18th International
RIVER
SYMPOSIUM
Brisbane Australia
21–23 September 2015
HEALTHY RIVERS - HEALTHY ECONOMIES

Contributions of Environmental Flows Science to River Conservation and Restoration

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Australia

www.rivers.edu.au

Griffith UNIVERSITY

10th Annual International Riversymposium & Environmental Flows Conference Brisbane, September 2007

750 delegates from over 50 countries produced:

Brisbane Declaration 2007 http://www.watercentre.org/news/declaration

- A new definition of e-flows
- 7 e-flow principles
- 9-point Global Action Agenda to protect rivers globally by maintaining or restoring environmental flows

Environmental Flows – a new definition

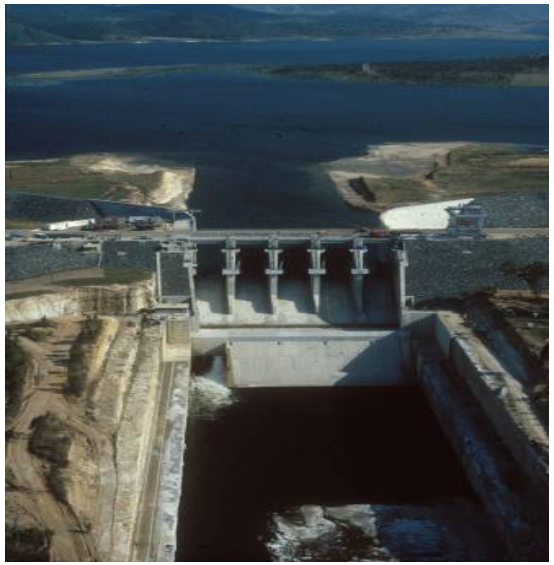
Environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon these systems

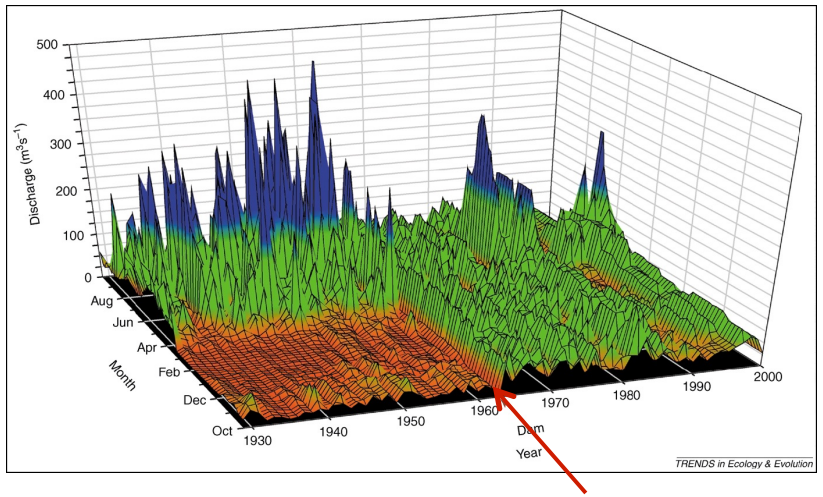
Brisbane Declaration 2007
International Environmental Flows Conference, Brisbane, September 2007
750 delegates from over 50 countries

Brisbane Declaration 2007

- Freshwater and estuarine ecosystems have evolved with, and depend upon, naturally variable flows of high-quality fresh water

- **Flow alteration imperils freshwater and estuarine ecosystems**





Flaming Gorge Dam 1963
Lytle & Poff (2004)

Brisbane Declaration 2007

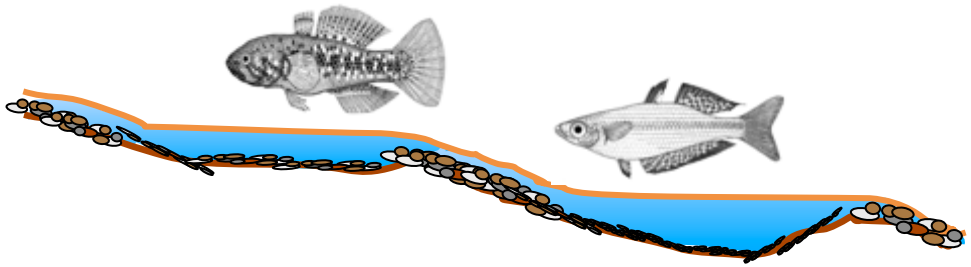
- **Greater attention to environmental flows must be exercised** when attempting to manage floods, water supplies, hydropower generation, navigation and recreation

- **Scientifically credible e-flow methodologies must quantify** the variable – not just minimum – flows needed for each water body by *explicitly* linking environmental flows to specific ecological functions and social values

Scientifically credible e-flow methodologies

70% of global methods are based on:

- hydrological rules, e.g. % of historical flow
- hydraulic analysis, e.g. wetted perimeter
- habitat modelling, e.g. PHABSIM (IFIM)



Valuable contributions to habitat protection and restoration
Significant new advances in habitat modelling, e.g. SEFA

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SEFA: System for Environmental Flow Analysis

Tom Payne, Bob Milhous, Ian Jowett

http://sefa.co.nz/

SEFA contains:

- one and two dimensional habitat analysis
- habitat suitability criteria (e.g. fish)
- water temperature, dissolved oxygen modeling
- sediment analysis (deposition, flushing flows)
- riparian inundation modeling
- time series analysis of flows & aquatic habitat

Aquatic biodiversity and natural flow regimes

Connectivity

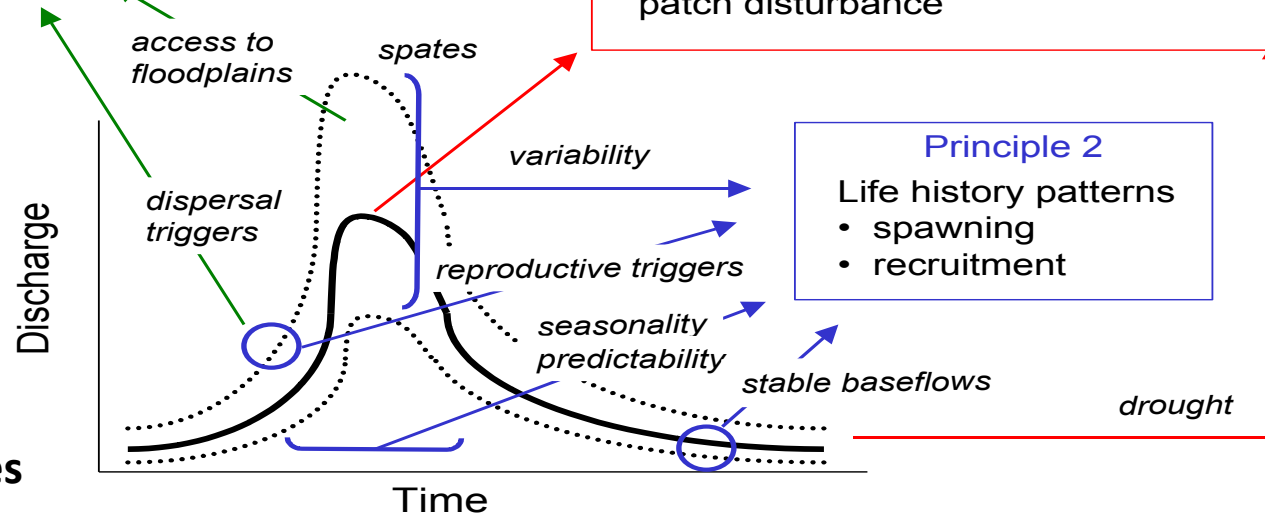
Alien and invasive species

Principle 3
lateral connectivity
longitudinal connectivity

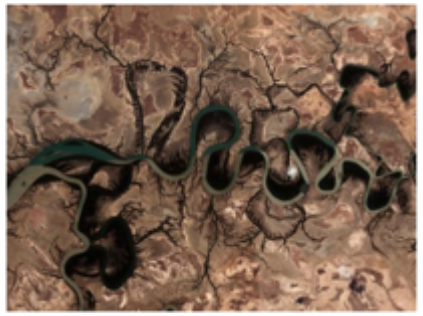
Principle 1
channel form
habitat complexity → biotic diversity
patch disturbance

Principle 2
Life history patterns
- spawning
- recruitment

Principle 4
natural regime discourages invasions



Channel form and habitat



Life history

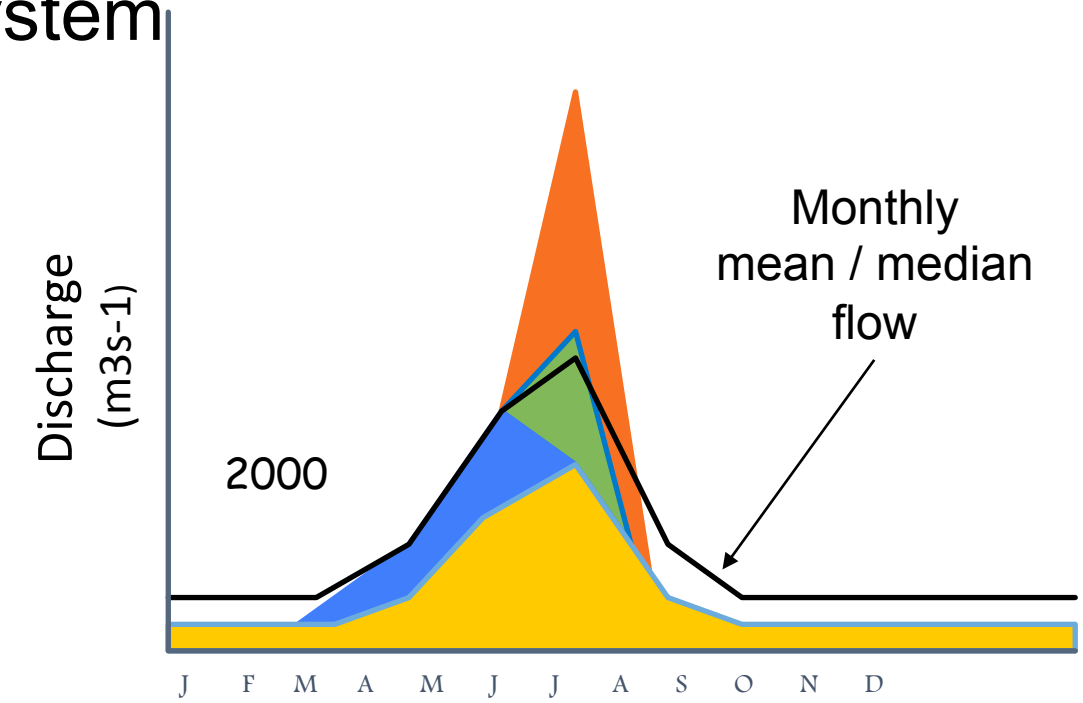
Bunn & Arthington (2002)

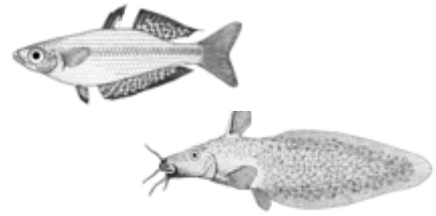
Holistic – Ecosystem E-flow Methods - 1991

- E-flows for riverine ecosystem from source to terminal waterbody, including:

  - channel & habitat
  - algae
  - aquatic vegetation
  - invertebrates & fish
  - riparian vegetation
  - floodplain processes
  - fisheries

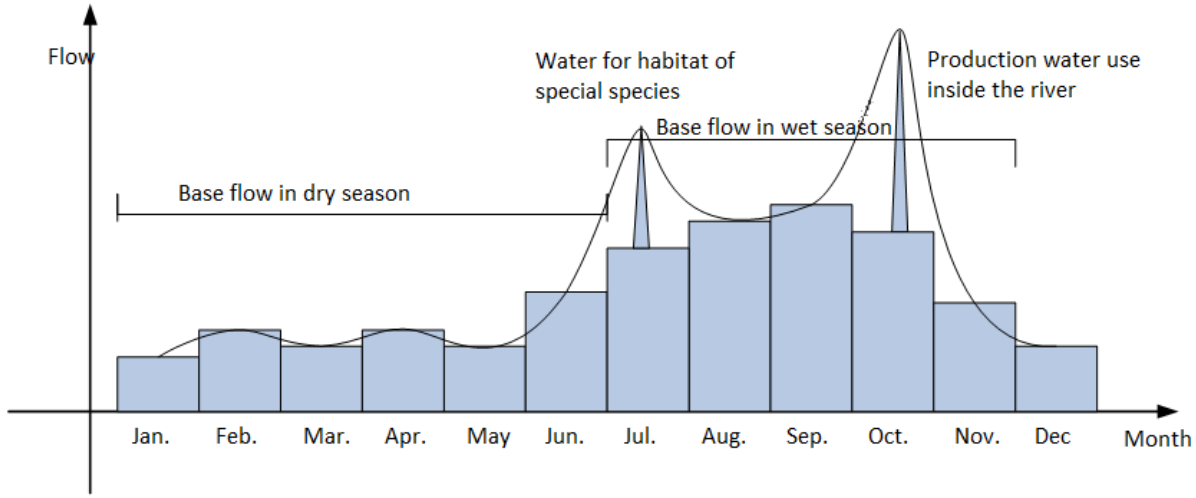
Hill *et al.* (1991)





Arthington *et al.* (1992)

Mapping ecological components to natural hydrograph



Speed *et al*. (2011)

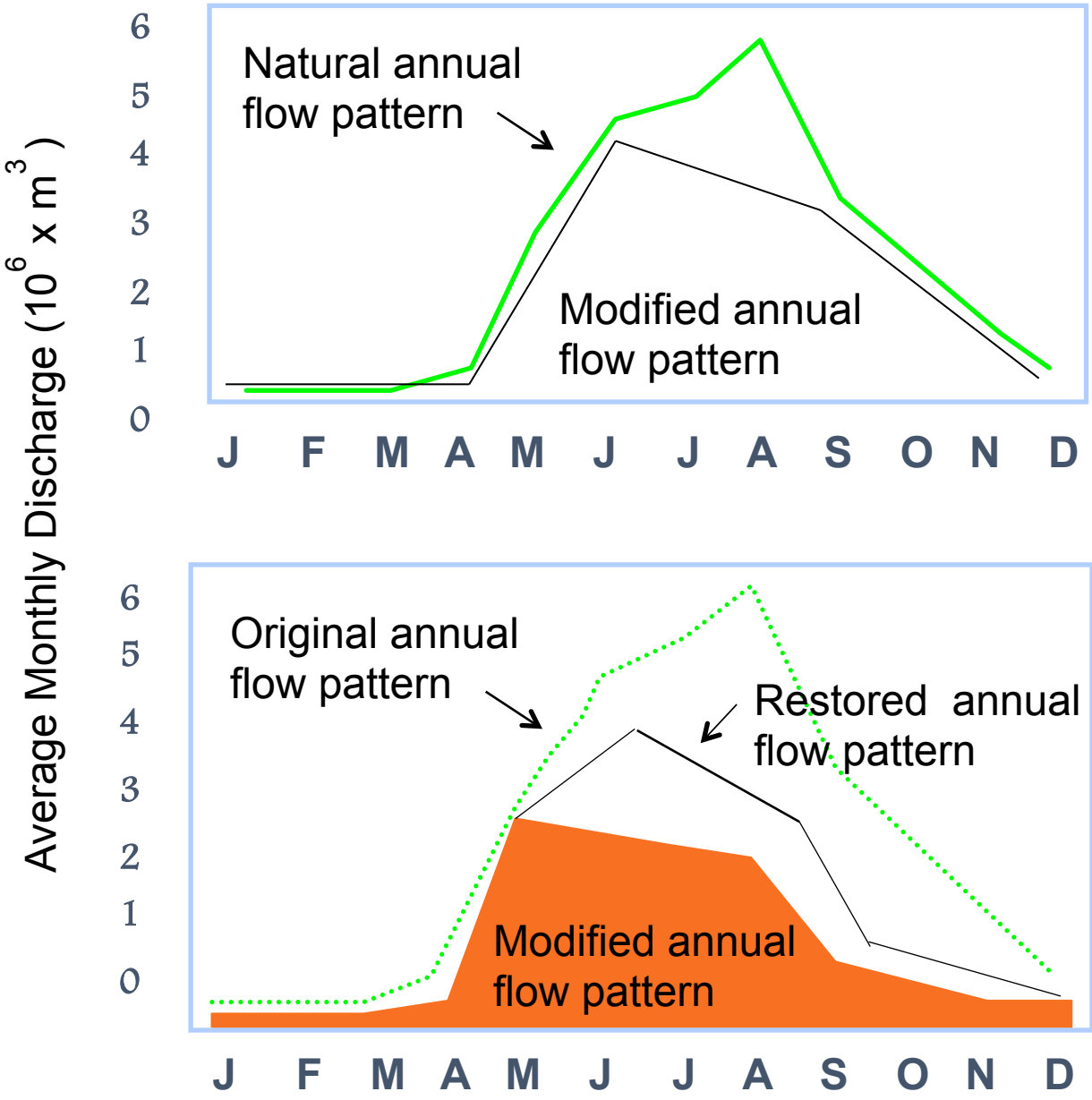
Building Block Methodology – BBM
Sth Africa - King & Louw (1998)

Expert/Scientific Panels, FLOWS, Flow Events Method - Australia

CAMS (Catchment Abstraction Management Strategies) UK

Holistic-ecosystem applications:

* **River conservation**
* **River restoration**



River Conservation

- Maintain flow regime as near to natural as possible

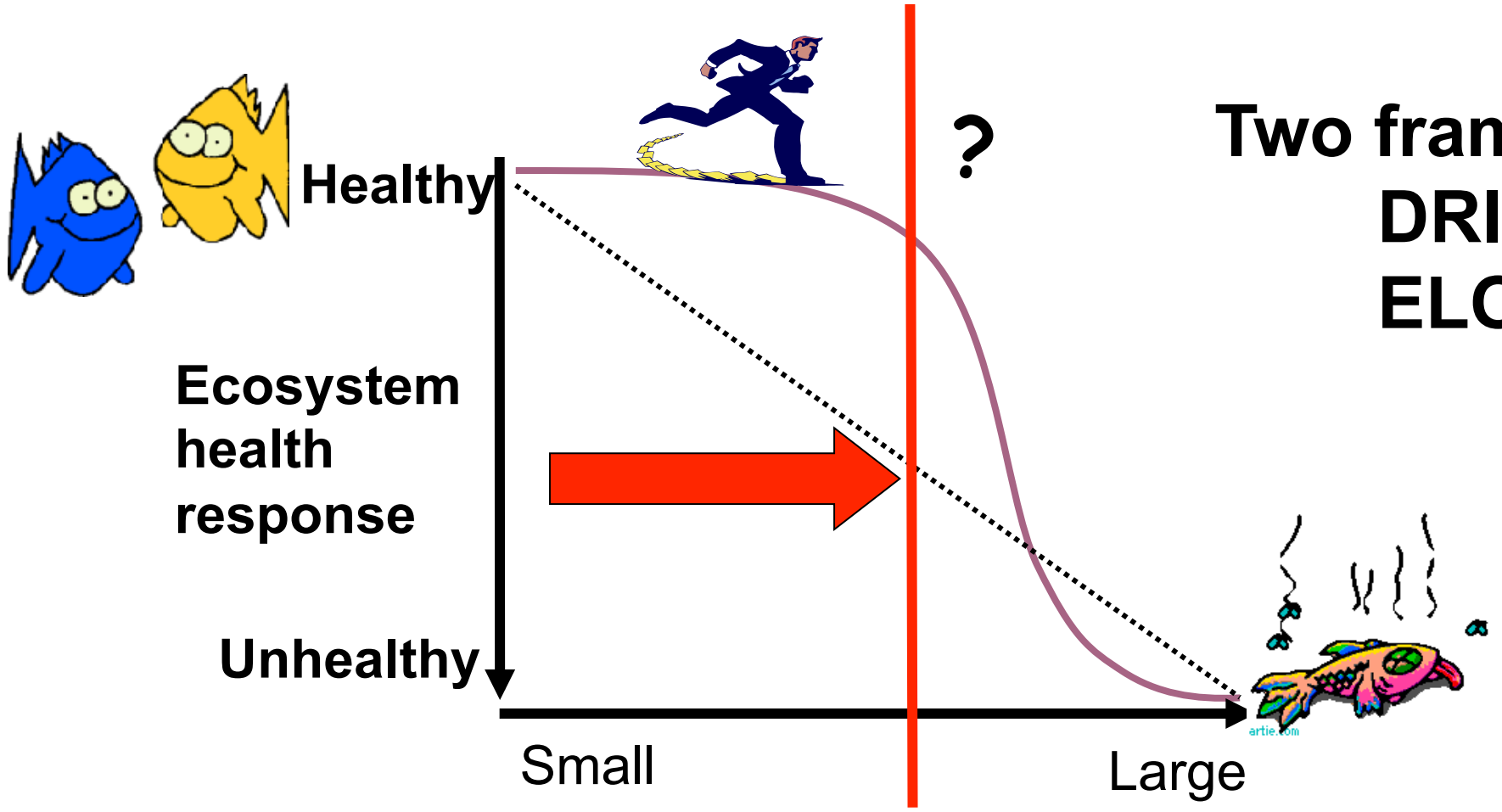
- Identify unacceptable thresholds of ecological change

River Restoration

- Restore flow regime towards natural pattern

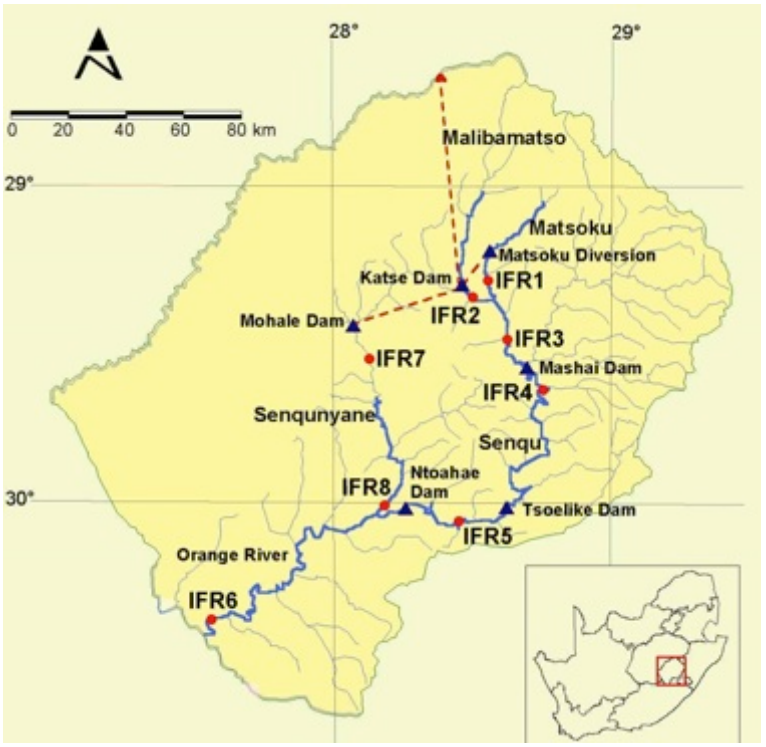
- Identify ecological end points that can be achieved by flow restoration given constraints

Identifying unacceptable levels of ecological change



Two frameworks:
DRIFT
ELOHA

DRIFT – Downstream Response to Imposed Flow Transformation



Lesotho Highlands Water Project

Objectives:

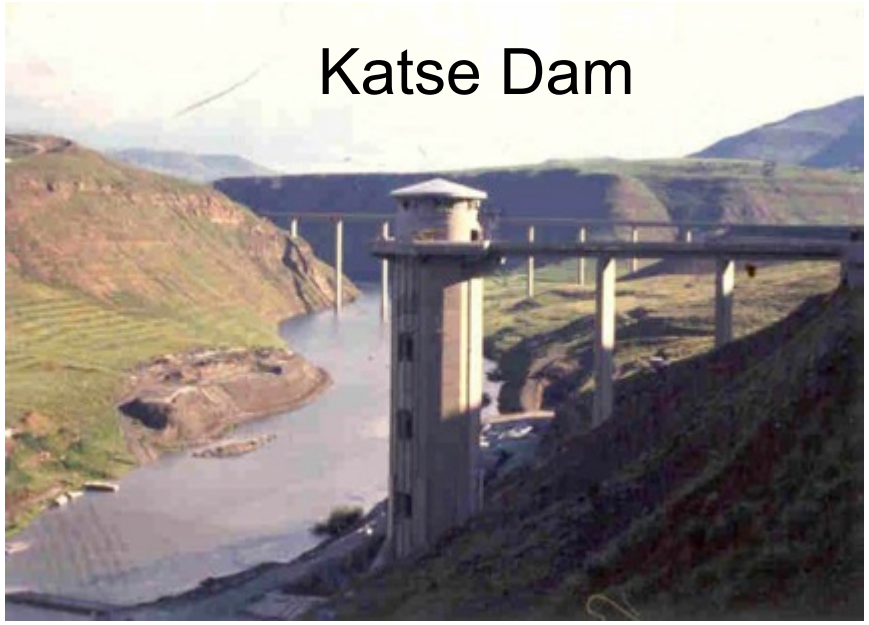
Export water to SA
Hydro-electricity in Lesotho

Multi Phase project

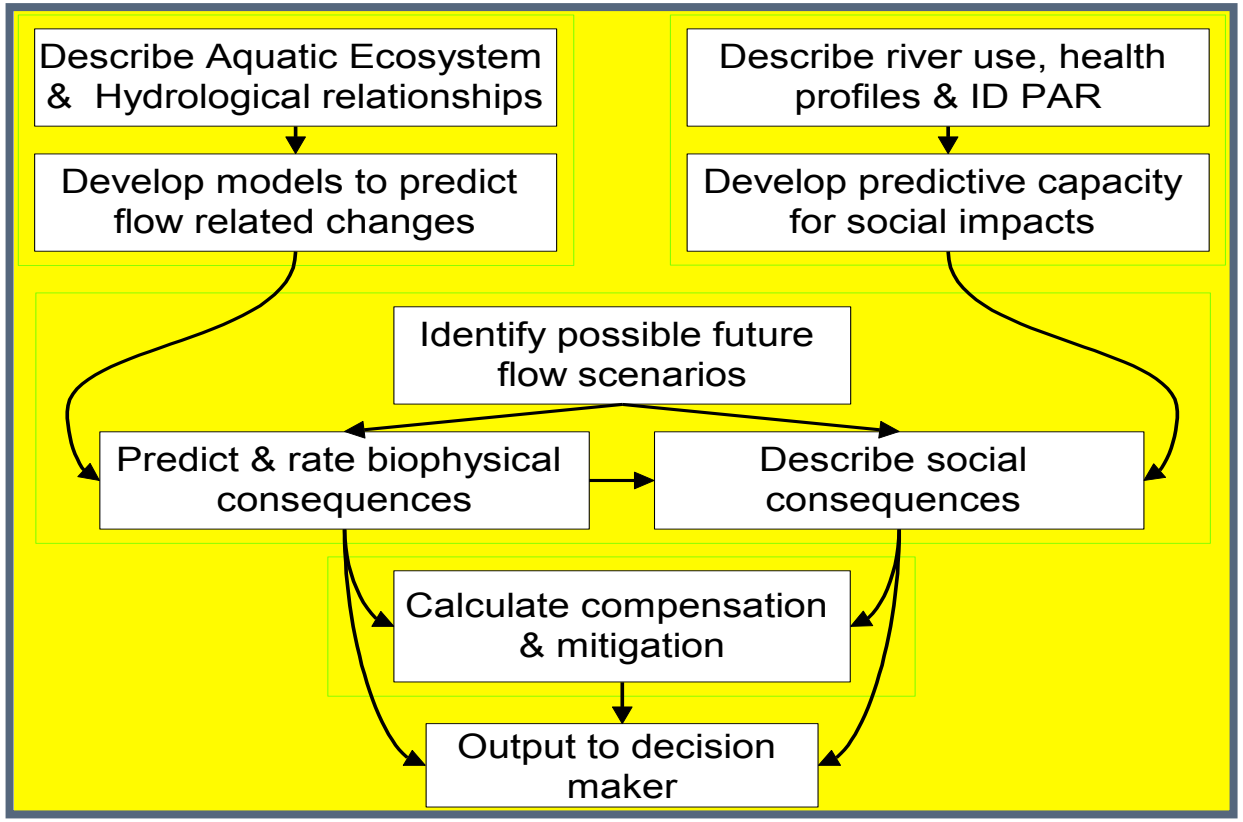
6 Dams
Delivery & transfer tunnels
Infrastructure

Define scenarios of e-flows

- rivers with proposed or existing water infrastructure



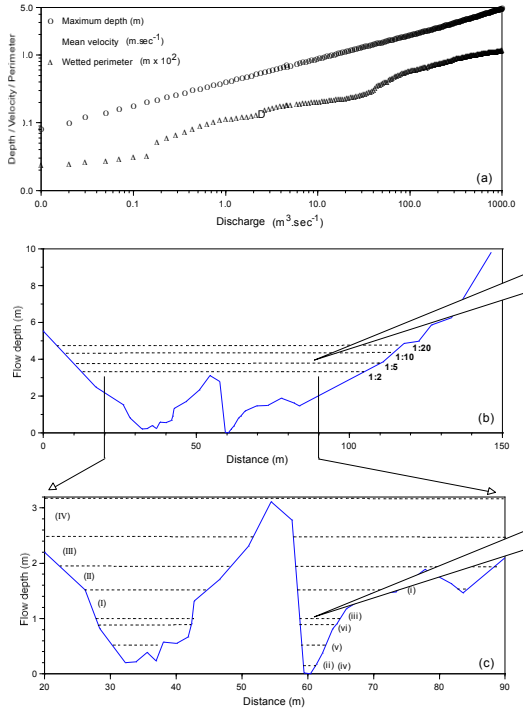
DRIFT Framework



King *et al*. (2003)

DRIFT Fish: Predicting impacts of flow regime change on fish

e.g. Maloti Minnow
Pseudobarbus quathlambae



Ecological requirements affected - reduction in floods

Ecological requirements affected - reduction in low flows

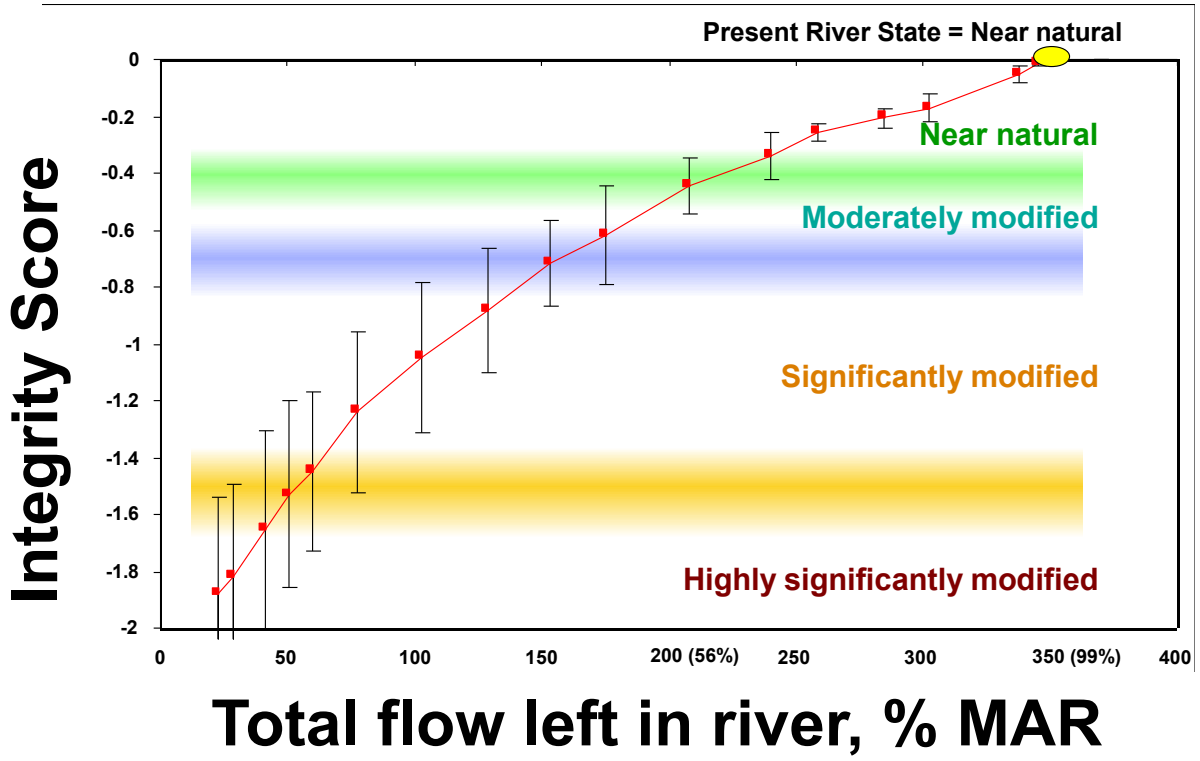
Impacts on fish
Change in health
Change in mortalities

Severity/ confidence

Social consecquence

Arthington *et al*. (2003)

DRIFT outputs



- **Combined Integrity Score** vs flow left in river
- **E-flow options tested** against development scenarios
- **Social & financial implications** of development scenarios
- **Integrated Basin Flow Management** (IBFM) King & Brown (2010)

DRIFT applications - Africa, SE Asia, South America

Lesotho Highlands Water Project, 17 river systems & Lake Sibaya (South Africa)
Lower Zambezi River & Delta (Mozambique)
Mzingwane River (Zimbabwe)
Okavango Basin (Angola, Namibia, Botswana)
Neelum-Jhelum Basin, Poonch River (Pakistan)
Lower Mekong River (SE Asia)

King & Brown (2010)

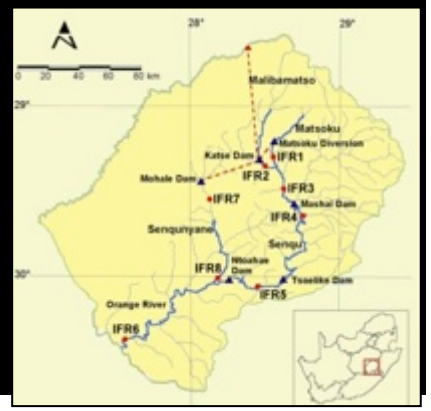
DRIFT recognised as a good practice E-Flows methodology by:
World Bank, ADB, IFC, IUCN, OKACOM, and the South African, Tanzanian and Pakistan governments

Project ➡ basin-scale ➡ regional e-flow assessment

DRIFT - single dam to basin scale e-flows

E-flows for river reaches based on expert prediction of ecological responses to flow alteration

King & Brown (2010)

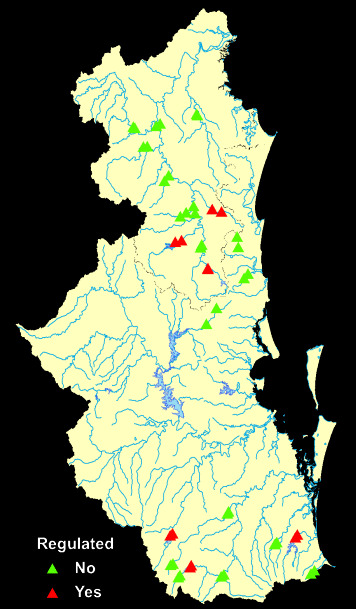


ELOHA - Ecological Limits of Hydrologic Alteration

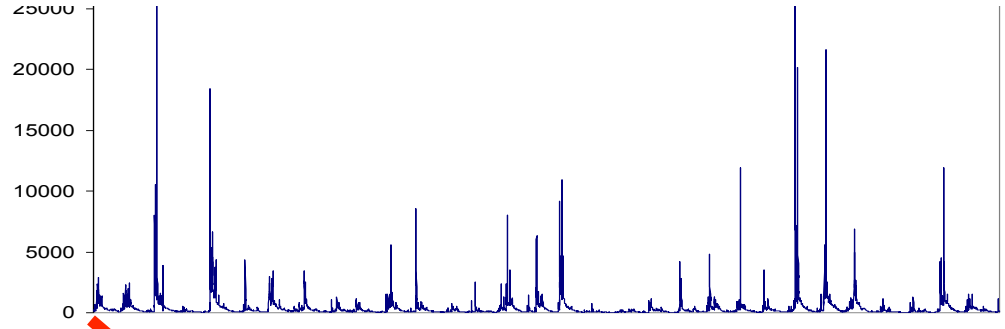
Regional-scale, multi-basin e-flows
e.g. bioregion, province

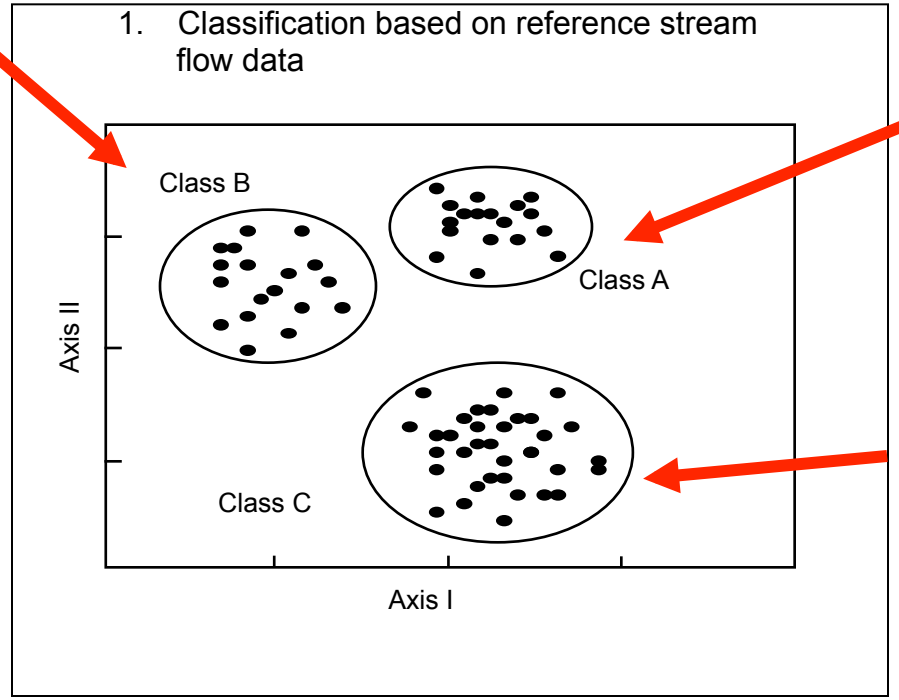
E-flow 'standards' for many rivers based on analysis of existing or new ecological data, along gradients of flow alteration

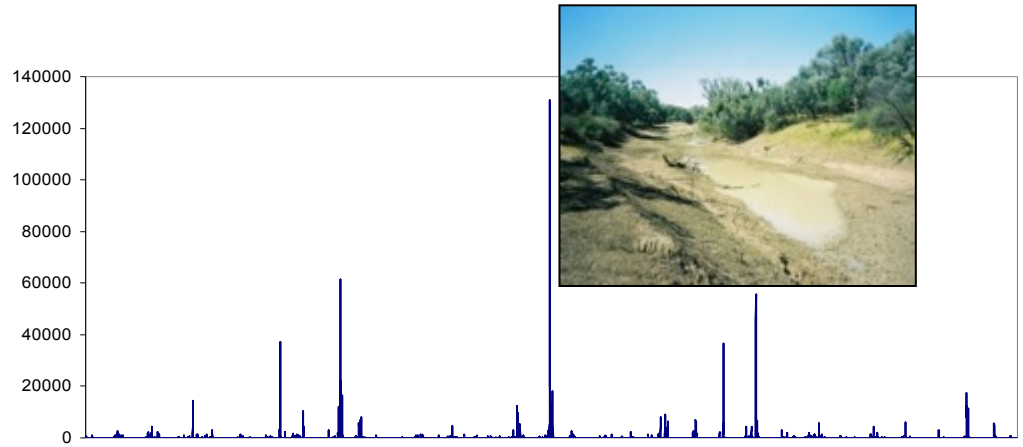
Arthington *et al*. (2006); Poff *et al*. (2010)

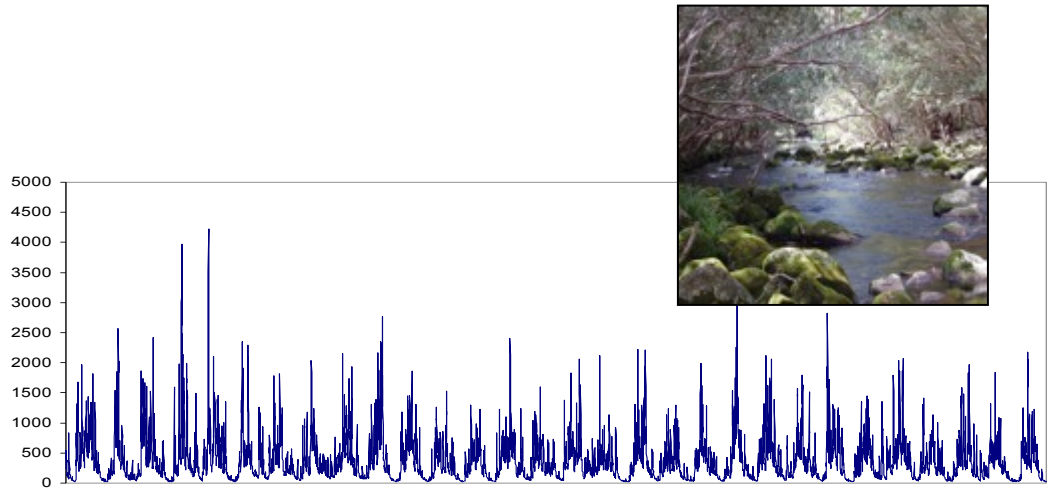


Classification of regional flow regimes into different types
E-flows for each river type





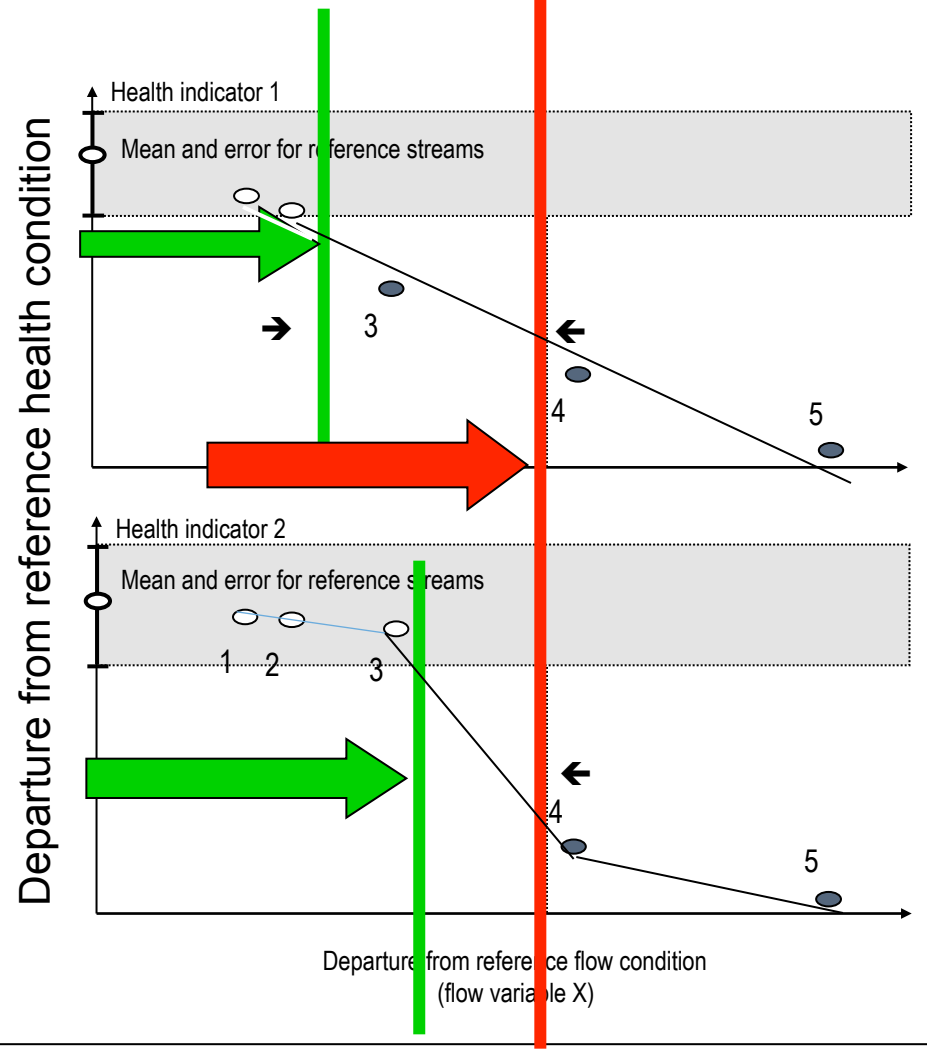




Plots of ecological condition along flow alteration gradients for each flow metric / river type

Sustainable level of flow change

4. Flow-response relationships for ecological health data from reference and flow-modified streams for each flow variable



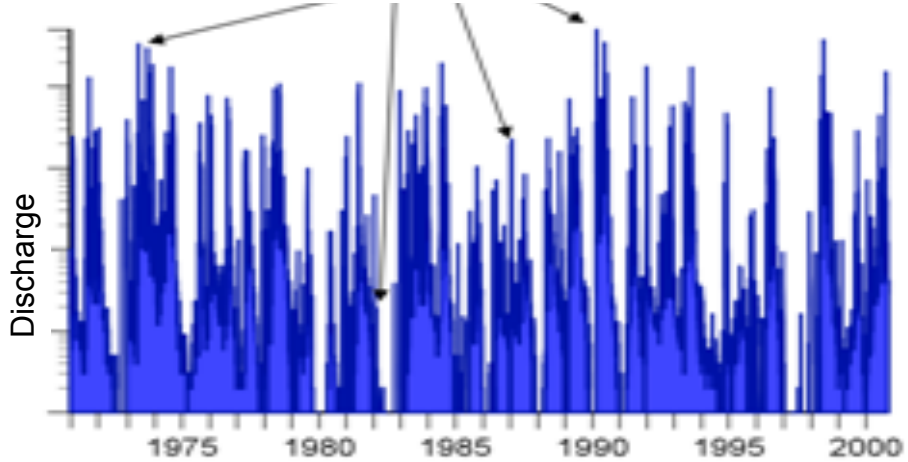
Unsustainable level of flow change

Flow-ecology relationships: Arthington *et al.* (2012)

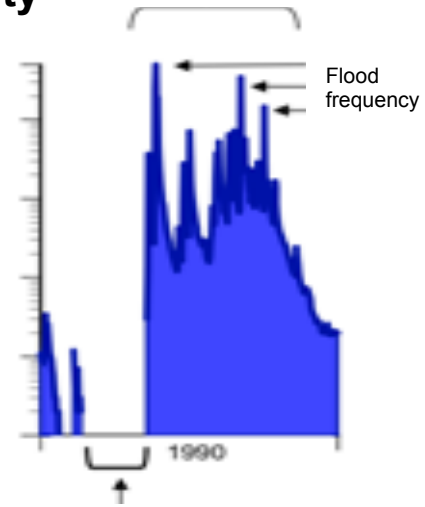
-ve
Riparian species richness
vs constancy and predictability

-ve
Basal area late succession riparian species,
No. regenerating species per ha
vs CV daily flows

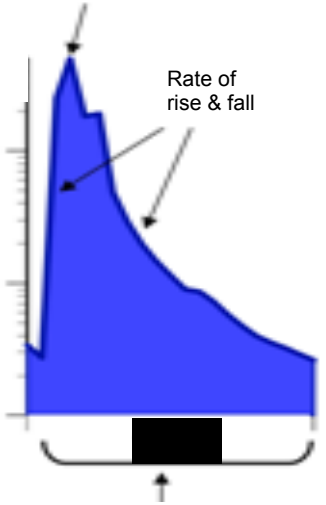
Inter-annual variability and predictability



Seasonal timing



Flood magnitude



-ve
Species richness density
vs median daily flow,
10-year ARI

-ve
Aquatic plant cover
vs high spell duration

Zero and low flow duration

Flood duration

Mixed response
Fish species richness
vs change in CV daily flows

+ve I
Density alien fish species
vs no. zero flow days

-ve
Aquatic plant cover
vs flow to mobilise substrates,
+ve response aquatic plant cover
vs change in low spell

ELOHA - Ecological Limits of Hydrologic Alteration

Poff, Richter, Arthington, Bunn *et al.* (2010)

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

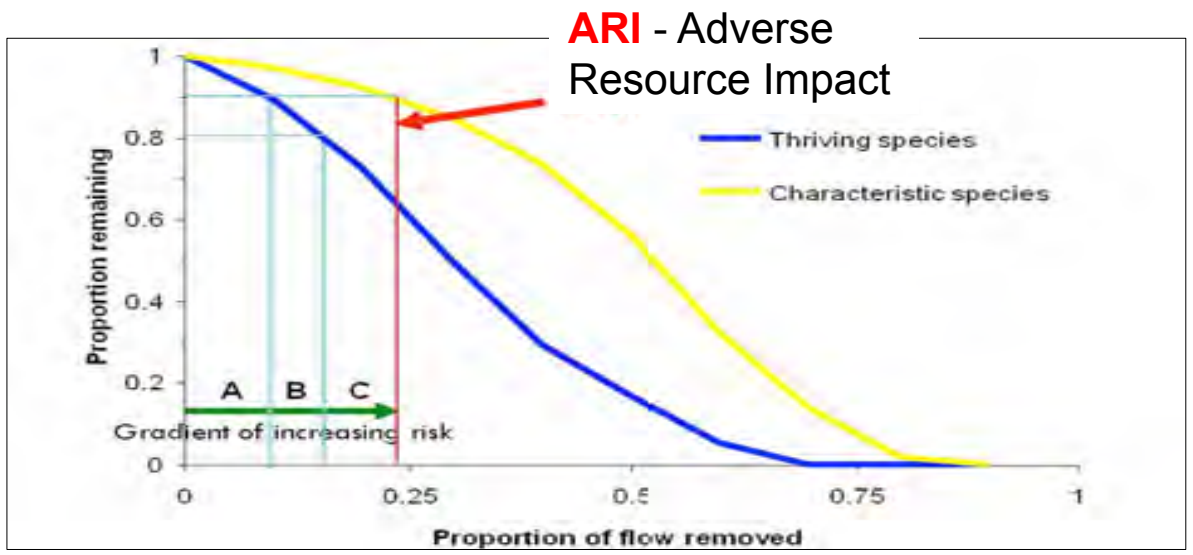
Societal Values and Management Needs

Adaptive Adjustments

ELOHA applications to e-flows at regional scale

- 6 US states and 3 interstate river basins

A practical guide to environmental flows for policy and planning
Kendy *et al*. (2012) www.conservationgateway.org



- Mexico
- Colombia
- China
- European Union
- Australia
  - northern rivers
  - SE Queensland
  - Murray-Darling Basin

Murray-Darling Basin

>1 million km^2, 4 states and ACT

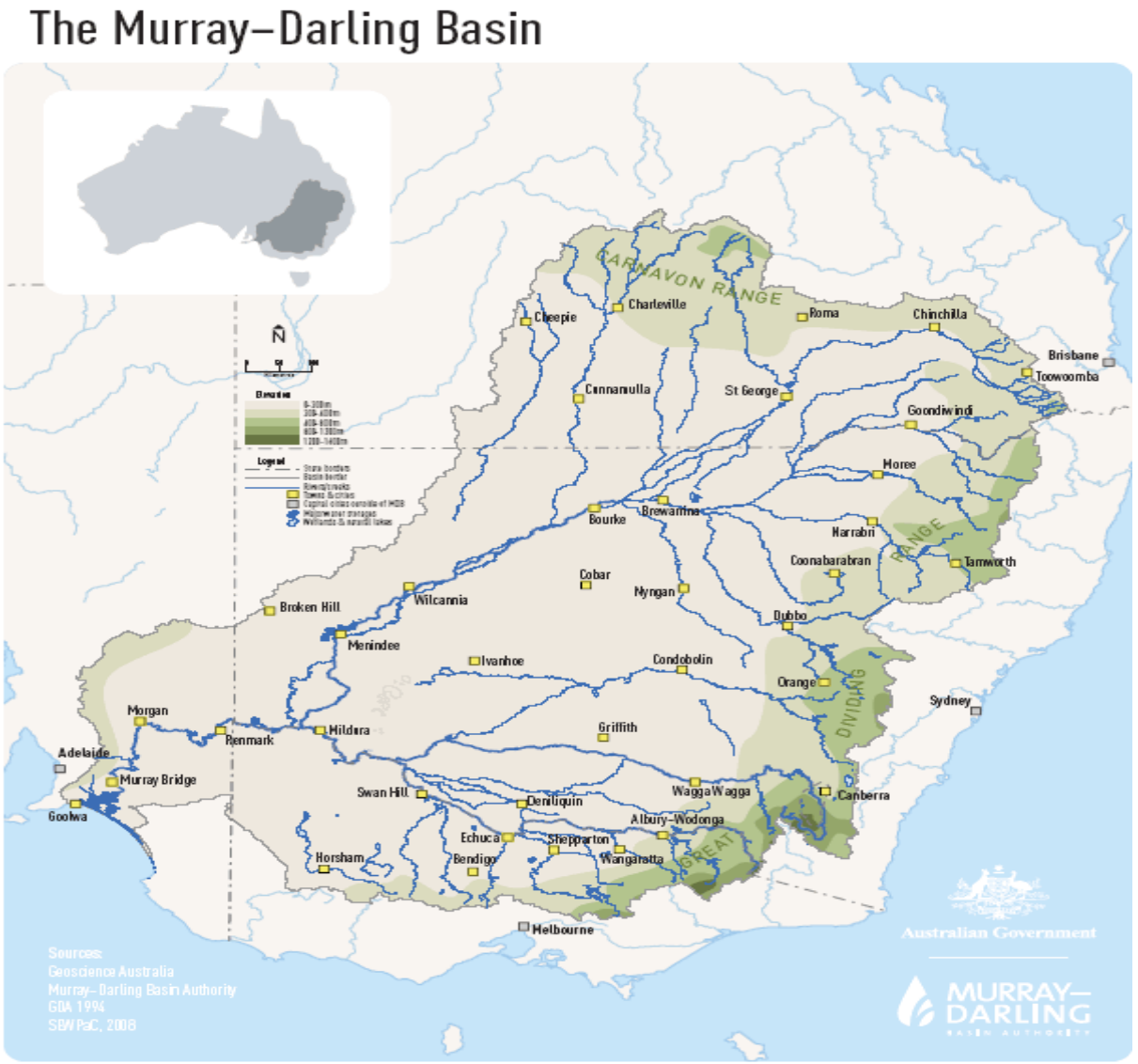
>77,000 km of rivers, creeks and watercourses, 30,000 wetlands

Inflows 31,600 (6,700 -117,900) GL / year

Water use audit 1995, water take capped

Water Act 2007, M-D Basin Plan 2012

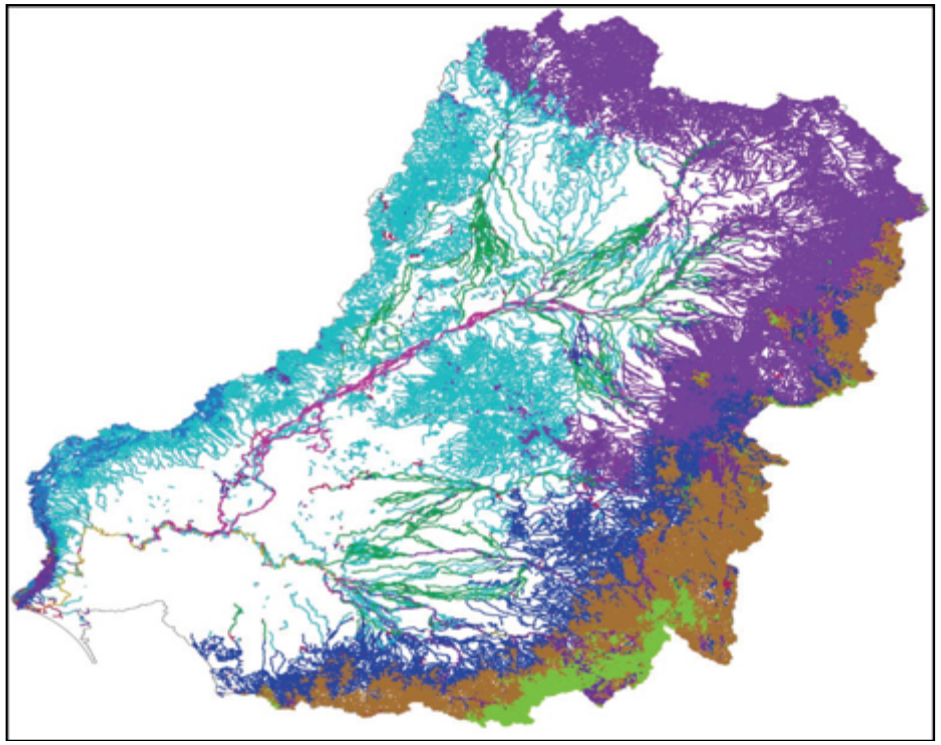
$AUD 9 billion for e-water purchases and improvements in water infrastructure (20% reduction in consumptive use)



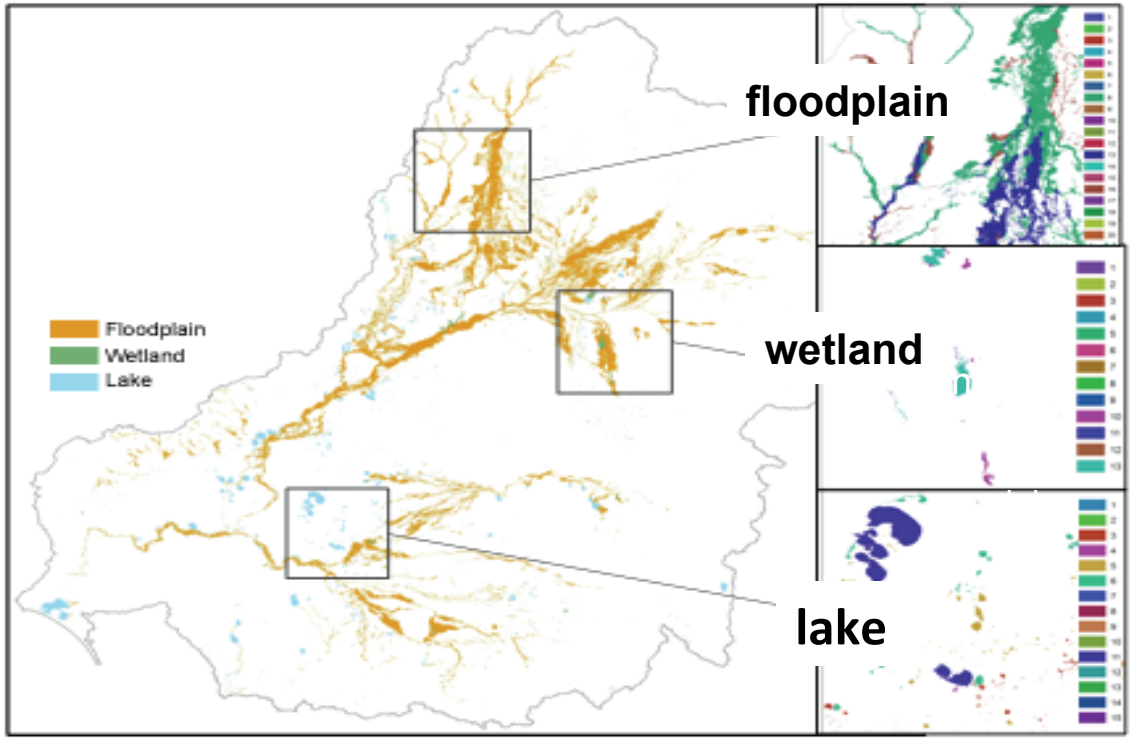
Geosciences Australia & MDBA (2008)

Basin-scale classification & mapping of ecological assets

Bunn *et al.* (2014)
http://www.finterest.com.au/wp-content/uploads/2015/03/Bunn-et-al.-2014-Ecological-reponses-synthesis-lo-res.pdf



Distribution of 14 riverine classes across the M-DB - large lowland rivers to small headwater streams



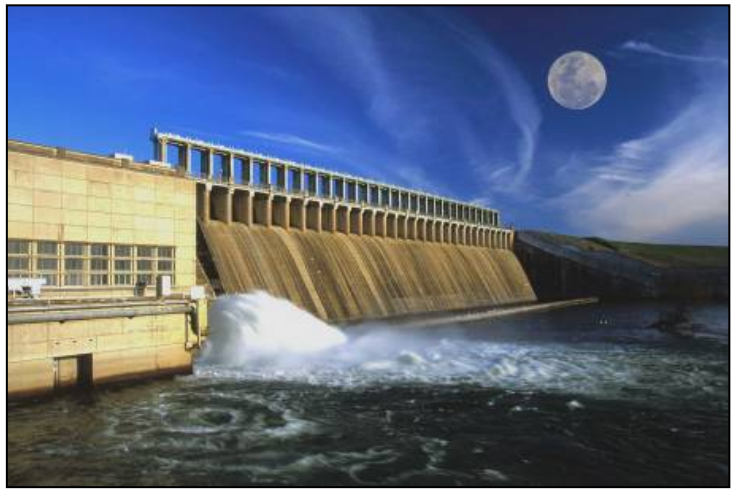
Distribution of floodplain, wetland & lake classes across the M-DB

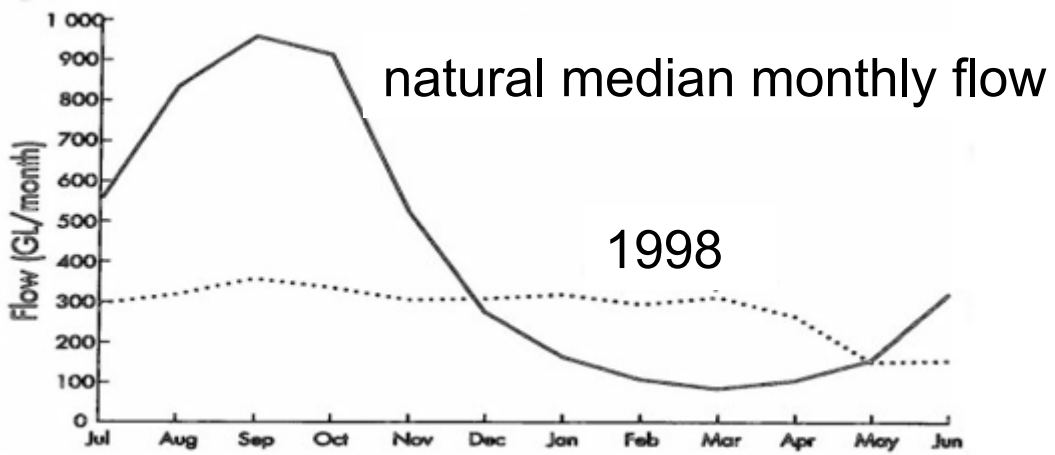
Flow-ecology response models for different components of the flow regime - IPCC terminology (Mastrandrea *et al.* 2010)

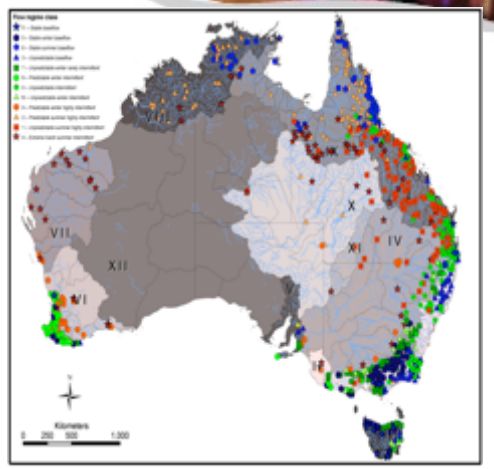
Artificially stable high flows in summer are *likely* to reduce the spawning and recruitment success for native fish (*medium to high confidence*)

Reversed seasonality of flows is *likely* to reduce recruitment of riparian trees and increase the risk of blackwater (low oxygen) events in-channel, if flood flows inundate floodplains rich in organic matter during summer (*high confidence*)

MDBC



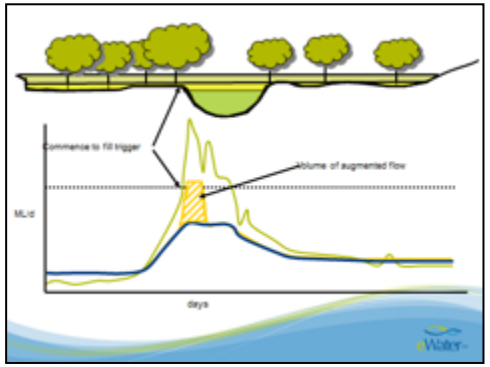




ELOHA Innovations

New approaches to:

Constructing hydrologic time series, flow regime & waterbody classification
(Kennard *et al*. 2010; Olden *et al*. 2011; Mackay *et al*. 2014; Bunn *et al*. 2014)



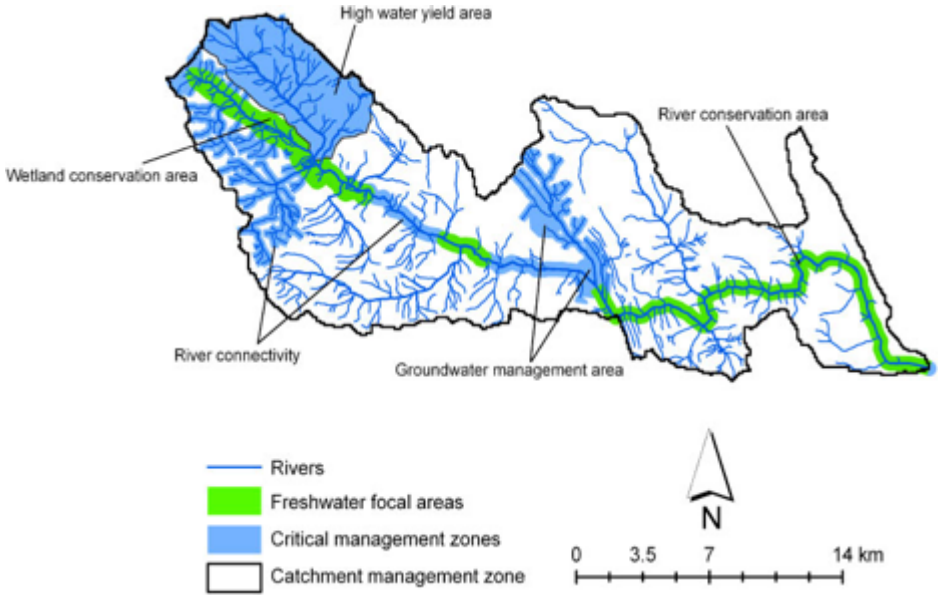
Modelling ecological roles of flow & effects of flow alteration

Stakeholder engagement, inclusion of indigenous values & needs
(Finn & Jackson 2011)

Monitoring e-flow outcomes, identification of knowledge gaps, R&D priorities

ELOHA enables river managers to:

- deliver e-flows for rivers of distinctive flow regime type
- minimise ecological impacts at most sensitive, high value waterbodies
- prioritize river segments for flow regime restoration at basin and regional scale
- envisage / predict how rivers may change under different water infrastructure / management / climate scenarios



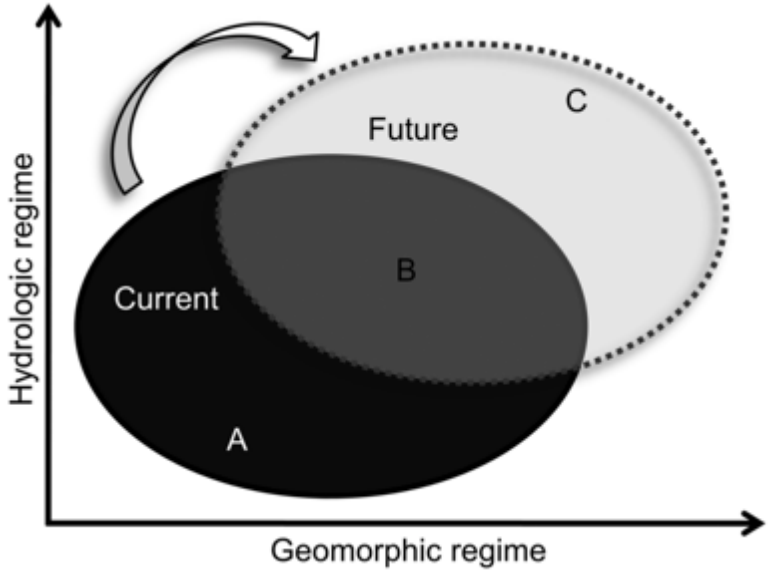
Abel *et al.* (2007)

Looking to the future

- Climates, flow regimes and freshwater ecosystems will change
- E-flows are a vital tool for adaptation to climate & environmental change
- E-flows science must generate deeper ecological understanding to inform river flow management in changing environments
- Monitoring e-flow outcomes is essential to inform the e-flow scientists and managers of the future

Ecological states under shifting hydrological & geomorphic regimes

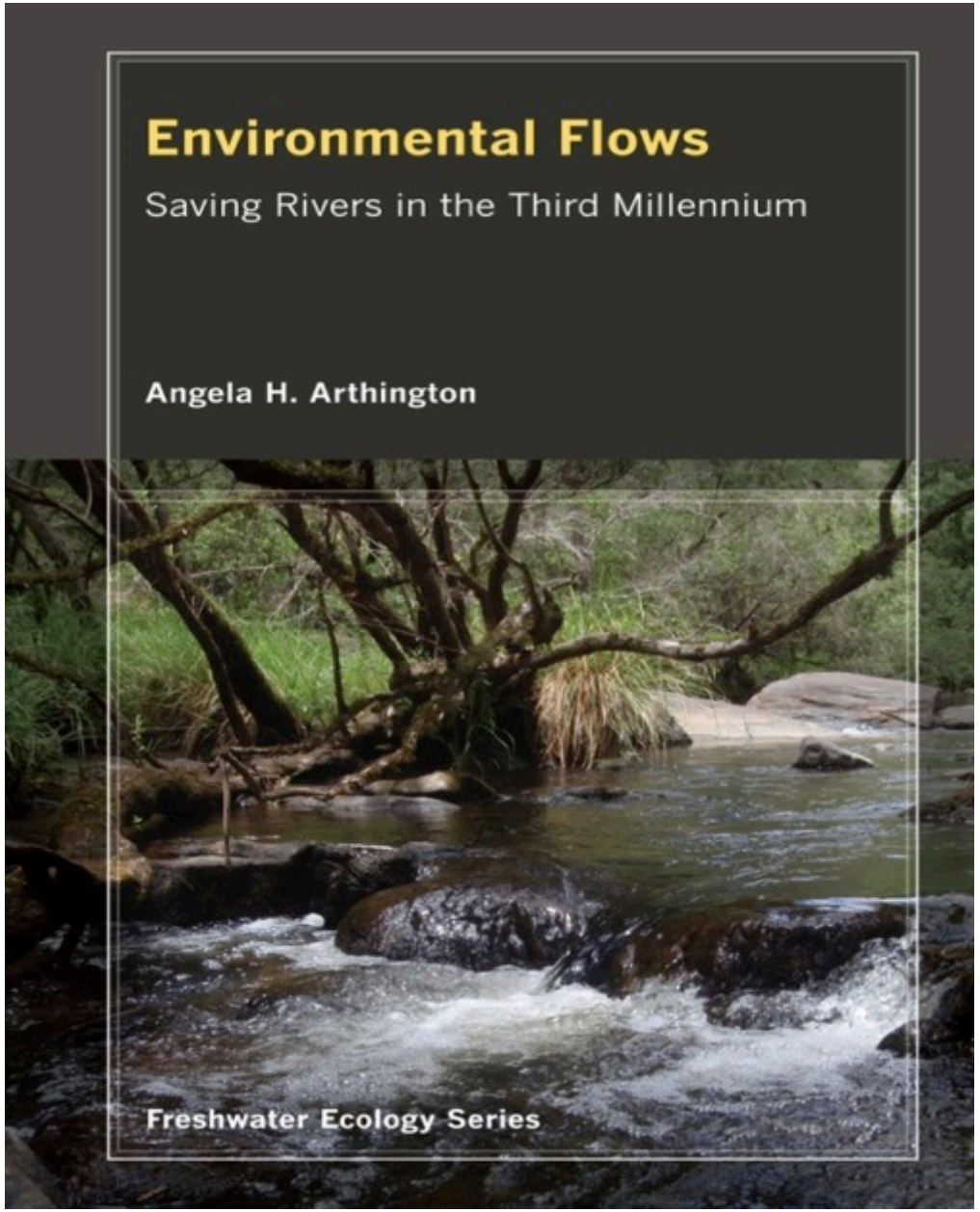
Auerbach *et al*. (2009)



Further light reading

University of California Press
http://www.ucpress.edu/book.php?isbn=9780520273696

Inbooks.com
www.inbooks.com.au

Amazon.com
http://www.amazon.com/Environmental-Flows-Saving-Rivers-Millennium/dp/0520273699

eBay