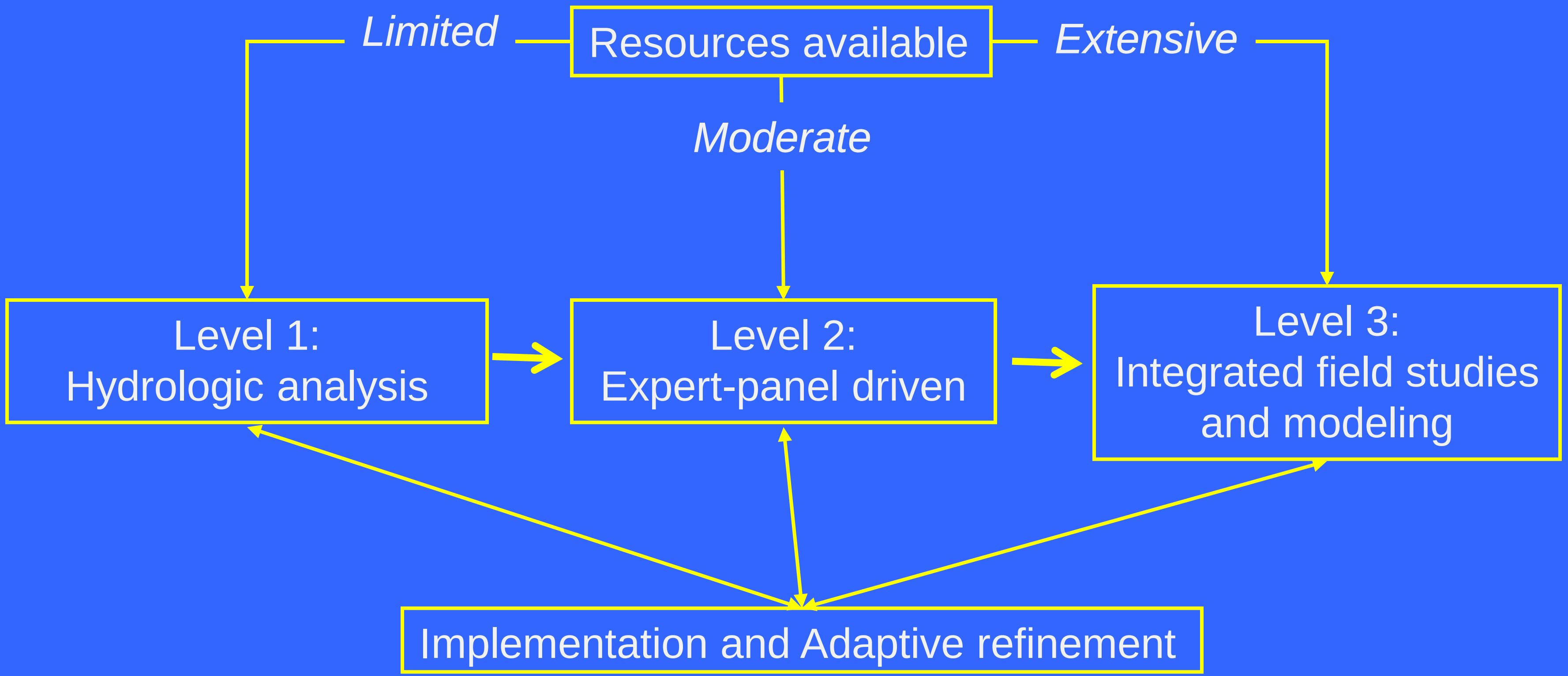
Three-Level Hierarchy

(1) Strategic resource deployment: methods are matched to the level of certainty required and the level of funding available.

(2) Iterative: information generated at one level provides the foundation for, and identifies the need for, higher levels

(3) Accelerates implementation.

Three Levels of Comprehensive Environmental Flow Assessment

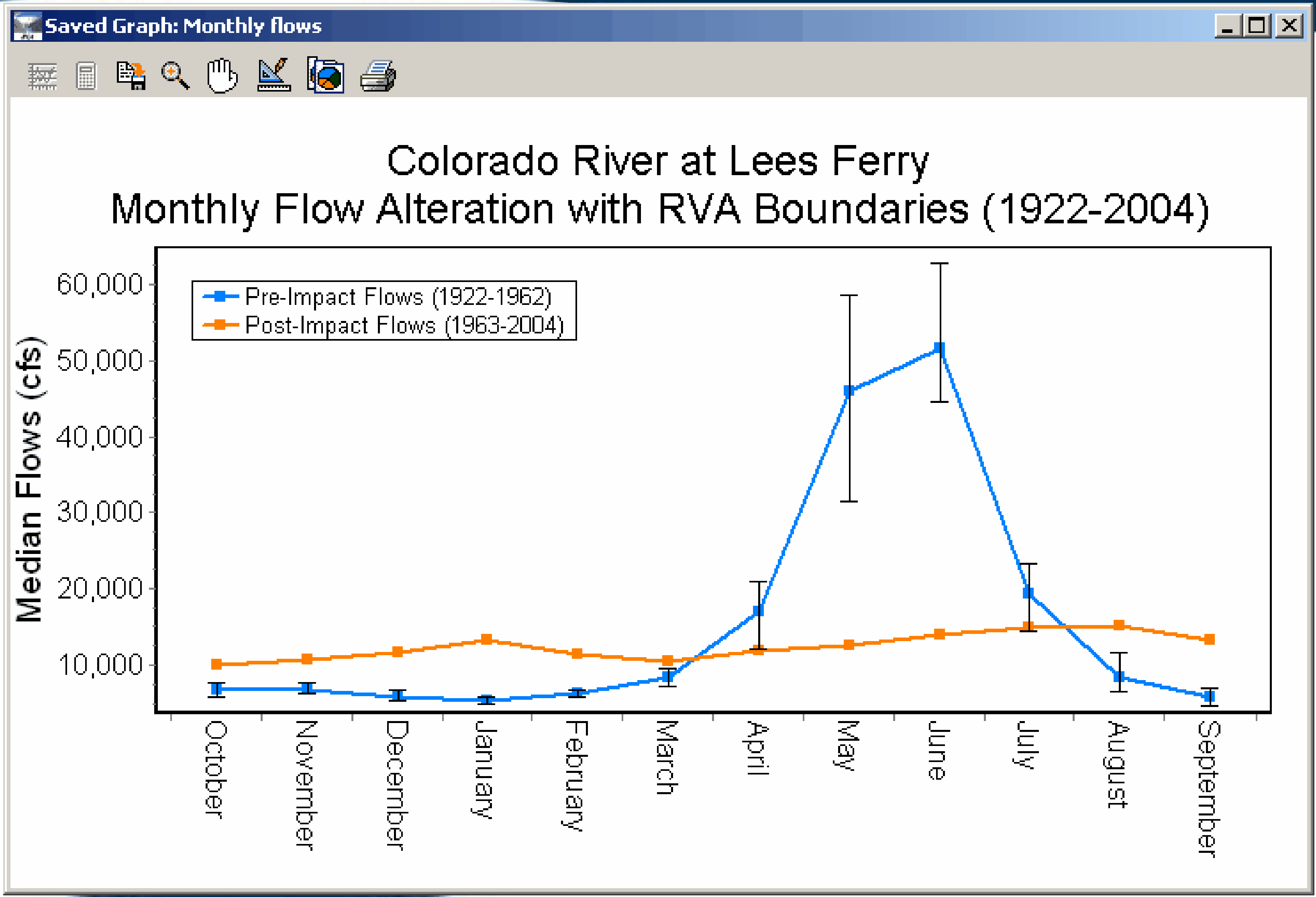


- **As much a social process as it is a technical approach: foster collaboration to get durable results**
- **Can be sequential**

Level 1: Hydrologic analysis

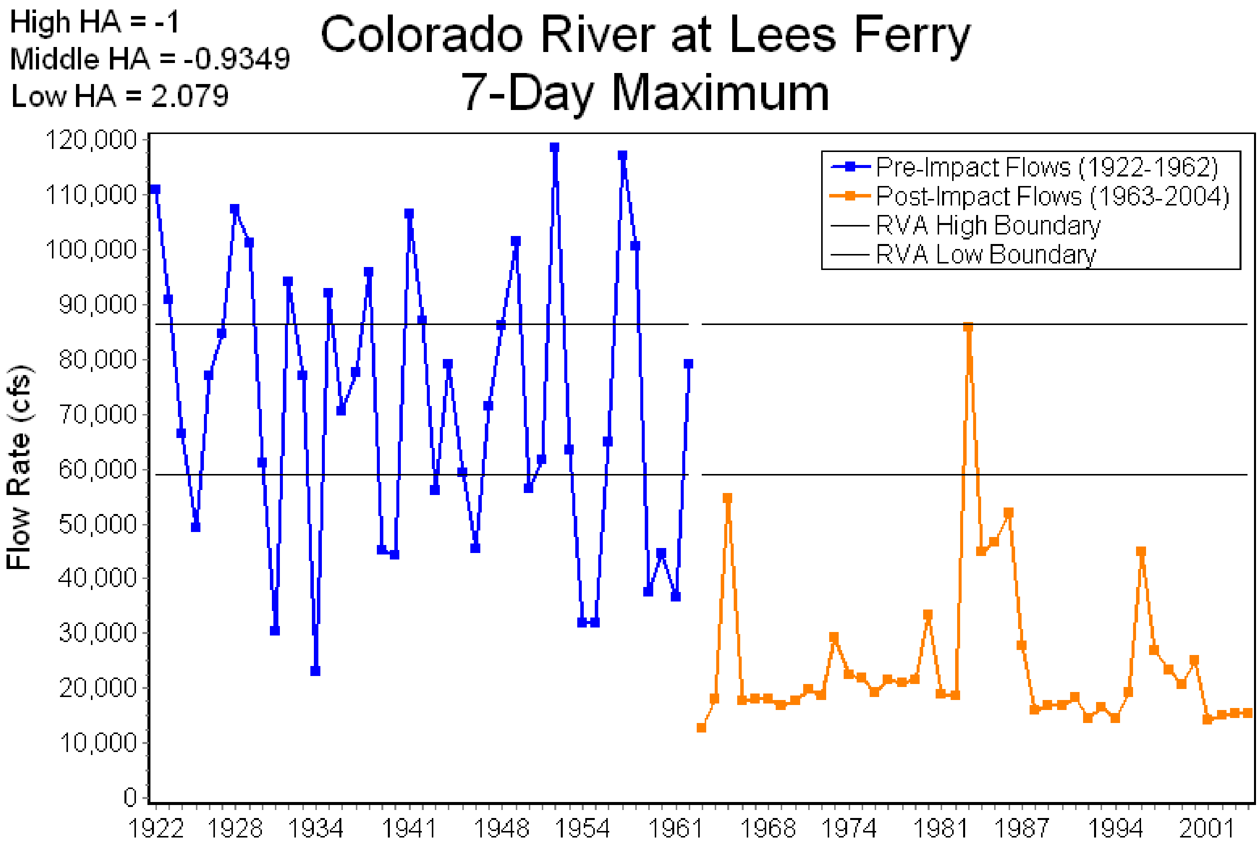
- Can be first step prior to implementing other levels; screening-level approach
- Precautionary stand-alone approach; over time, augmented with higher level approaches
- Can use tools such as Indicators of Hydrologic Alteration (IHA) that can account for the range of ecological flow components necessary for maintaining river processes

Level 1 example: Hydrologic analysis using IHA



Range of Variability Analysis

• Measures the natural range of variability of these 33 flow statistics, and quantifies how this variability has been altered.

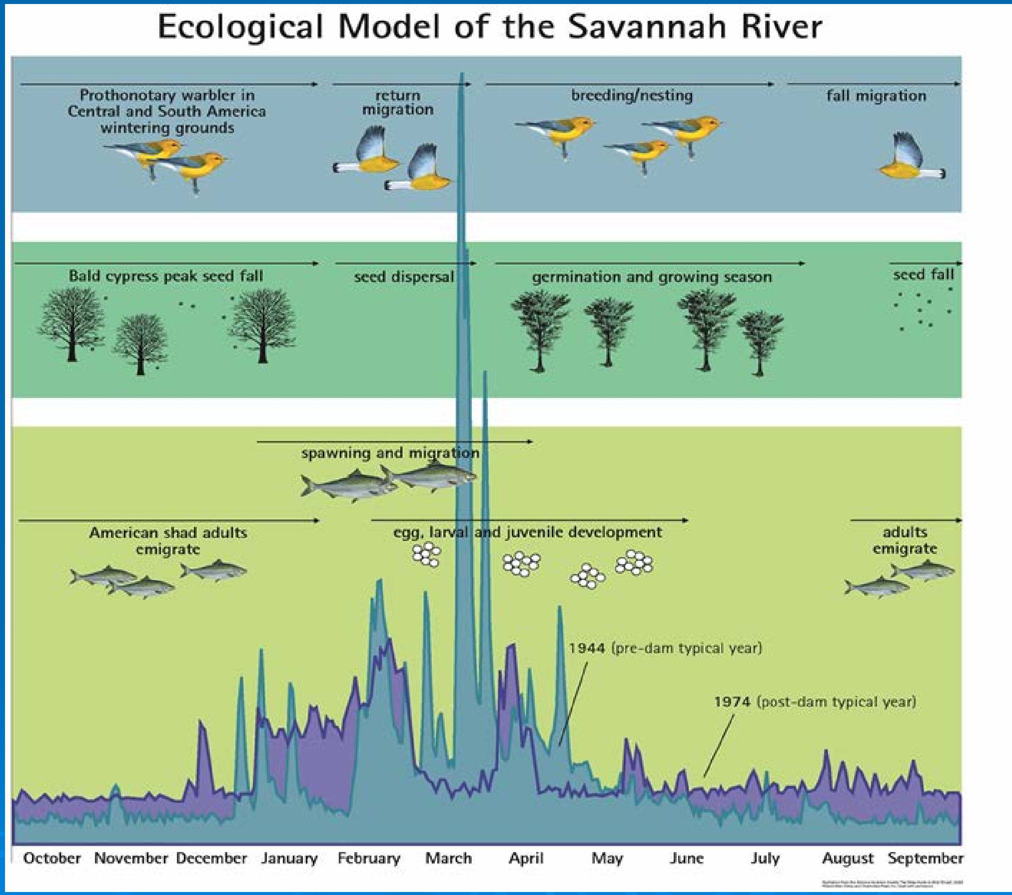


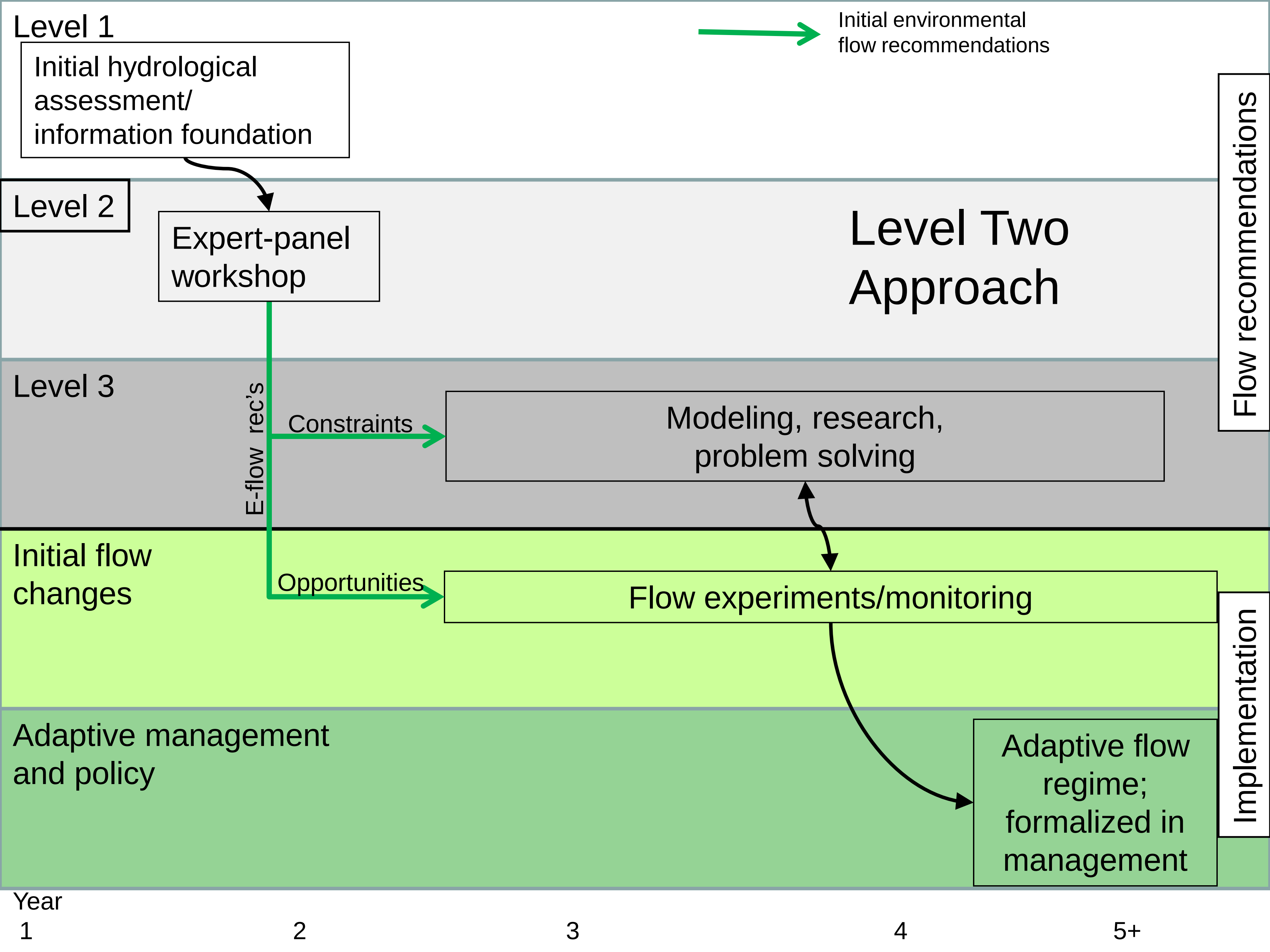
Richter et al. 1997, "How Much Water Does a River Need?" (*Freshwater Biology*)

Level 2: Expert-panel driven approach

- Advanced significantly in Australia and South Africa for rivers with few data available

- TNC published "Savannah Process" based on collaborative process for e-flow determination with US Army Corps




Level 1
Initial environmental flow recommendations
Initial hydrological assessment/ information foundation
Level 2
Expert-panel workshop
Level Two Approach
Flow recommendations
Level 3
E-flow rec's
Constraints
Modeling, research, problem solving
Initial flow changes
Opportunities
Flow experiments/monitoring
Implementation
Adaptive management and policy
Adaptive flow regime; formalized in management
Year
1
2
3
4
5+

Hypotheses, uncertainties

→ Research, models, methods

Winter/Spring Bankfull Pulses

Recommendation:

Time period: Nov 15 - Mar 15

Number of events: 1 - 5 depending on precipitation

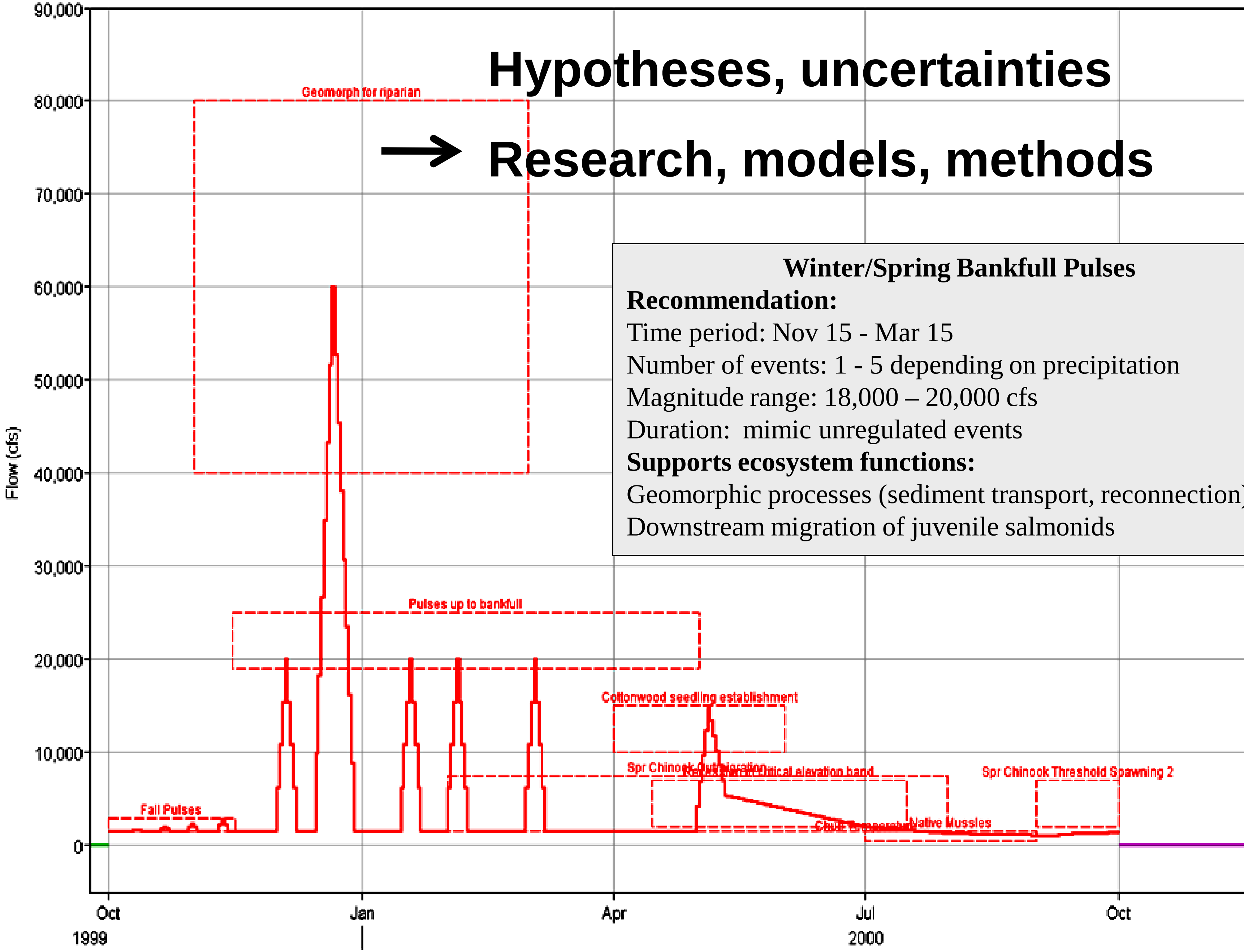
Magnitude range: 18,000 – 20,000 cfs

Duration: mimic unregulated events

Supports ecosystem functions:

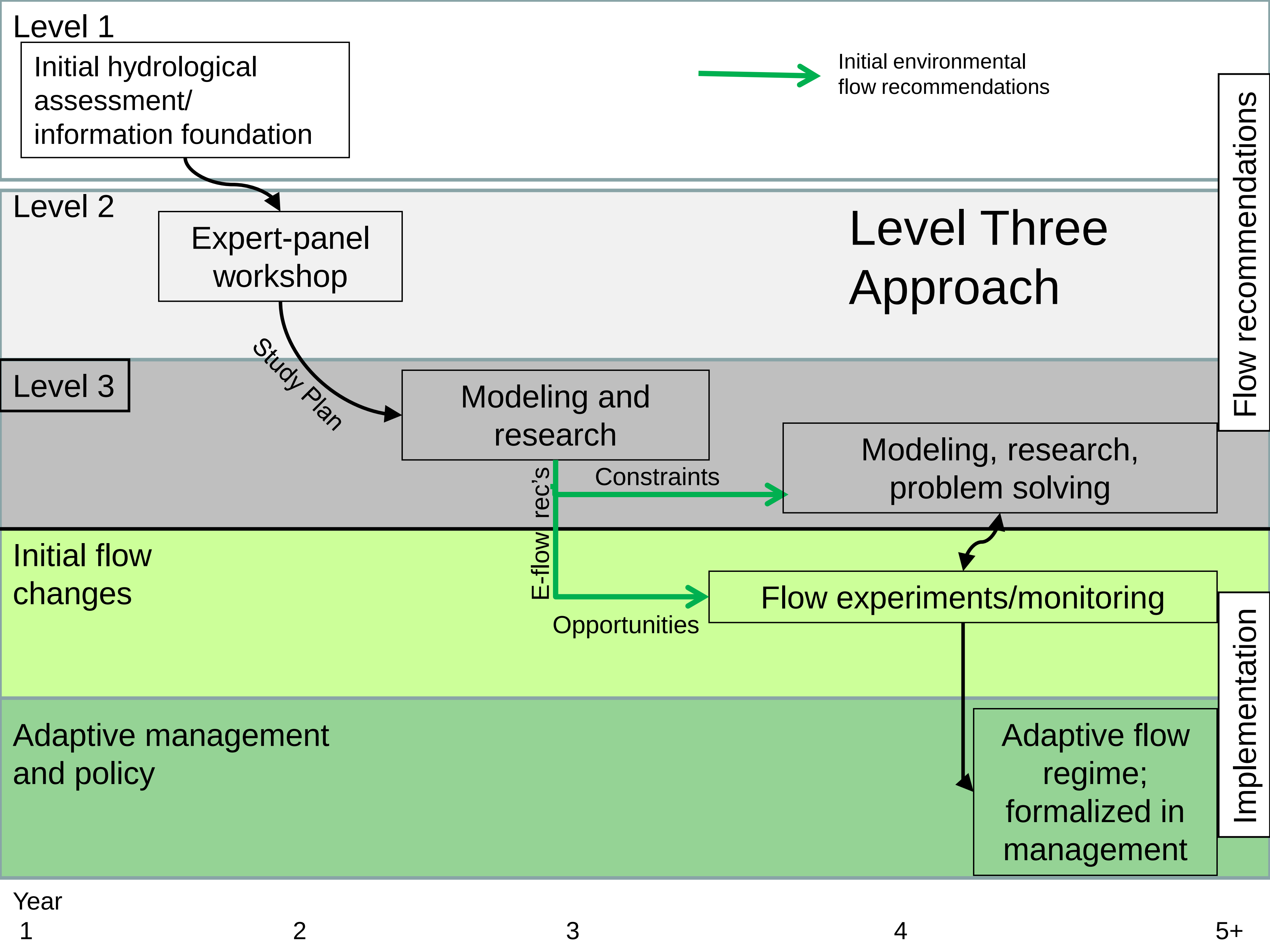
Geomorphic processes (sediment transport, reconnection)

Downstream migration of juvenile salmonids



Level 3: Integrated field studies and modeling

- For systems with extensive existing data or the funding and time to develop new data
- For situations in which greater certainty is desired or required (for example, if lawsuits are likely)
- Can encompass and integrate many existing methods, ideally using decision support system


Level 1
Initial hydrological assessment/ information foundation
Initial environmental flow recommendations
Level 2
Expert-panel workshop
Level Three Approach
Flow recommendations
Study Plan
Level 3
Modeling and research
Modeling, research, problem solving
E-flow rec's
Constraints
Initial flow changes
Flow experiments/monitoring
Opportunities
Implementation
Adaptive management and policy
Adaptive flow regime; formalized in management
Year
1
2
3
4
5+

Level 3 example: Sacramento River Ecological Flows Tool

Steelhead
(*Oncorhynchus mykiss*)

Chinook Salmon
(*Oncorhynchus tshawytscha*)

Green Sturgeon
(*Acipenser medirostris*)

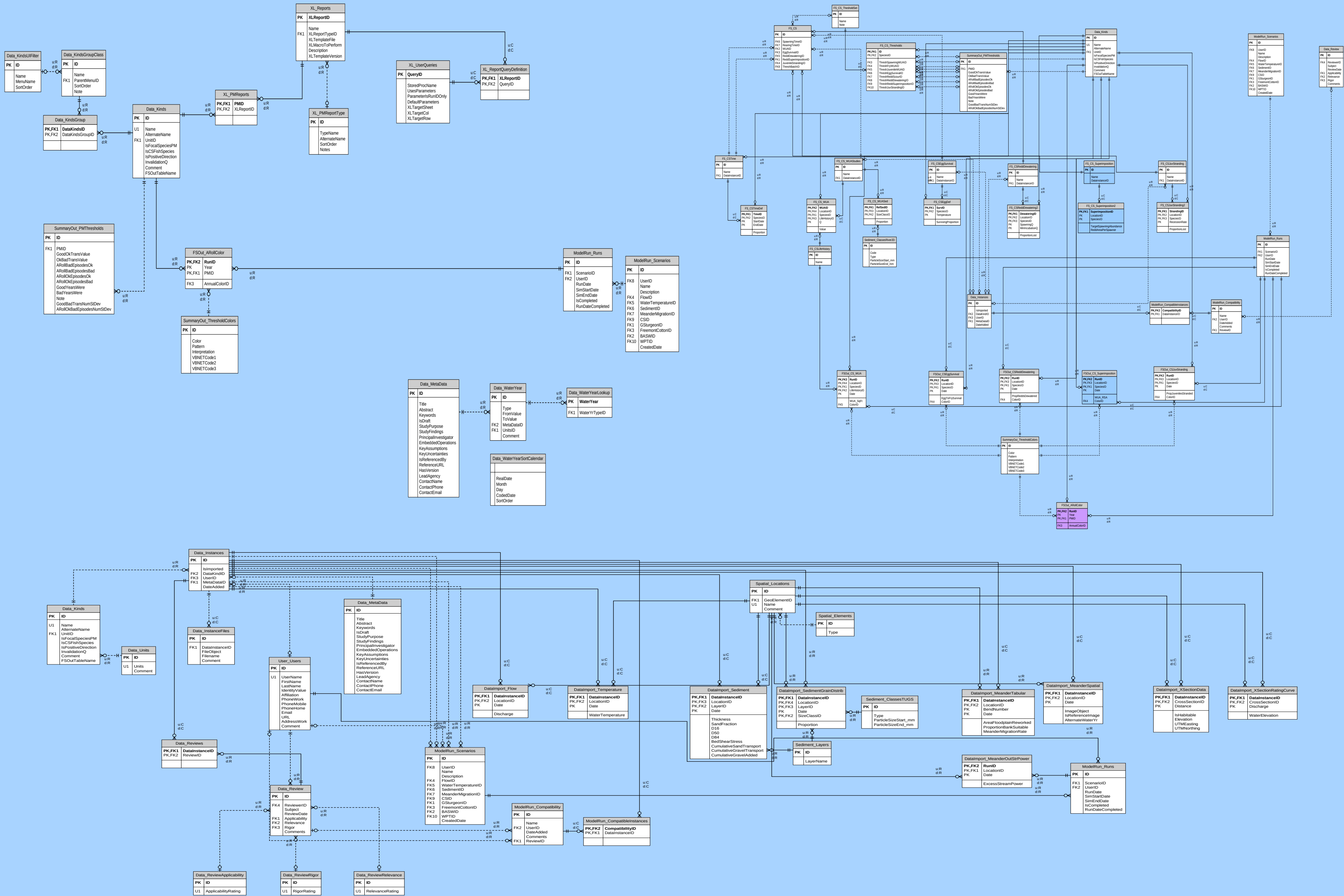
Bank Swallow
(*Riparia riparia*)

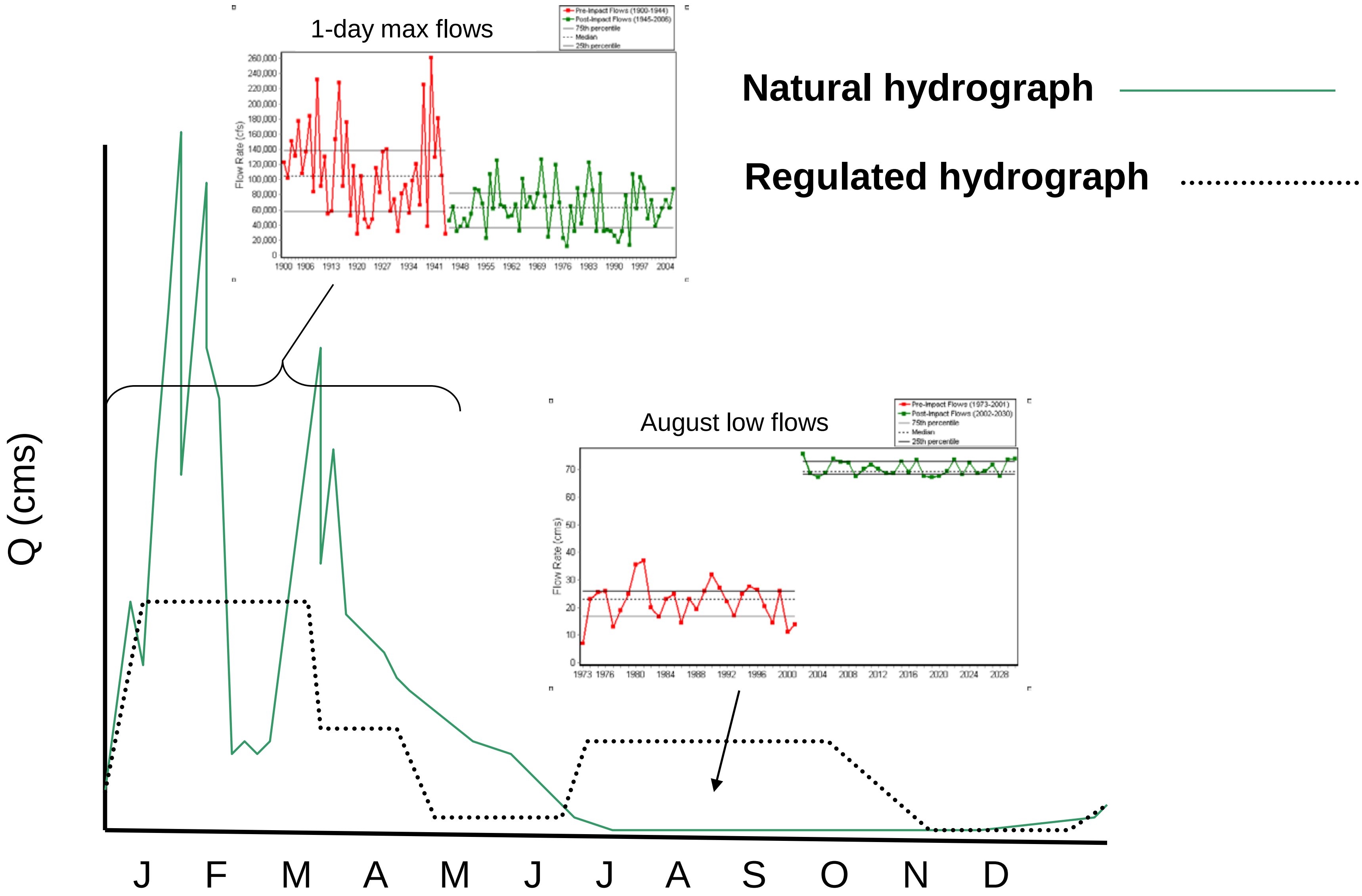
Western Pond Turtle
(*Clemmys marmorata*)

Fremont Cottonwood
(*Populus fremontii*)

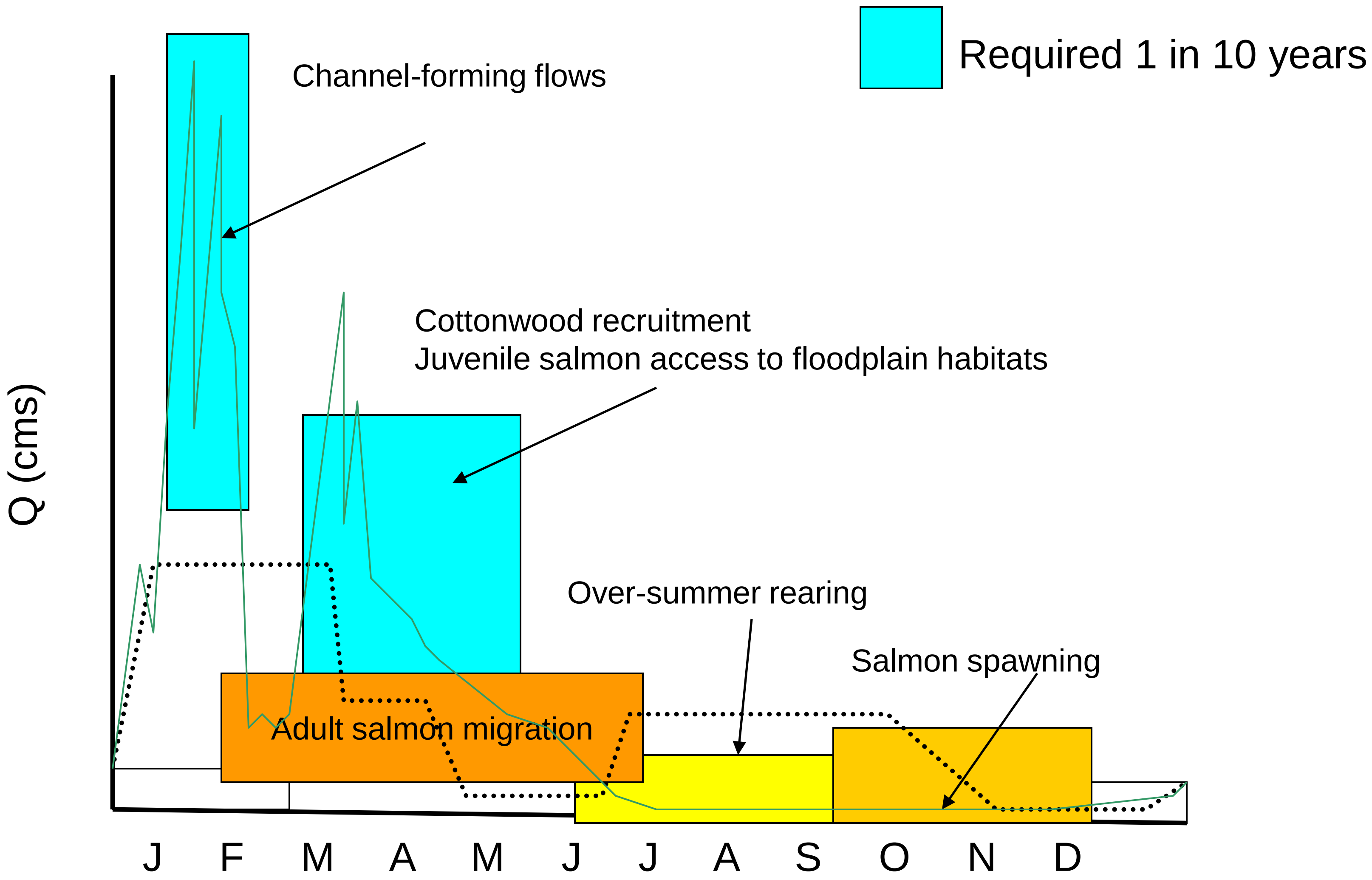
Decision Support System: SacEFT used manage data and link different tools/datasets

SacEFT
Sacramento River Ecological Flows Tool

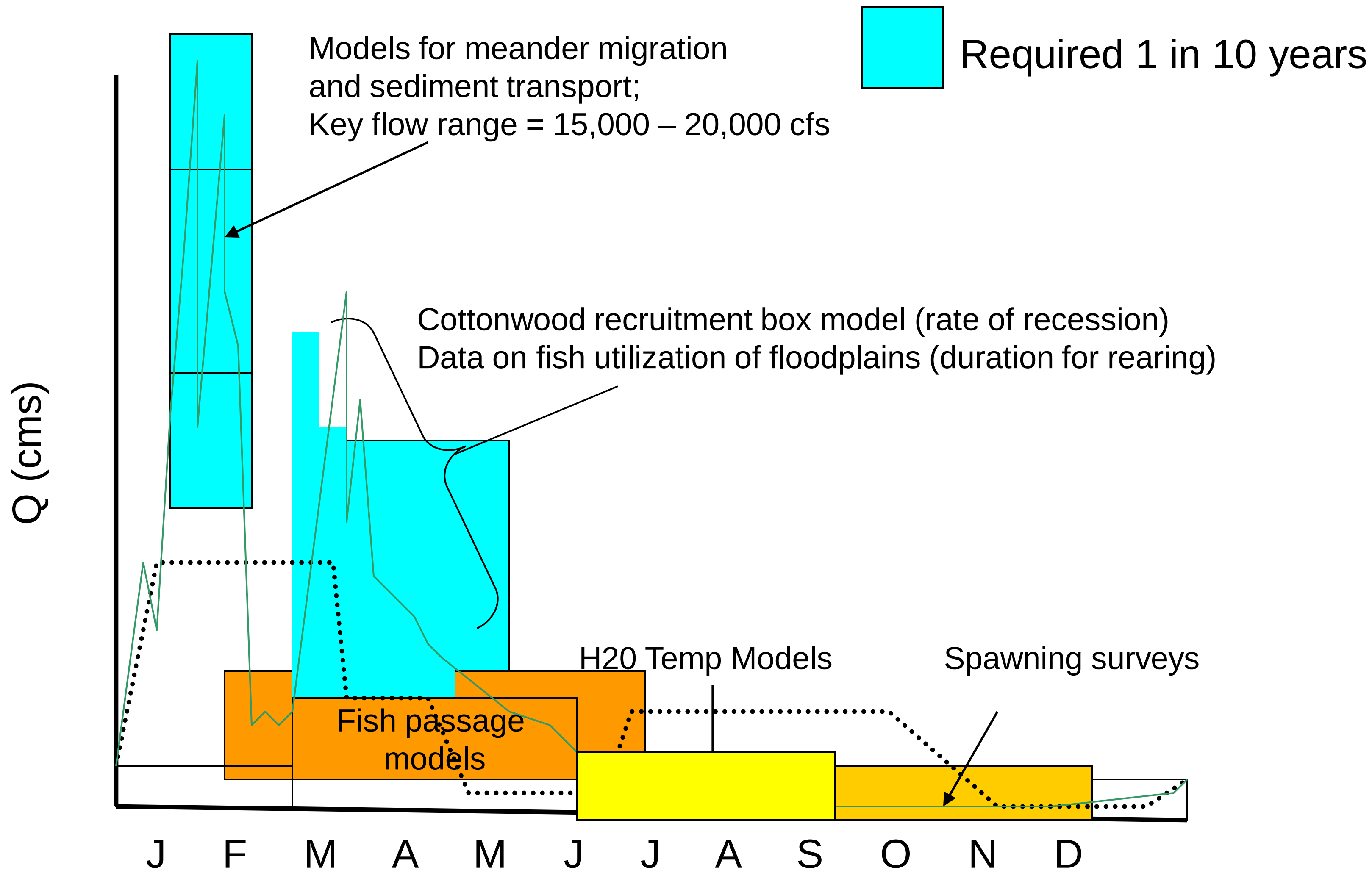




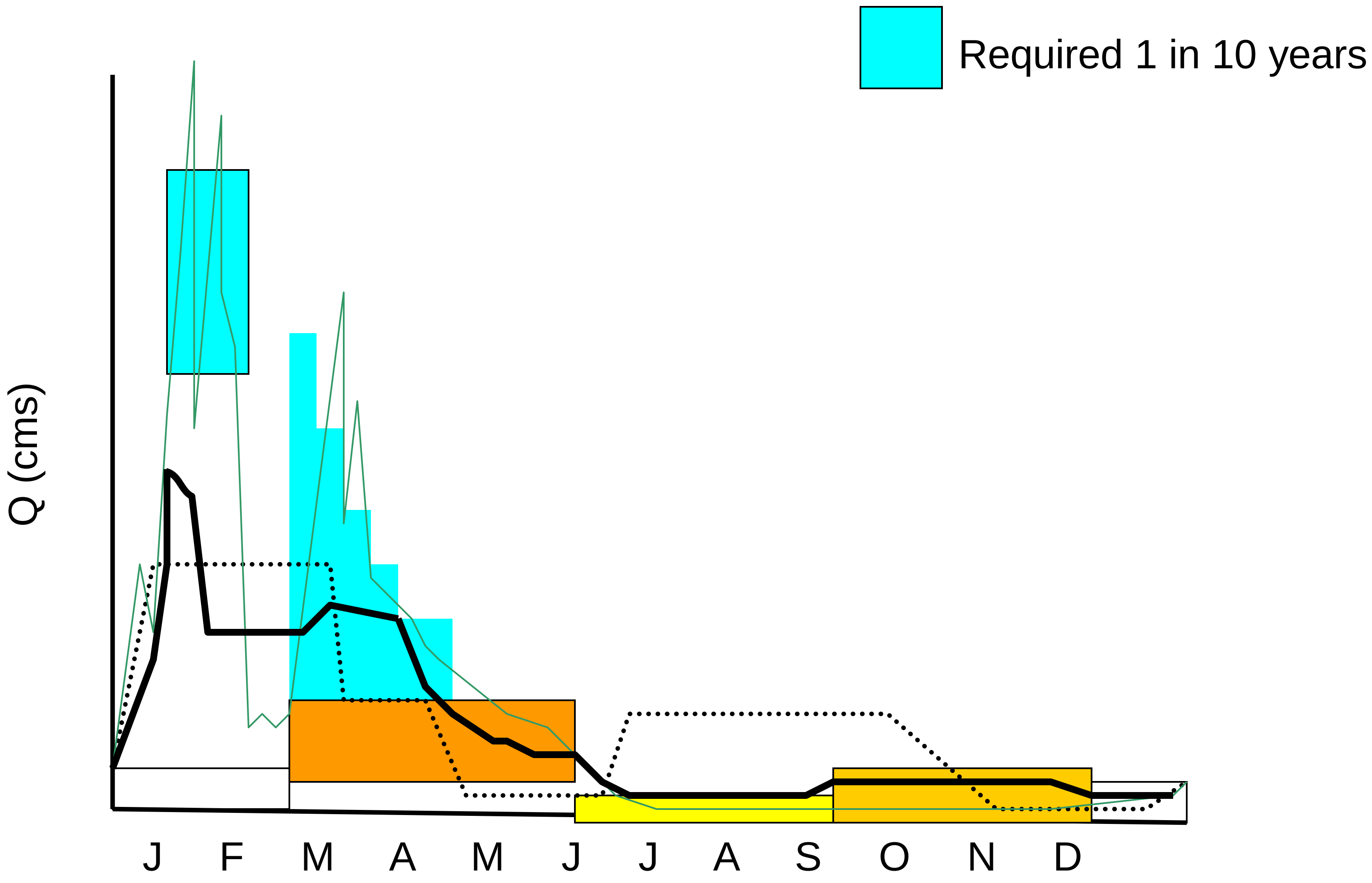
Level 1: Hydrologic desktop analysis



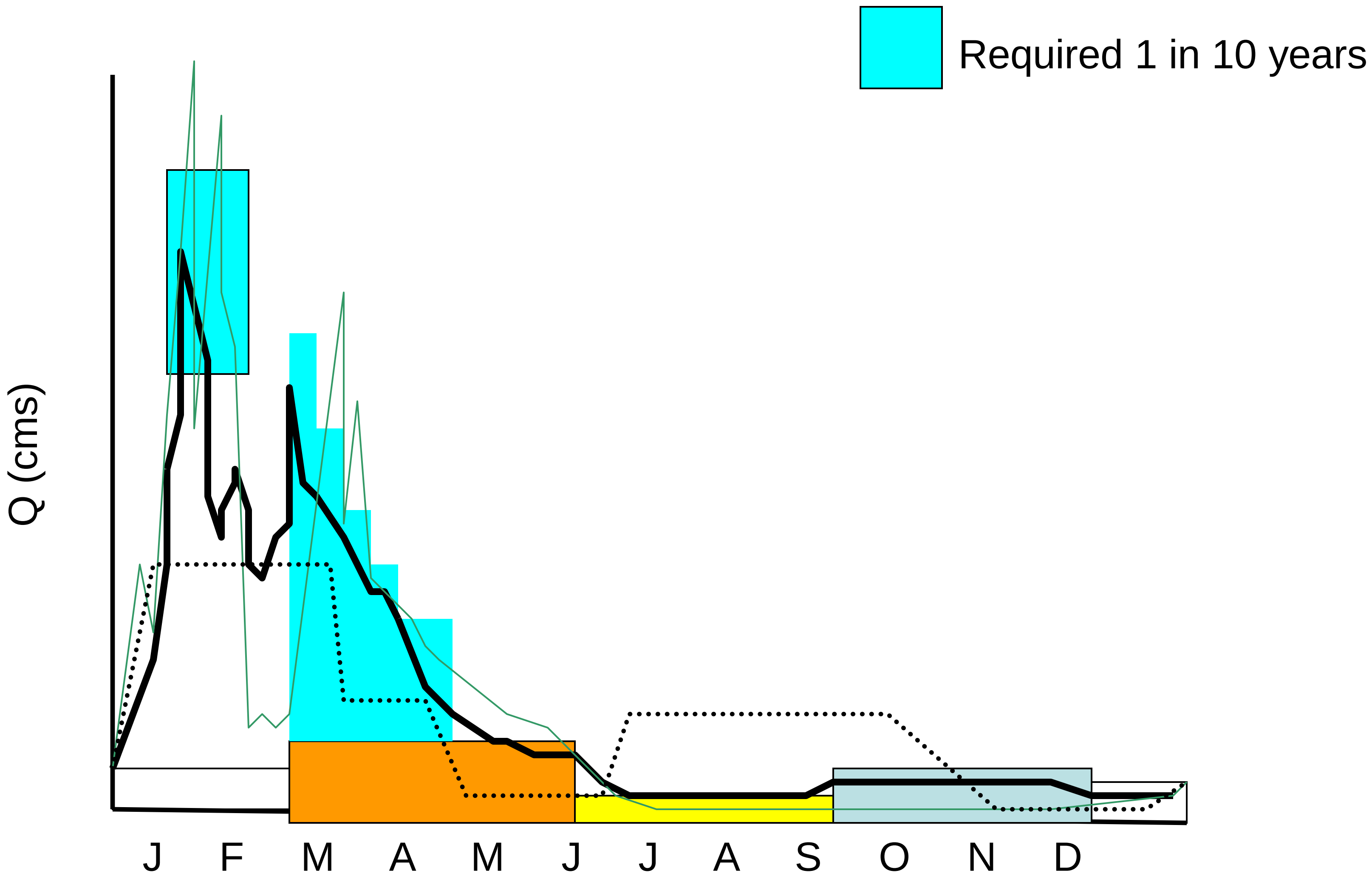
Level 2: Expert panel approach to define initial flow recommendations, framed as hypotheses



Level 3: Using modeling, field sampling and analyses to reduce uncertainties and refine flow needs



Average-year hydrograph to meet flow recommendations



Wet-year hydrograph to meet flow recommendations

Cost and time comparison

Months 0 - 5	Level 1: Hydrologic analysis	$100 - $10,000
Months 6 - 12	Level 2: Expert-panel driven	$10,000 - $200K
	Level 3: Integrated field studies and modeling	Often $1,000,000 +
Years 2 – 5 +		
	Adaptive refinement	Requires sustainable budget

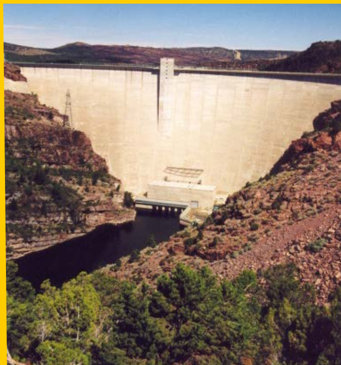
Criteria for a Regional Environmental Flow Method

- 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

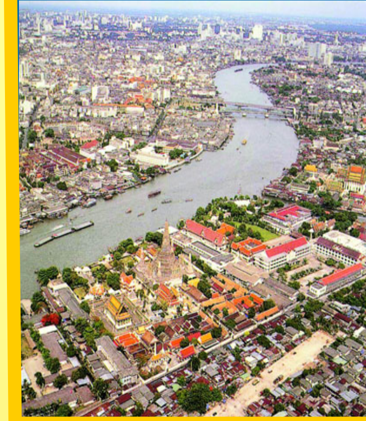






Ecological Limits of Hydrologic Alteration (ELOHA)

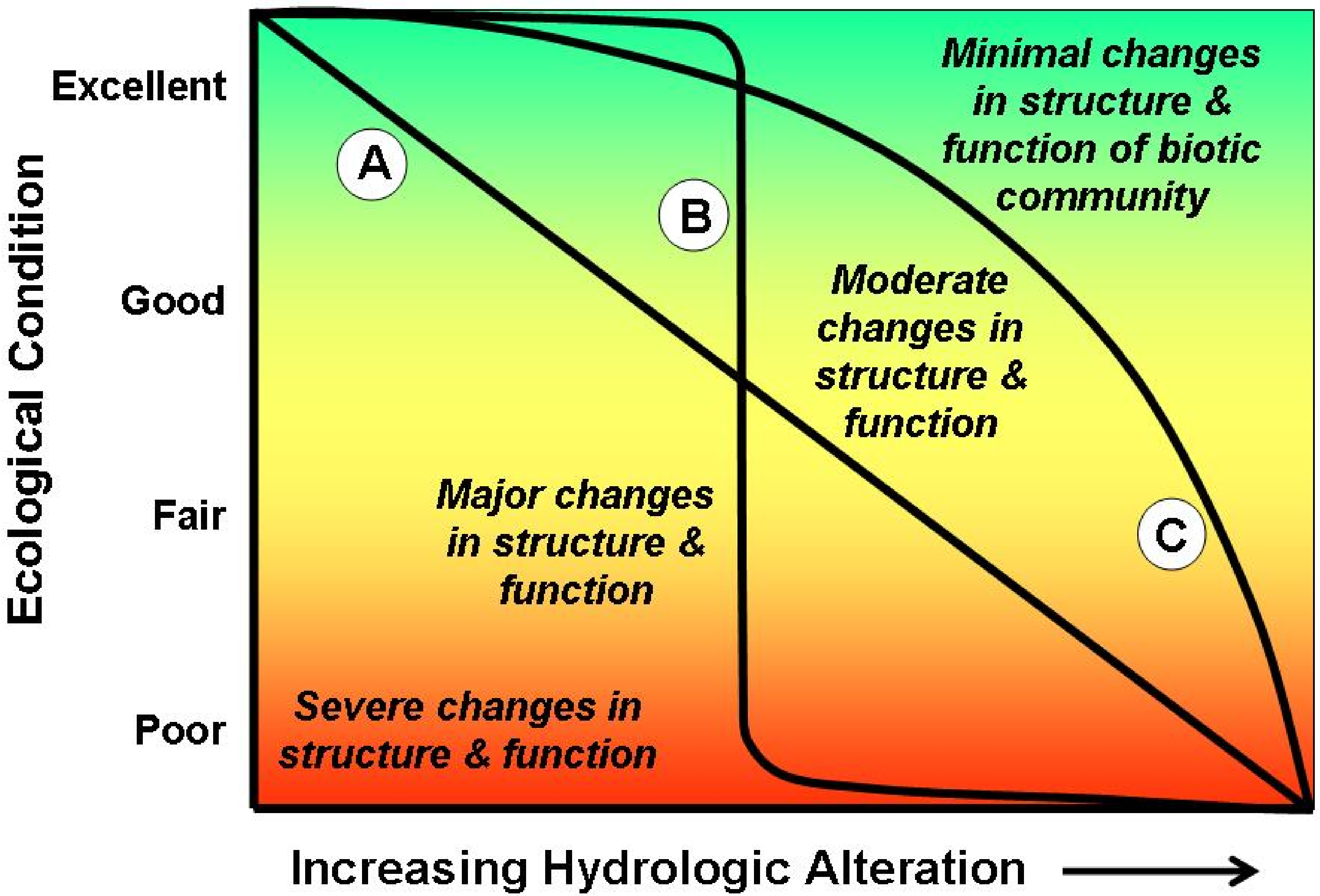


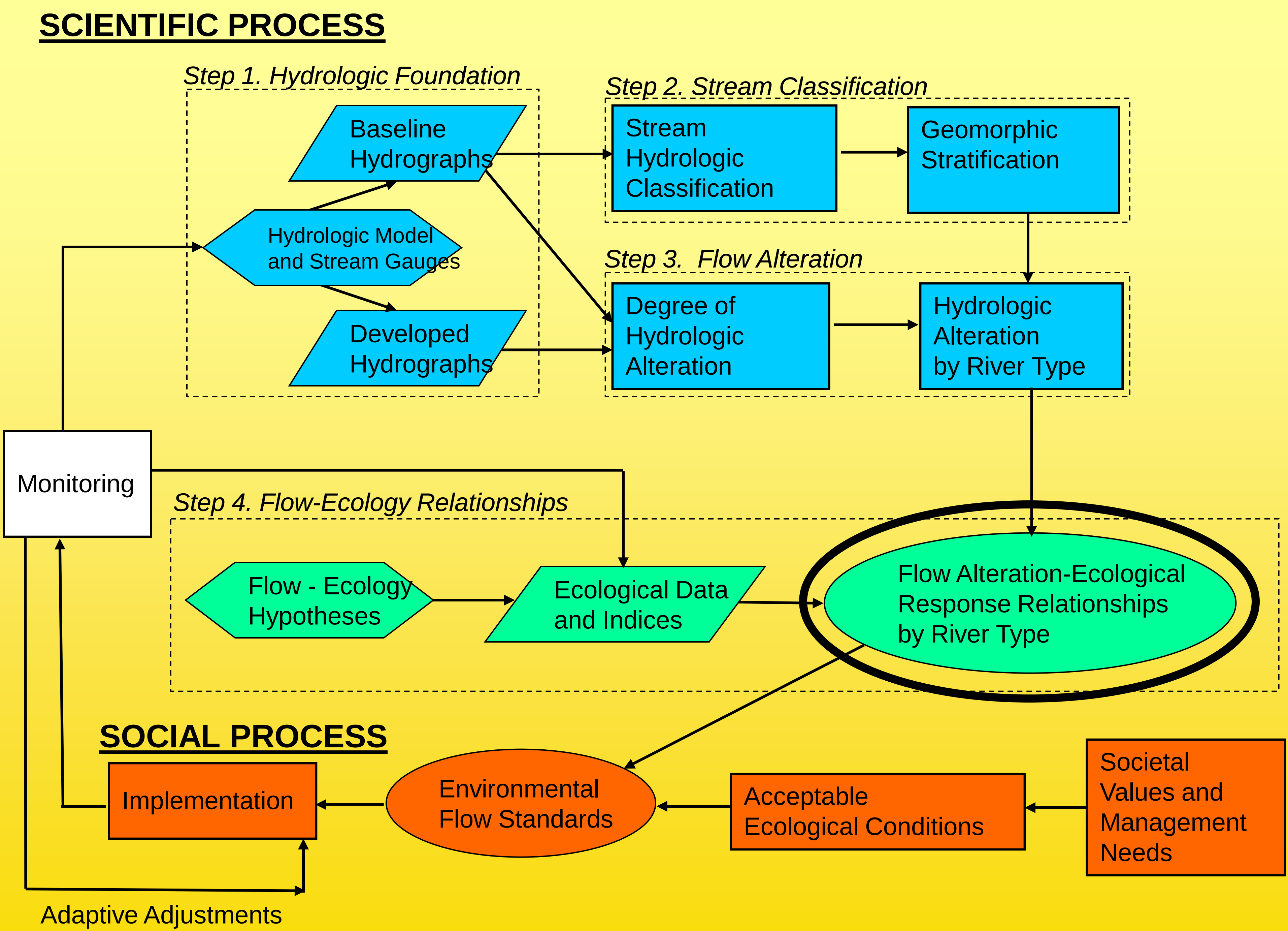
- Quantifies trade-offs between streamflow alteration and ecological degradation
- Informs the determination of environmental flow targets
- Integrates environmental flows into a computerized DSS



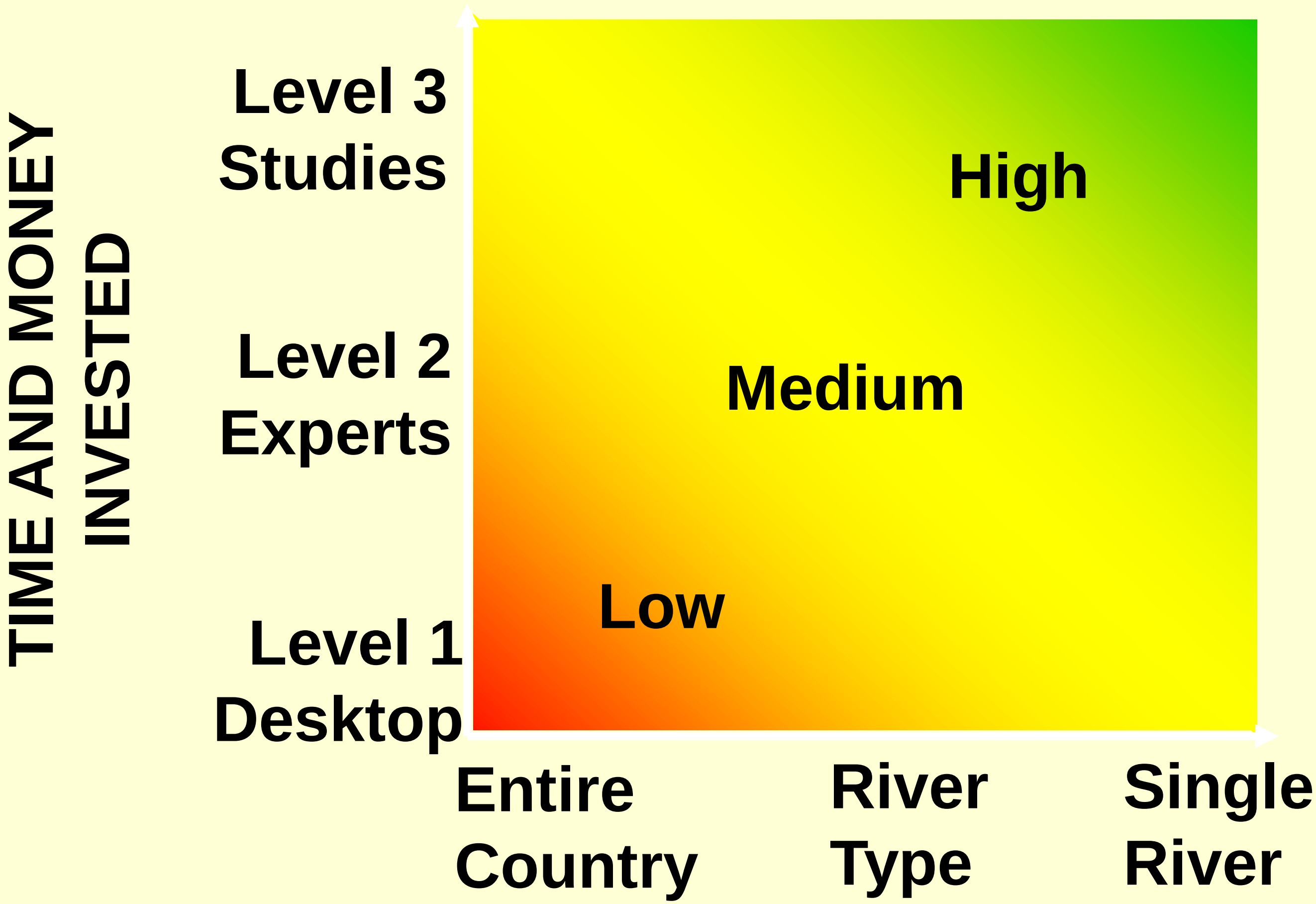


Flow Alteration - Ecological Response Curve




SCIENTIFIC PROCESS
Step 1. Hydrologic Foundation
Baseline Hydrographs
Hydrologic Model and Stream Gauges
Developed Hydrographs
Step 2. Stream Classification
Stream Hydrologic Classification
Geomorphic Stratification
Step 3. Flow Alteration
Degree of Hydrologic Alteration
Hydrologic Alteration by River Type
Monitoring
Step 4. Flow-Ecology Relationships
Flow - Ecology Hypotheses
Ecological Data and Indices
Flow Alteration-Ecological Response Relationships by River Type
SOCIAL PROCESS
Implementation
Environmental Flow Standards
Acceptable Ecological Conditions
Societal Values and Management Needs
Adaptive Adjustments

Confidence in Protecting Healthy Rivers



Essential Knowledge for Environmental Flows:

Situation Analysis

- Natural hydrology, biology, geomorphology
- Rare and endangered species
- Existing and future development
- Degree of controversy
- Water policy framework
- Upstream and downstream constraints
- Stakeholder needs and interests
- Resource and capacity constraints
- Available information

References

Mathews, R., and B. D. Richter. 2007. Application of the Indicators of Hydrologic Alteration software in environmental flow setting. *Journal of the American Water Resources Association* 43.

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http://www.conservationgateway.org/topic/freshwater

Evolution of a river management paradigm

1950s-60s	Water resource development for society
1960s-70s	Minimum flows for pollution dilution
1970s-80s	Minimum flows for fish
1990s	**Environmental flows** for ecosystems
1990s-2000s	Holistic integration of full range of values of healthy rivers for nature and people