# Managing sediment flux in semi-arid river systems

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# Key themes

1. An overview of sediment flux at the catchment scale: sediment budgets & the sediment delivery problem

2. Three key geomorphic messages
   – Reach-scale capacity for adjustment/sensitivity
   – Catchment-scale connectivity
   – Evolutionary trajectory

3. Managing sediment flux in semi-arid environments

# Part One

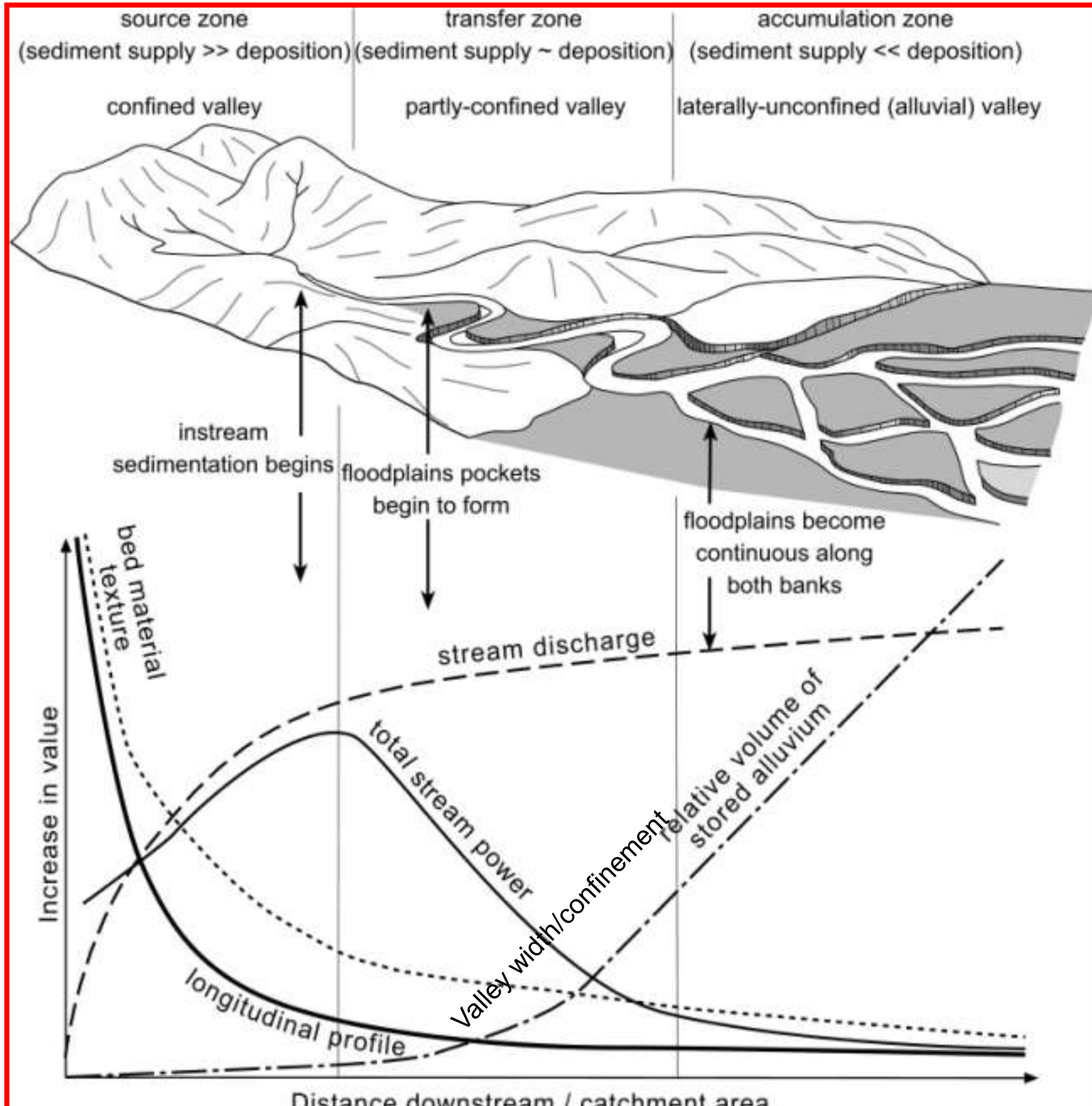
## An overview of sediment flux at the catchment scale: sediment budgets & the sediment delivery problem

# Catchment-scale patterns of sediment source, transfer and accumulation zones

**Schumm (1977)**

**Church (1992)**

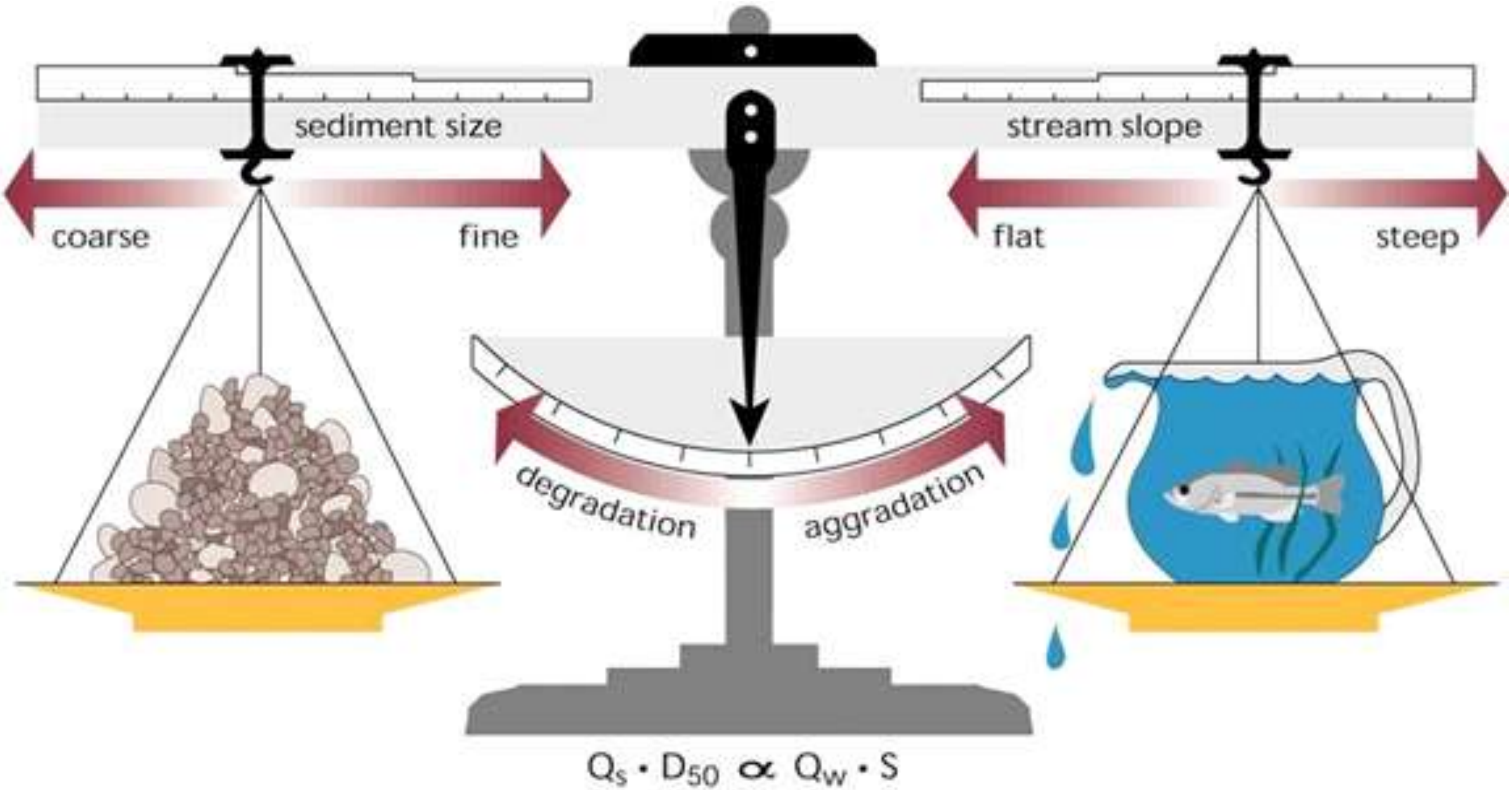
**Montgomery (1999)**




Fryirs & Brierley (2013)

# Source to sink relationships: Whataroa River, South Island, New Zealand

# The Lane Balance



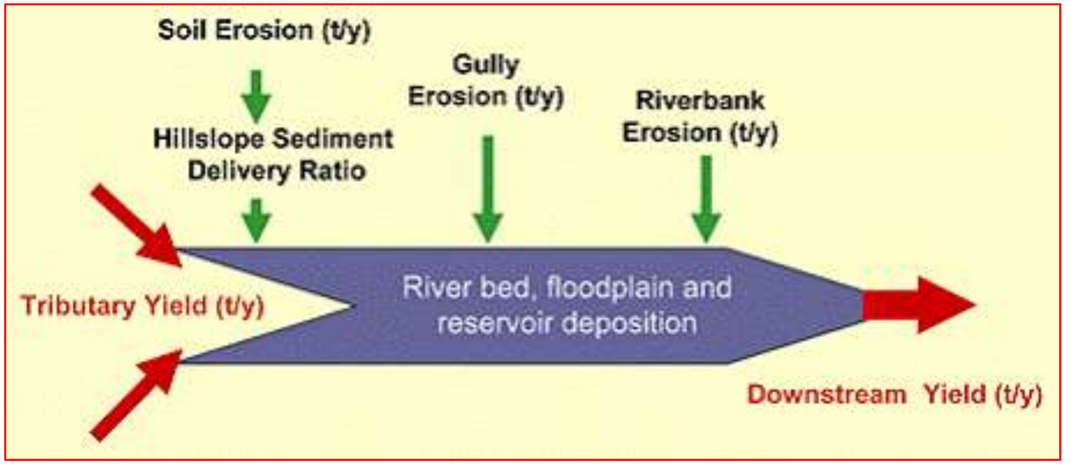
# Sediment budgets and the sediment delivery ratio

$$O - I \pm \Delta S = 0$$

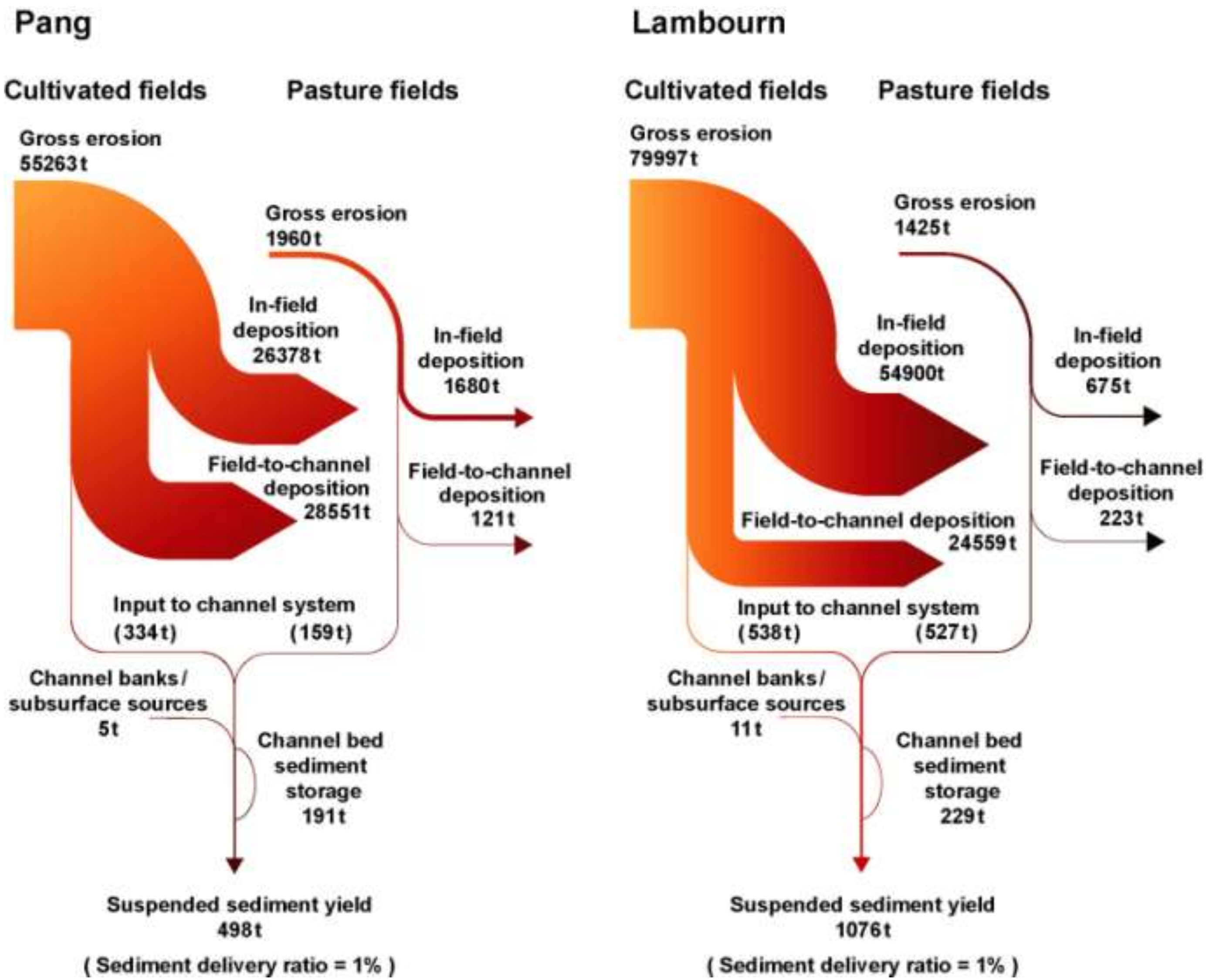
O = sediment output,

I = sediment input and

Δ S refers to the change in sediment storage over a given timeframe



# An example of a catchment-scale sediment budget Walling et al. (2006). Journal of Hydrology 330: 126-141



# Key considerations in appraising sediment budgets

- Sediment availability: re-generation and depletion (exhaustion)

- Sediment stores and sinks
  - Accommodation space
    - Channel and floodplain compartments
    - Patterns in landscapes
  - Residence time

- Frequency of reworking: The jerky conveyor belt of sediment movement in river systems

- Natural variability & human disturbance (Multiple, cumulative impacts)

- Imprint from the past (legacy sediments)

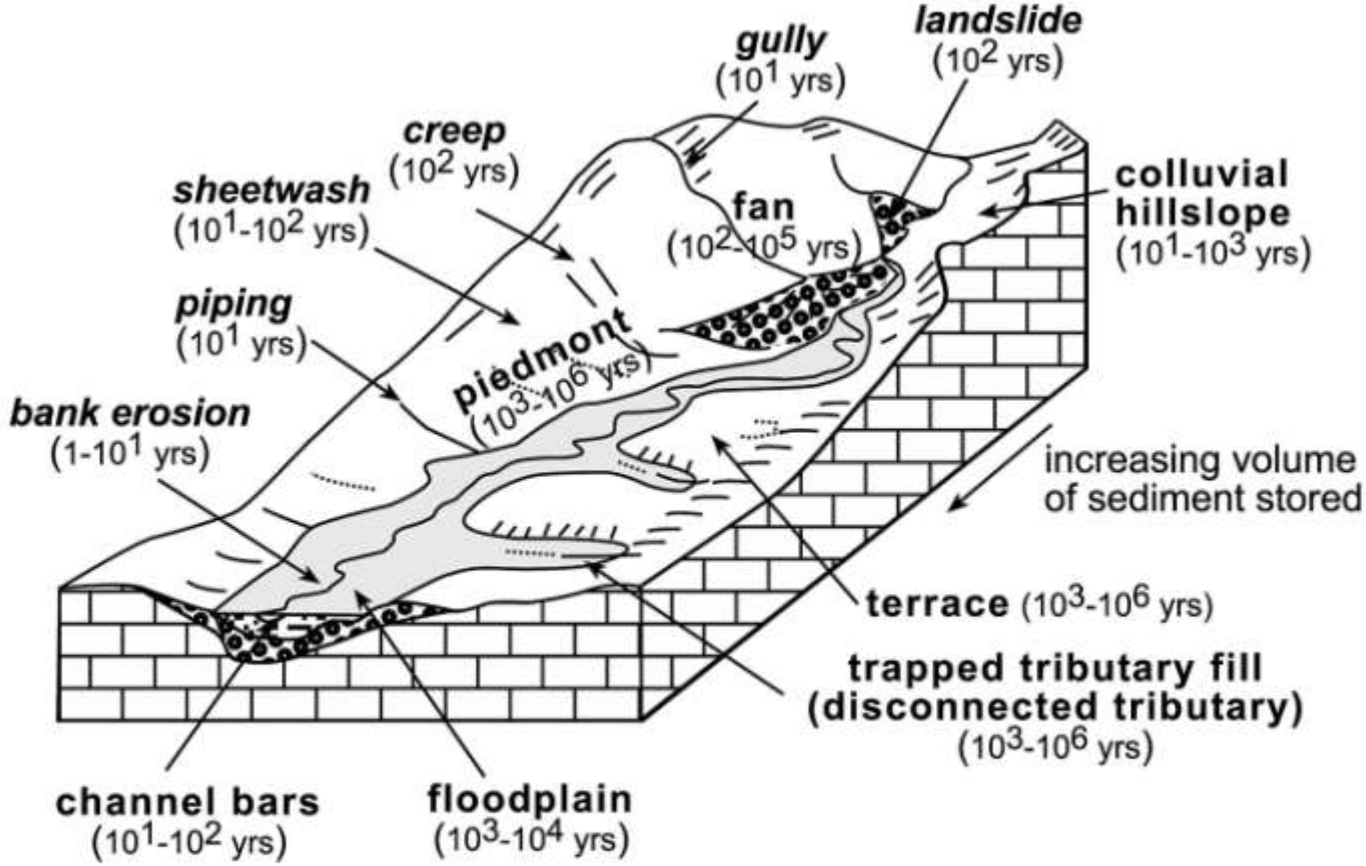





**Figure 14.1** Timeframes of sediment (re)generation for differing sediment sources and residence times for sediment stores in river systems. Differing colluvial and alluvial landforms operate as sediment sources and stores/sinks over variable timeframes, ranging from years to many thousands of years. The recurrence with which sediments are sourced or stored is largely dependent on position in a catchment and the recurrence of geomorphically effective disturbance events.

# Part Two

## Three key geomorphic messages

a. *Reach-scale capacity for adjustment/sensitivity*

b. *Catchment-scale connectivity*

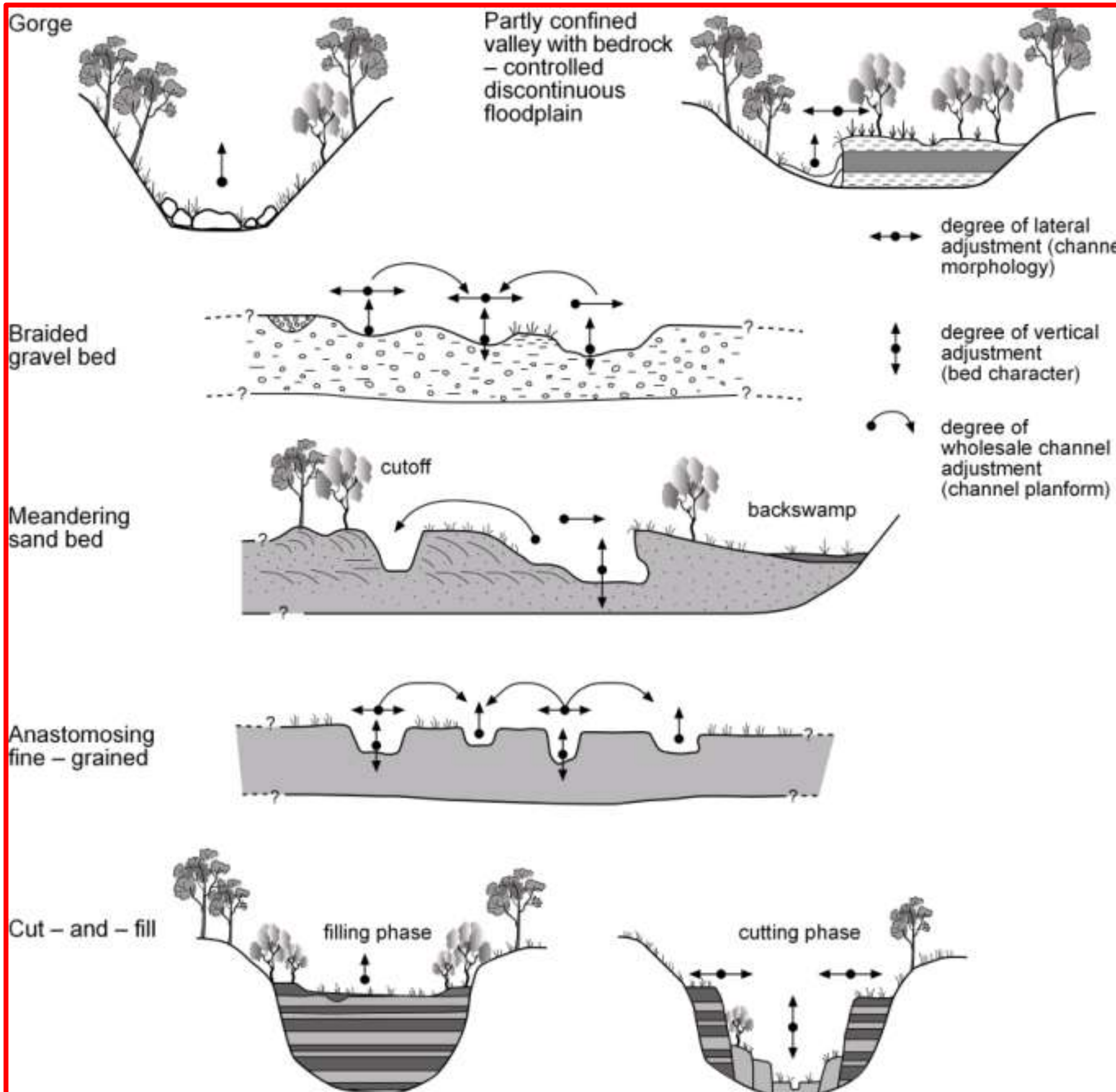
c. *Evolutionary trajectory*

# a. Reach-scale river adjustments

Differing forms of adjustment

Variable capacity for adjustment and rates of activity (sensitivity)

Differing channel and floodplain sediment stores and sinks (and ease of reworking)



# b. Catchment-scale patterns of rivers and their connectivity

- How reaches fit together (interact) at the catchment scale … patterns of differing types of river, and their ‘connectivity’

- Fundamental role of landscape configuration (drainage density, landscape dissection, drainage pattern tributary-trunk stream relationships)

# Connectivity relationships

*Longitudinal*

- Upstream-downstream relations (base level control)
- Tributary-trunk stream relations (sedimentary links)

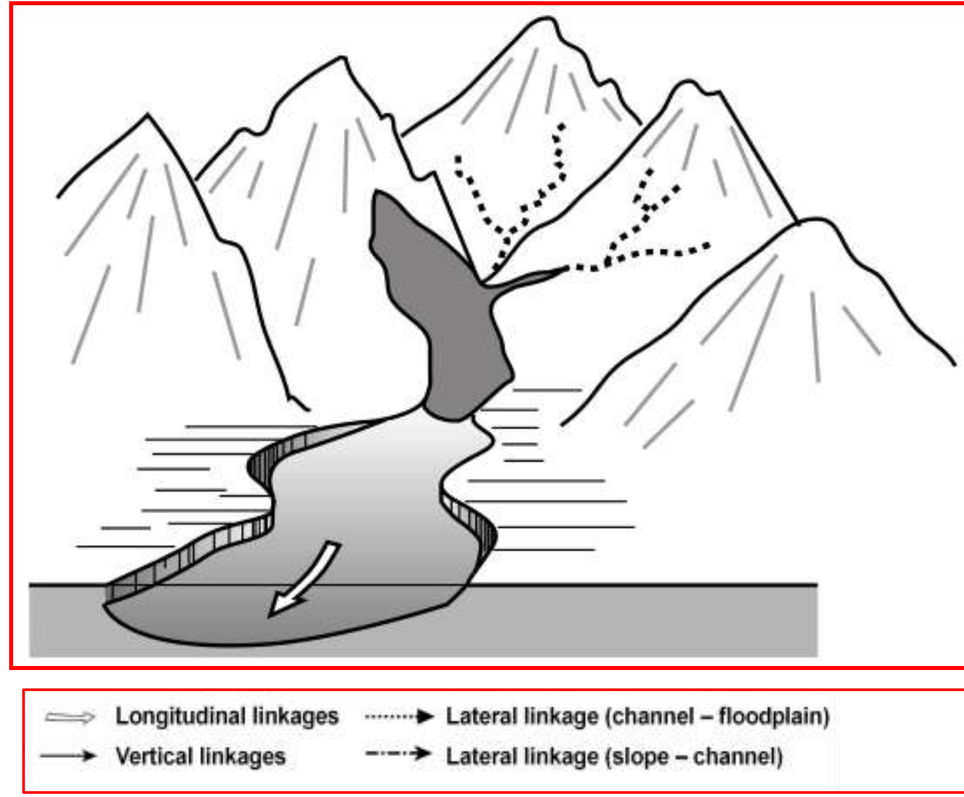
*Lateral*

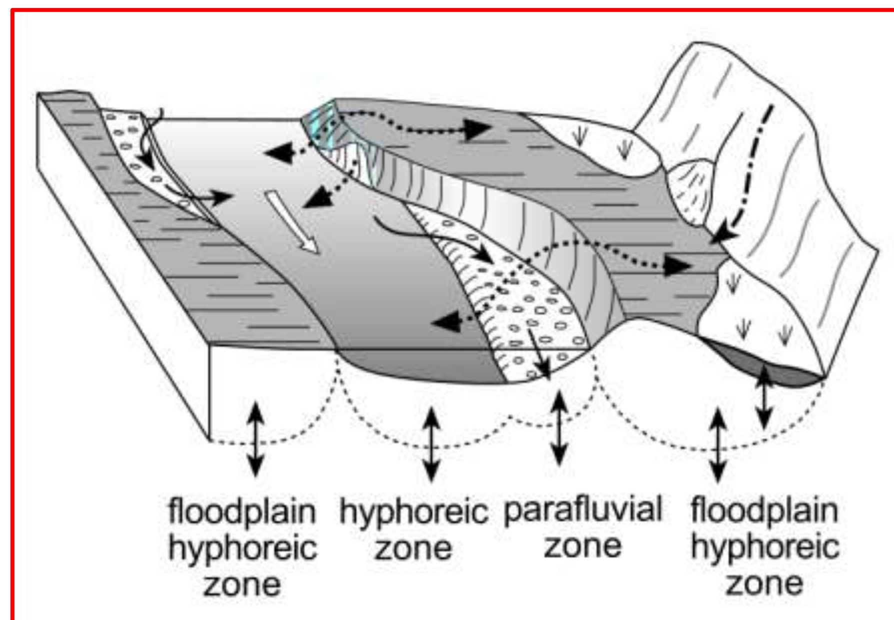
- Hillslope-valley floor
- Channel-floodplain

*Vertical*

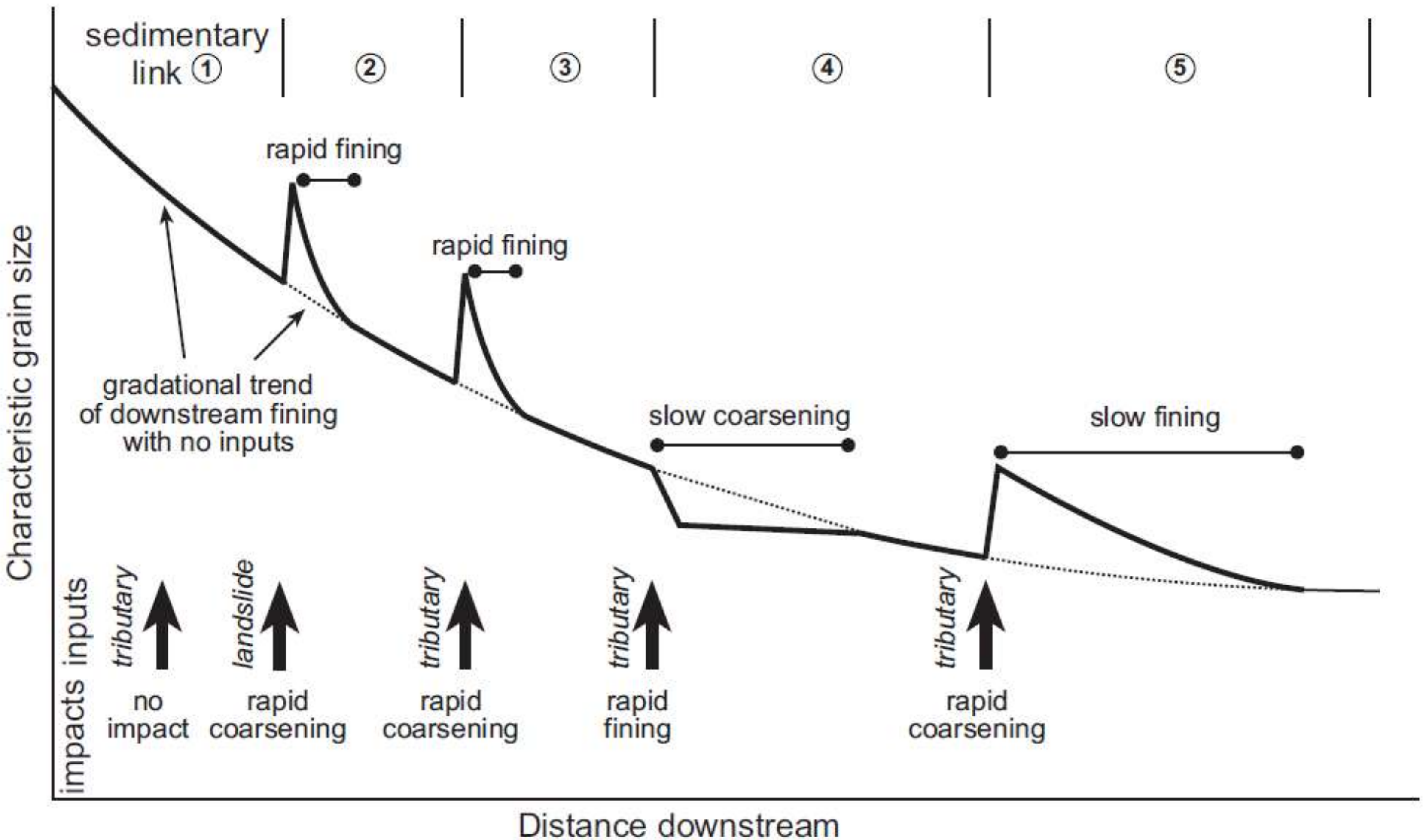
- Surface-subsurface relationships

*Connectivity relationships change over time*



# Sediment links in river systems: Geomorphically effective & ineffective tributaries



# Landforms that induce disconnectivity in sediment flux (Fryirs et al., 2007)

**Buffers**

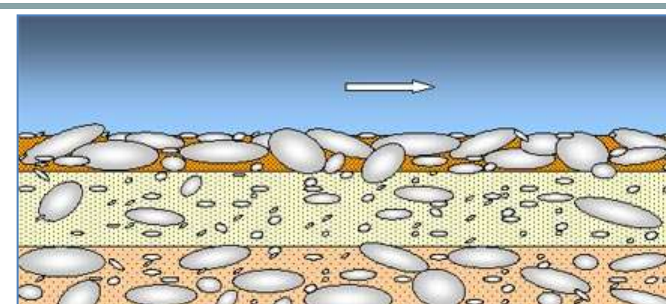
Prevent sediment from entering the channel network

**Barriers**

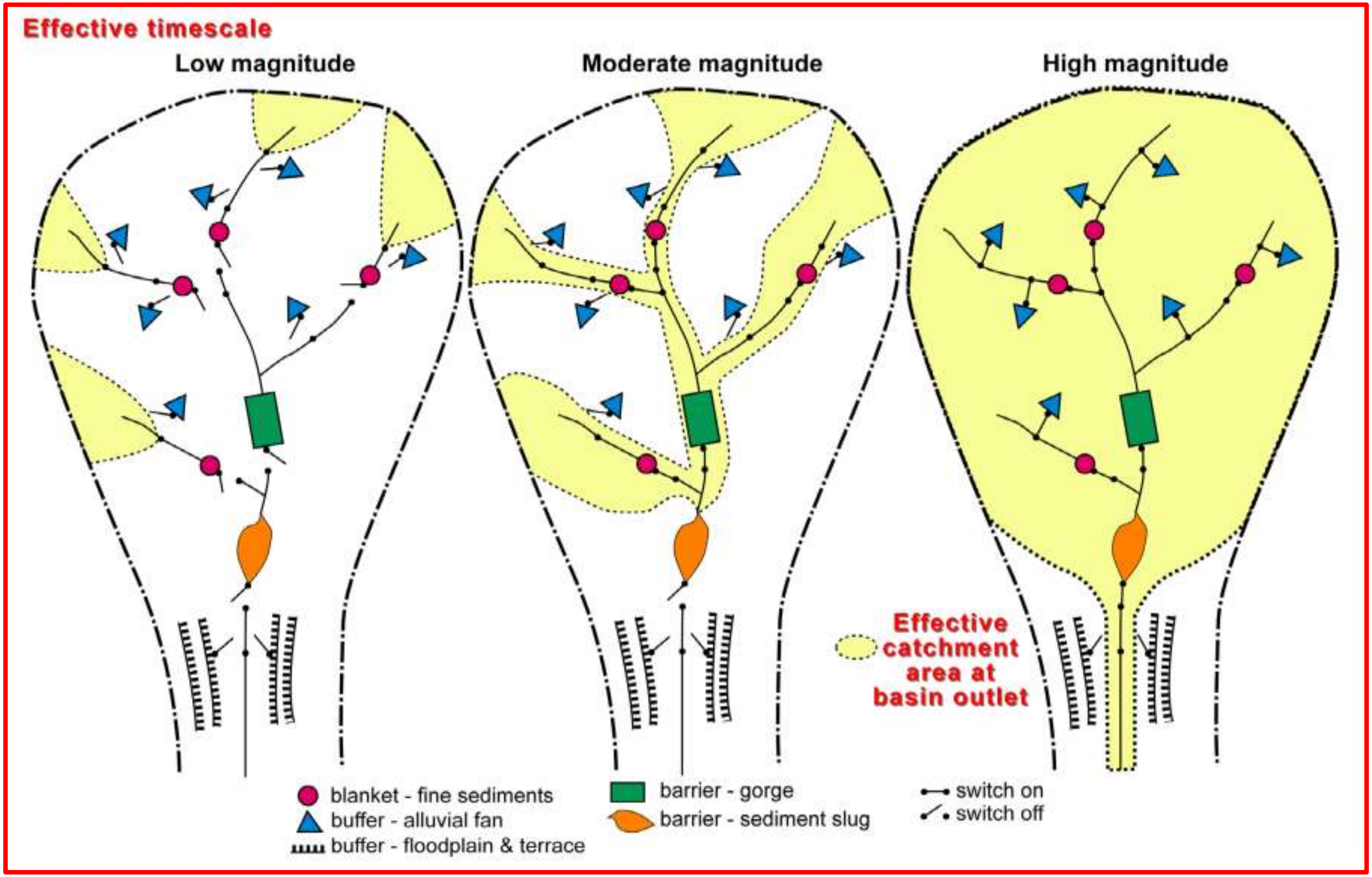
Disrupt sediment transfer along the channel

**Blankets**

Protect sediment from being reworked



# Landscape disconnectivity: Switches in catchments (Fryirs et al., 2007)



# Connected and disconnected landscapes (riverscapes)

**Coupled hillslope-channel system**

**Connected landscape**

**Major implications for flow and sediment flux**

**COST Project in Europe**

**Decoupled hillslope-channel system**

**Disconnected landscape**

# Differing relations in differing landscape settings (New Zealand versus Australia; Fryirs et al., 2007)




- connected
- hillslope dominated
- high conveyance
- short residence time

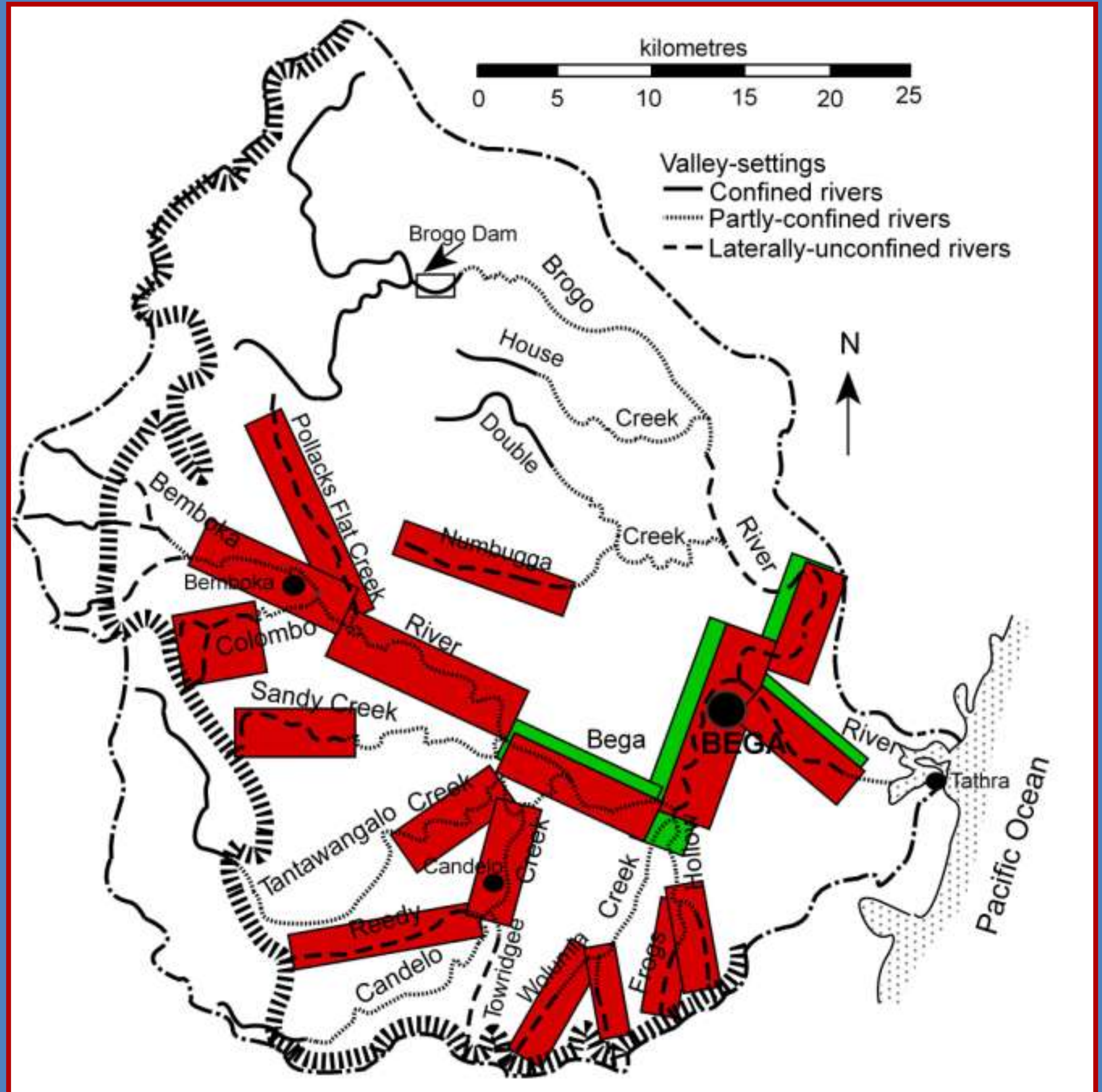



- disconnected
- valley floor dominated
- low conveyance
- long residence time

# c. Evolutionary trajectory

- Scenario-setting … Concern for river (environmental) futures … proactive basis for decision-making
- Place-based understandings … catchment-specific situations (Reading the Landscape)
- Use of new technologies for measurement and monitoring
- Modelling applications
- Fundamental importance of sediment stores (exhaustion, over-supply), reworking events and connectivity

# River changes in Bega catchment since European settlement

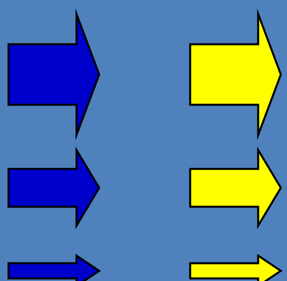


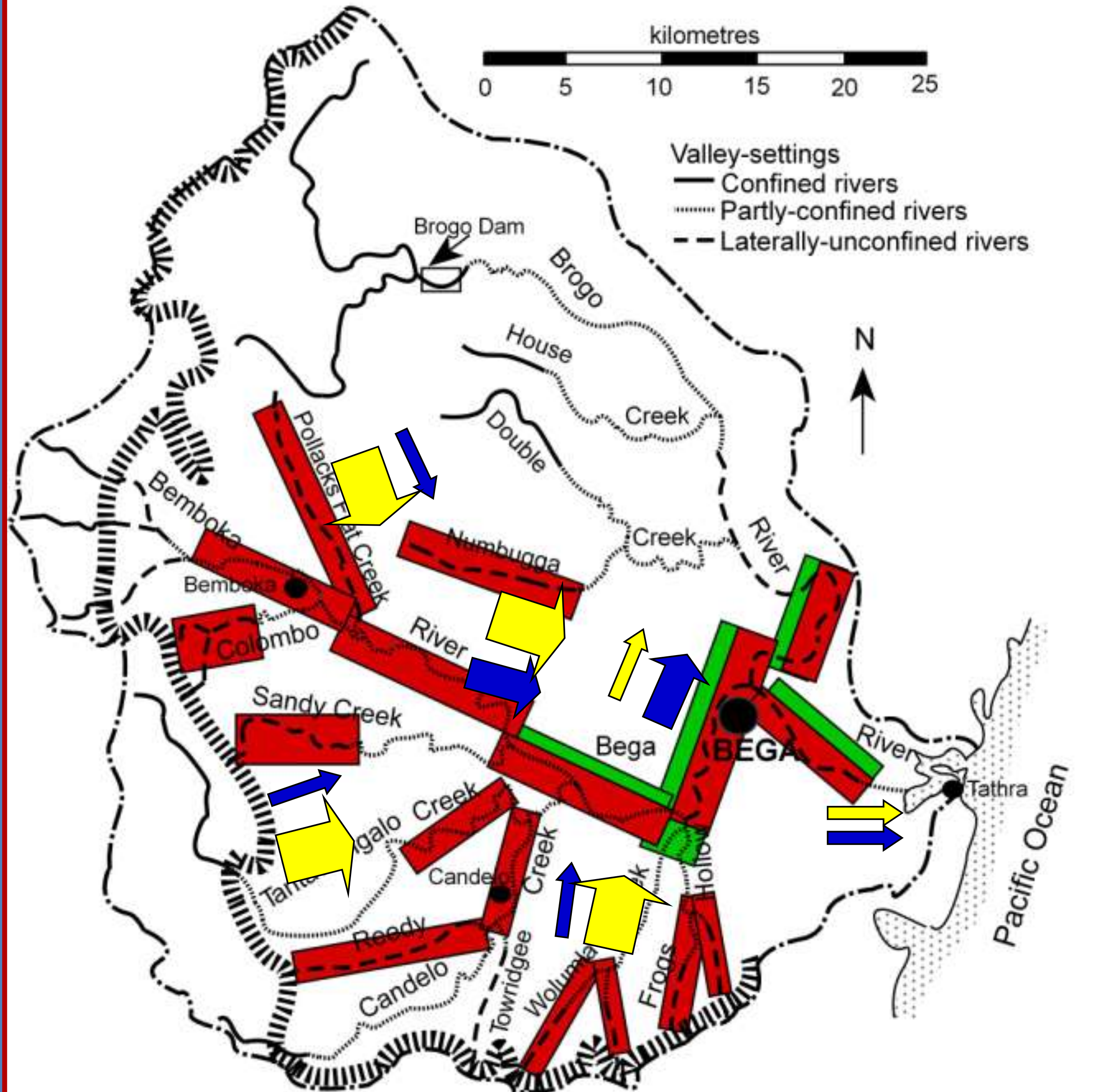

Erosion

Deposition

# Landscape connectivity in Bega catchment

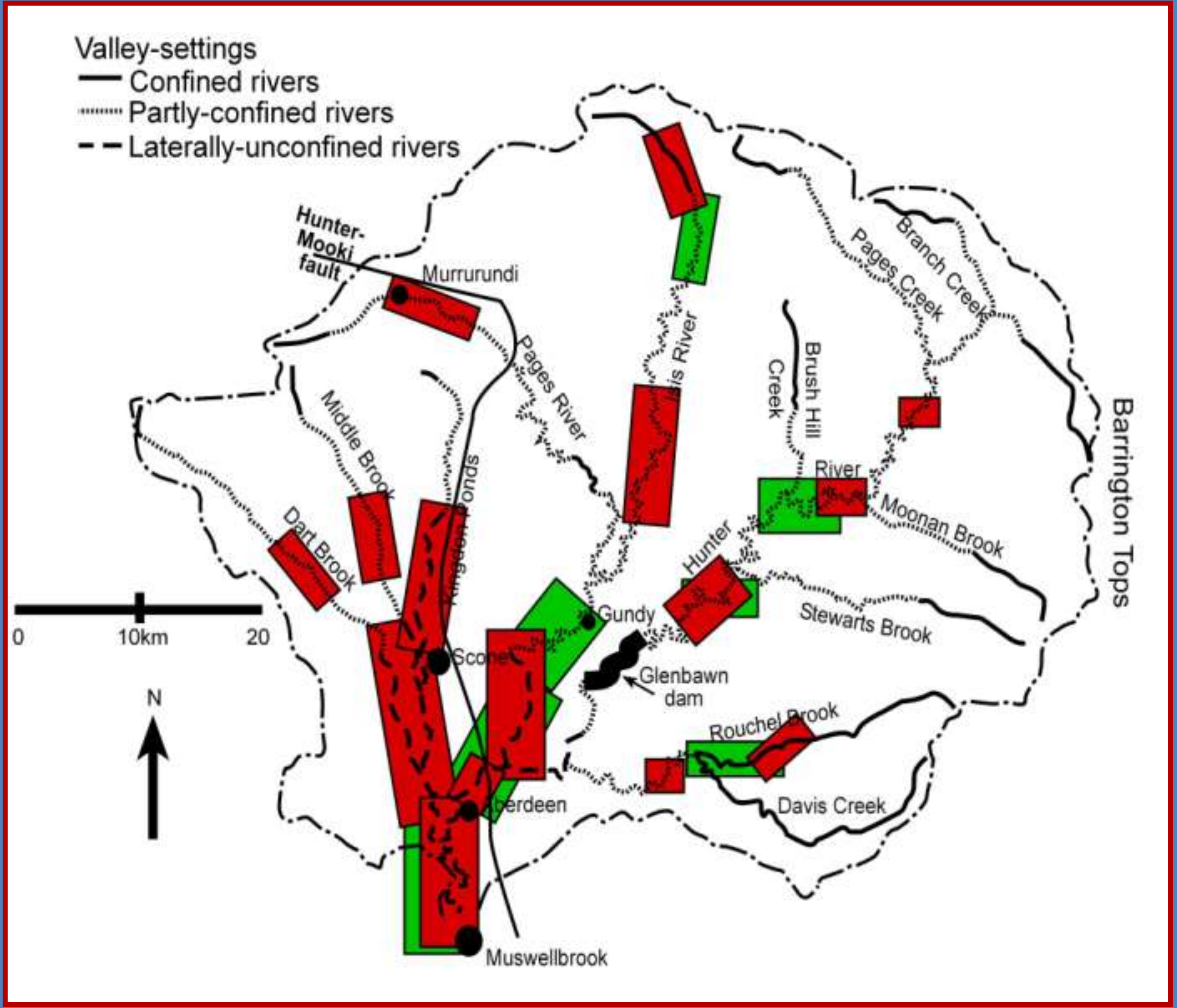
| | Pre ES | Post ES |
|---|---|---|
| strong | | |
| weak | | |
| disconn. | | |






Enhanced connectivity since European settlement

# River changes in Upper Hunter catchment since European settlement




Erosion

Deposition

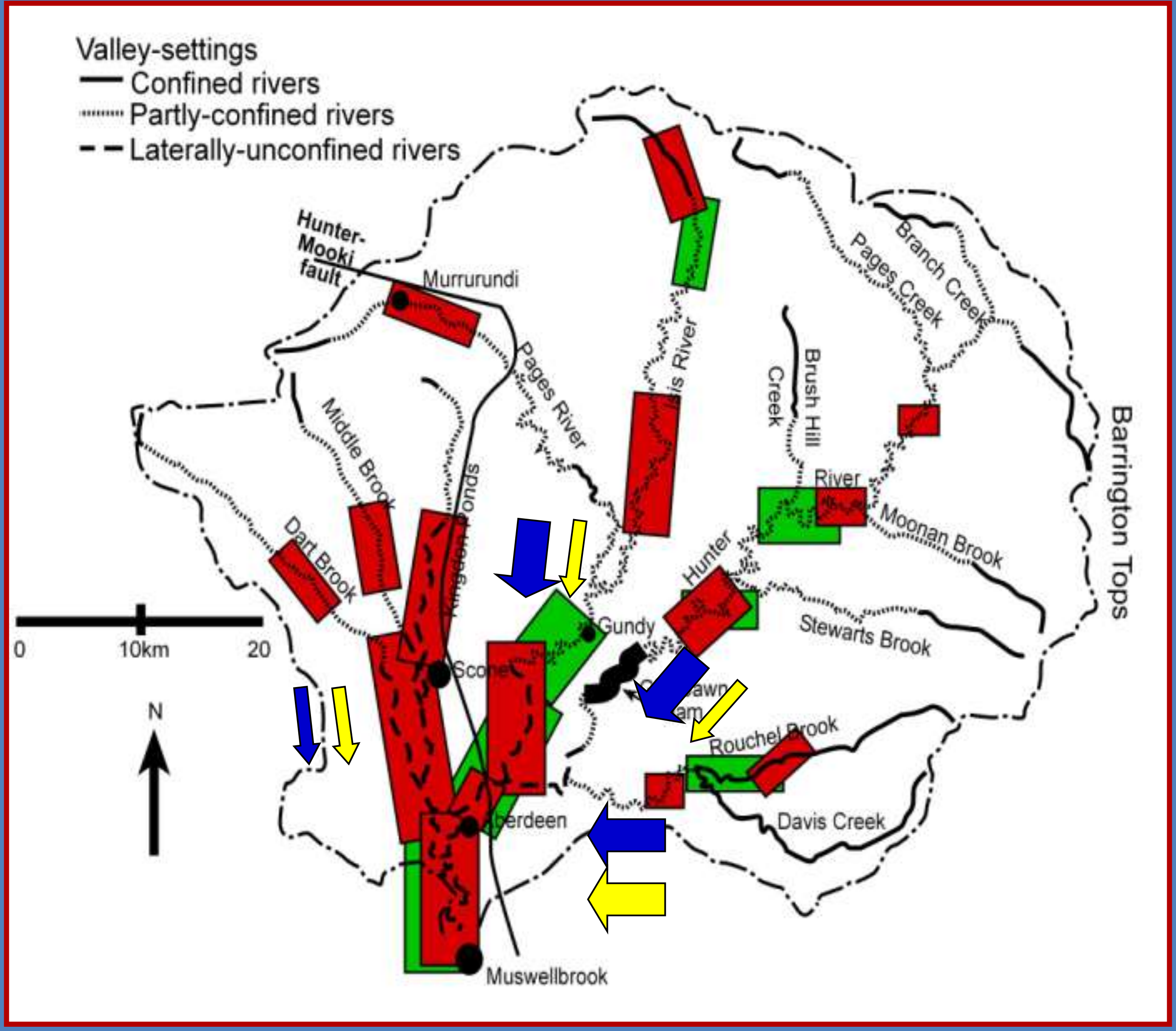
# Landscape connectivity in the Upper Hunter catchment

Pre ES Post ES

strong

weak

disconn.




Remains relatively disconnected since European settlement

# Implications for management of sediment flux

- Bega Catchment
  - Increased connectivity - lock up sediments in incised valley fills in headwater reaches
- Upper Hunter Catchment
  - Maintain disconnectivity

# Part Three: Managing sediment flux in semi-arid landscapes

- Geomorphically sensitive environments that are prone to rapid and dramatic alteration
  - Ephemeral flow regime and impacts upon magnitude-frequency relationships
  - Role of vegetation cover (e.g. Upper Yangtze versus Upper Yellow River)
  - Importance of cut-and-fill landscapes
- Limited prospects for recovery in many instances
- Must be managed very carefully

# Key considerations in framing management applications

Based upon determination of prevailing and likely future sediment flux, we need to assess:

- Vision – what is realistically achievable? Must link reach-scale target conditions into the catchment-framed vision

- Prioritize management activities

- Monitor process relationships, and amend vision and management responses as required

# THE RIVER STYLES FRAMEWORK

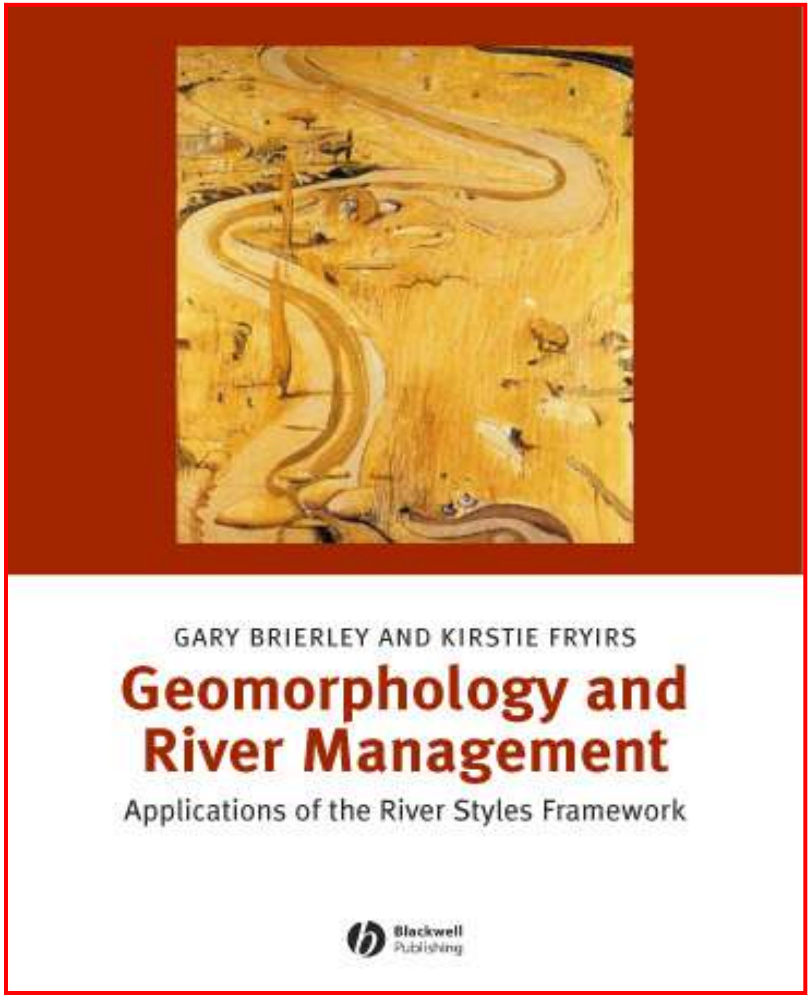
Stage 1: Catchment-scale analysis of river character, behaviour and pattern

Stage 2: Catchment-scale analysis of river evolution & geomorphic condition

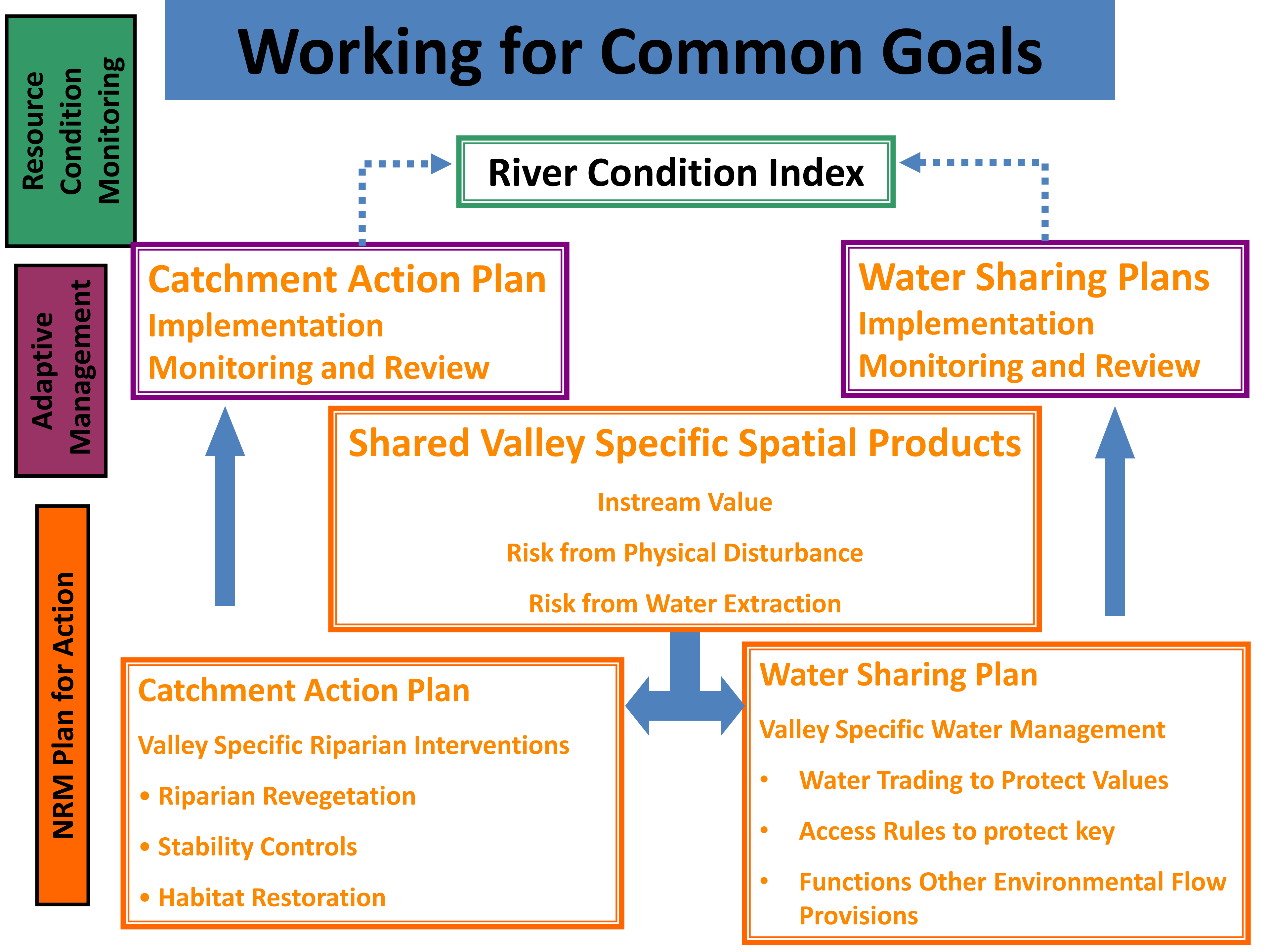
Stage 3: Catchment-scale analysis of river recovery potential (trajectory)

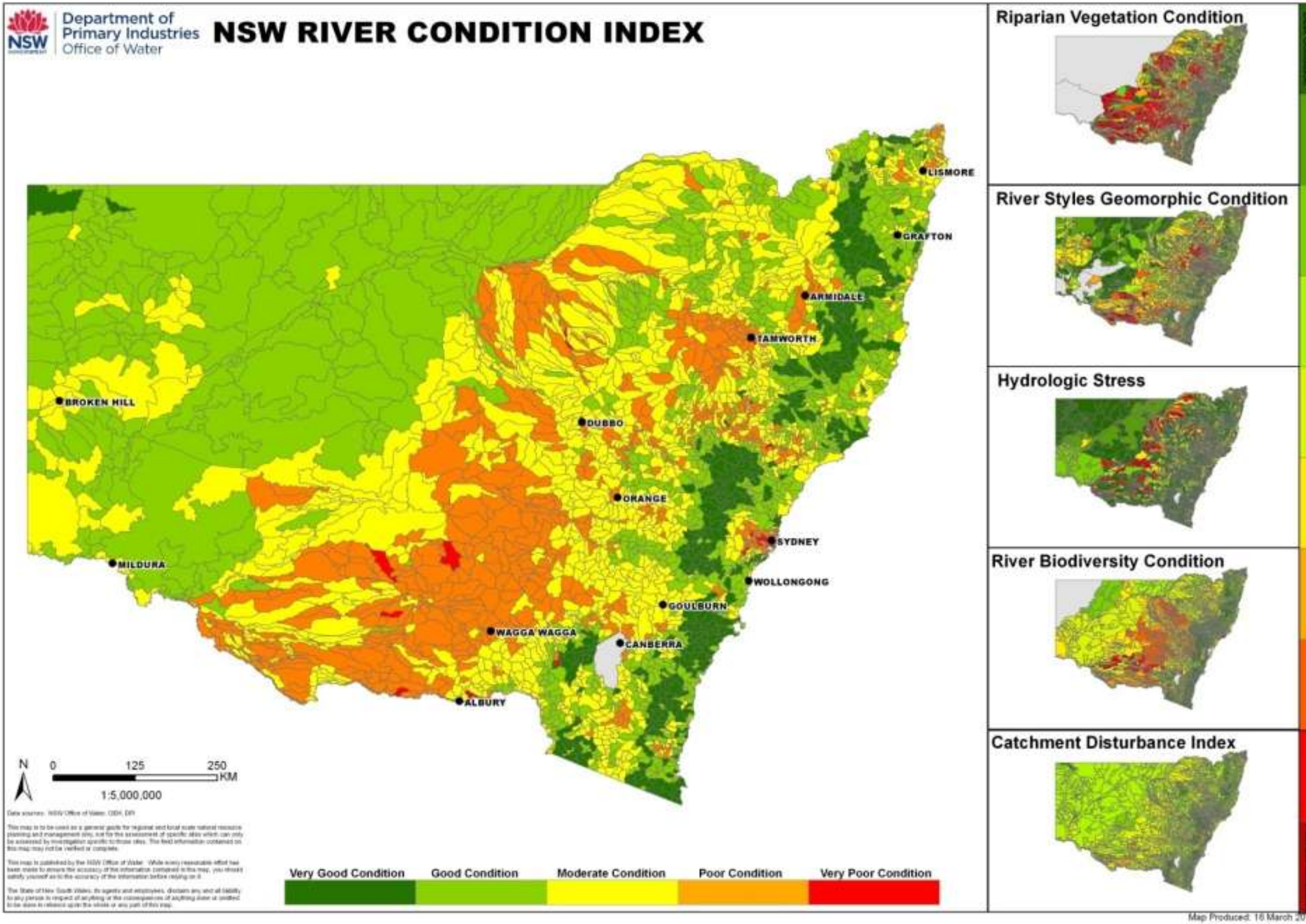
Stage 4: Management applications

- Catchment-scale vision
- Target conditions
- Prioritisation
- Monitoring



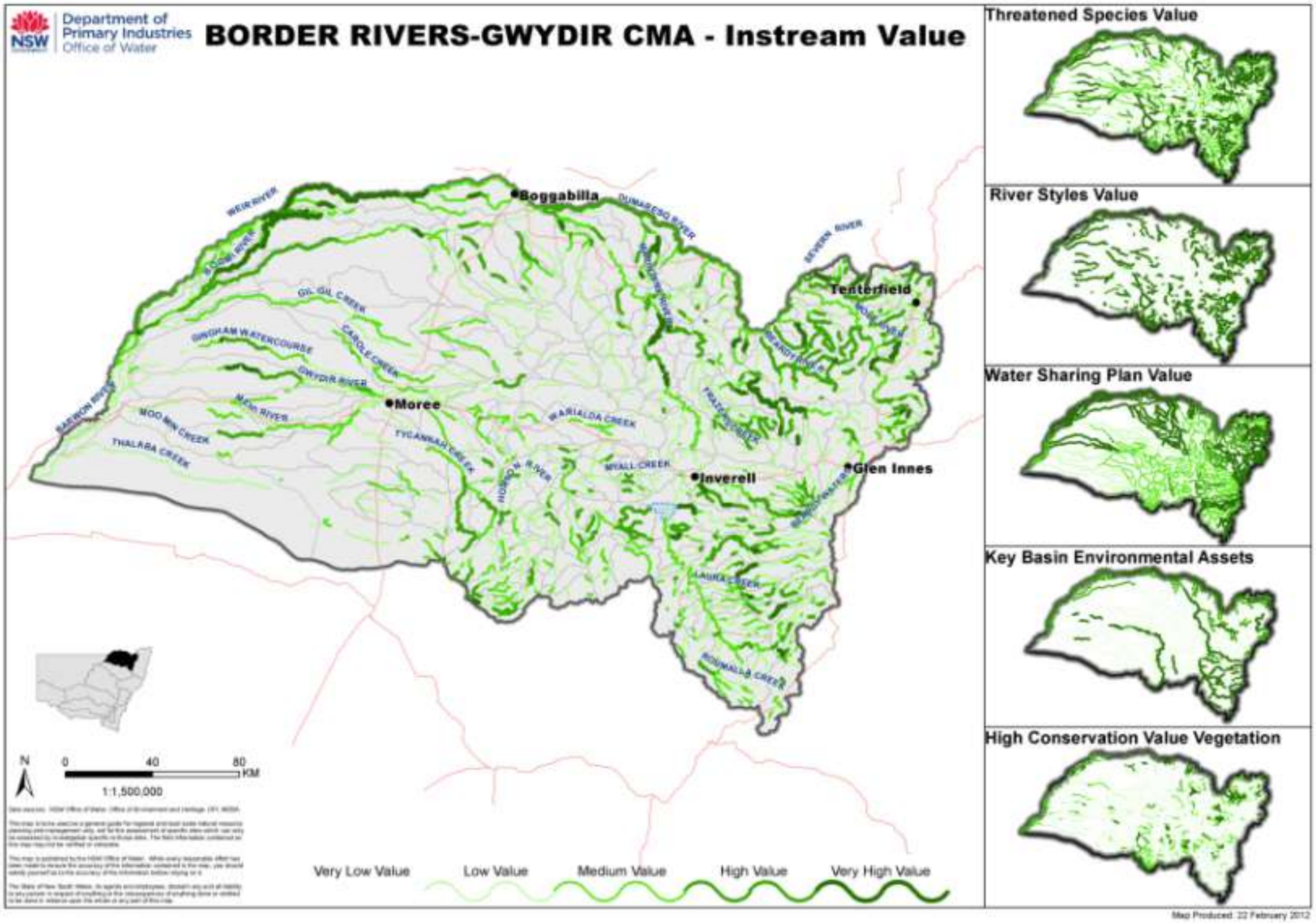

Brierley & Fryirs (2005)
www.riverstyles.com


Working for Common Goals
Resource Condition Monitoring
Adaptive Management
NRM Plan for Action
River Condition Index
Catchment Action Plan
Implementation
Monitoring and Review
Water Sharing Plans
Implementation
Monitoring and Review
Shared Valley Specific Spatial Products
Instream Value
Risk from Physical Disturbance
Risk from Water Extraction
Catchment Action Plan
Valley Specific Riparian Interventions
• Riparian Revegetation
• Stability Controls
• Habitat Restoration
Water Sharing Plan
Valley Specific Water Management
• Water Trading to Protect Values
• Access Rules to protect key
• Functions Other Environmental Flow Provisions



Department of
Primary Industries
Office of Water
NSW
NSW RIVER CONDITION INDEX
LISMORE
GRAFTON
ARMIDALE
TAMWORTH
BROKEN HILL
DUBBO
ORANGE
SYDNEY
MILDURA
WOLLONGONG
GOULBURN
WAGGA WAGGA
CANBERRA
ALBURY
N
0
125
250
KM
1:5,000,000
Very Good Condition
Good Condition
Moderate Condition
Poor Condition
Very Poor Condition
Riparian Vegetation Condition
River Styles Geomorphic Condition
Hydrologic Stress
River Biodiversity Condition
Catchment Disturbance Index
Map Produced: 16 March 2012

# River Value – for trading / dealing rules in Water Sharing Plans



# Risk assessment

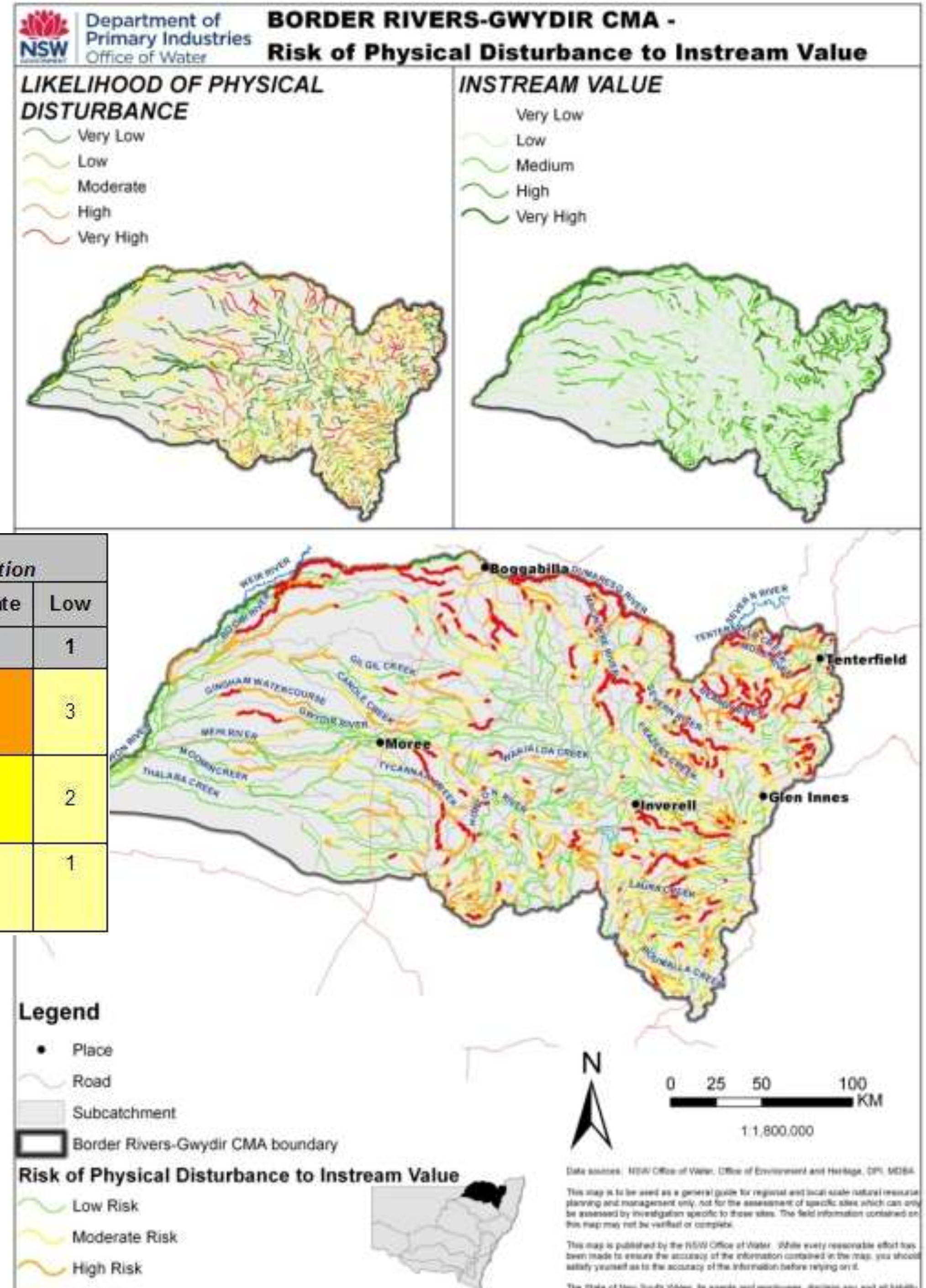
**Risk = Likelihood** (of irreversible change from physical disturbance)

**x**

**Consequence** (instream value)

Likelihood matrix:

| | | | THREAT<br>*River Styles Recovery Potential – based on Condition* | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Conservation | Strategic | Rapid | High | Moderate | Low |
| | | | 6 | 5 | 4 | 3 | 2 | 1 |
| *VULNERABILITY* | *River Styles Fragility* | | | | | | | |
| | High | 3 | 18 | 15 | 12 | 9 | 6 | 3 |
| | Medium | 2 | 12 | 10 | 8 | 6 | 4 | 2 |
| | Low | 1 | 6 | 5 | 4 | 3 | 2 | 1 |



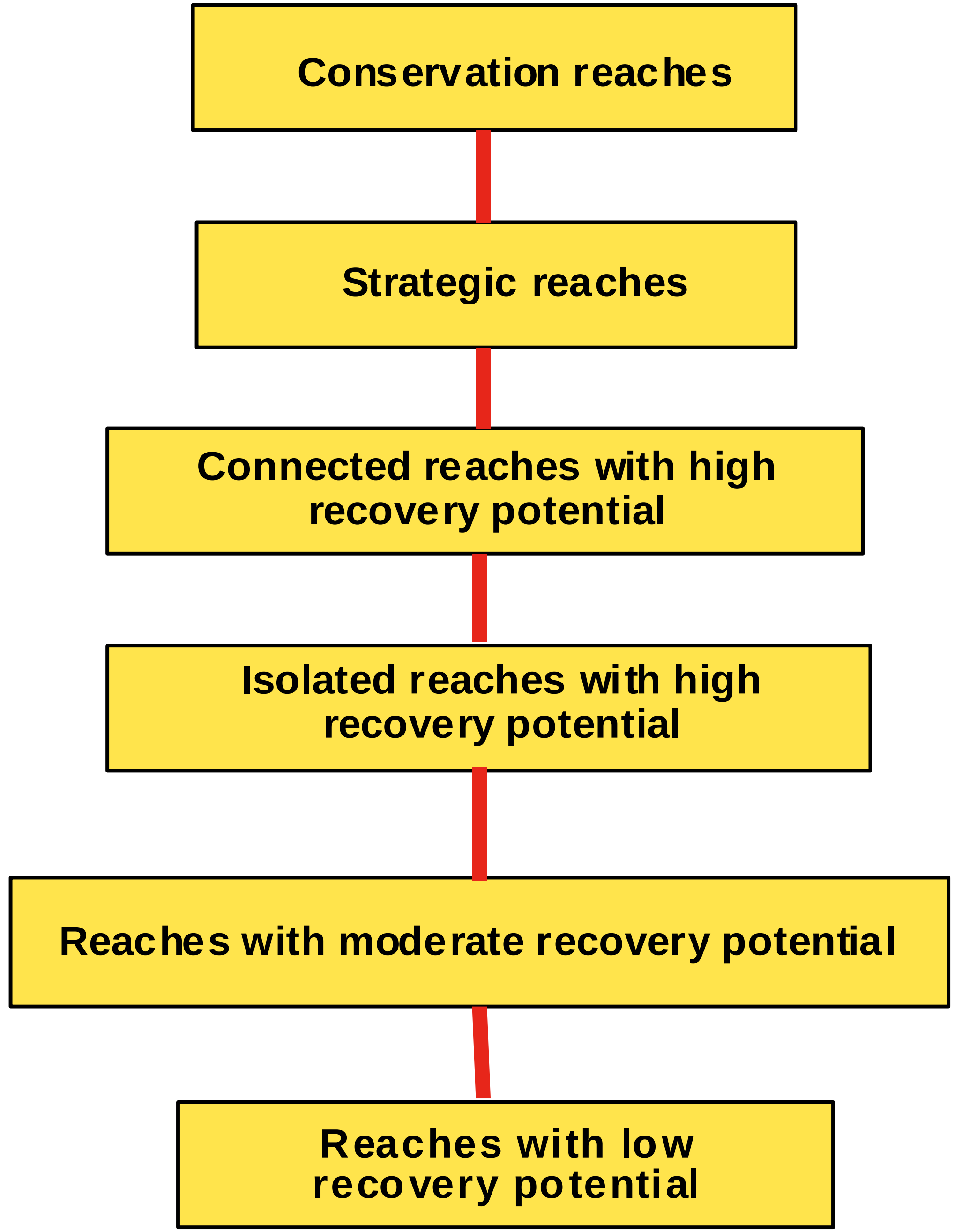

**Extension to analysis of ecosystem services, based on 'capacity for adjustment'**

# The River Styles approach to catchment-framed prioritization of river conservation and rehabilitation programs

Conservation first: Look after the good bits and unique attributes

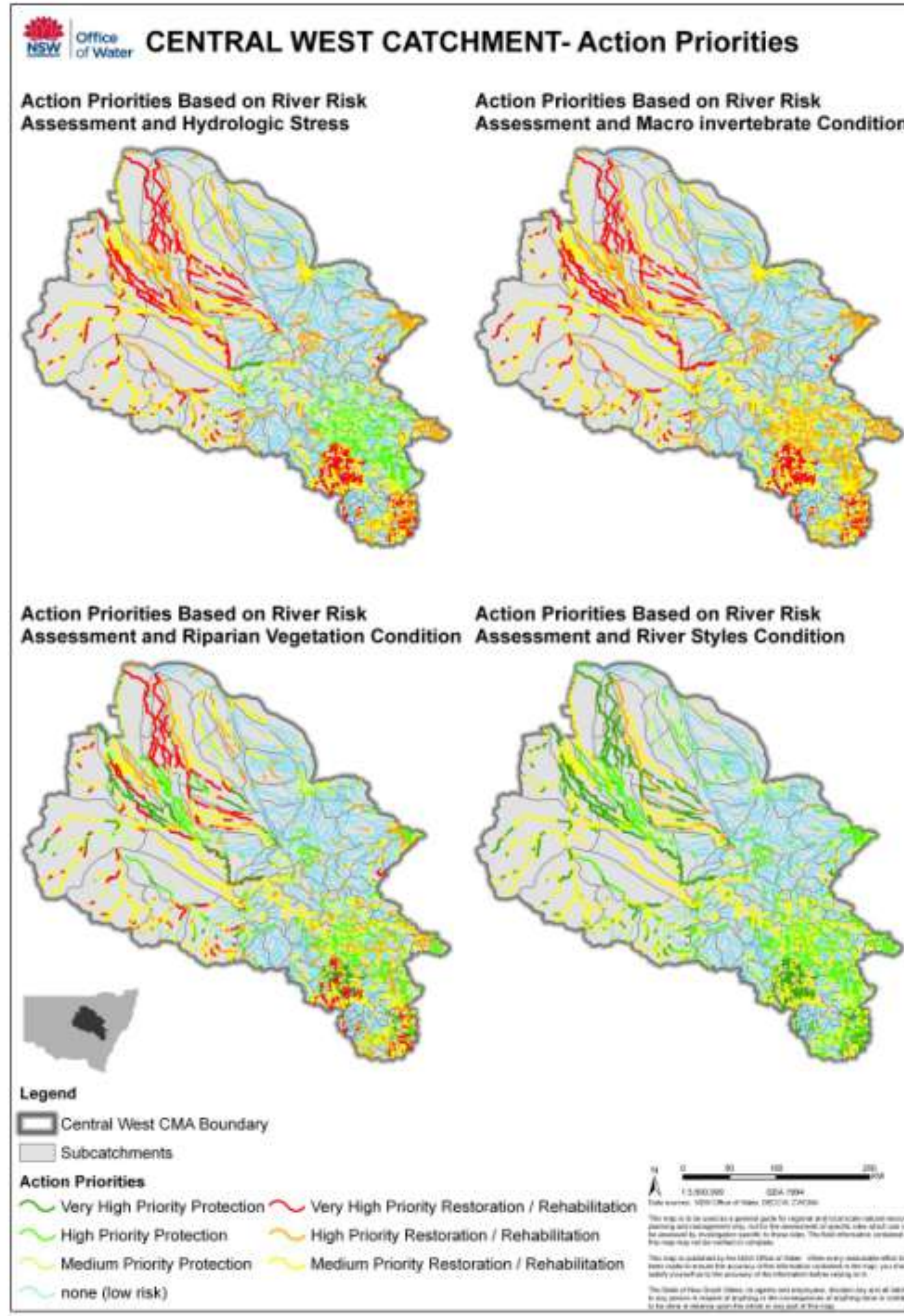
Target key problems in a proactive manner (causes, not symptoms)

Minimize off-site impacts - Link reaches to enhance prospects for sustainable success (sand slugs, head cuts, etc)



# Regional-scale prioritisation of management actions

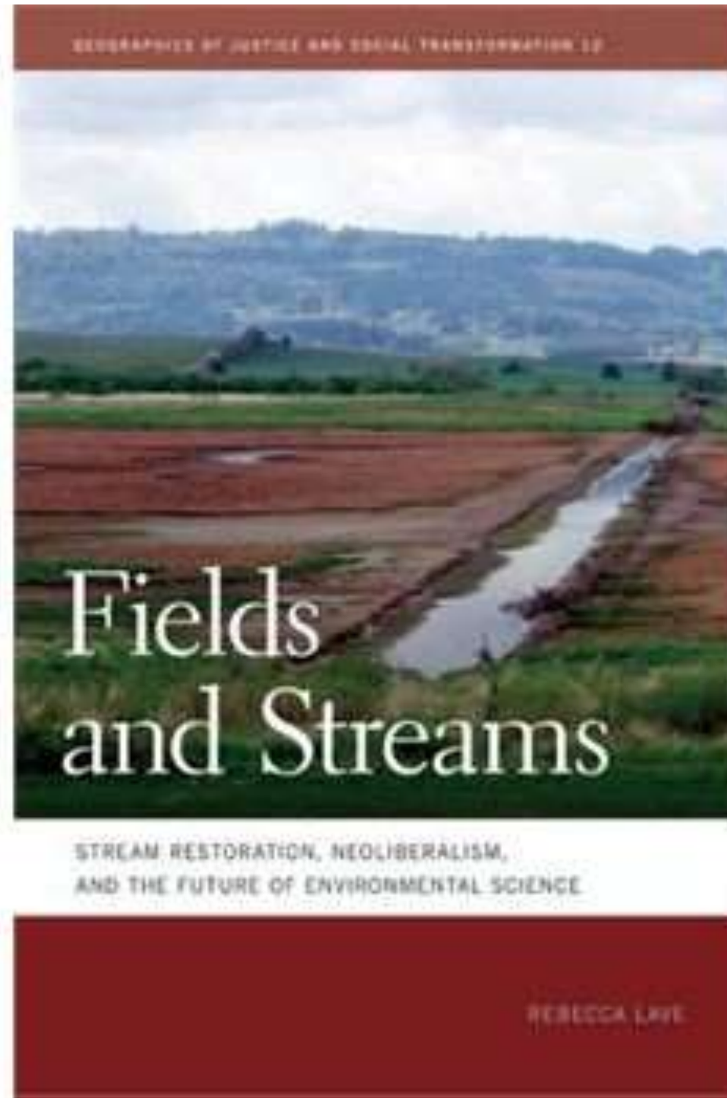
Also used to assess river value for trading in water sharing plans (Brierley et al., 2011)



# River classification: Theory, practice, politics

Tadaki et al. 2014 (*WIREs Water*) DOI: 10.1002/wat2.1026

- An emerging river classification industry?
- A key site of interdisciplinary practice and management applications
- Emerging forms of governance are supported by – and made possible through - certain forms of biophysical knowledge
- From ‘natural’ to ‘political’ kinds




Rebecca Lave 2012

# SUMMARY

Effective management of catchment-scale sediment flux builds upon sound understanding of:

- Types of river, their behavioural regime (erosion/deposition processes, ways they adjust, and how they store/rework sediments)
- How reaches interact to determine sediment flux at the catchment scale (connectivity relationships)

These understandings are an integral component of Catchment Action Plans – must have a clear rationale and prioritized plan of management activities