REFORM

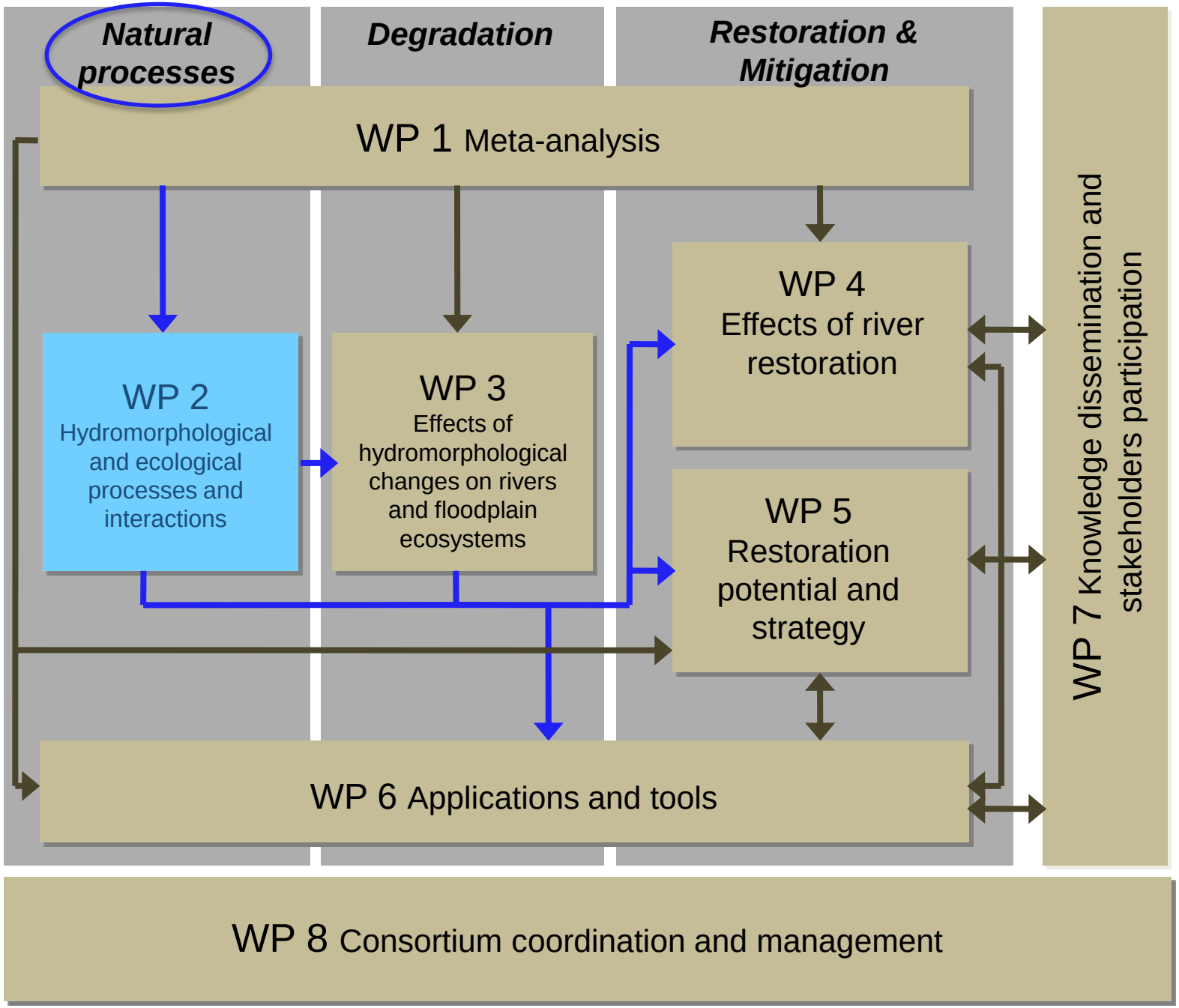
REstoring rivers FOR effective catchment Management

MULTI-SCALE PROCESS-BASED FRAMEWORK FOR RIVER CHARACTERISATION AND RESTORATION

Angela Gurnell

Queen Mary University of London

CONTEXT


Natural processes
Degradation
Restoration & Mitigation
WP 1 Meta-analysis
WP 2
Hydromorphological and ecological processes and interactions
WP 3
Effects of hydromorphological changes on rivers and floodplain ecosystems
WP 4
Effects of river restoration
WP 5
Restoration potential and strategy
WP 6 Applications and tools
WP 7 Knowledge dissemination and stakeholders participation
WP 8 Consortium coordination and management

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WP involves 13 Partners

Participant number	Short name	Country
1	Deltares	Netherlands
4	BOKU	Austria
5	Irstea	France
9	FVB.IGB	Germany
10	JRC	Belgium
12	NERC (CEH)	United Kingdom
13	QMUL	United Kingdom
15	SYKE	Finland
18	UNIFI	Italy
19	UPM	Spain
20	VU-IVM	Netherlands
21	WULS	Poland
25	ISPRA	Italy

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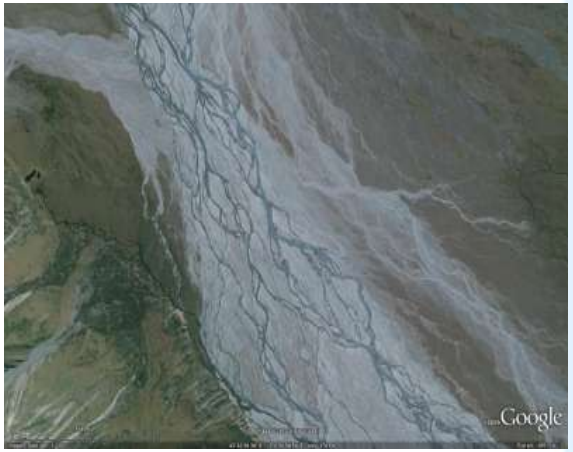
CONTEXT

COMPLEX MULTI-SCALE CONTROLS ON RIVER-FLOODPLAINS



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RATIONALE

Many current river assessment methods emphasise the reach scale.

The reach scale IS the key scale (such assessments provide a wealth of useful, information).

However, when reach scale surveys are the only data source for assessment they have several limitations. . . . . .

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RATIONALE

1. Rarely record information beyond channel and its margins
2. Give a snapshot of river characteristics (*forms* rather than *processes)*
3. Take limited account of the cascade of larger-scale factors and processes that influence hydromorphology and ecology.
4. Rarely take account of time lags between changes at one site / spatial scale and adjustments at another site / scale.
5. Often provide descriptions / counts of features, but little interpretation as indicators of reach functioning *now*, *in the past* or *in the future*.

HIERARCHICAL FRAMEWORK

The Hierarchical Framework:

1. A way of thinking about rivers
2. Adopts a multi-scale approach
3. Extremely flexible and open-ended

- Uses available data
- Can incorporate existing methodologies

4. Guides users on information required, how it can be collected – estimated – analysed.
5. Provides a basis for predicting how a reach might react to changes (e.g. removal of engineering modifications, reinstatement of sediment supply)

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HIERARCHICAL FRAMEWORK

REACH

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HIERARCHICAL FRAMEWORK

River Restoration?……

1. Which reach / reaches might benefit from some restoration?
2. What is its / their present condition?
3. What type of restoration actions might be appropriate and sustainable?

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HIERARCHICAL FRAMEWORK

River Restoration?……

1. Which reach / reaches might benefit from some restoration?
2. What is its / their present condition?
3. What type of restoration actions might be appropriate and sustainable?

Also consider……..

1. How are reach(es) affected by past / present interventions and processes.
2. ……at reach and larger spatial scales
3. …..in the context of future changes

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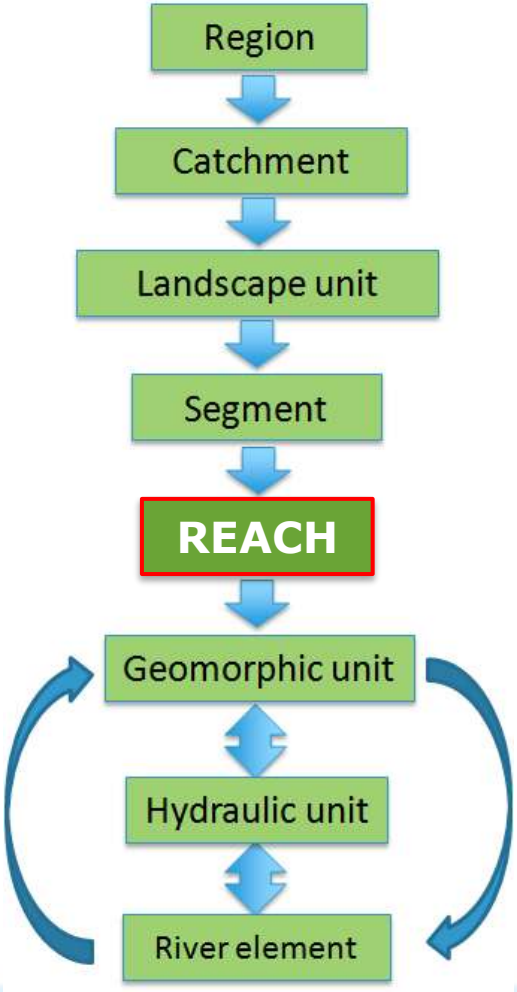
HIERARCHICAL FRAMEWORK



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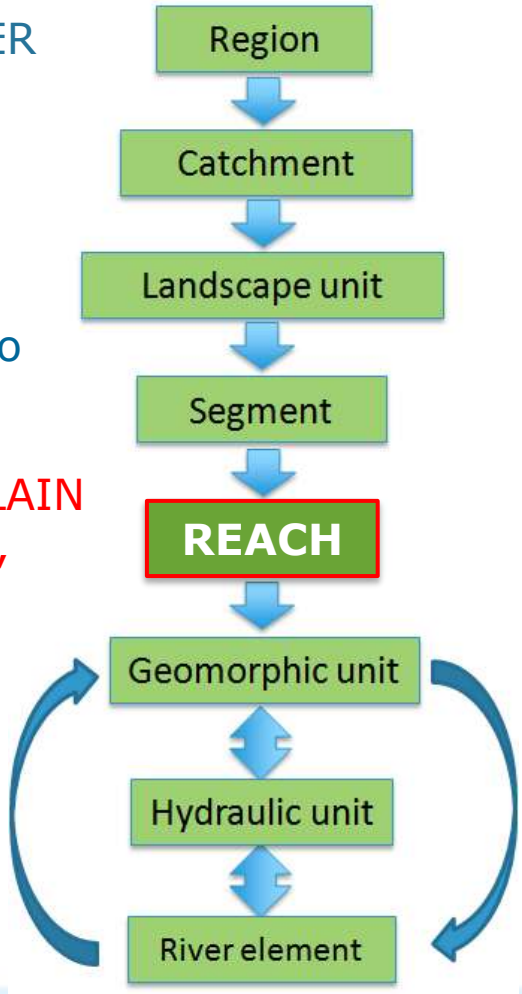
HIERARCHICAL FRAMEWORK

CONTROLS ON RIVER BEHAVIOUR (confinement; gradient; delivery of water, sediment, plant propagules, wood to river reaches)

RIVER AND FLOODPLAIN TYPE, DYNAMICS, SENSITIVITY

DYNAMIC SUITE OF RIVER AND FLOODPLAIN FEATURES (physical habitats)



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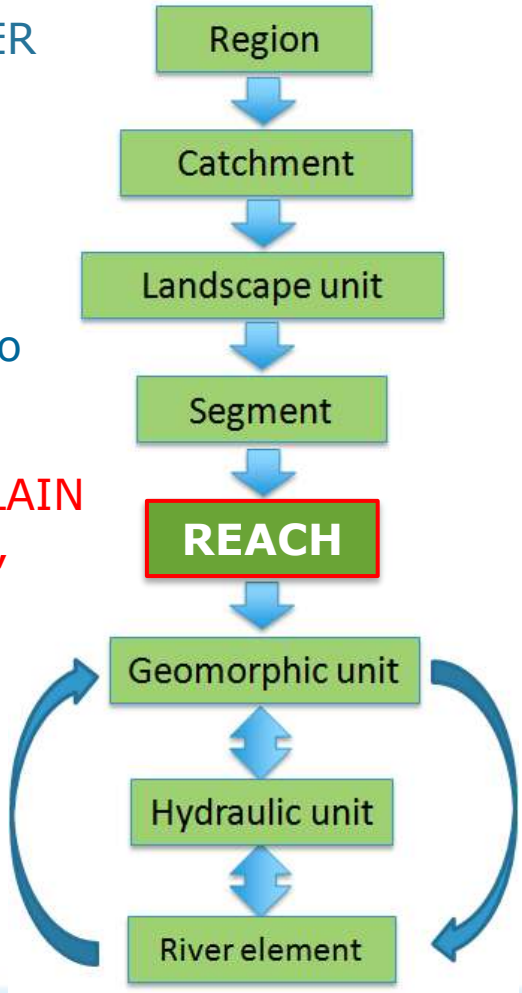
HIERARCHICAL FRAMEWORK

PRESENT

CONTROLS ON RIVER BEHAVIOUR (confinement; gradient; delivery of water, sediment, plant propagules, wood to river reaches)

RIVER AND FLOODPLAIN TYPE, DYNAMICS, SENSITIVITY

DYNAMIC SUITE OF RIVER AND FLOODPLAIN FEATURES (physical habitats)



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HIERARCHICAL FRAMEWORK

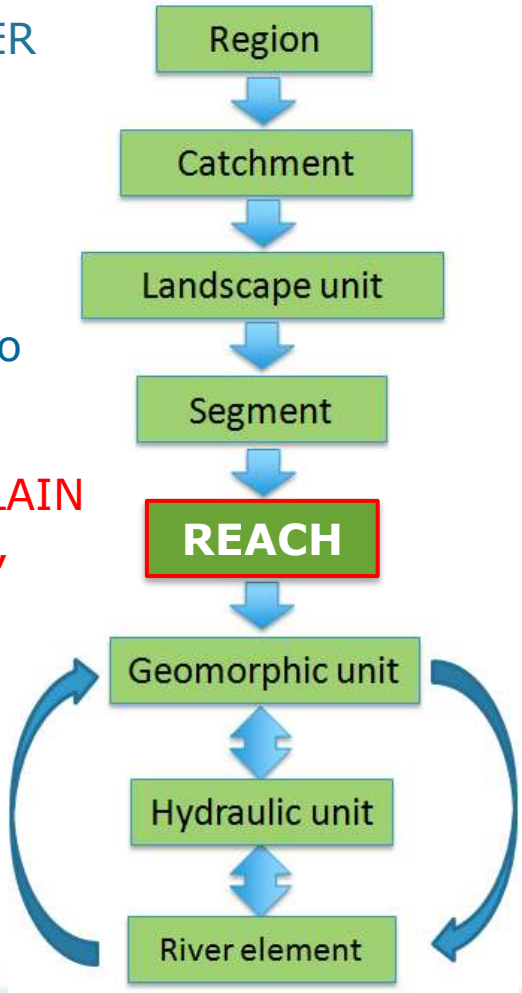
PAST

PRESENT

CONTROLS ON RIVER BEHAVIOUR (confinement; gradient; delivery of water, sediment, plant propagules, wood to river reaches)

RIVER AND FLOODPLAIN TYPE, DYNAMICS, SENSITIVITY

DYNAMIC SUITE OF RIVER AND FLOODPLAIN FEATURES (physical habitats)



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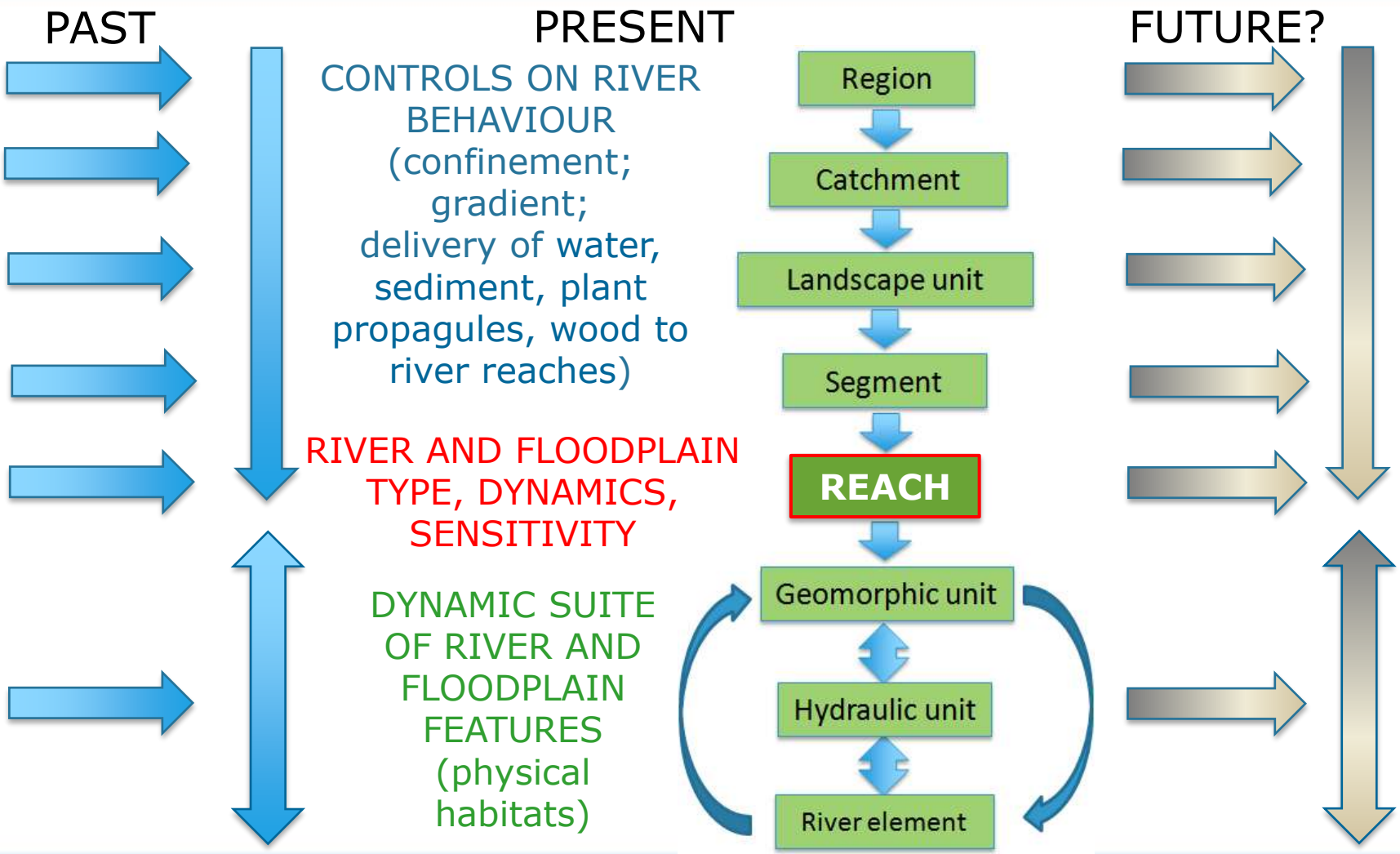
HIERARCHICAL FRAMEWORK



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STAGES OF ANALYSIS

DELINIATION

1. Deliniate spatial units from biogeographical region to reach

CHARACTERISATION → INDICATORS

1. Current character of the spatial units
2. Past character of the spatial units
3. River and floodplain types

CONDITION AND TRAJECTORIES OF CHANGE

1. Current condition of reach(es)
2. Inventory of changes
3. Sensitivity of reach(es) to change
4. Future scenarios and trajectories of change

INDICATORS

Spatial Unit	Key Process	Properties Assessed by Indicators
CATCHMENT	*Water Yield*	Catchment area Runoff ratio (coefficient) Geology Land cover
LANDSCAPE UNIT	*Water Production*	Rapid runoff production (low infiltration areas, potential saturated areas) Delayed runoff production (high infiltration areas, deep drainage areas)
	Sediment production	Fine sediment production Coarse sediment production
SEGMENT	*Water flow*	River flow regime
	Sediment flow	Sediment supplied to the channel Sediment transport and storage
	River form adjustments	Valley controls on channel dynamics Riparian corridor features
	Wood production	Potential wood delivery
REACH	*Flooding*	Flood area
	Channel self-maintenance / reshaping	Flow energy Sediment size **Channel dimensions, type and features**
	Channel Change / Adjustments	Lateral migration, planform change Narrowing / widening Bed Incision / aggradation Vegetation encroachment Constraints on channel adjustment
	Vegetation succession	Aquatic vegetation extent, structure Riparian vegetation extent, structure, age
	Wood delivery	Large wood and organic debris

CHANNEL (& FLOODPLAIN) TYPOLOGY

BED MATERIAL CALIBRE **(dominant type in bold)**	PLANFORM							
	Braided	Island Braided	Anabranching (high energy)	Wandering	Pseudo-meandering (sinuous with alternate bars)	Sinuous - Straight	Meandering	Anabranching (low energy)
	No exposed bed material							
Entirely artificial bed						0		
	Bedrock and Colluvial Channels							
Bedrock						1		
Coarse - Mixed						2		
Mixed						3		
	Alluvial (confined single-thread)							
Boulder - Cobble						4 (Cascade)		
Boulder - Cobble						5 (Step-pool)		
Boulder - **Cobble** – Gravel						6 (Plane Bed)		
Cobble - **Gravel**						7 (Riffle-pool)		
	Alluvial (partly-confined / unconfined single thread; confined / partly-confined / unconfined transitional / multi-thread)							
Cobble - **Gravel** – Sand	8	9	10	11	12	13	14	
Fine Gravel – **Sand**	15				16	17	18	19
Fine Sand - **Silt** – Clay						20	21	22

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EXAMPLE: THE RIVER FROME, UK

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EXAMPLE: THE RIVER FROME, UK

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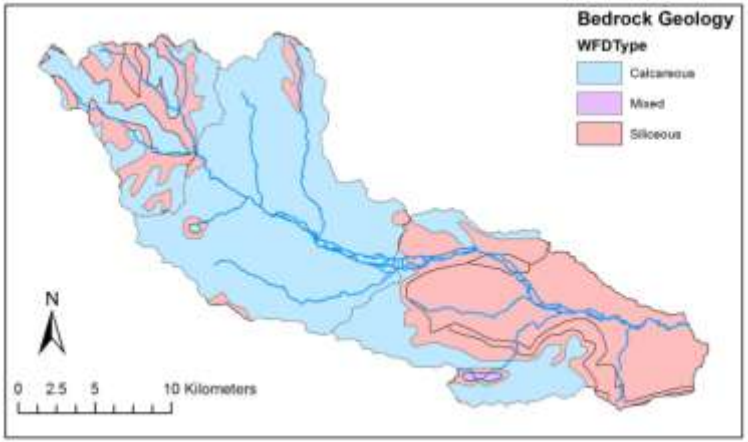
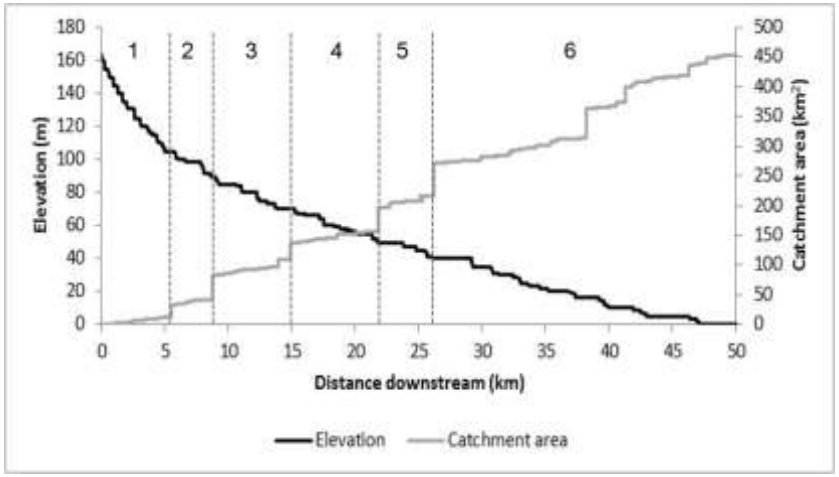
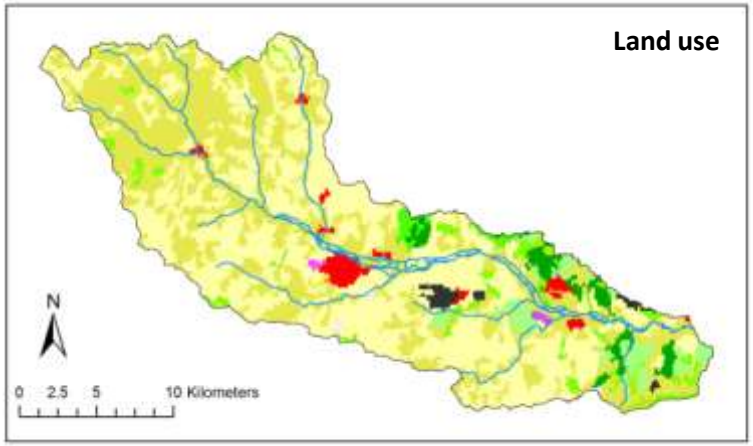
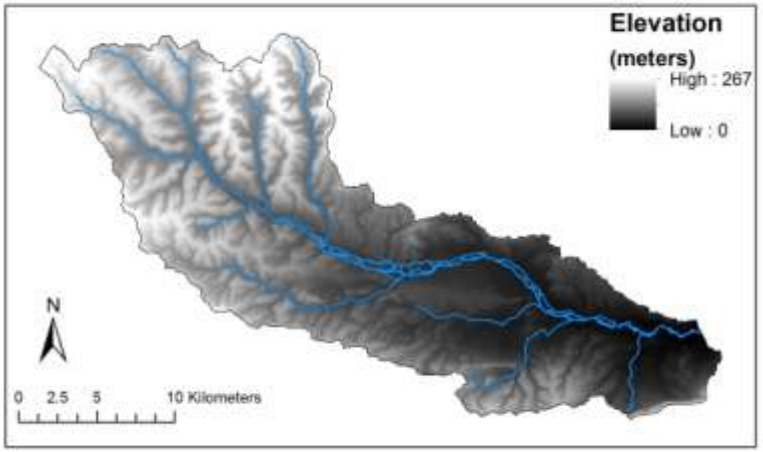
DELINEATION









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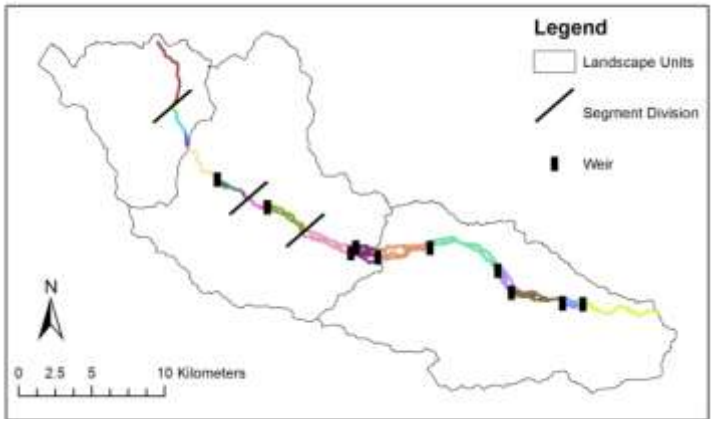
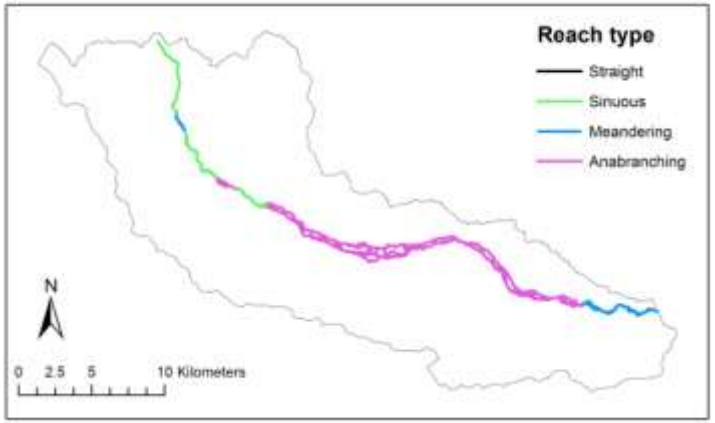
EXAMPLE: THE RIVER FROME, UK

DELINEATION

Land-scape Unit	Seg-ment	Reach	Confinement	Channel Threads	Planform	Down-stream Structure
1	1	1	Unconfined	Single	Sinuous	
	2	2	Unconfined	Single	Sinuous	
		3	Unconfined	Single	Meandering	
		4	Unconfined	Single	Sinuous	
2	3	5	Unconfined	Single	Sinuous	Weir
		6	Unconfined	Multiple	Anabranching	
		7	Unconfined	Single	Sinuous	
	4	8	Unconfined	Single	Sinuous	Weir
		9	Unconfined	Multiple	Anabranching	
	5	10	Unconfined	Multiple	Anabranching	Weir
		11	Unconfined	Multiple	Anabranching	Weir
3	6	12	Unconfined	Multiple	Anabranching	Weir
		13	Unconfined	Multiple	Anabranching	Weir
		14	Unconfined	Multiple	Anabranching	Weir
		15	Unconfined	Multiple	Anabranching	Weir
		16	Unconfined	Multiple	Anabranching	Weir
		17	Unconfined	Single	Meandering	





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EXAMPLE: THE RIVER FROME, UK

CURRENT REACH CONDITION

Longitudinal continuity
Lateral continuity
Adjustment potential

Spatial extent
Age structure
Patchiness

Abundance
Supply

Reach No.	River Type	HYDROMORPHOLOGY			RIPARIAN VEGETATION		WOOD BUDGET	
		Function	Artificiality	Adjustment	Function	Artificiality	Function	Artificiality
1	17	Intermediate	Artificial	None	Poor		Functioning	
2	17	Intermediate	Low Artificiality	Widening & aggrading	Poor	Artificial	Functioning	
3	18	Intermediate	Some artificial elements	Aggrading	Partial		Functioning	
4	17	Good	Artificial	Aggrading	Partial		Partial	
5	17	Good	Artificial	Narrowing	Partial	Artificial	Poor	V. degraded
6	19	Good	Artificial	Narrowing	Poor		Partial	
7	17	Good	Artificial	Narrowing	Poor	Artificial	Poor	V. degraded
8	17	Intermediate	Artificial	Narrowing & aggrading	Partial	Artificial	Poor	V. degraded
9	19	Intermediate	Artificial	Narrowing & aggrading	Partial	Artificial	Poor	V. degraded
10	19	Intermediate	Artificial	Narrowing & aggrading	Partial	Artificial	Poor	V. degraded
11	19	Intermediate	Artificial	None?	Poor	Artificial	Poor	V. degraded
12	19	Intermediate	Artificial	Narrowing	Partial	Artificial	Poor	V. degraded
13	19	Good	Artificial	Narrowing & aggrading	Poor	Artificial	Poor	V. degraded
14	19	Intermediate	Artificial	Widening & aggrading	Partial	Artificial	Poor	V. degraded
15	19	Intermediate	Artificial	None?	Poor	Artificial	Poor	V. degraded
16	19	Good	Artificial	Narrowing & aggrading	Partial	Artificial	Poor	V. degraded
17	18	Intermediate	Artificial	Aggrading	Partial	Artificial	Poor	V. degraded

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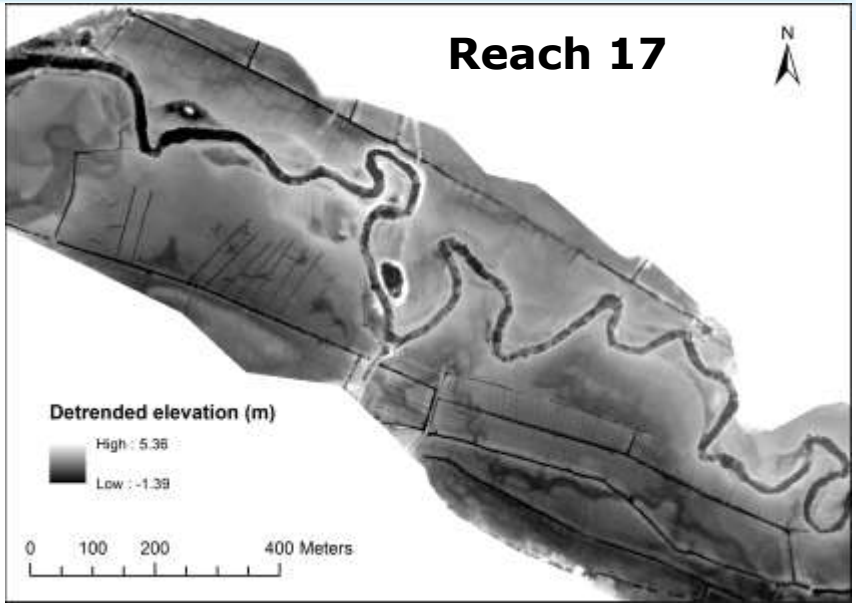
EXAMPLE: THE RIVER FROME, UK

CURRENT REACH CONDITION

Longitudinal continuity
Lateral continuity
Adjustment potential

Reach No.	River Type	HYDROMORPHOLOGY Function	Artificiality	Adjustment
1	17	Intermediate	Artificial	None
2	17	Intermediate	Low Artificiality	Widening & aggrading
3	18	Intermediate	Some artificial elements	Aggrading
4	17	Good	Artificial	Aggrading
5	17	Good	Artificial	Narrowing
6	19	Good	Artificial	Narrowing
7	17	Good	Artificial	Narrowing
8	17	Intermediate	Artificial	Narrowing & aggrading
9	19	Intermediate	Artificial	Narrowing & aggrading
10	19	Intermediate	Artificial	Narrowing & aggrading
11	19	Intermediate	Artificial	None?
12	19	Intermediate	Artificial	Narrowing
13	19	Good	Artificial	Narrowing & aggrading
14	19	Intermediate	Artificial	Widening & aggrading
15	19	Intermediate	Artificial	None?
16	19	Good	Artificial	Narrowing & aggrading
17	18	Intermediate	Artificial	Aggrading



River Type?
Function: channel and floodplain features?
Artificiality: bank/bed reinforcement, structures impeding longitudinal and lateral hydrological continuity?
Adjustment: features indicating channel widening, narrowing, incision, aggradation?

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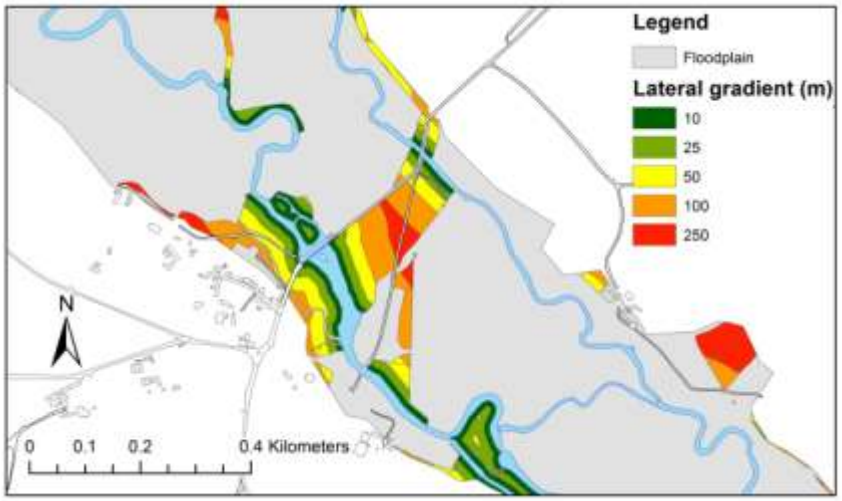
EXAMPLE: THE RIVER FROME, UK



Riparian Vegetation
Function: Balanced age structure, patchy, lateral gradient in structure?
Artificiality: Unbalanced (mature) age structure, uniform, low proportion of riparian corridor under riparian vegetation?
Wood budget
Function: Presence of wood in channel, eroding wooded river banks?
Artificiality: Lack of wood in channel, features indicating bank erosion, lack of trees on banks?

Spatial extent
Age structure
Patchiness

Abundance
Supply

RIPARIAN VEGETATION		WOOD BUDGET	
Function	**Artificiality**	**Function**	**Artificiality**
Poor		Functioning	
Poor	Artificial	Functioning	
Partial		Functioning	
Partial		Partial	
Partial	Artificial	Poor	V. degraded
Poor		Partial	
Poor	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded
Poor	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded
Poor	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded
Poor	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded
Partial	Artificial	Poor	V. degraded

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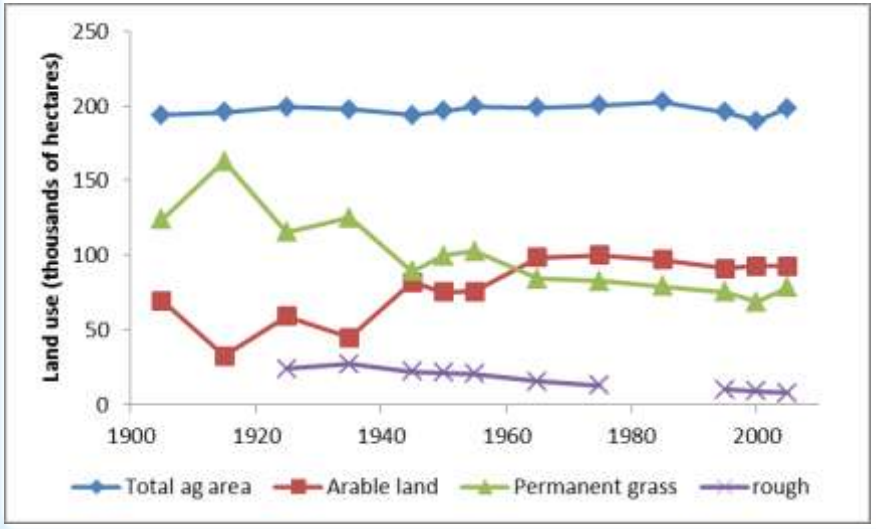
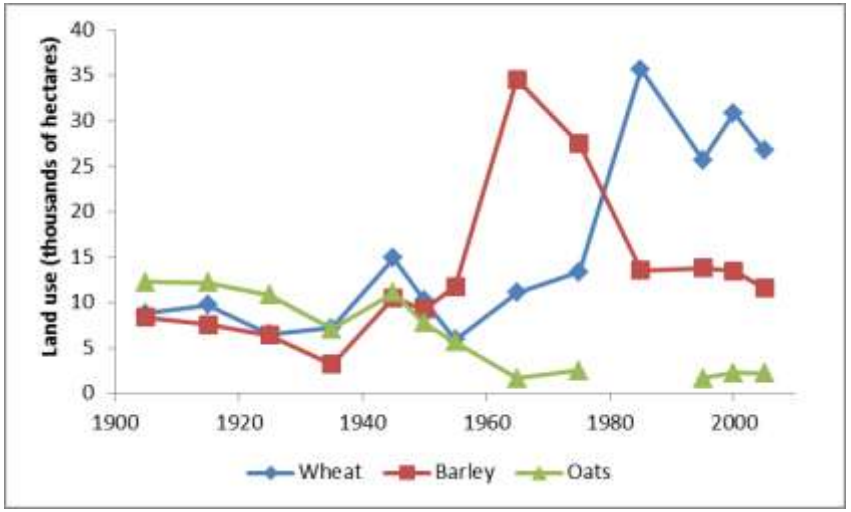
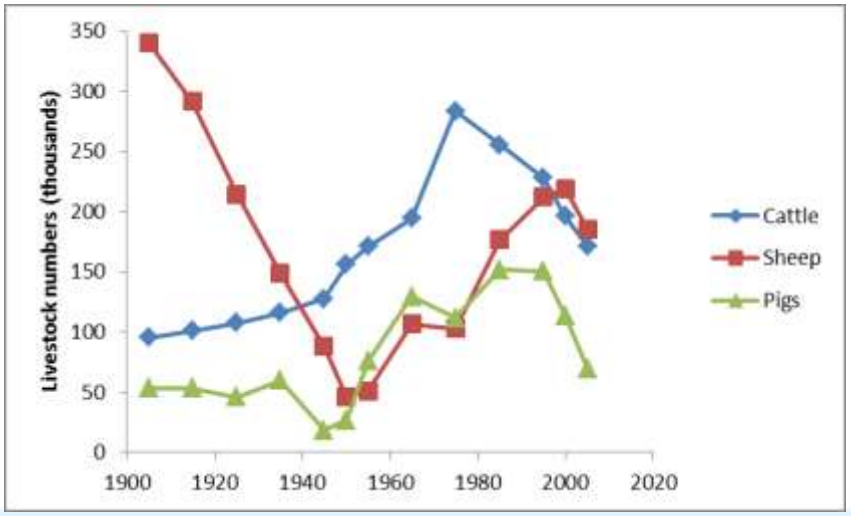
EXAMPLE: THE RIVER FROME, UK

INVENTORY OF CHANGES: CATCHMENT – LANDSCAPE UNIT

Permeable catchment
Subdued topography
Mainly agricultural – trends?
- More arable, Less pasture
- More wheat and barley, Less oats
- Increased yields
- More pigs and cows, less sheep







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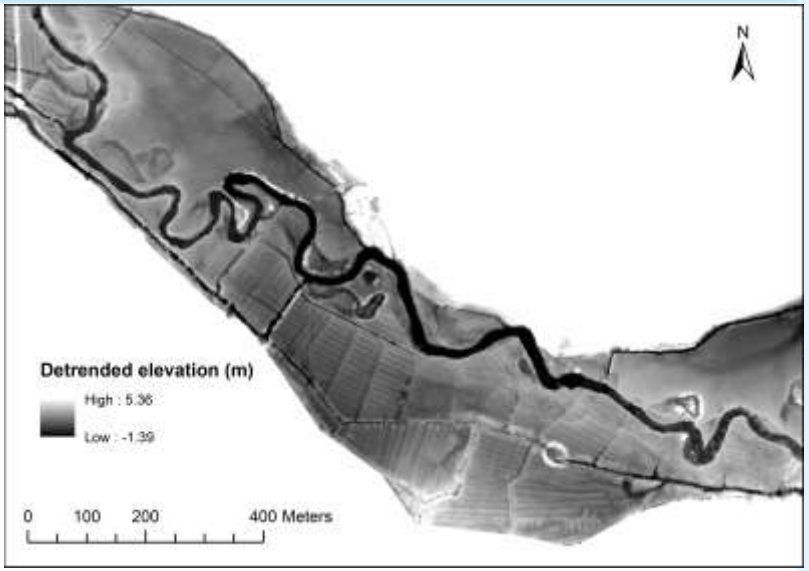
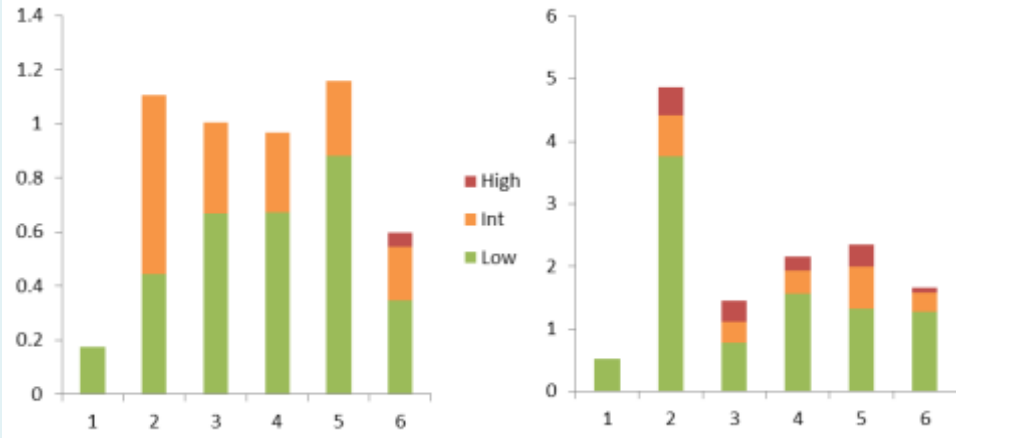
EXAMPLE: THE RIVER FROME, UK

INVENTORY OF CHANGES: SEGMENT

Changes over centuries:
- river corridor drainage
- weirs
- water meadows

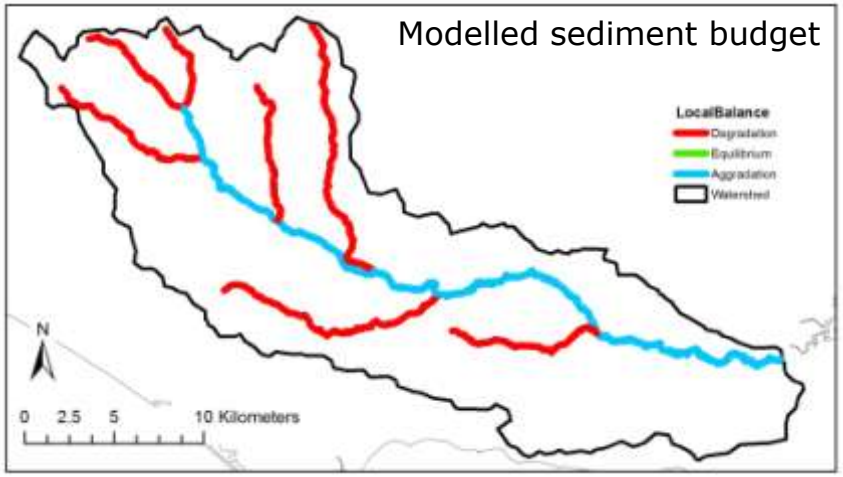
Changes over decades:
- Discharge regime unchanged
- Fine sediment delivery increased
- Positive fine sediment budget in main river





Blocking structures/km river

Spanning structures/km river



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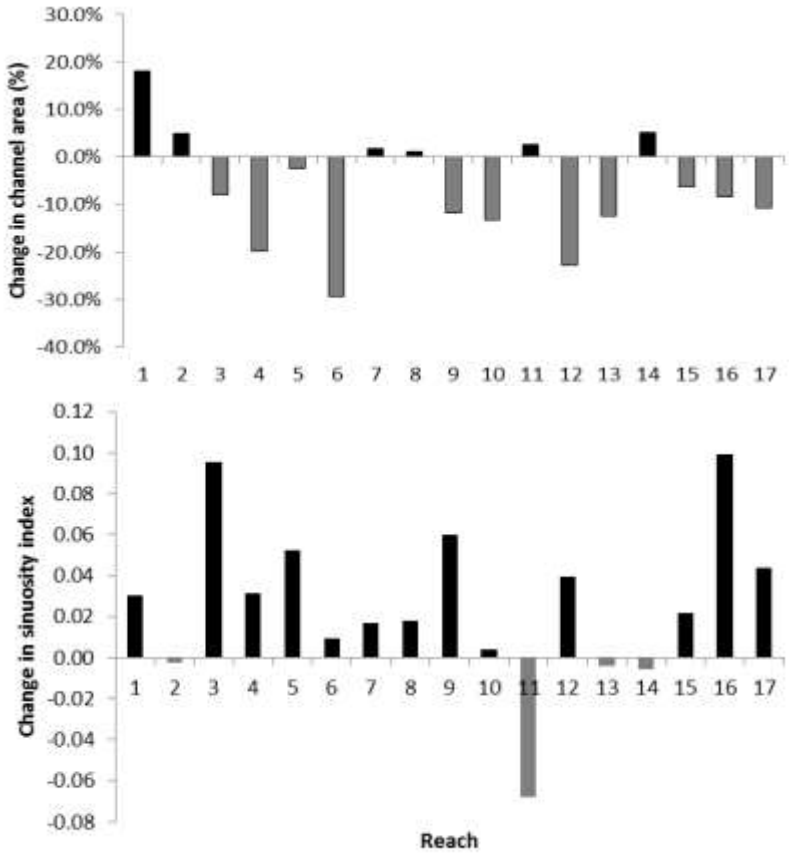
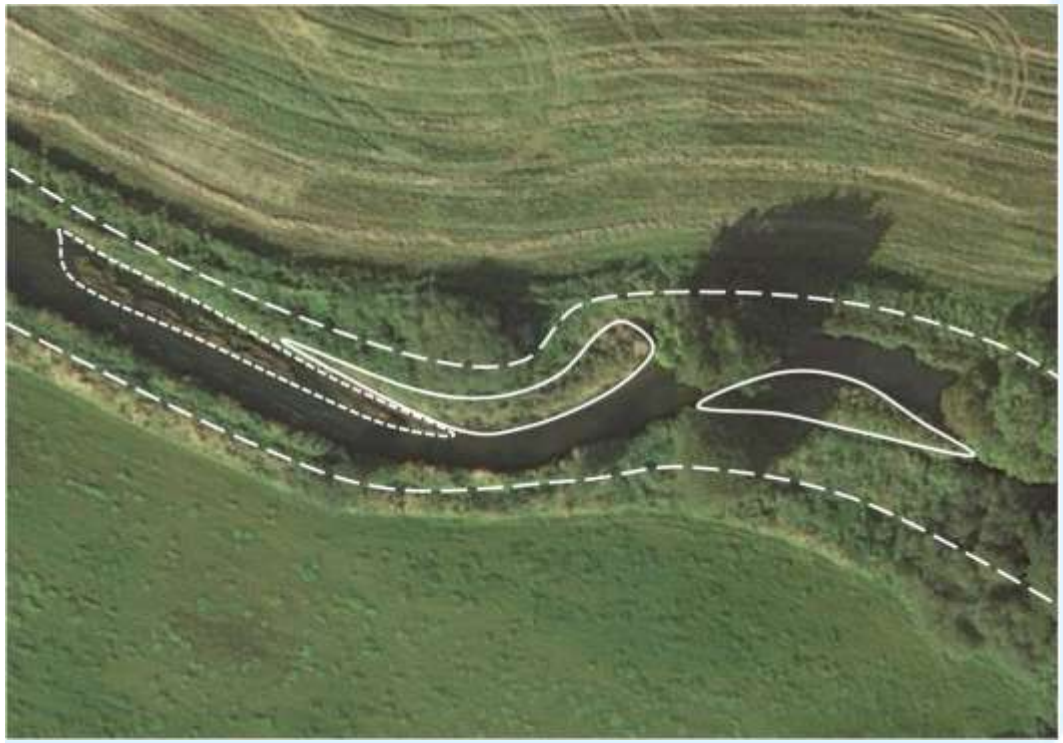
EXAMPLE: THE RIVER FROME, UK

INVENTORY OF CHANGES: REACH

1889-2103: decrease in channel area; increase in sinuosity

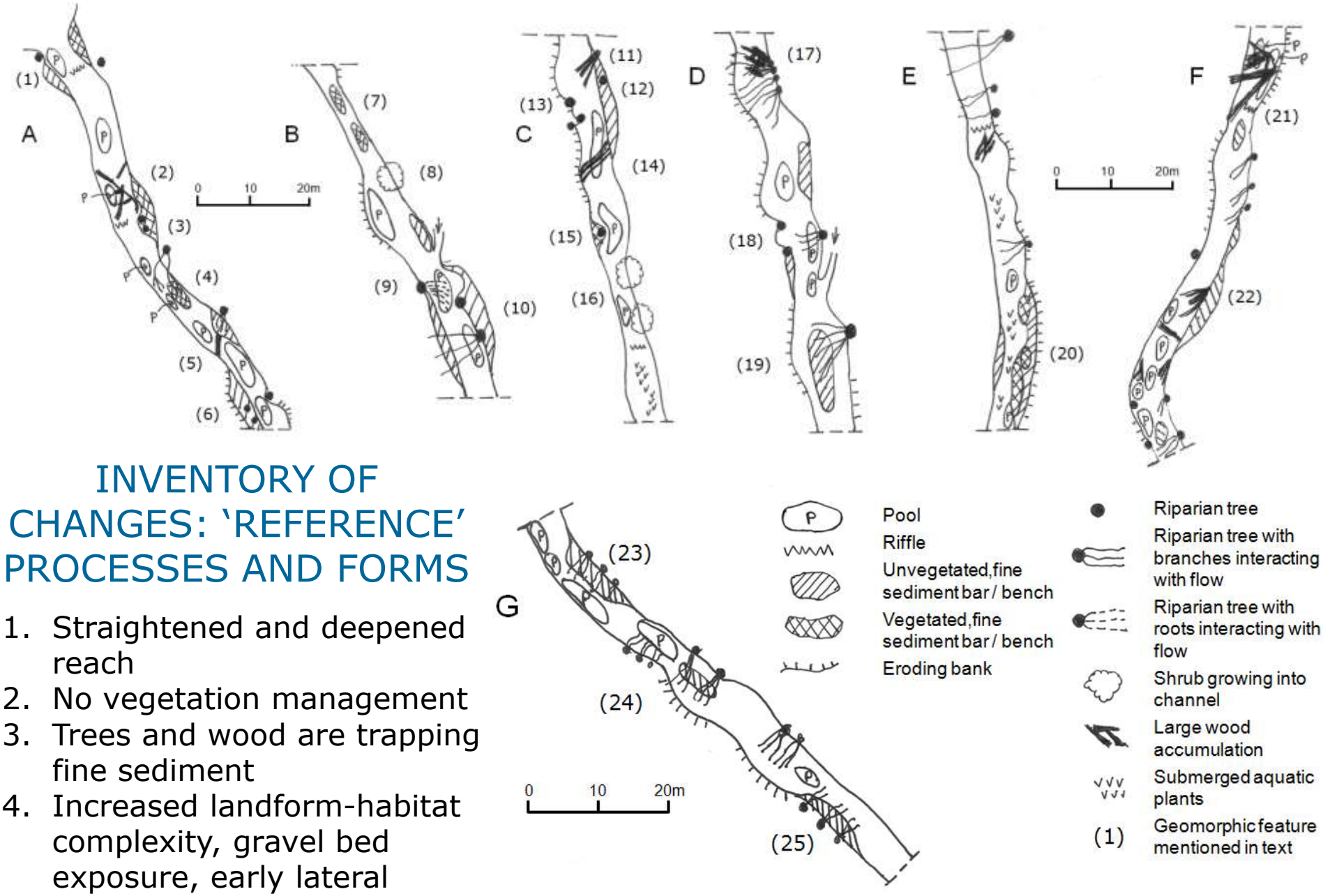


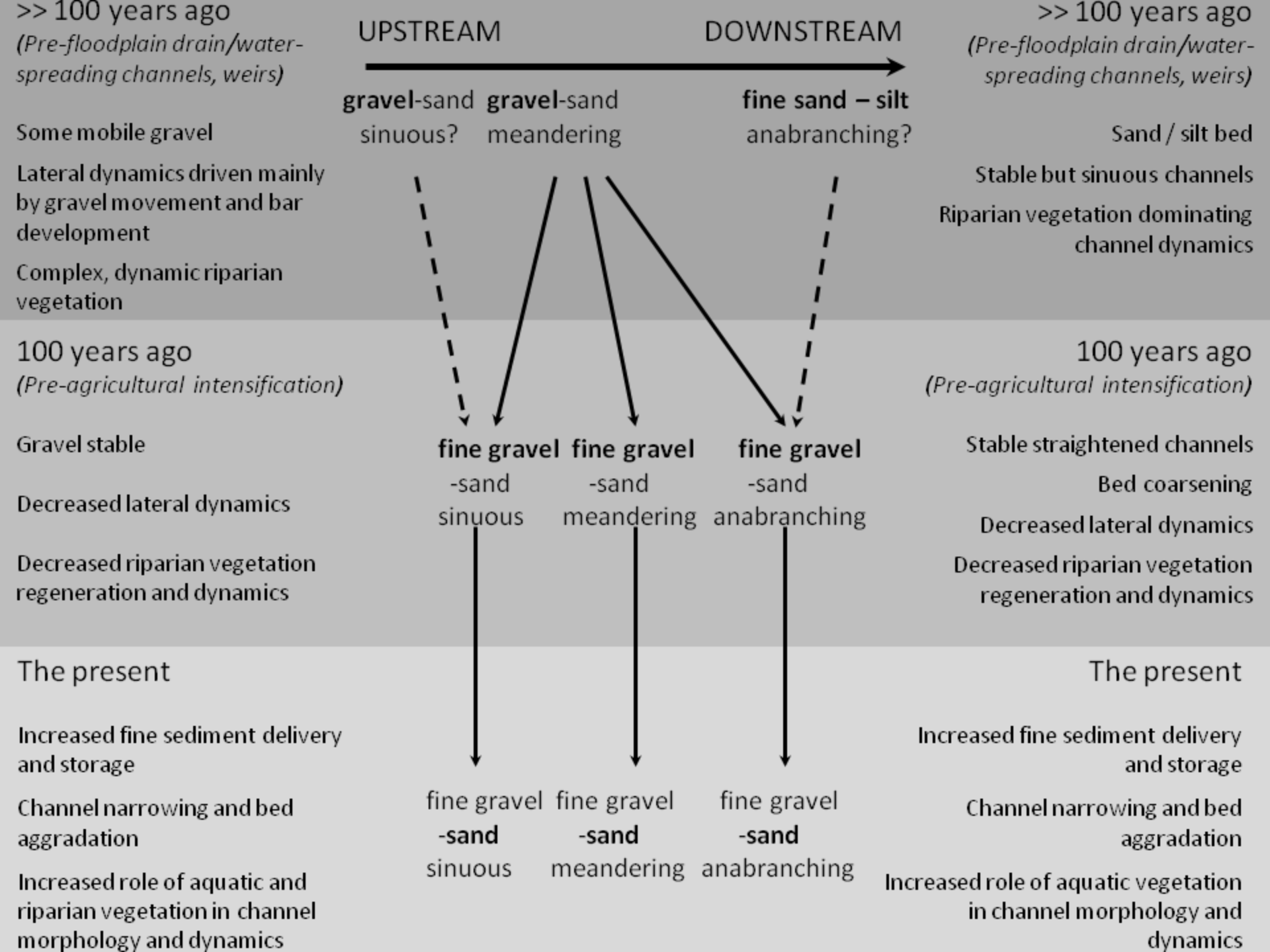
Fine sediment trapped by vegetation; vegetated bars and benches narrow channel and increase sinuosity (of straightened reaches)



INVENTORY OF CHANGES: 'REFERENCE' PROCESSES AND FORMS

1. Straightened and deepened reach
2. No vegetation management
3. Trees and wood are trapping fine sediment
4. Increased landform-habitat complexity, gravel bed exposure, early lateral movement




>> 100 years ago
(Pre-floodplain drain/water-spreading channels, weirs)
UPSTREAM
DOWNSTREAM
>> 100 years ago
(Pre-floodplain drain/water-spreading channels, weirs)
gravel-sand sinuous?
gravel-sand meandering
fine sand – silt anabranching?
Some mobile gravel
Lateral dynamics driven mainly by gravel movement and bar development
Complex, dynamic riparian vegetation
Sand / silt bed
Stable but sinuous channels
Riparian vegetation dominating channel dynamics
100 years ago
(Pre-agricultural intensification)
100 years ago
(Pre-agricultural intensification)
Gravel stable
Decreased lateral dynamics
Decreased riparian vegetation regeneration and dynamics
fine gravel -sand sinuous
fine gravel -sand meandering
fine gravel -sand anabranching
Stable straightened channels
Bed coarsening
Decreased lateral dynamics
Decreased riparian vegetation regeneration and dynamics
The present
The present
Increased fine sediment delivery and storage
Channel narrowing and bed aggradation
Increased role of aquatic and riparian vegetation in channel morphology and dynamics
fine gravel -sand sinuous
fine gravel -sand meandering
fine gravel -sand anabranching
Increased fine sediment delivery and storage
Channel narrowing and bed aggradation
Increased role of aquatic vegetation in channel morphology and dynamics

EXAMPLE: THE RIVER FROME, UK

SENSITIVITY

CHANGES

CATCHMENT SCALE – agriculture

SEGMENT SCALE - flood plain drainage, weirs, riparian vegetation management

REACH SCALE – aquatic vegetation management, numerous weirs.

RESPONSES

Broad river channel pattern retained

Loss of in-channel features, channels narrowing and aggrading, floodplain severely degraded but lateral dynamics slowly reinstating

Slow response: current trajectory of change is likely to persist for decades even if controls are altered / managed.

Small degree of adjustment indicates moderate sensitivity and a high resilience to larger scale changes.

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EXAMPLE: THE RIVER FROME, UK

FUTURE SCENARIOS AND TRAJECTORIES OF CHANGE

1. CLIMATE: warming climate with increased rain storm intensity (*increased aquatic vegetation biomass, sediment retention in channels, flooding and floodplain aggradation, water temperature*).
2. STRUCTURES: removal of some channel structures (*modest increase in conveyance and fine sediment mobilisation*)
3. LAND COVER: change in agricultural land cover and management (*significant reduction in fine sediment delivery from minor adjustment in cropping regime and vegetated 'set aside' along channels*)
4. VEGETATION: relaxation of riparian and aquatic vegetation management (*reduced fine sediment delivery; improved habitat complexity, riparian extent / age structure; reduced aquatic vegetation cover, increased channel conveyance, cooler water temperatures*).

REFORM

REstoring rivers FOR effective catchment Management

CONCLUSIONS

Reach hydromorphological condition depends on dynamic interactions between water, sediment and plants. Therefore:

1. Needs to be placed in a catchment context (*to capture impact of catchment process cascade and human interventions*)
2. Needs to be evaluated over time (*to capture sensitivity, dynamics and trajectories of change*)

The Framework benefit users involved in WFD implementation by:

1. Providing a flexible assessment framework
2. Providing indicators of hydromorphological condition that can be derived from commonly measured or freely available data sets
3. Improving understanding of linkages between hydrology, channel and floodplain morphodynamics, and ecology.
4. Informing sustainable approaches to ecohydromorphological management and restoration of river reaches