Defining Hydromorphological Conditions and Links to Ecology

The changing role of Geomorphology in River Management and Restoration

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Topic 1

1. How has the role of fluvial geomorphology in river management changed over the last several decades?

2. What direction should the role of geomorphology in water resources management take in the next 10-20 years?

What is Fluvial Geomorphology?

- The study of river landforms and the processes that generate and maintain them
  Malcolm Newson and David Sear (1995)

- The final triumph of nomenclature over common sense
  Dave Derrick (1998)

How has the role of fluvial geomorphology in river management changed over the last several decades?

Mega-trends in Process and Applied Fluvial Geomorphology stem from:-

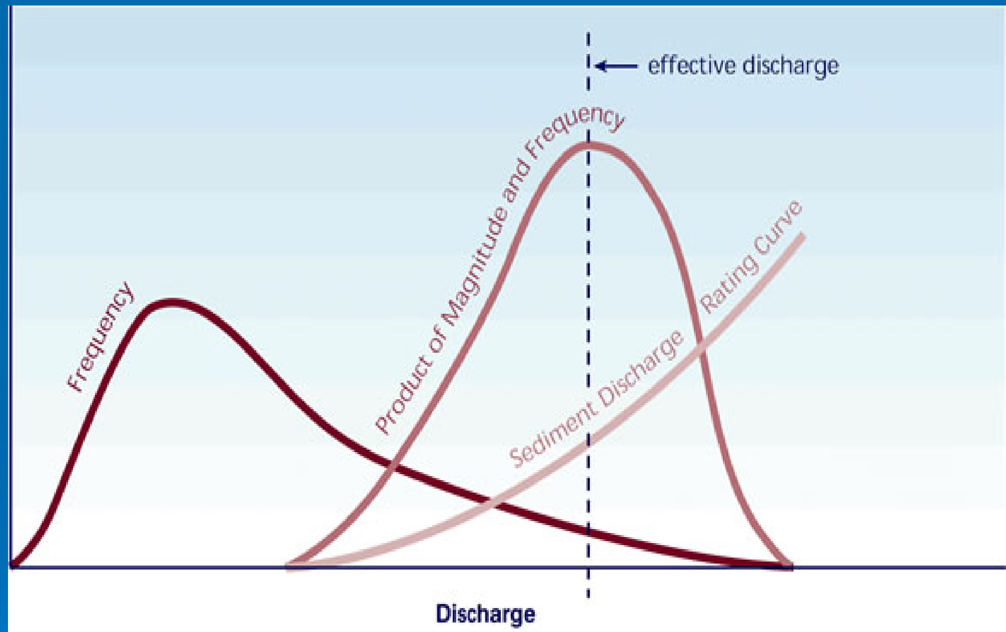
- The outcomes of original research
- Emergence of new paradigms
- Revolutions in data acquisition, models and computing power
- Distillation of experience - good and bad

1970s – Fluvial forms and processes

- Magnitude-frequency analysis:
  Defining the dominant (design) discharge

- Hydraulic geometry analyses:
  Stable channel design

- River channel patterns braided, meandering and straight:
  Planform classification, thresholds and prediction

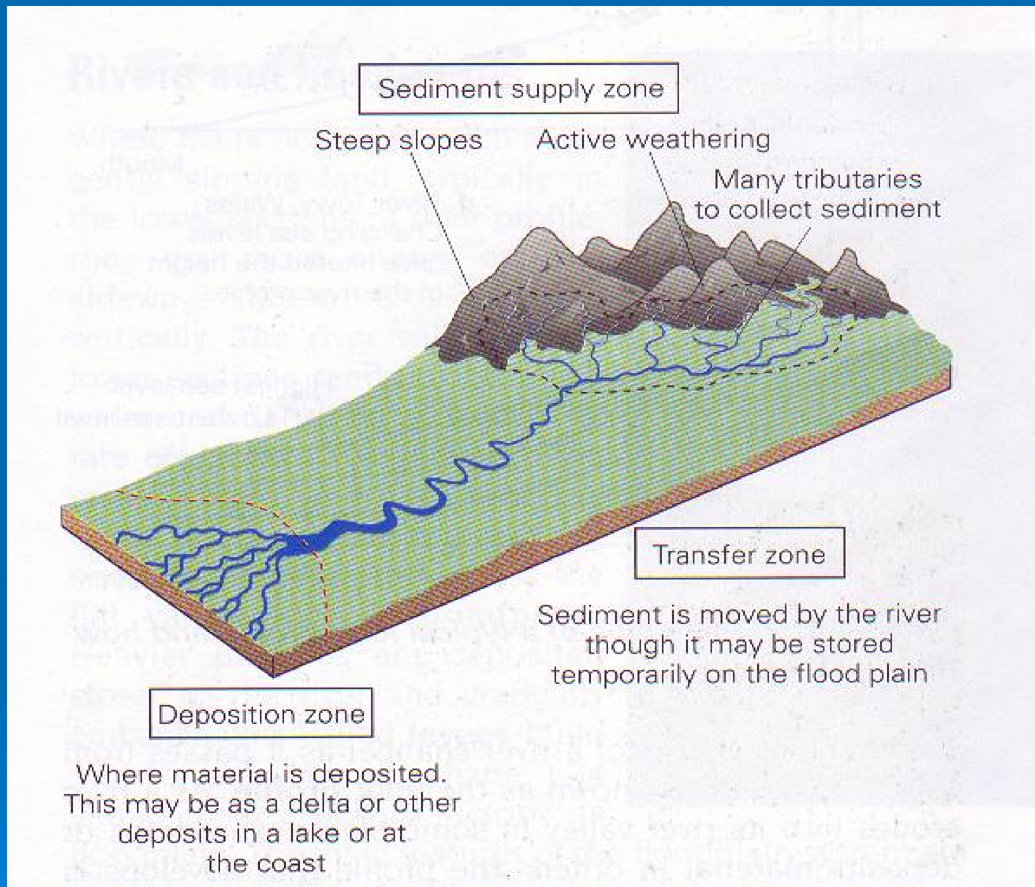


From Wolman and Miller, 1960.

Fig. 7.5 – Effective discharge determination from sediment rating and flow duration curves.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

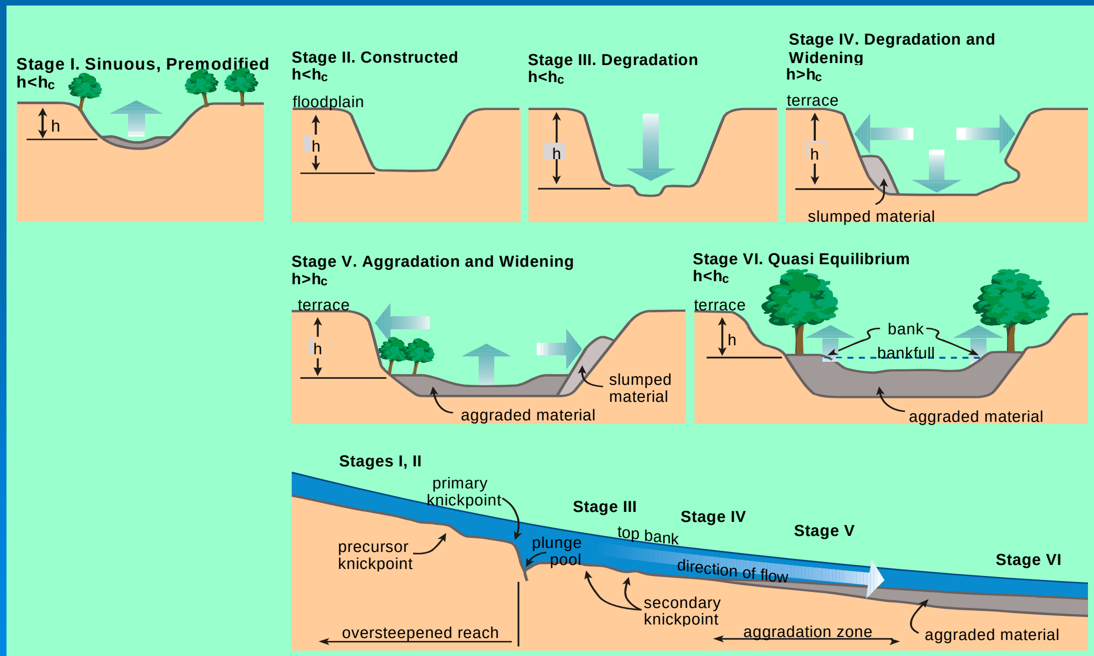
1980s – The Fluvial System

- Sediment Dynamics:
  Source, transfer and storage zones
- Process-response:
  Feedback loops and complex response
- Sensitivity and Effectiveness:
  Response to disturbance



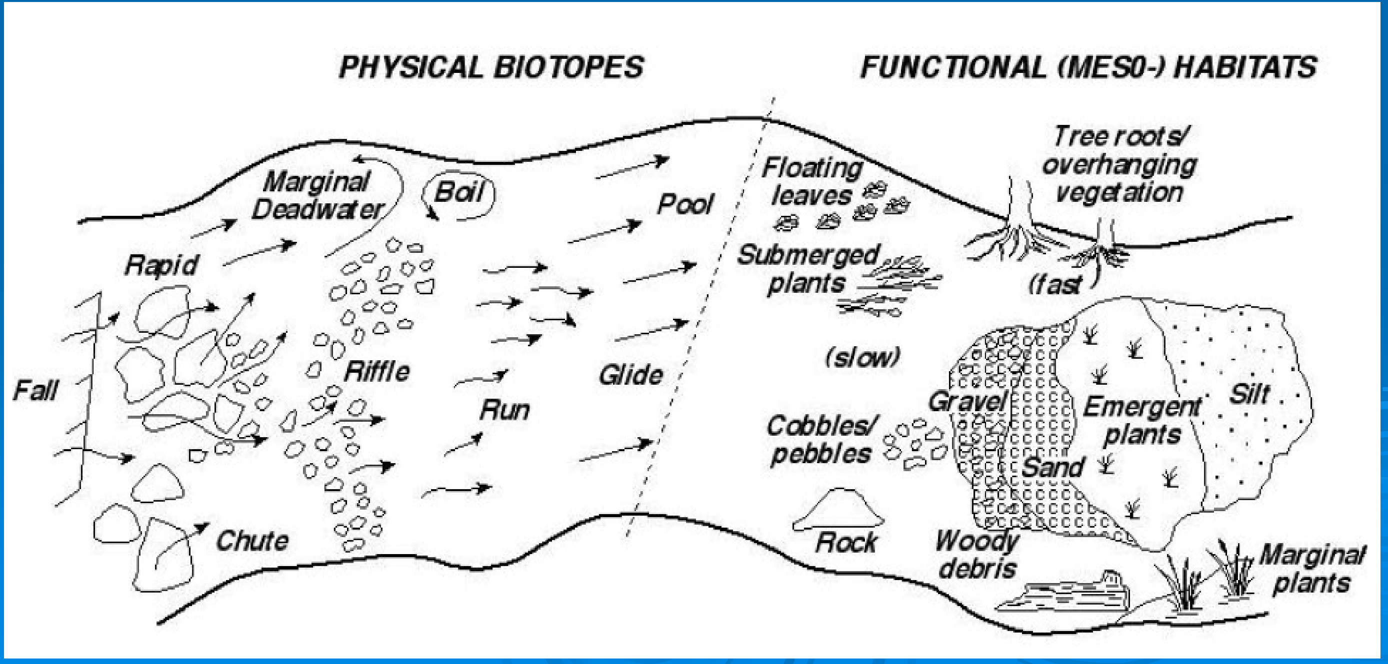
1990s – Classification and Conceptual Models

- Classification and natural channel design
- Characterising local variability
- Identifying common trends of adjustment in unstable channels – Channel Evolution Models



2000s – Modelling Morphology and Habitat interactions

- Sediment dynamics at the system scale: Regional sediment management
- Ecohydraulics: niches and patches
- Physical Biotopes – Functional Habitats



Current Trends – Science and Methods to support legislation

- Embracing Uncertainty
- Wood and debris dynamics
- Better Tools and Tool boxes for sediments, habitats and applied fluvial geomorphology
- Models:

  Linking multi-dimensional flow, hyporheic and geomorphological modelling to species

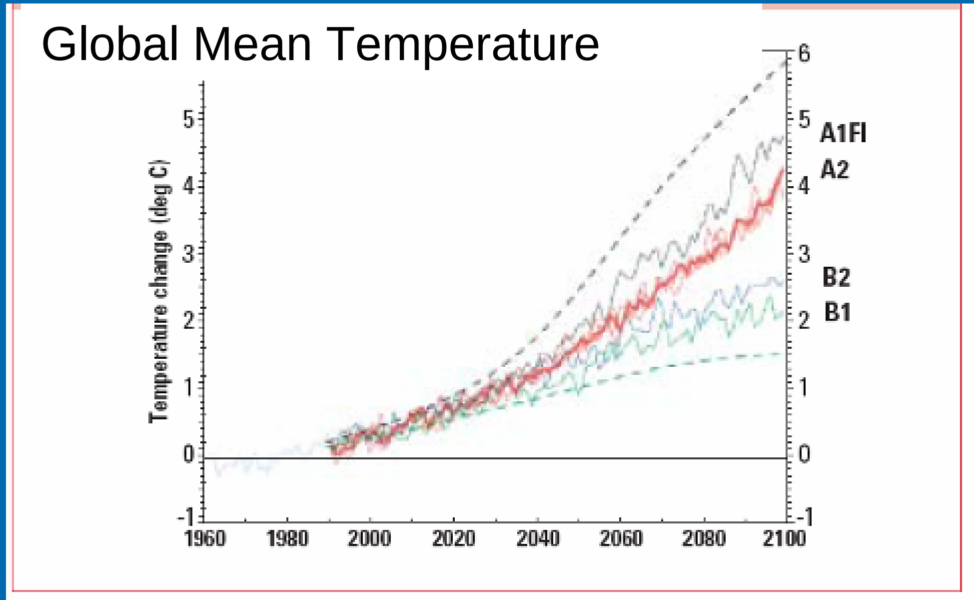
  Longterm sediment modelling

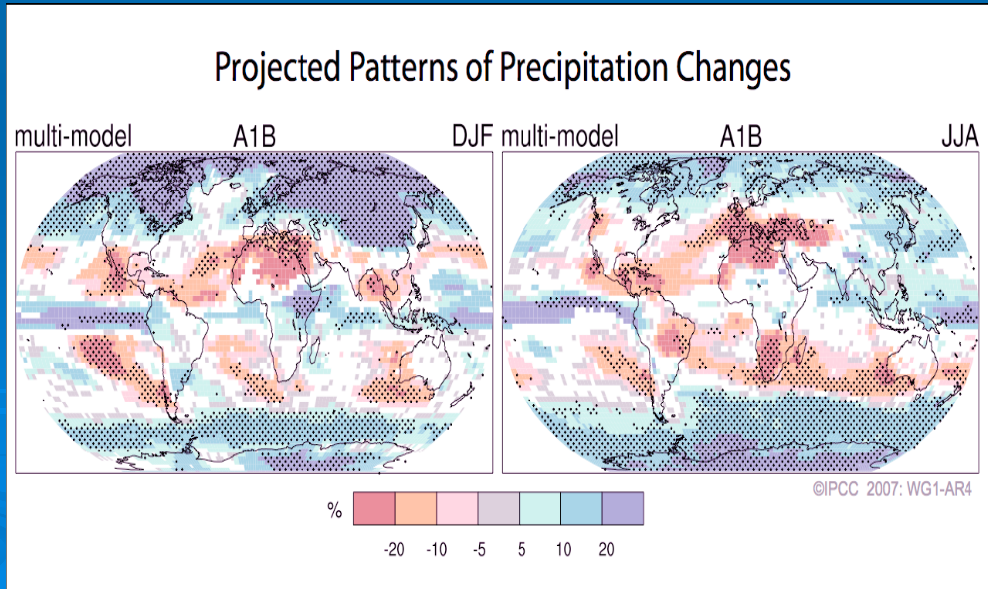
What direction should the role of geomorphology in water resources management take in the next 10-20 years?

- Geomorphology must provide leadership in accounting for river dynamics driven by changes in:
  - Climate
  - Land-use
  - Socio-economics
  - Societal values and Environmental Regulation

Climate change

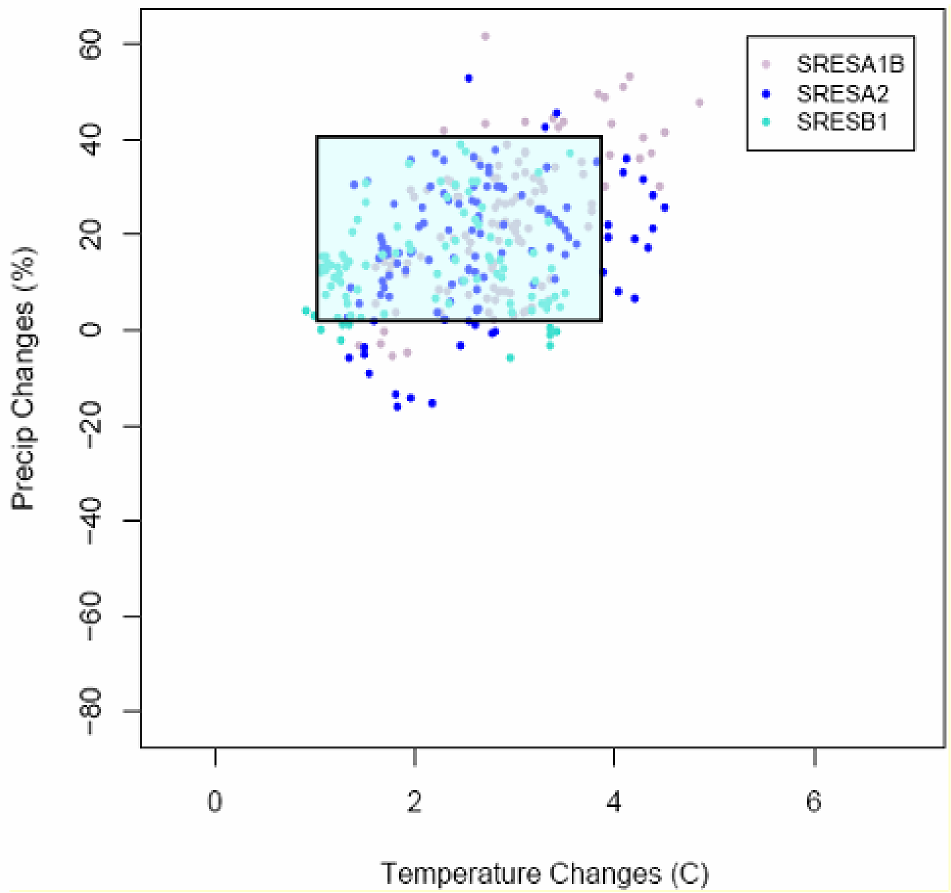
- The climate is changing globally and has been for some time.
- There is every reason to expect established trends to continue.
- It is now essential to account for climate change during the design life of any project intended to last more than ~30 years.



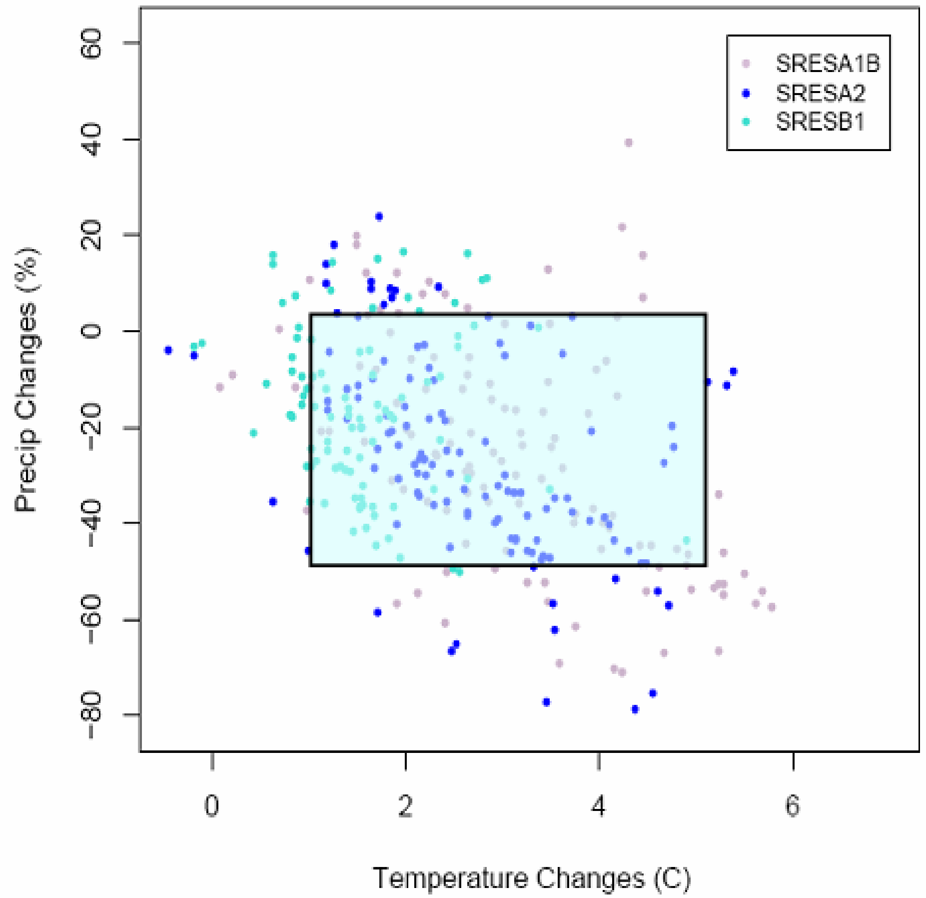


Climate change projections are highly uncertain – CEH, UK

a) Changes in winter precipitation and temperature



b) Changes in summer precipitation and temperature



Climate change at the coast

- Climate change effects include relative sea level rise.
- RSL rise may exceed a rivers ability to naturally adjust.
- Uncertainty concerning RSL is also high.

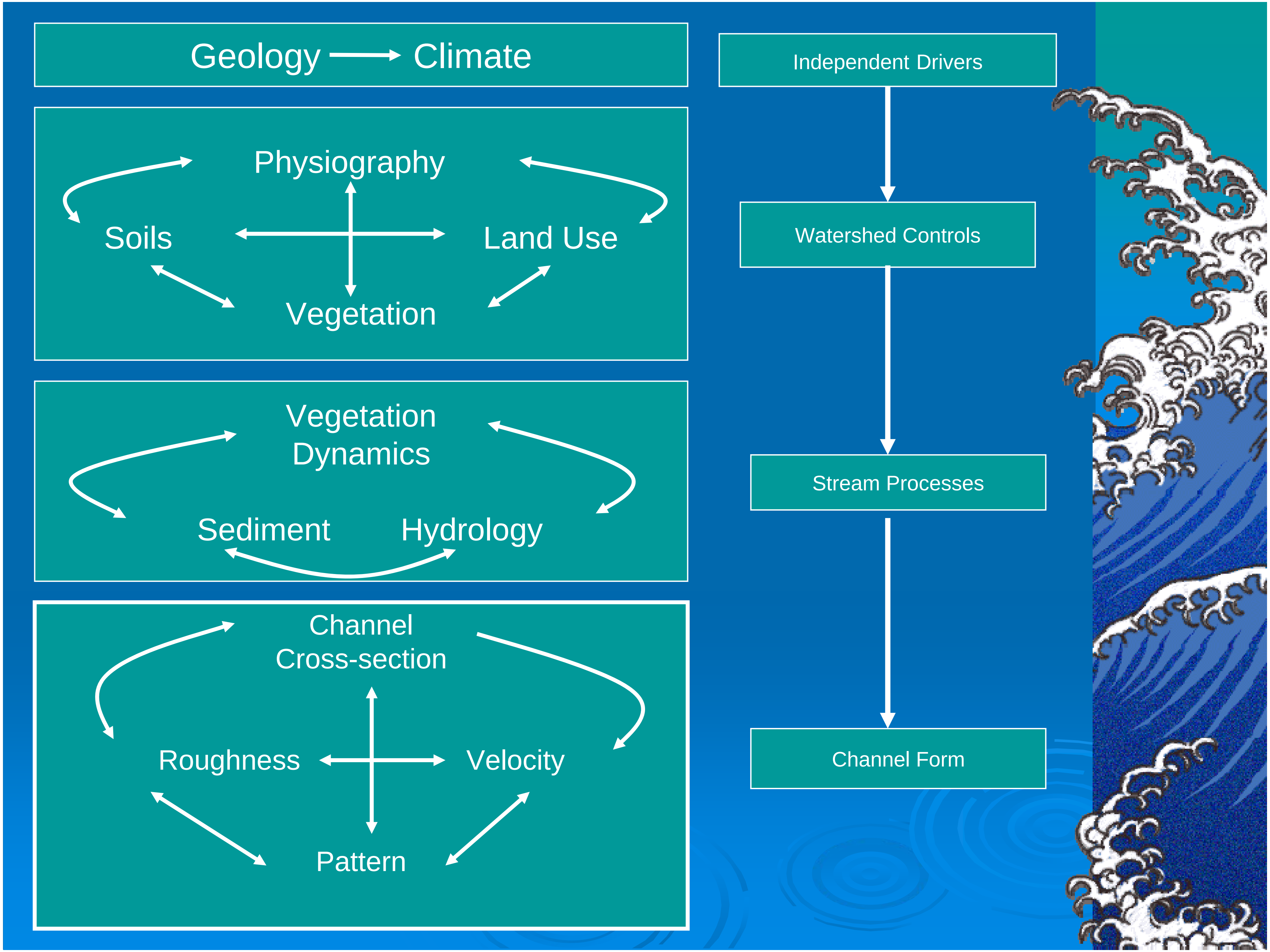
UKCIP02 (SRES) scenario	Global-mean sea-level rise scenarios (cm)							
	Third Assessment			Fourth Assessment				
	Low	Mean	High	Low	Mean	High	Ice sheet break-down	High +
Low emissions (B1)	9	29	48	17	29	41	50	91
Medium-low emissions (B2)	11	33	54	18	32	46	66	112
Medium-high emissions (A2)	13	36	59	19	36	52	84	136
High emissions (A1FI)	16	43	69	22	42	62	100	162

Comparison of global-mean scenarios from the IPCC Third Assessment Report and the IPCC Fourth Assessment Report for 1990 to the 2080s (from Meehl et al., 2007).

Which variables will be affected?

- Precipitation
  - Annual average and inter-annual variability
  - Seasonality
  - Event intensity and duration
  - Rain-snow partitioning
- Vegetation and land-use
- Evapotranspiration
- Rainfall-runoff relationships
- Base level (RSL and changing lake levels)

(Goudie, 2006)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Sediment
Hydrology
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Roughness
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Independent Drivers
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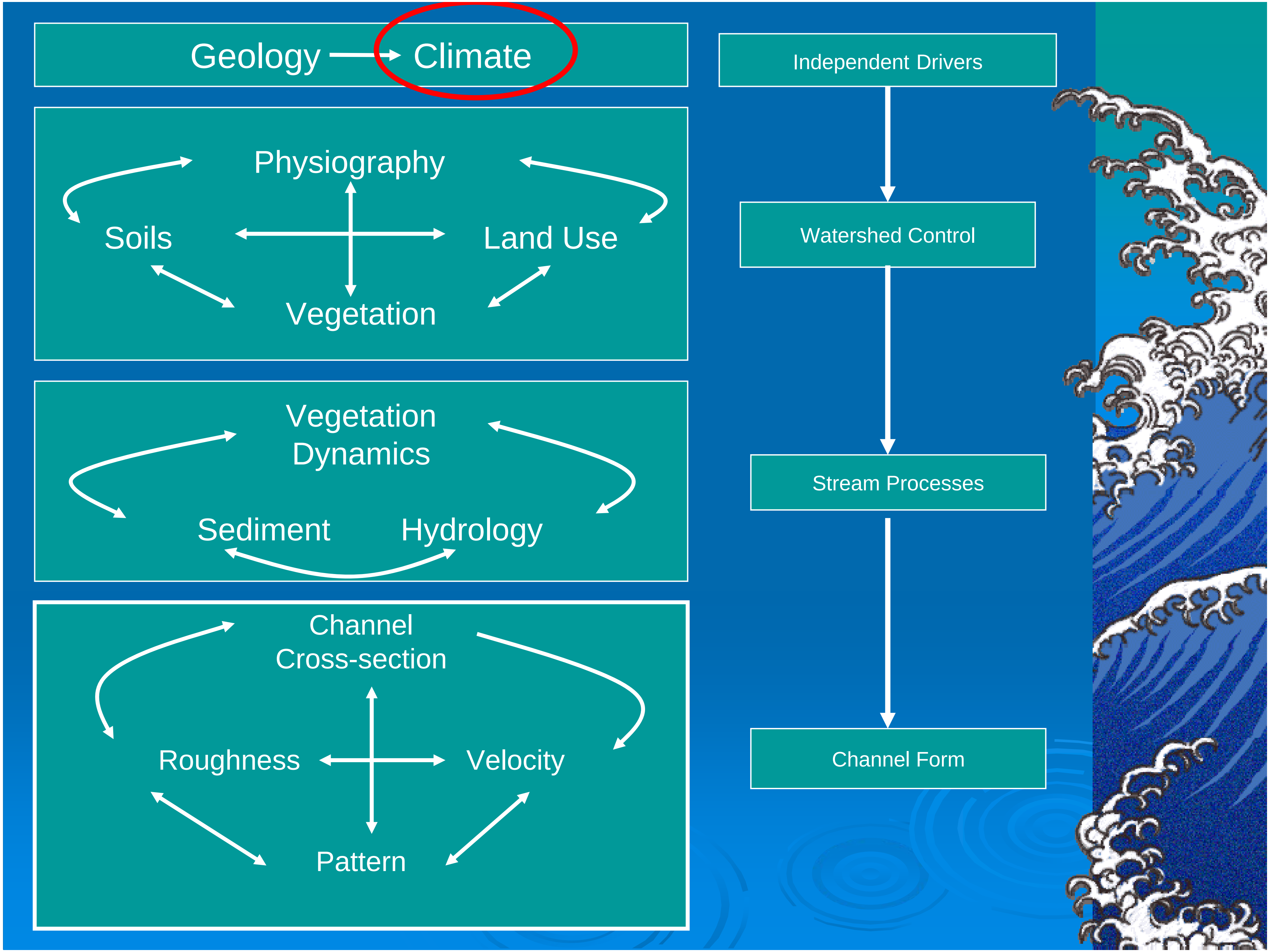
Stream Processes
Channel Form



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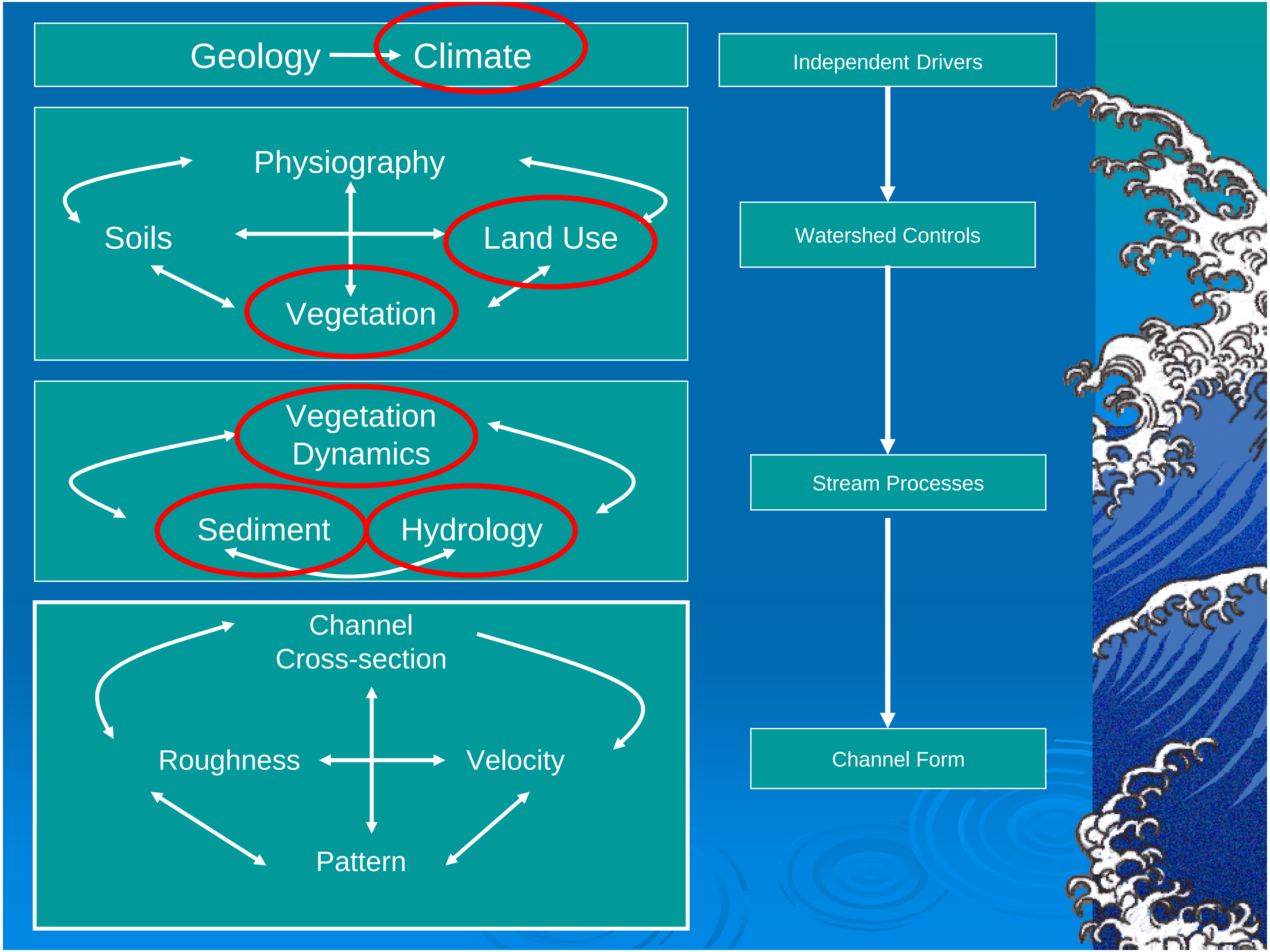
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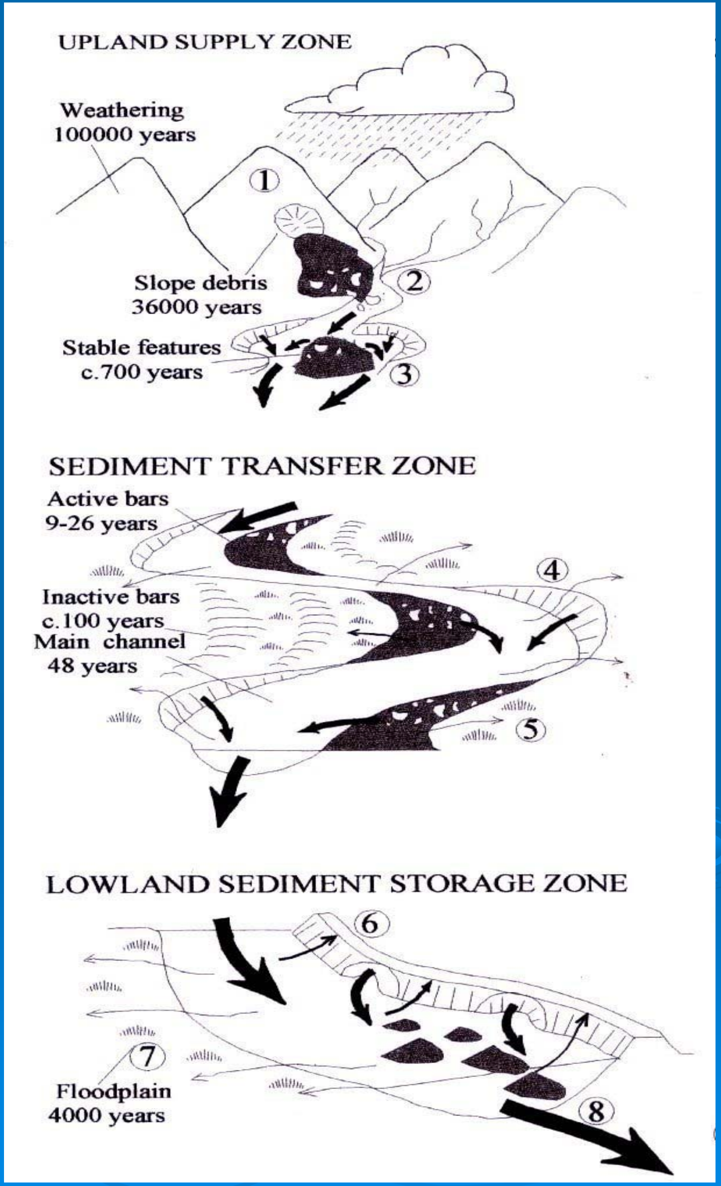
How will fluvial systems respond?

- Sediment supply: controlling variable is intense, short duration rainfall events (Reid *et al.*, 2007). Predictions suggest increased frequency of delivery events (Lane *et al.*, 2008).
- Sediment transfer: gravel is exchanged in middle reaches, accelerating lateral migration or aggradation (FRMRC, 2006).
- Sediment storage: fine sediment is deposited in lower reaches, accelerating channel and floodplain sedimentation.



What does all this mean for management and restoration?

- The future ‘do nothing’ or baseline condition is no longer static.
- It is unsafe to rely on past or present flow and sediment regimes as the basis for reference conditions.
- Reference reaches may not provide a usable template.
- ‘No-analogue’ communities and ecological surprises are to be expected (Williams and Jackson, 2007).
- The types and timings of future morphological responses to climate (and other) changes are not just uncertain, they are unknowable.

What does this require of the role of geomorphology?

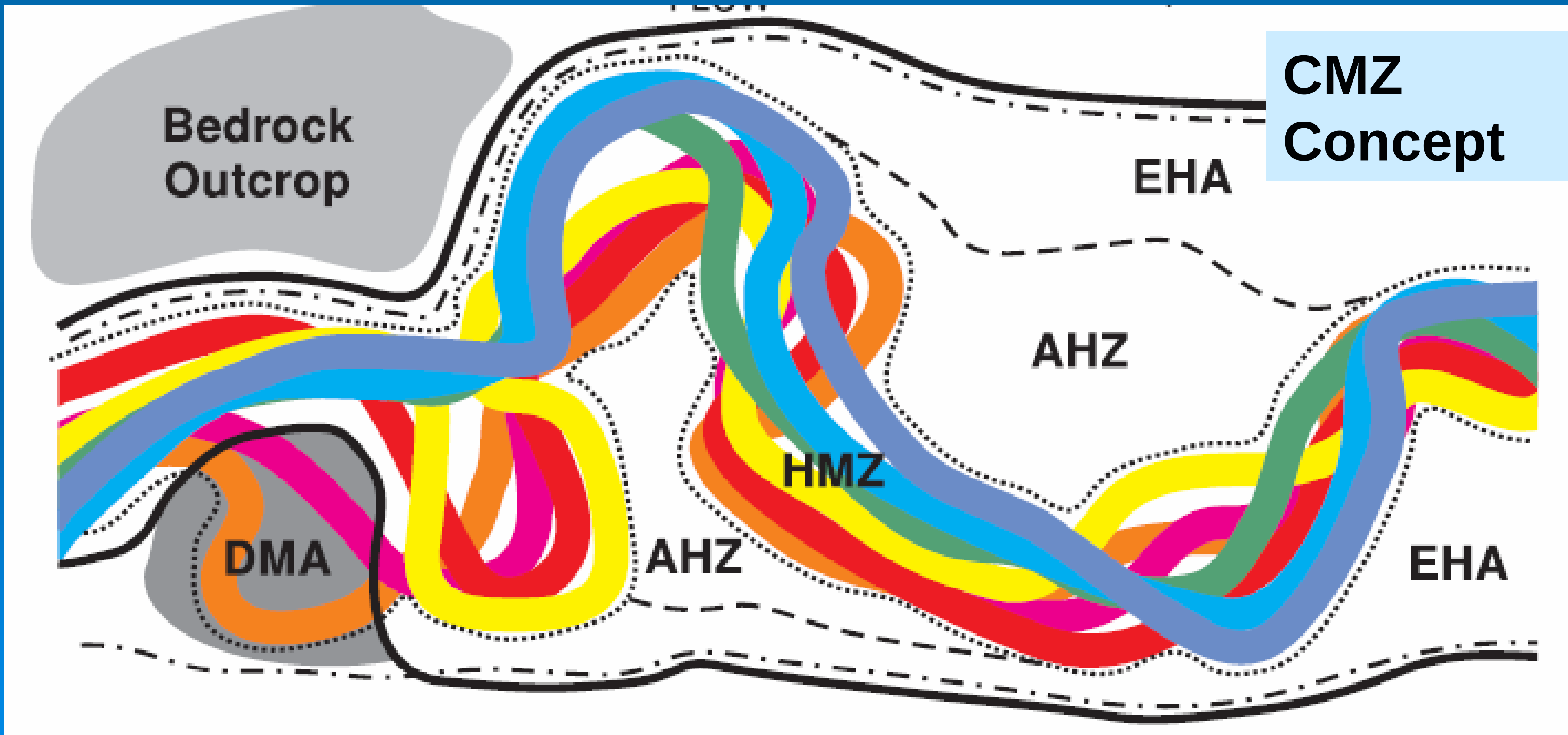
- Restored channels must have the capability to evolve in response to the actual sequence of future driving events - which can never be predicted deterministically.
- Uncertainties are best handled using future scenarios and ensemble models.
- In alternatives analysis, a risk-based approach is required.
- The ‘best’ scheme is one that is resilient to changing climate and robust - successful however the future unfolds.

Geomorphology in the next 10-20 years?
Four challenges

1. Explaining why we must remove as many artificial constraints as possible to allow rivers to respond to climate change through mutual adjustments to all dimensions of channel form.

Challenges – 2

2. Proving the case for making additional space for morphological adjustment to lower future risks to habitats, people and property.

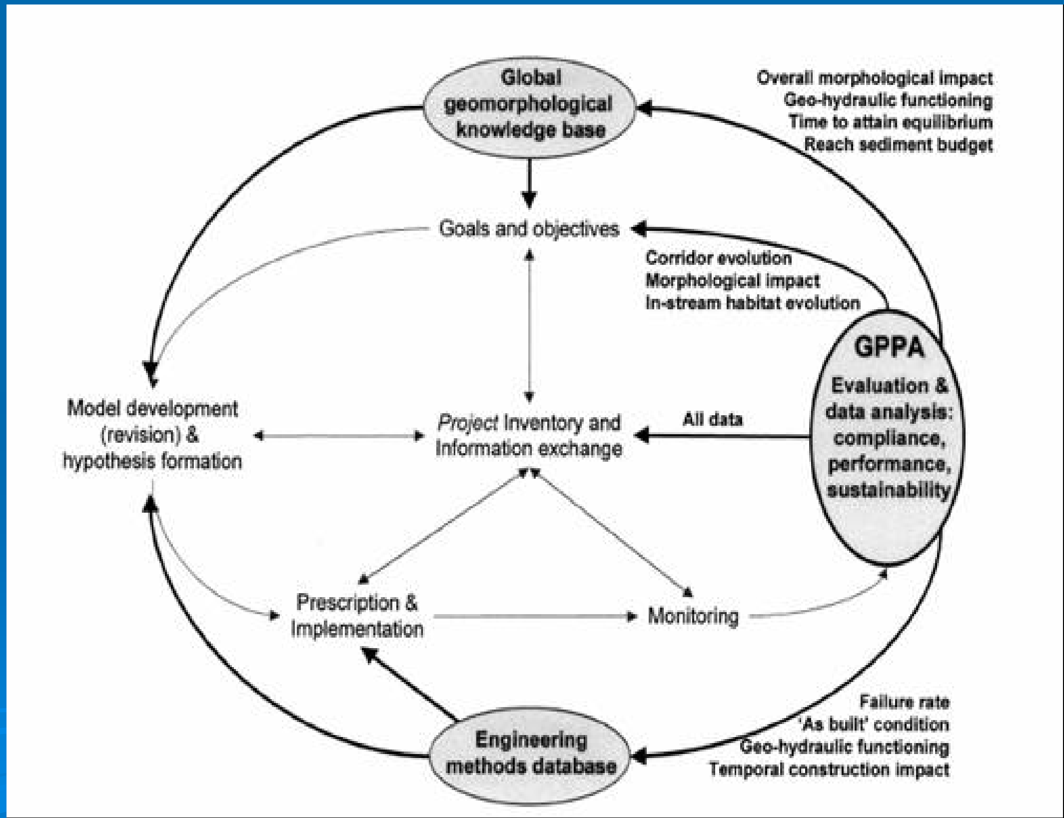


Challenge – 3

3. Informing redesign of remaining artificial constraints (culverts, bridges, weirs, grade controls, bank protection etc.) to allow for future changes in flow and sediment regimes. This includes 'designing for failure'.

Challenge - 4

4. Insisting of monitoring and geomorphic post project appraisal to support adaptive management of climate/land use change impacts as they occur.



(Downs & Kondolf, 2002, adapted from Haney & Power 1996)

Reference Conditions

Reference conditions can only be effective provided that they have a sound basis in science, the governance is properly arranged and stakeholders accept them as bring reasonable and valid. Hence the over-arching question:

In defining, applying, policing and sustaining reference conditions what is that:

- *Only River Scientists and Engineers can do?*
- *Only the Government and policy/law makers can do?*
- *Only Regulators can do?*
- *Only project proponents and designers can do?*
- *Only the Stakeholder Community (land owners, public and private utilities, river users etc.) can do?*

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