



Key flow-ecology considerations in environmental flow assessment

An International View

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Training/Workshop on Environmental Flow Assessment-Approaches

CWC, Bhuvneshwar, Odisha; 18 April 2019



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What is an environmental flow?

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Environmental flows are one of many types of flows quantified, allocated, and delivered in water resource management to meet specific objectives.

The most common objectives worldwide relate to the level of vitality and function (health or integrity) of aquatic and riparian ecosystems.

In some legal settings (e.g. Europe) these objectives are formulated along gradients from high to low, while in others (e.g. India) they are not specific.

Tools for Integrated Water Resources Management

- Pollution prevention programs
- Soil conservation programs
- Water conservation programs
- Fisheries rules & restrictions
- Protected area designation and management
- **Environmental flows**



“IWRM is a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (GWP, 2000)

Global Water Partnership. 2000.
Integrated Water Resources
Management. TAC Background
Papers No. 4.



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The need to maintain some minimum level of flow in rivers has been recognized, studied, and communicated for more than a century. Origins are blurry, but increasing references can be found in both public health and fisheries biology literature between 1850 and 1950.



The Great Stink of Thames River in London 1858, due to sewage. Source: Punch, June 18, 1859



Commercial salmon fishing on the Eel River, California 1850s. Source: Humboldt County Historical Society

Environmental flows can be achieved by limiting abstractions...



Chewaucan River, Oregon. Photo credit: US Forest Service



Orange River. Photo credit: Orania Beweging

... or they can be achieved by requiring releases



Reventazón Dam, Costa Rica
Photo credit: The Tico Times

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The Brisbane Declaration 2018

“Environmental flows describe the **quantity, timing, and quality** of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being.”

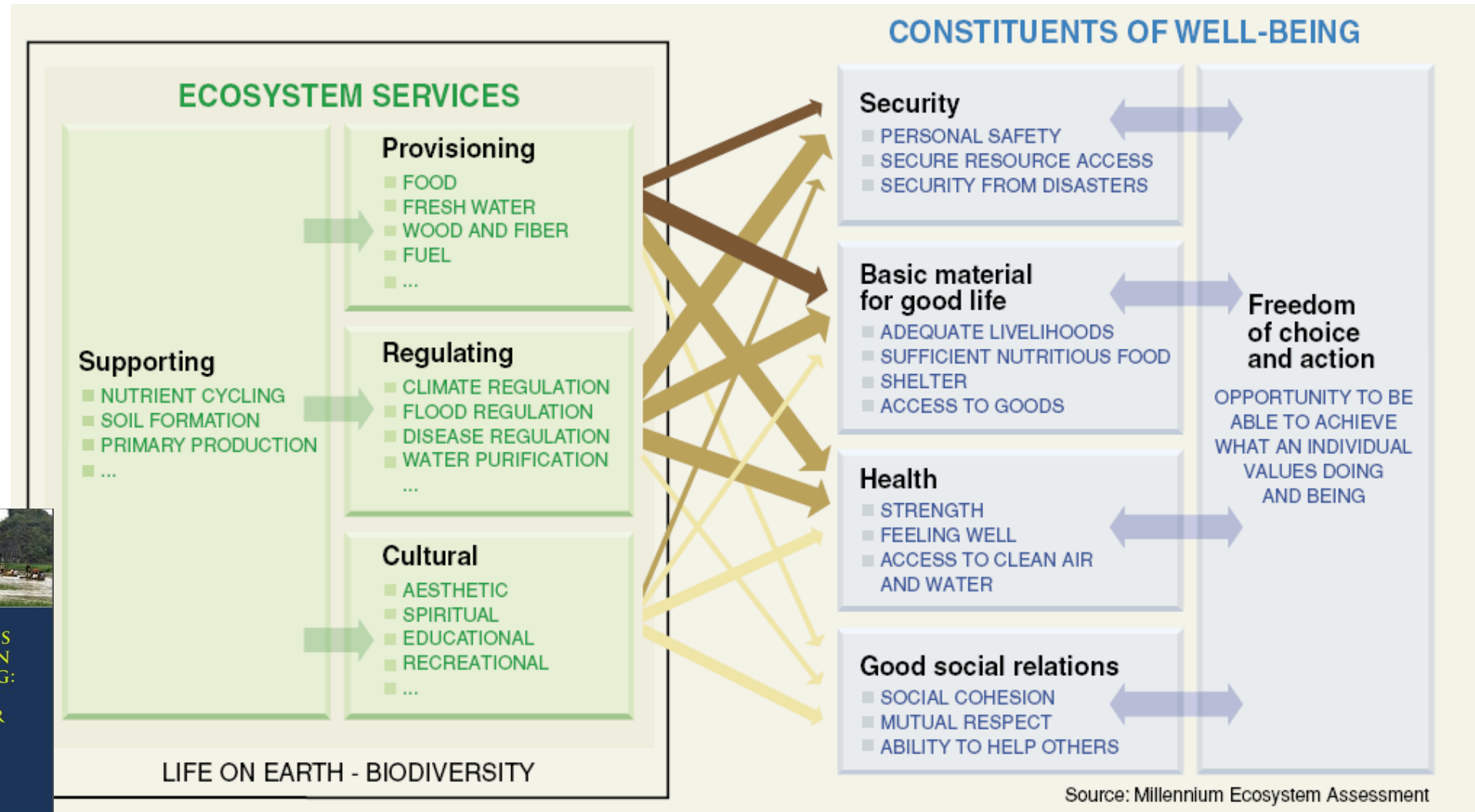


Skeena River & Estuary, Canada. Photo credit: Ocean Ecology

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Ecosystem Services



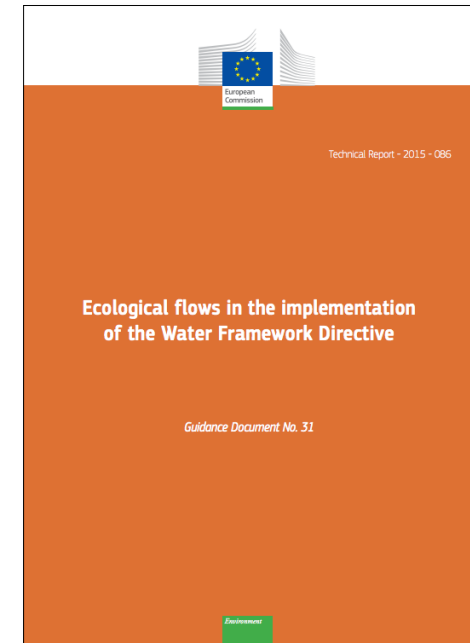
Millennium Ecosystem Assessment, 2005. ECOSYSTEMS AND HUMAN WELL-BEING: WETLANDS AND WATER Synthesis. World Resources Institute, Washington, DC.

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The European Union Water Framework Directive

Ecological flows are considered within the context of the WFD as “a hydrological regime consistent with the achievement of the environmental objectives of the WFD in natural surface water bodies as mentioned in Article 4(1)”.



Considering Article 4(1) of the WFD, the environmental objectives refer to: - non deterioration of the existing status - achievement of good ecological status in natural surface water body, - compliance with standards and objectives for protected areas, including the ones designated for the protection of habitats and species where the maintenance or improvement of the status of water is an important factor for their protection, including relevant Natura 2000 sites designated under the Birds and Habitats Directives.

[European Commission. 2015. Ecological flows in the implementation of the Water Framework Directive Guidance Document No. 31.](#)

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Classification of ecological status

Status	Description	Actions
High	Reference conditions	Maintain as high
Good	Small deviation from reference conditions	Maintain as good
Moderate	Moderate deviation	Implement actions to improve the status
Poor	Large deviation	
Bad	Heavily contaminated	

European Union Water
Framework Directive

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Republic of South Africa Water Act 1998

“Reserve” means the quantity and quality of water required –

(a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be - (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and

(b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource

[Republic of South Africa Water Act 1998](#)



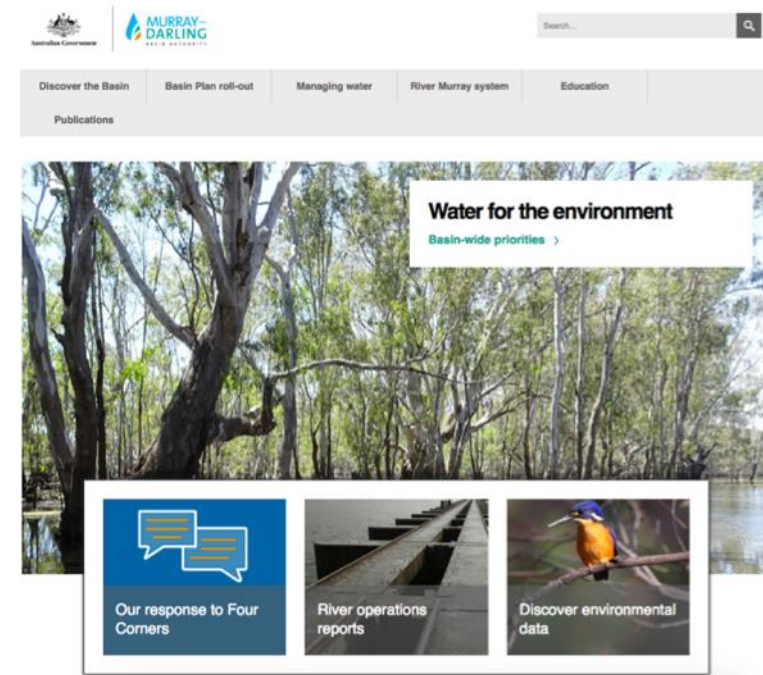
Sabie River, South Africa

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Murray Darling Basin Authority

The amount of water required to support priority ecosystem functions that can be managed with environmental water in priority environmental assets that can be managed with environmental water.



<https://www.legislation.gov.au/Details/F2012L02240>

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What are the Priority Environmental Assets in the Mahanadi Delta?

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Flow-Ecology Relationships

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Ecological functions of flow

Principle 3

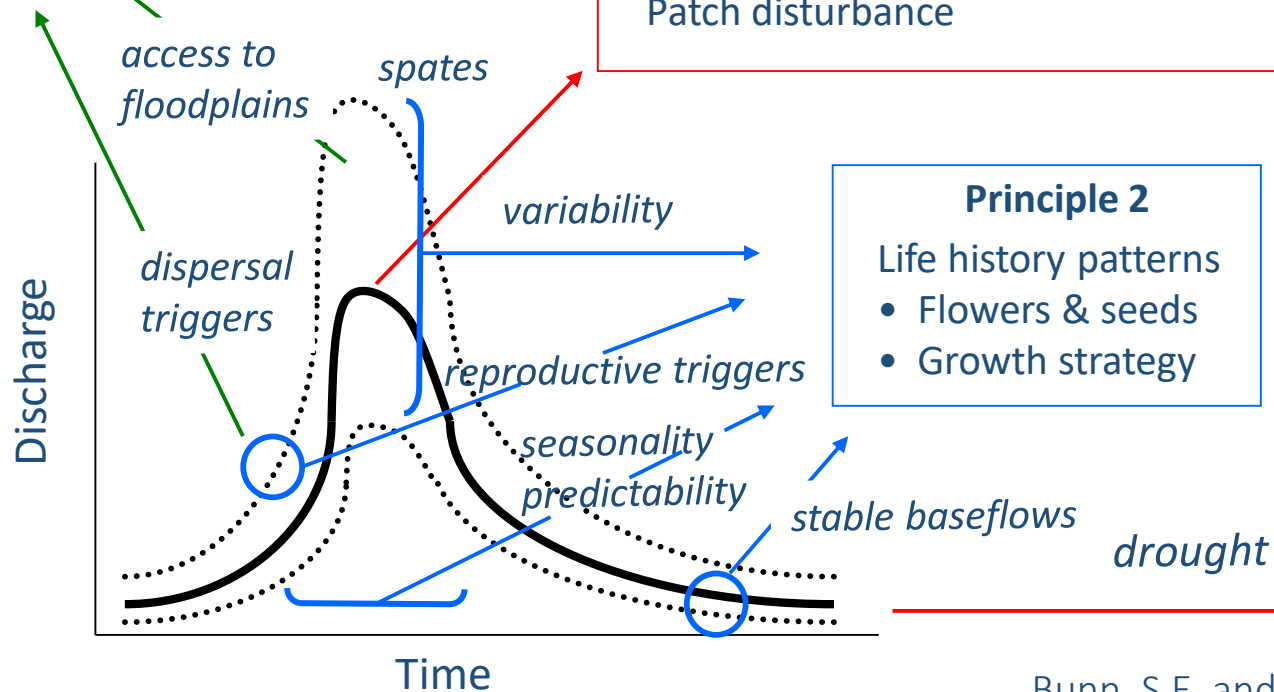
Lateral connectivity
Longitudinal connectivity

Principle 1

Channel form
Habitat complexity → Biotic diversity
Patch disturbance

Principle 2

Life history patterns
• Flowers & seeds
• Growth strategy



Principle 4

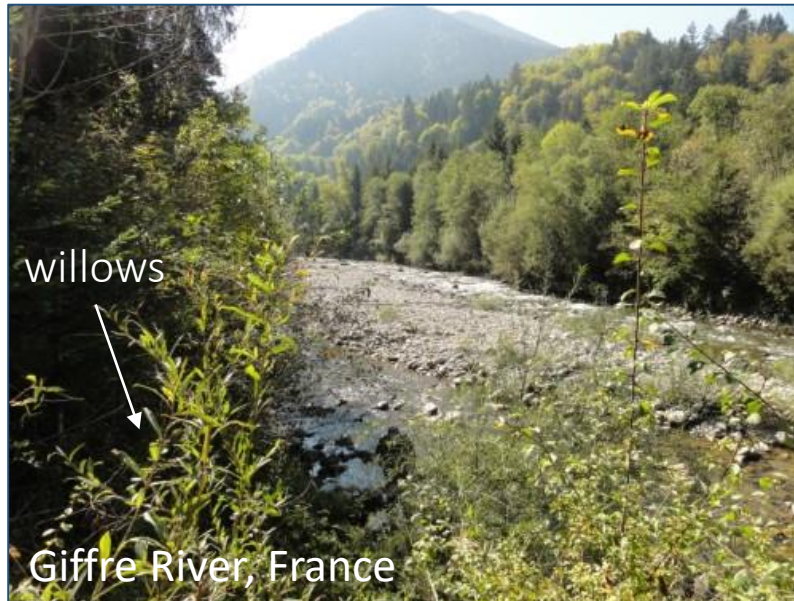
Natural regime discourages invasions

Bunn, S.E. and Arthington, A.H., 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental management*, 30(4), pp.492-507.

Principle 1: Flow is a major determinant of physical habitat in streams, which is in turn a major determinant of biotic composition



- Distribution of aquatic and riparian species determined by substrate, flow velocities, and stability of flows.



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Principle 1: Flow is a major determinant of physical habitat in streams, which is in turn a major determinant of biotic composition



Debi Distributary

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Principle 1: Flow is a major determinant of physical habitat in streams, which is in turn a major determinant of biotic composition

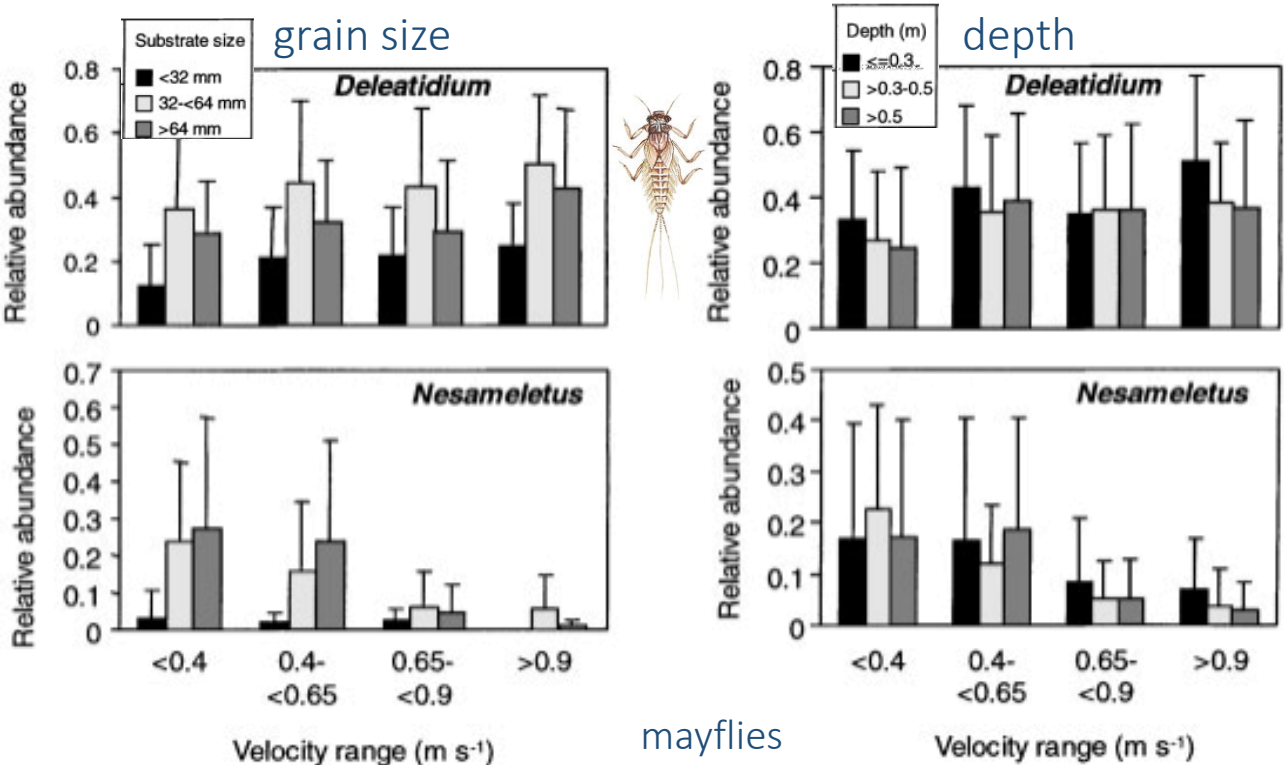
- Flow depths, velocities, and resulting substrate determine habitat for aquatic invertebrates.



Jowett, I. G. (2003), Hydraulic constraints on habitat suitability for benthic invertebrates in gravel-bed rivers. *River Research and Applications*, 19: 495–507



Video of Nesameletus
<http://www.waitakere.govt.nz/abtci/tei/ecowtr/macroinv/videos/Nesameletus.mpg>



mayflies

Deleatidium

Nesameletus

Principle 1: Flow is a major determinant of physical habitat in streams, which is in turn a major determinant of biotic composition



- Flow depths, velocities, and cover are important habitat characteristics for fish.



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Principle 2: Aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes.



- The onset of higher flows or stabilizing low flows are triggers for many fish and other riverine species to spawn.

Stable low flow

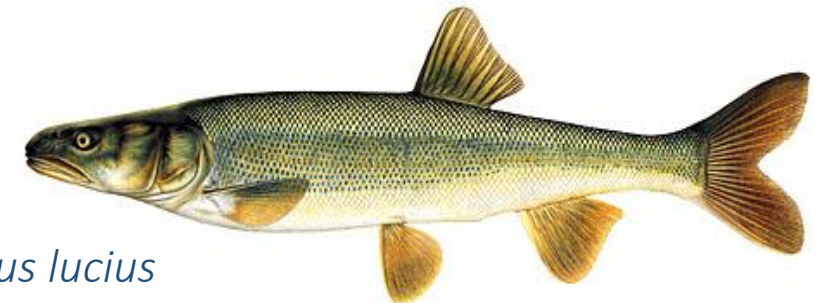


Australian Smelt: *Retropinna semoni*

High flow



Clanwilliam Yellow Fish: *Barbus capensis*



Colorado Pikeminnow: *Ptychocheilus lucius*

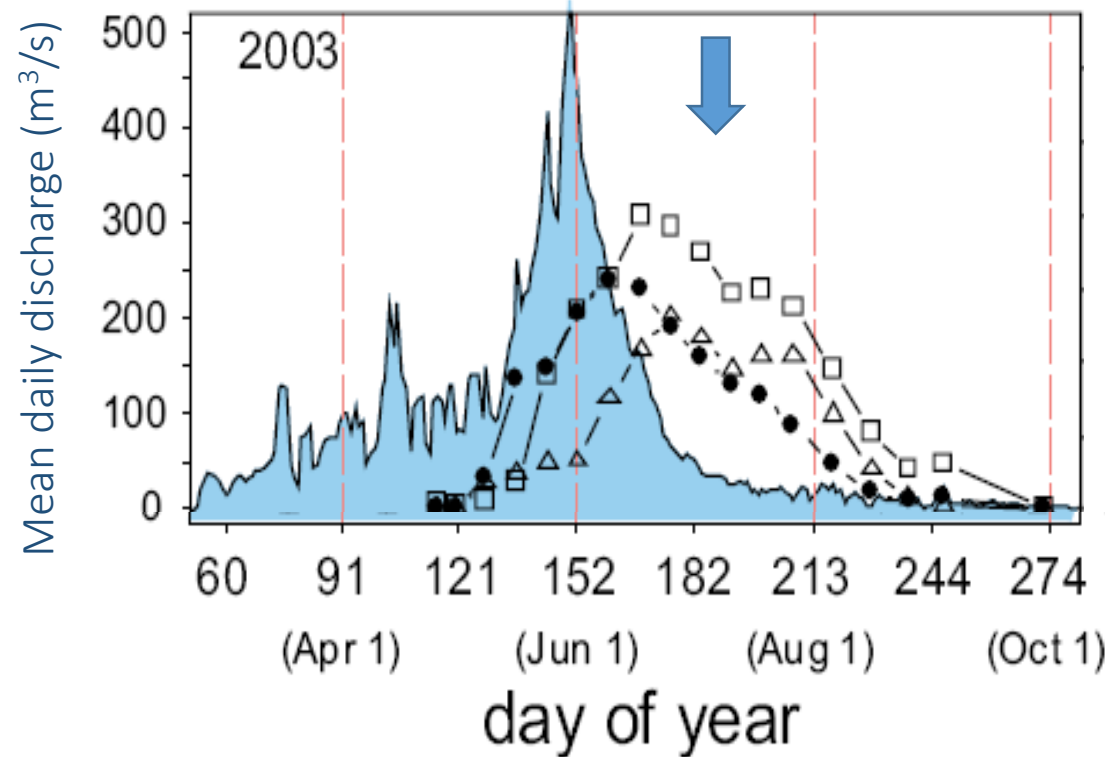
Principle 2: Aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes.



- The onset of higher flows triggers the release of seeds by riparian plants.



Populus fremontii



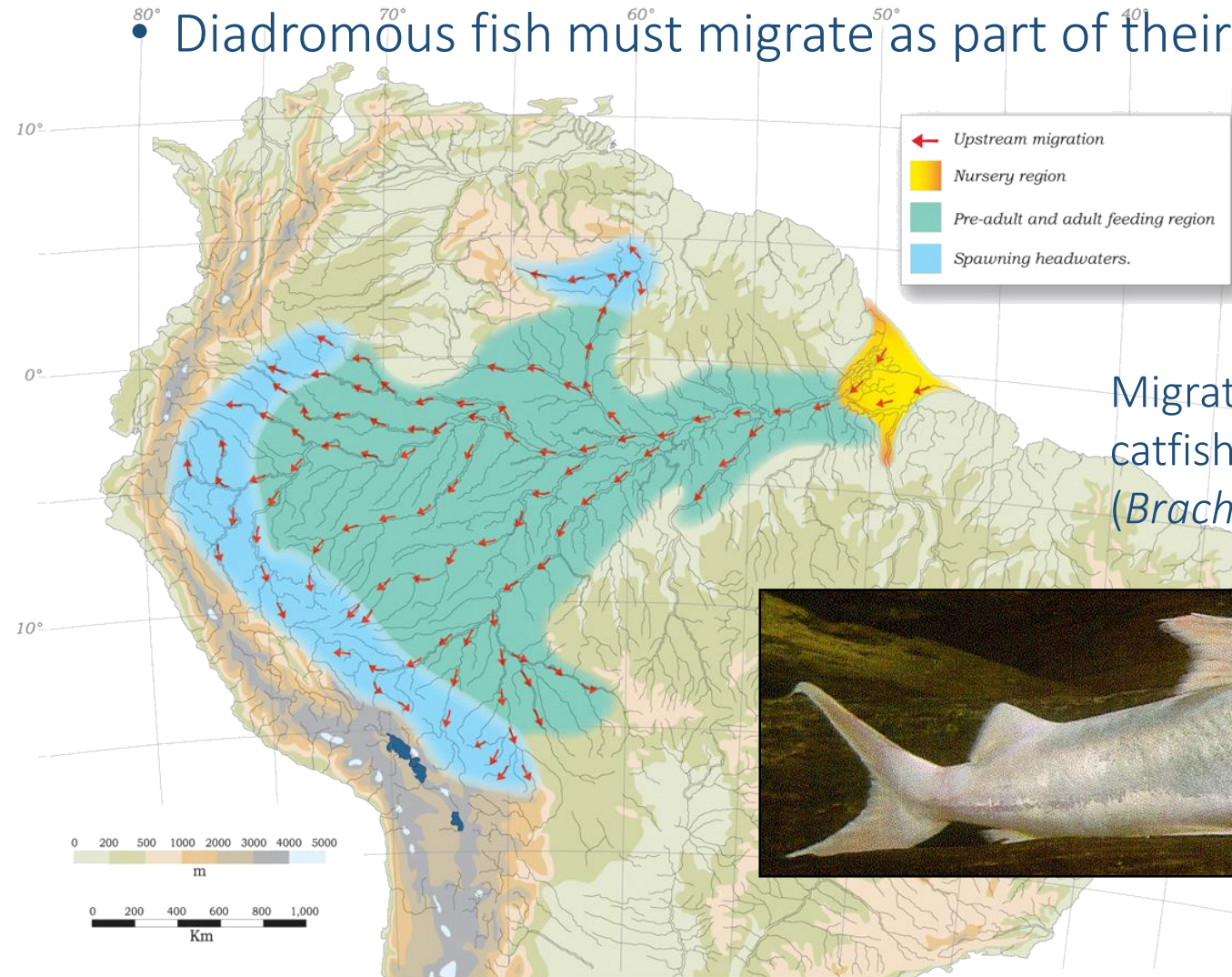
Populus seedlings

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Principle 3: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to many species.

- Diadromous fish must migrate as part of their life cycle.



Migration of the Dourado catfish in the Amazon River
(*Brachyplatystoma flavicans*)



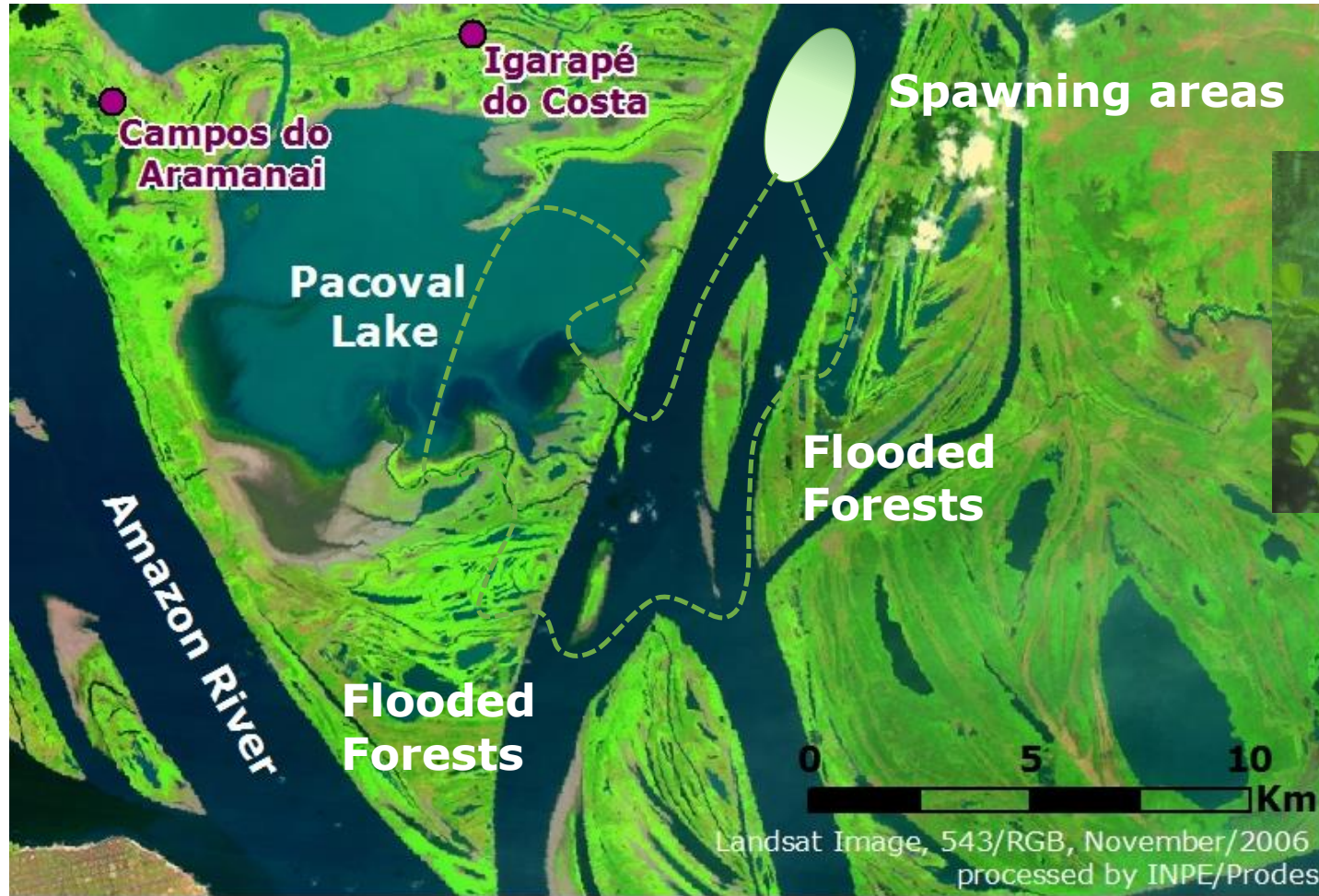
Principle 3: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to many species.



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Principle 3: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to many species.



Tambaqui (*Colossoma macropomum*) use of floodplain lakes and forests

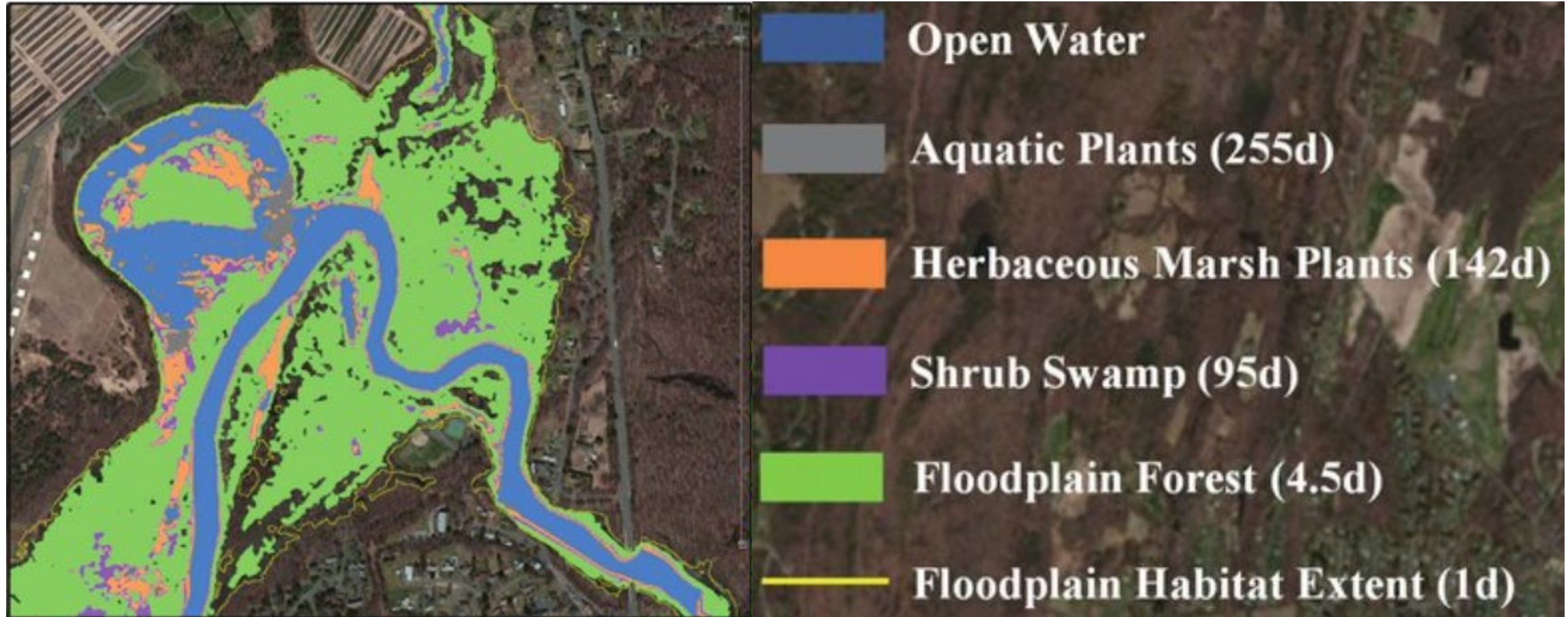
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Principle 3: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to many species.



Hydroperiod



Julian, D.W. et al., 2015. Decision support system for water and environmental resources in the Connecticut River basin. *Journal of Water Resources Planning and Management*, 142(1), p.04015038.

Principle 3: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to many species.



Levee on Mahanadi distributary

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Principle 4: The invasion and success of exotic and introduced species is facilitated by the altered flow regime



Northern
tamarisk
beetle



<http://www.flickr.com/photos/ironrodart/>

Tamarisk



<http://images.wikia.com/fallout/images/b/b5/Colorado-river-running-low.jpg>

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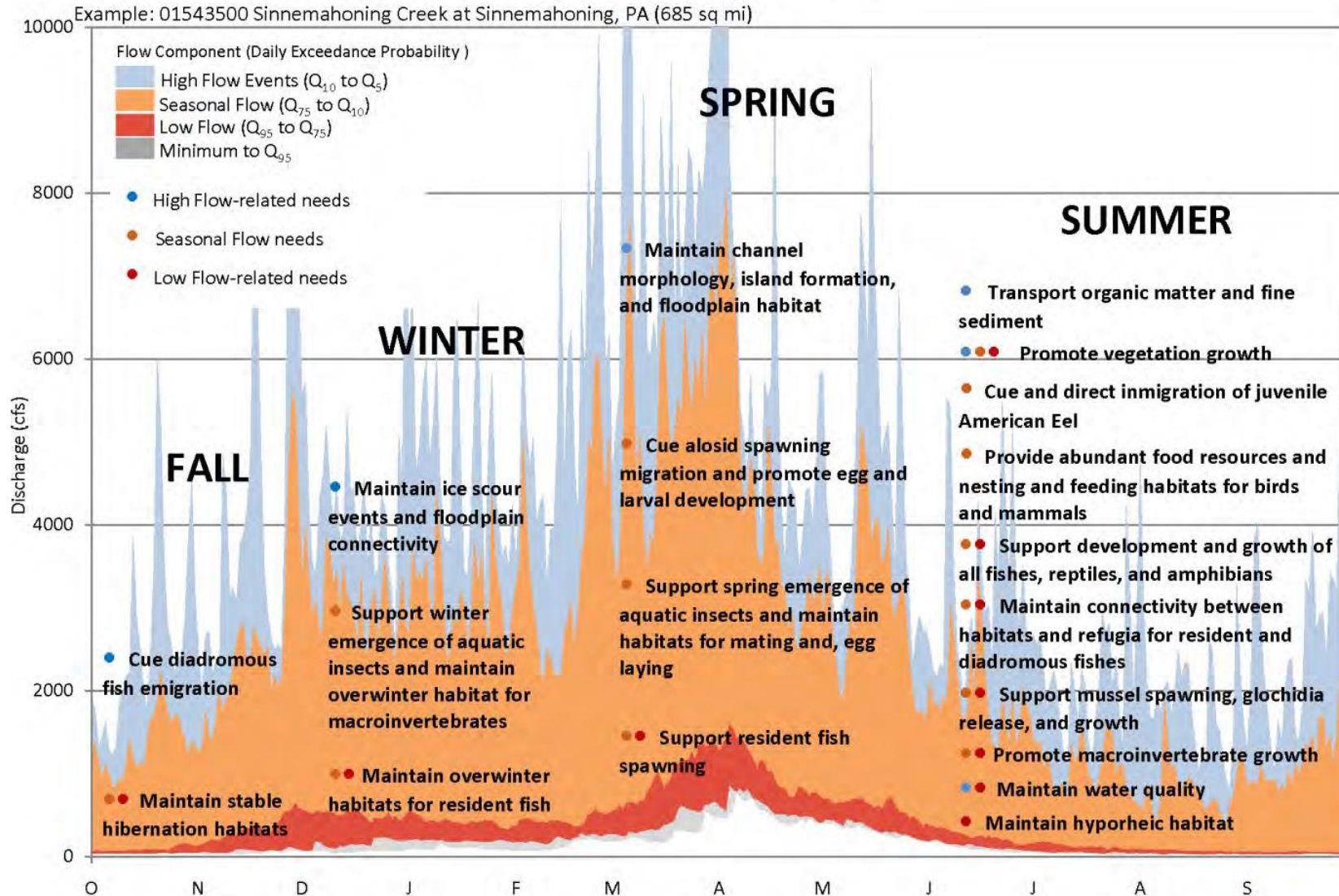
Principle 4: The invasion and success of exotic and introduced species is facilitated by the altered flow regime



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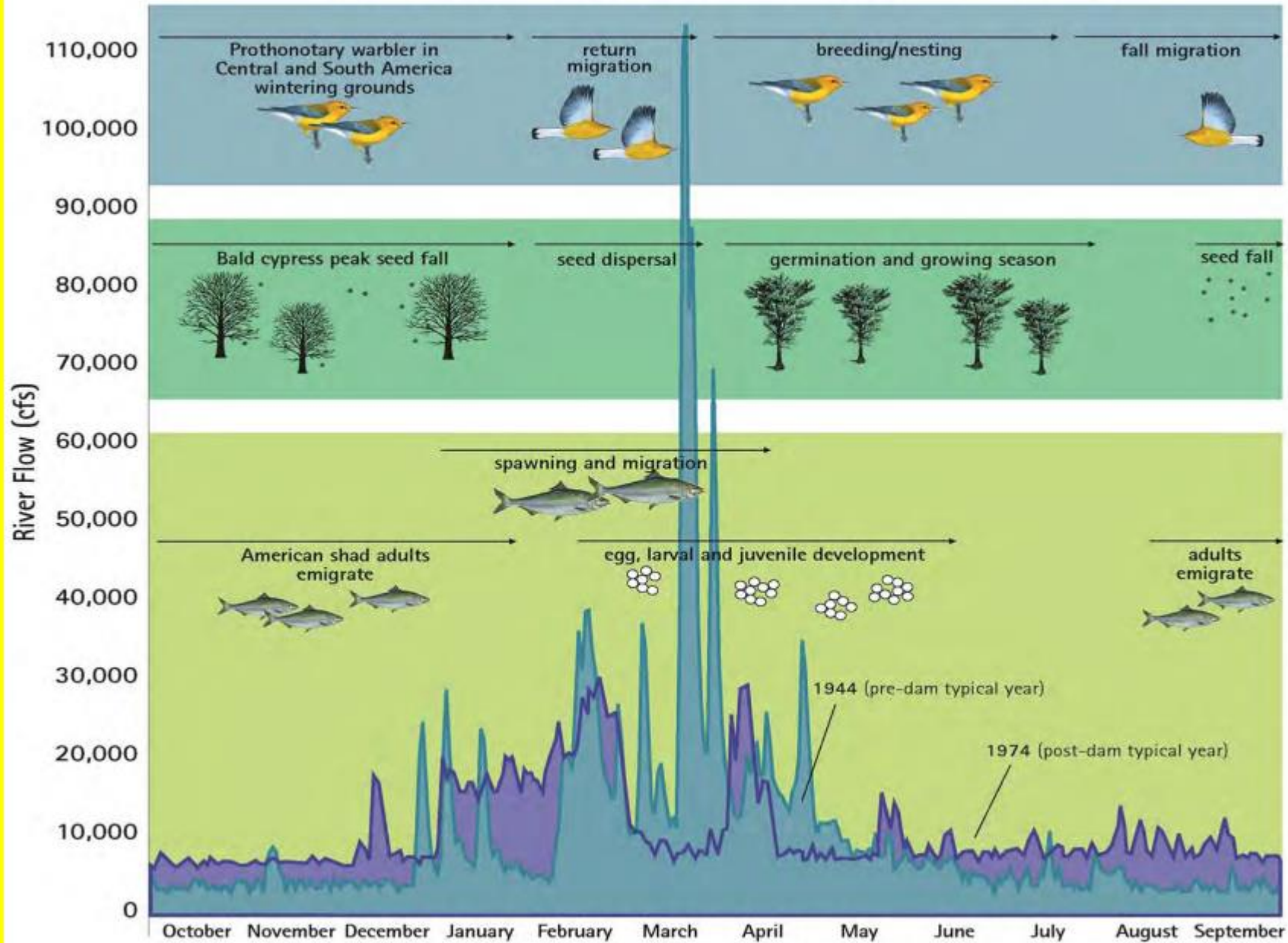
Flow Components and Needs: Major Tributaries



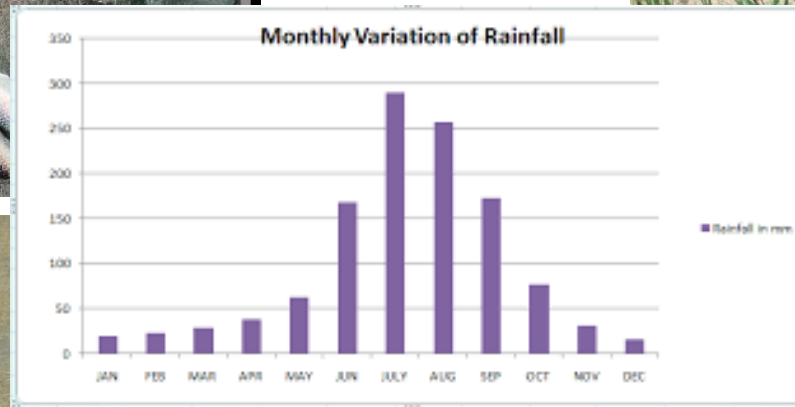
DePhilip and Moberg 2010

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Ecological Model of the Savannah River



What is the ecological model of the Mahanadi?



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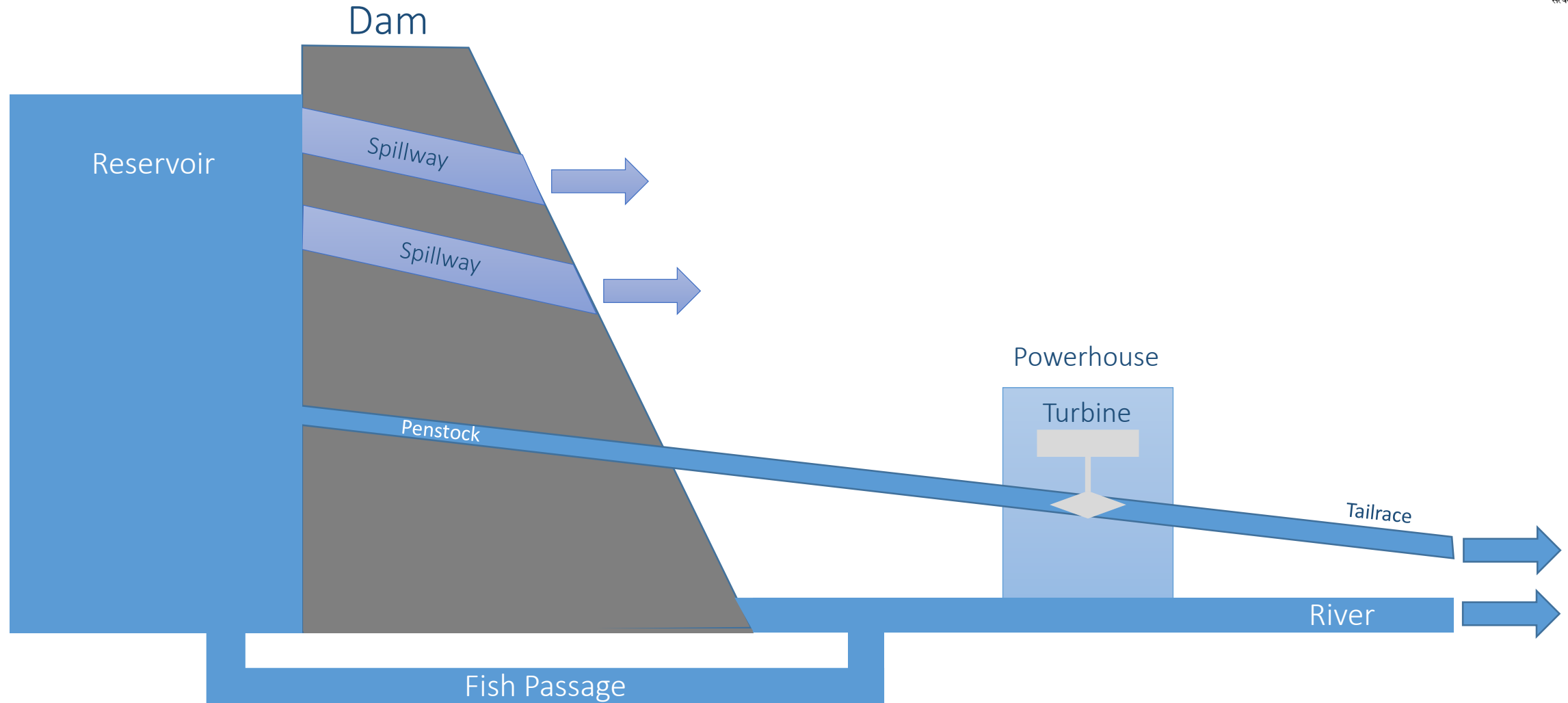


How to implement environmental flows ?

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Options for controlling flows from dams



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Hirukud Dam

Conditions
imposed on water
user/operator

conditions on storage
operators



cap on consumptive water
use



license/permit
requirements on
individual abstractors



Legal rights to
water for the
environment itself

environmental water
rights



ecological or
environmental
reserve



Horne, A.C., O'Donnell, E.L. and Tharme, R.E., 2017. Mechanisms to allocate environmental water. In *Water for the Environment* (pp. 361-398).

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Conditions on storage operators

STORAGE (RECORDED DATE)	STORAGE CAPACITY (ML)	CURRENT VOLUME (ML)	PERCENT FULL %	NET CHANGE IN PAST WEEK %
Nepean Dam Saturday 02 December	67,730	48,673	71.9	-0.7



LATEST ENVIRONMENTAL FLOW RELEASES

Nepean Dam ▼

Today's requirements
16 ML

Past week
143 ML

Past year
9,578 ML



Nepean Dam, Australia

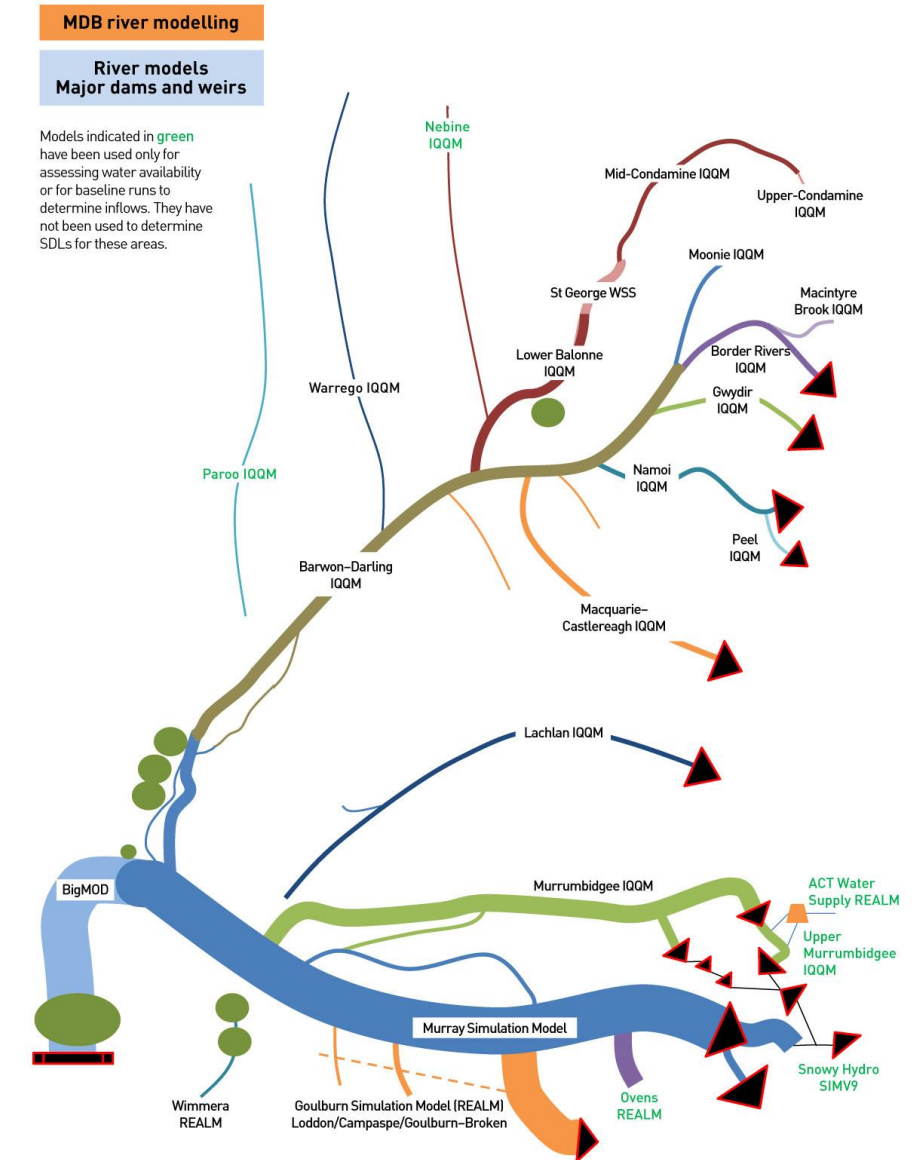
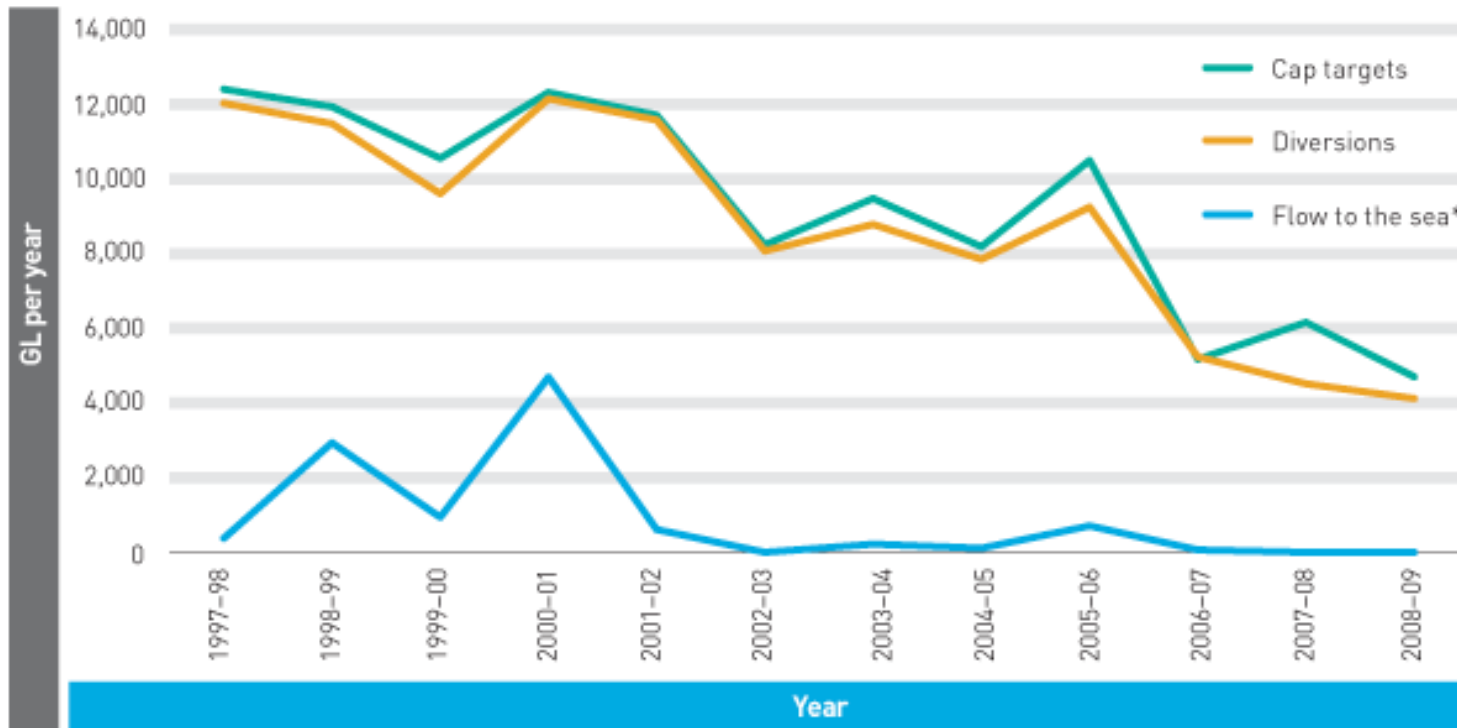
<http://www.watarnsw.com.au/supply/dam-levels/greater-sydneys-dam-levels>

Source: Water New South Wales, Australia

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Caps on consumptive water use

“The volume of water that would have been diverted under 1993/94 levels of development”.



<https://www.mdba.gov.au/news/modelling-future-flows-managing-basin%E2%80%99s-water>

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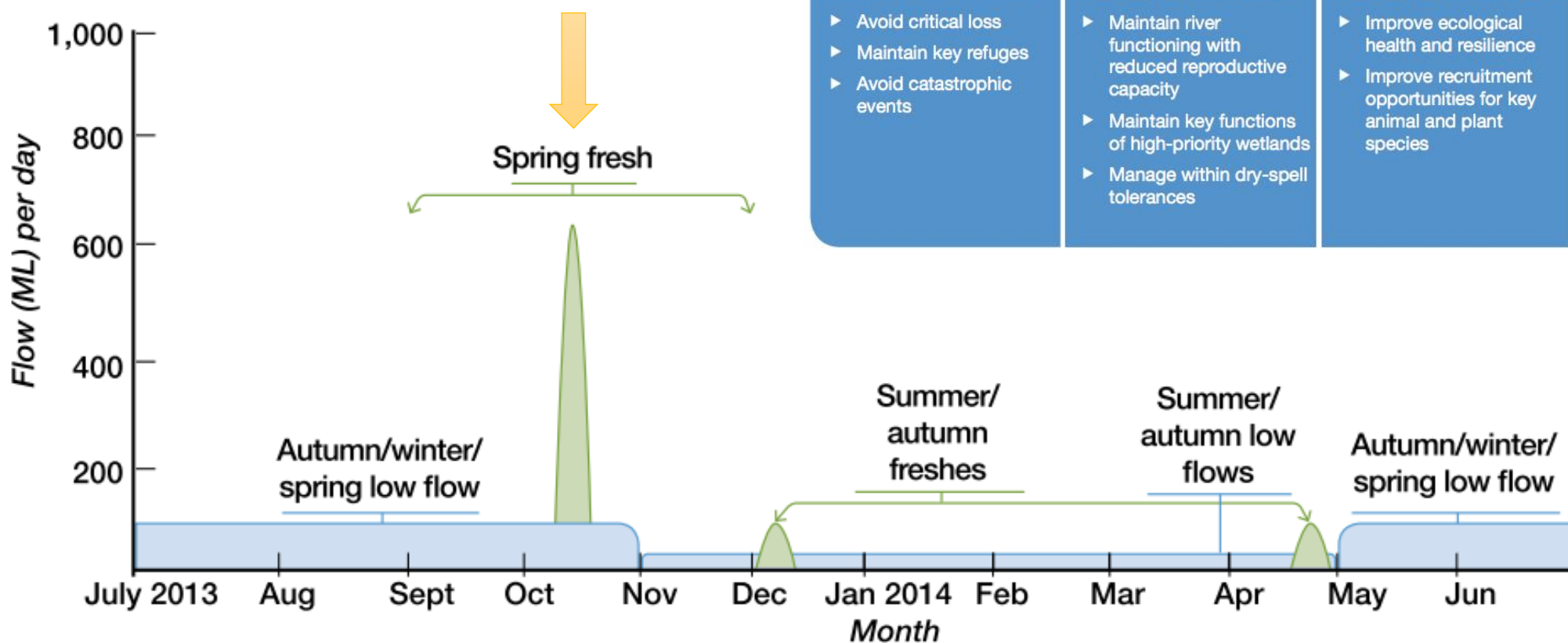
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Environmental water rights



Drought Main objective: PROTECT <ul style="list-style-type: none"> ▶ Avoid critical loss ▶ Maintain key refuges ▶ Avoid catastrophic events 	Dry Main objective: MAINTAIN <ul style="list-style-type: none"> ▶ Maintain river functioning with reduced reproductive capacity ▶ Maintain key functions of high-priority wetlands ▶ Manage within dry-spell tolerances 	Average Main objective: RECOVER <ul style="list-style-type: none"> ▶ Improve ecological health and resilience ▶ Improve recruitment opportunities for key animal and plant species 	Wet to very wet Main objective: ENHANCE <ul style="list-style-type: none"> ▶ Restore key floodplain and wetland linkages ▶ Enhance recruitment opportunities for key animal and plant species

Loddon River in Victoria, Australia



Doolan, J.M., Ashworth, B. and Swirepik, J., 2017. Planning for the active management of environmental water. In *Water for the Environment* (pp. 539-561).

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Ecological or environmental reserve

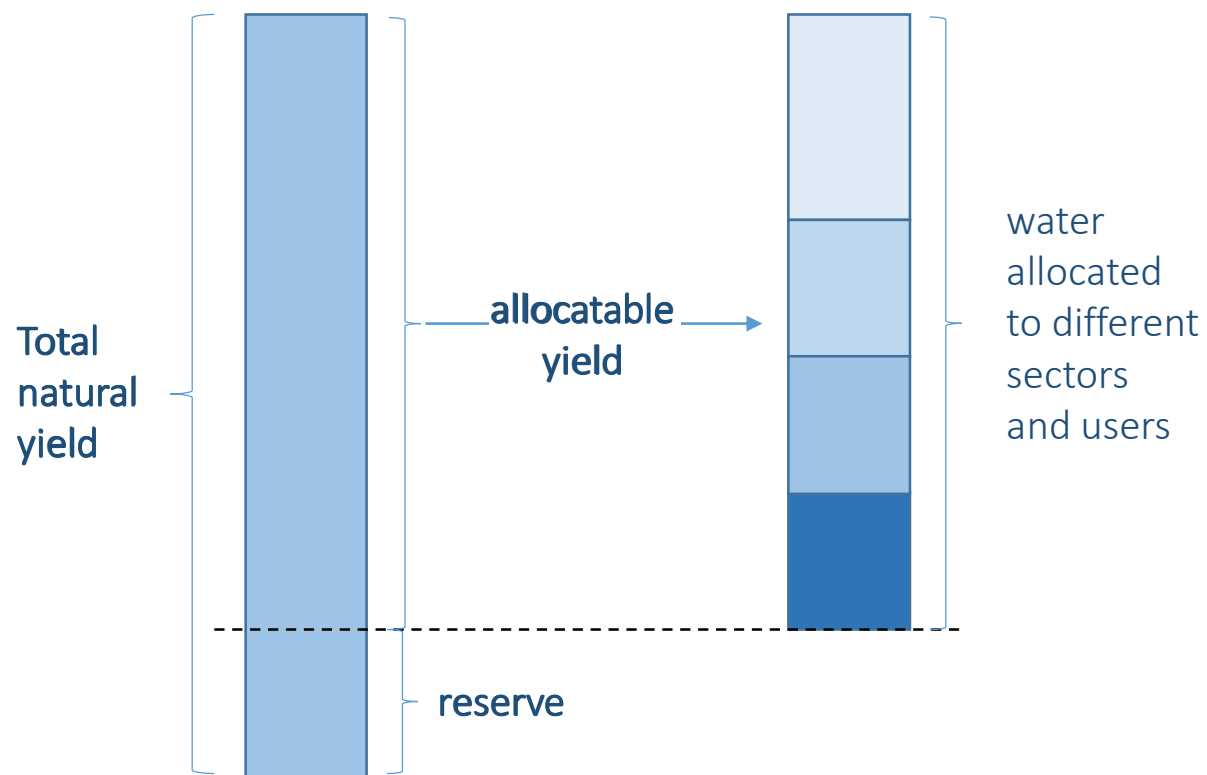
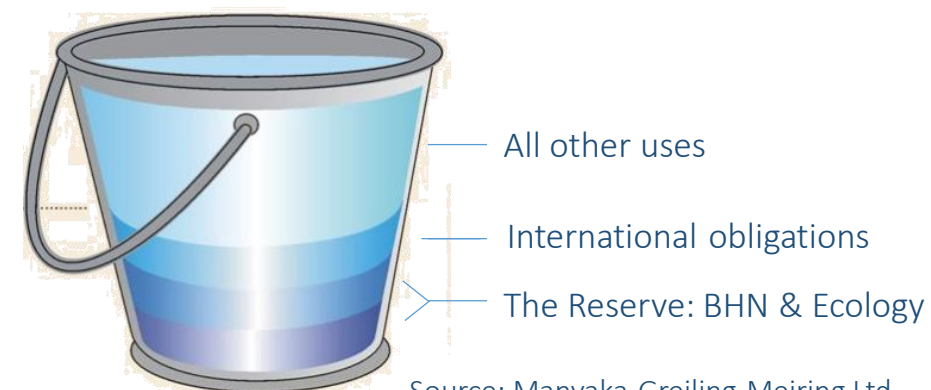


Illustration modeled after one in Speed et al. (2013) Basin Water Allocation Planning. Principles, procedures and approaches for basin allocation planning, UNESCO, Paris.

(a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be - (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and

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License and permit requirements for individual users

No Restrictions

Abstraction permitted up to permit limits

flood flow

Restriction Zone 1

No irrigation abstraction permitted. Domestic abstraction up to permit limits.

normal flow

Restriction Zone 2

Domestic abstraction rationed to 25 l/p/d.

reserve



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