Scottish Environment Protection Agency
Buidheann Dìon Àrainneachd na h-Alba

For the future of our environment

Will the river do the work?

A practical guide for when to deliver passive river restoration measures that allow the river to self-heal

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SEPA Hydromorphologist

Scottish Freshwater Group - 24th April, 2024

Current state of rivers

- River systems the most degraded on earth (WWF, 2016)
- Disproportionately high extinctions
- Habitat loss and degradation primary reason
  - Scotland - 4150 km or 17% of baseline waterbodies straightened
- Climate change
- Biodiversity crisis

Need to find techniques to halt and reverse the damage that has been done to simplify and degrade river systems

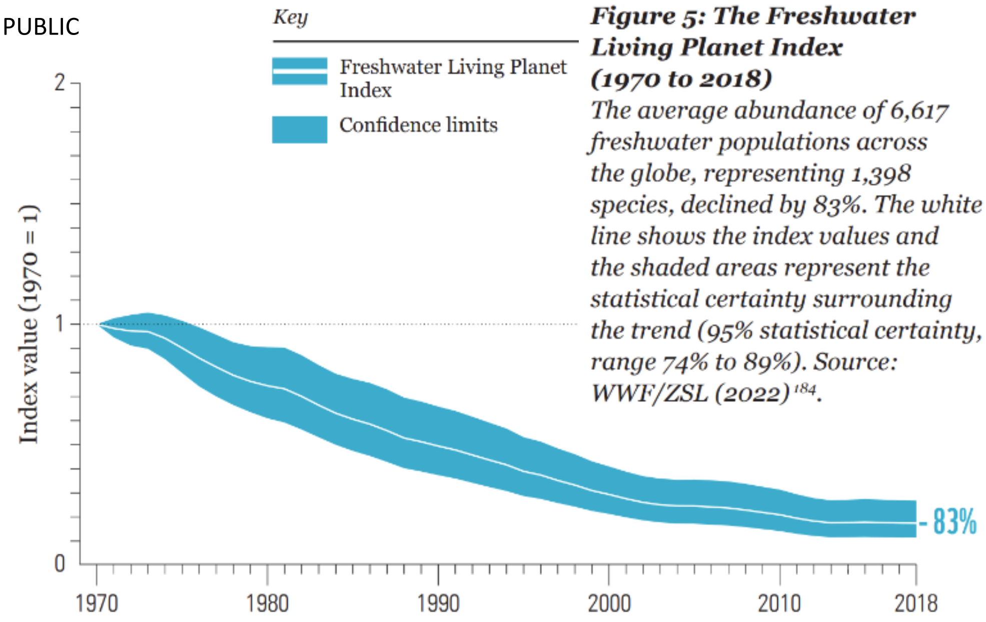
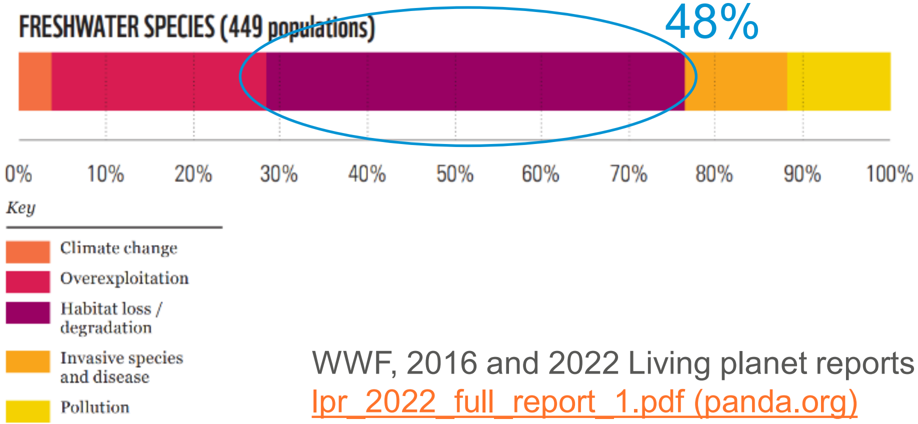


Figure 5: The Freshwater Living Planet Index (1970 to 2018)
The average abundance of 6,617 freshwater populations across the globe, representing 1,398 species, declined by 83%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (95% statistical certainty, range 74% to 89%). Source: WWF/ZSL (2022)[184].



WWF, 2016 and 2022 Living planet reports
[lpr_2022_full_report_1.pdf (panda.org)]

Self-healing river approach to restoration

- Delivering full restoration for all WFD failing rivers unfeasible
- Need techniques that;
  - Work with the natural functioning of the system
  - Maximise the scale of delivery & benefits
  - Minimise cost & effort

An alternate approach to manually digging new river channels is one where the river is allowed or encouraged to adjust and 'self-heal'. This involves removing impediments to adjustment and 'facilitating or restoring the physical processes of flooding, sediment transport, erosion, deposition, and channel change that create and maintain complex river forms' (Kondolf, 2011: 29).

- Dynamic channels that adjust (particularly laterally), create a greater diversity and abundance of ecologically valuable habitats

PUBLIC

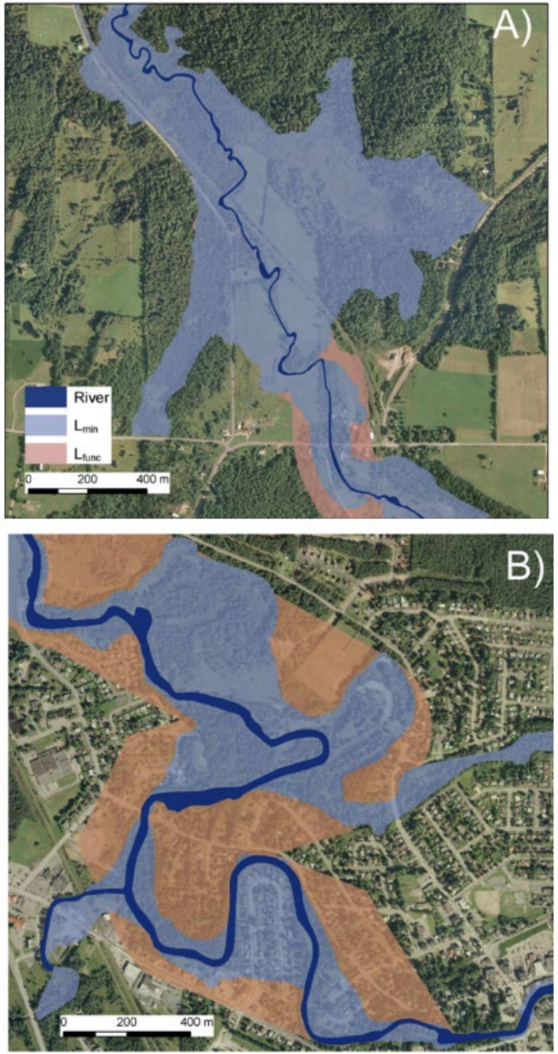
International examples of self-healing rivers?

- Well established in the literature – based around giving rivers space to adjust
  - US - Channel migration zones
  - Canada – Freedom space for rivers
  - France - erodible corridors or espace de liberte
- However, little guidance on how to assess if a river has the capacity to self-heal

If we give a reach of river room, will it recover or does it need help?

Freedom Space for Rivers: A Sustainable Management Approach to Enhance River Resilience

Pascale M. Biron · Thomas Buffin-Bélanger · Marie Larocque · Guénolé Choné · Claude-André Cloutier · Marie-Audray Ouellet · Sylvio Demers · Taylor Olsen · Claude Desjarlais · Joanna Eyquem



Recovery Potential Categories

River recovery potential – assesses the energy and sediment load of a river to determine if a river has the capacity to self-heal

- Focuses on the river's ability to self-heal rather than the room needed to contain natural adjustment
- Recovery potential categories then indicate the type of restoration that is likely to be successful;
    - Active restoration
    - Assisted natural recovery
    - Natural recovery

Resilient to change – Very high energy, but bedrock and boulders limits morphological adjustment possible

High recovery potential – High energy and channel readily able to adjust its form with little assistance necessary

Moderate recovery potential – Moderate energy. Can adjust but may require assistance to recovery within acceptable timescales

Low recovery potential – Low energy systems. Very low rate of adjustment likely to need active restoration.

Will the river do the work?

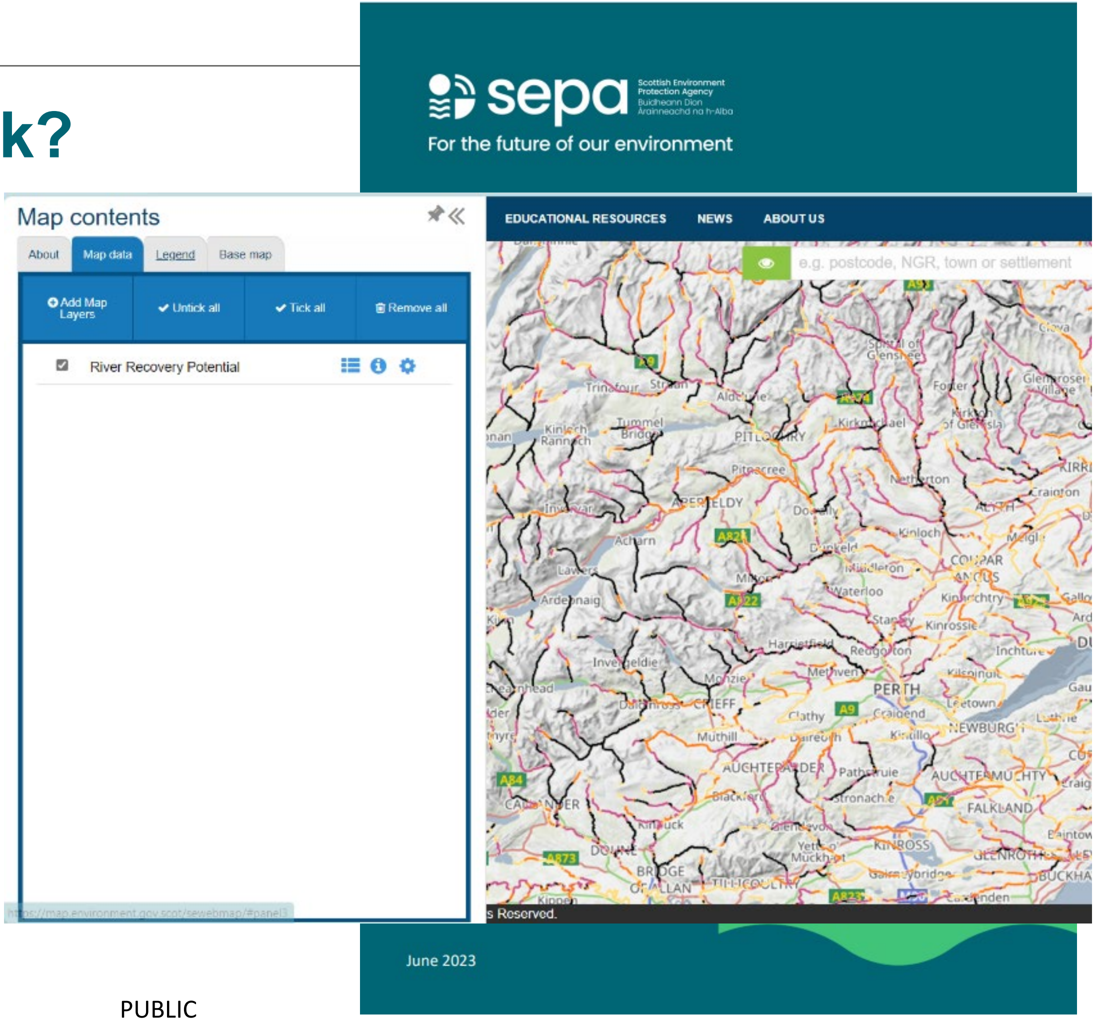
Presents a framework to understand if a river can self-heal or not within realistic timespans.

- **2 sources;**
  - Full report on SEPA website

https://www.sepa.org.uk/media/ifcaytdm/will-the-river-do-the-work.pdf

  - River recovery potential layer on SE WEB

https://map.environment.gov.scot/sewebmap/



Report components

Chapter 2 - Catchment-scale modelled assessment of recovery potential

Step 1: Catchment scale recovery potential?

- Aim – to map the recovery potential across Scotland
- Recovery potential categories are linked to river type
- Specific stream power (SSP) – a measure of energy derived from;
    - Channel slope
    - Discharge (QMED)
    - Normalised by channel width
    - Output = W/m2
    - Points calculated every 50 m along baseline network
- Extract SSP for different river types/ recovery potential categories

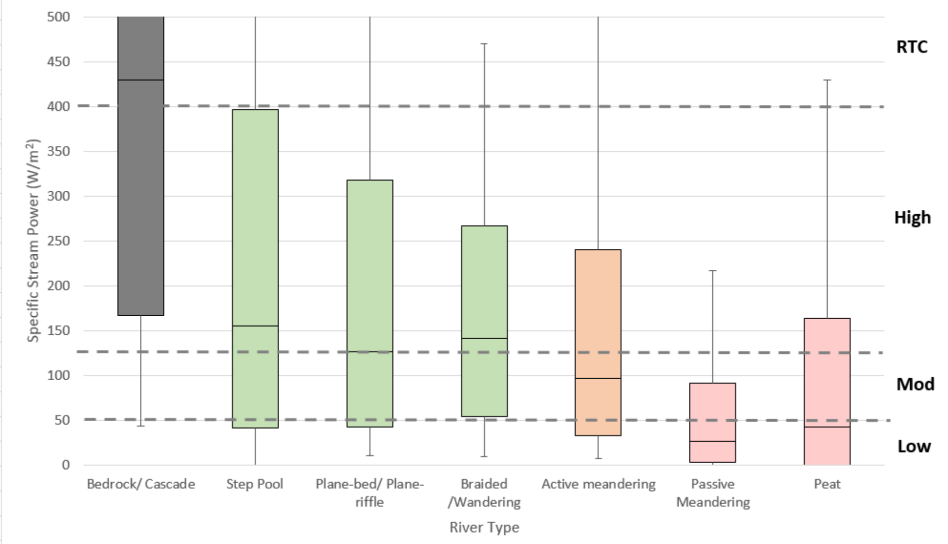
Recovery Potential Category	River Type
Resilient to Change (RTC) – Confined valley and bedrock dominated reaches, unable to undergo significant adjustment	Bedrock, Cascade
High Recovery Potential – An ability to adjust channel form rapidly in response to changes in channel processes with a high capacity to self-heal	Step-pool, Plane-bed, plane-riffle, braided, wandering
Moderate Recovery Potential - Still have the energy required to adjust following change but over longer timescales, compared to high recovery potential reaches	Active meandering
Low Recovery Potential – Low energy and therefore slow recovery times with limited capacity to self-heal within realistic timescales.	Passive meandering, Peat

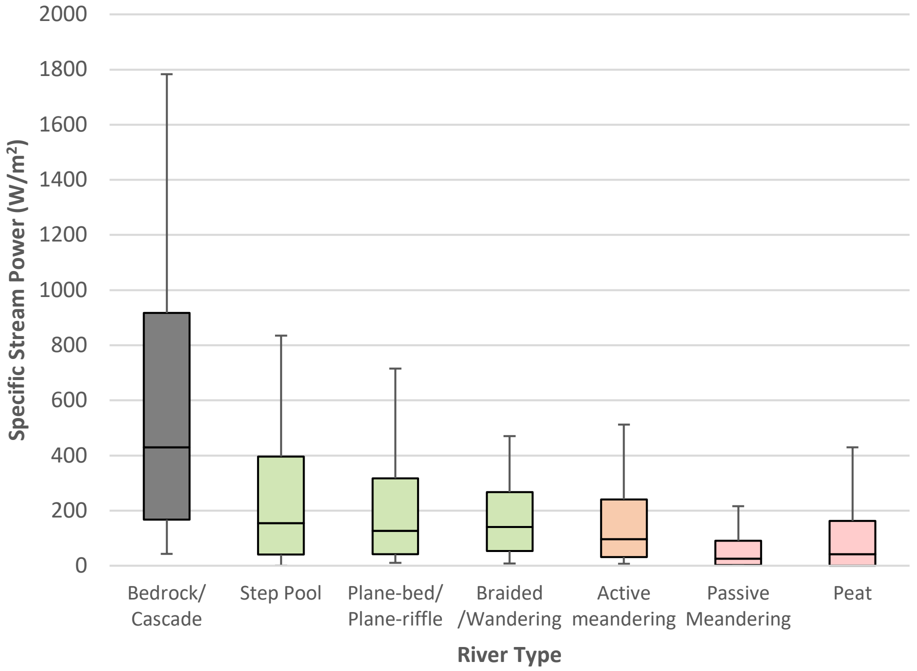
$$\Omega = \rho \, g \, Q \, s \qquad \omega = \Omega / w$$

Will the river do the work?

Catchment scale recovery potential

- 7000 km of waterbody manually mapped river type (high confidence in data)
- Used to set thresholds for recovery potential using specific stream power
- Map created of recovery potential across Scotland

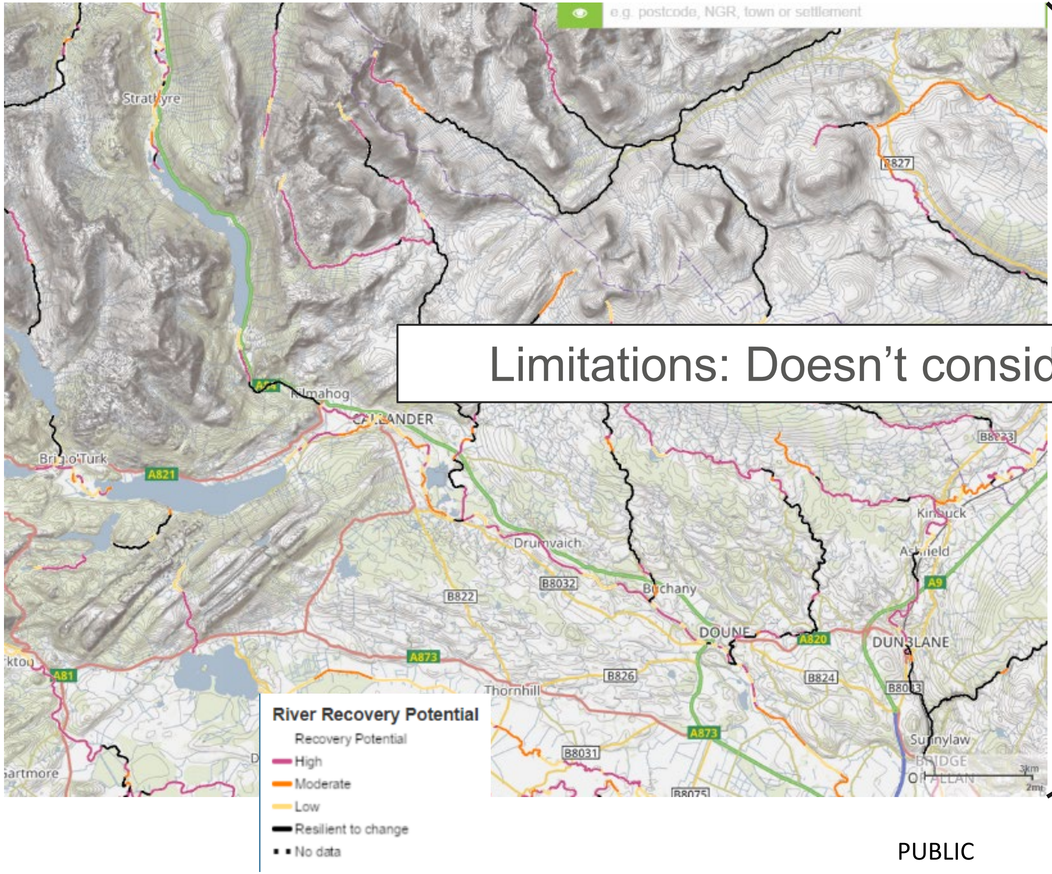


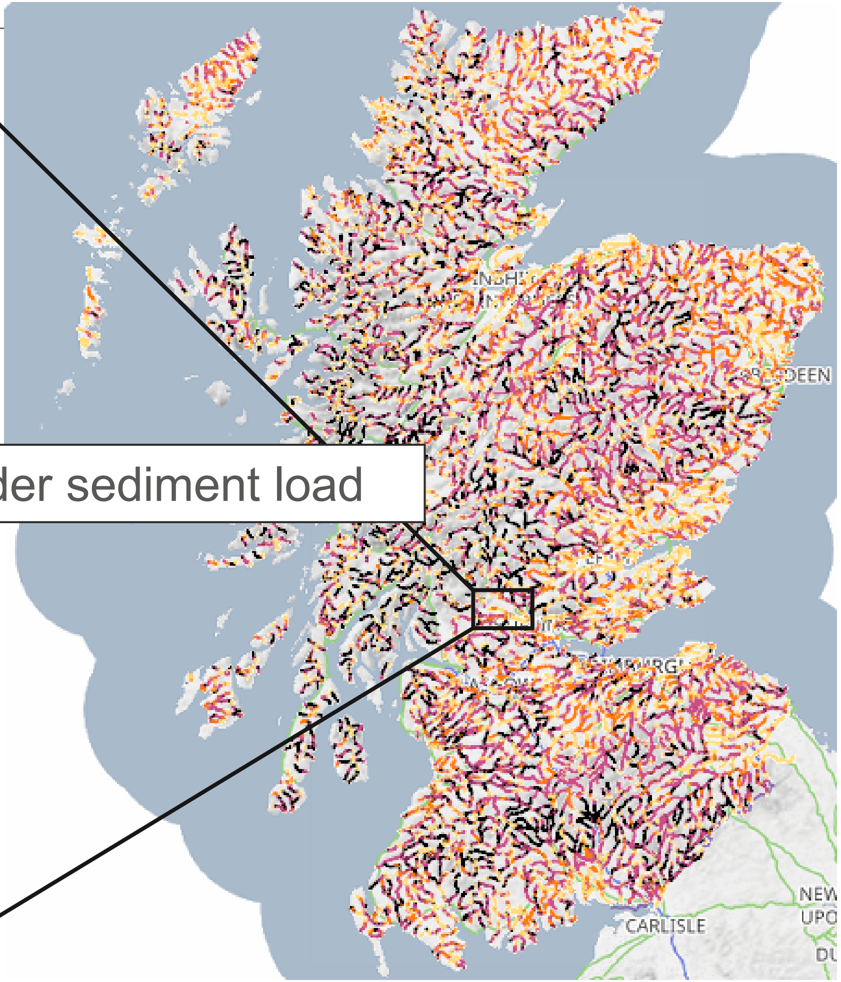


Recovery Potential Category	River Type
Resilient to Change (RTC)	Bedrock, Cascade
High Recovery Potential	Plane-bed, plane-riffle, step-pool, braided, wandering
Moderate Recovery Potential	Active meandering
Low Recovery Potential	Passive meandering, Peat

Will the river do the work?

Catchment scale map of recovery potential





Limitations: Doesn't consider sediment load

Step 2: Reach-scale field guide to assess recovery potential

- Step by step guide to assess river energy and sediment load using simple assessments of river attributes
- Reach-scale
- Coherent framework to get river practitioners to think like geomorphologists

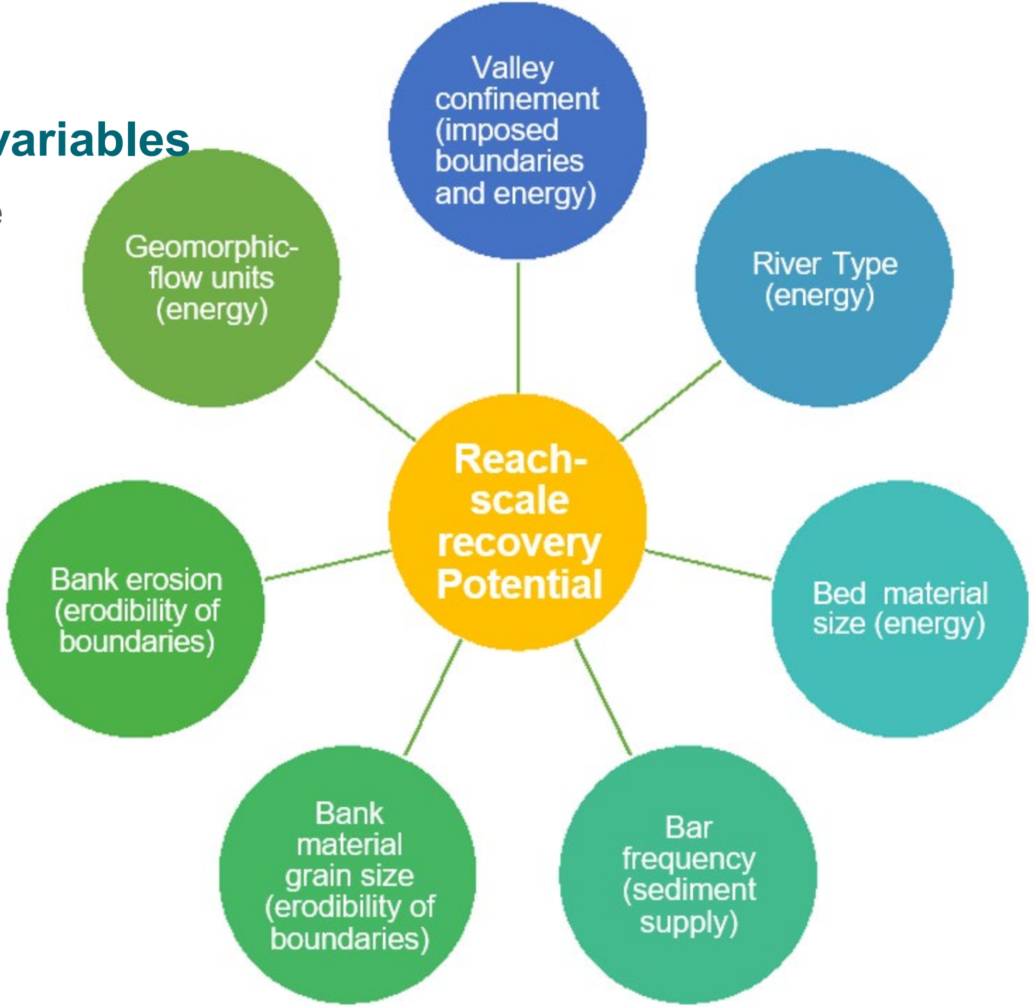
Geomorphic attributes =

energy & sediment load =

reach-scale recovery potential

Step 2: Reach-scale geomorphic variables

- Each variable describes some attribute of river recovery (e.g. adjustment likelihood)
  - *Valley Setting* – potential range of adjustment/ energy
  - *River Type* – function of energy and sediment load
  - *Bed Material size* – energy
  - *Number and extent of bar forms* – sediment supply/accommodation space
  - *Bank grain size* – resistance to erosion
  - *Bank erosion (extent and location)* – capacity for geomorphic work
  - *Flow types* - energy



Field sheets

- Simple
- Very rapid
- Aimed at a variety of river practitioners, not just geomorphologists
- Report provides guide for each variable with simple tables and pictures

potential score to summary table and use this to calculate overall recovery potential.

1. Valley confinement				
(X)	*(H)*	*(M)*	*(L)*	*(A)*
Describe your valley setting:				

2. River Type (Reference — i.e. what it would have been in its natural state)				
(X)	*(H)*	*(M)*	*(L)*	*(A)*
Describe the characteristics of your river type:				

3. Bed Material				
(X)	*(H)*	*(M)*	*(L)*	*(A)*
Describe range of bed material				

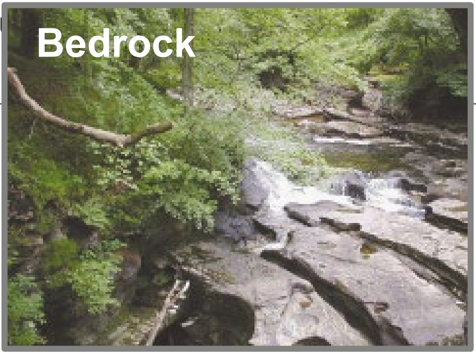
4. Bar Frequency				
None due to bedrock (X)	*Many (H)*	*Some or few (M)*	*None (L)*	*None due to anthropogenic (A)*
How frequent are bars within the reach and where are they located?				

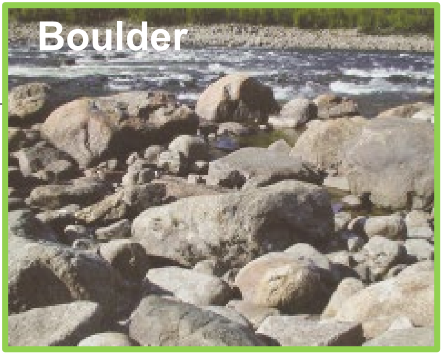
5. Bank Grain Size				
(X)	*(H)*	*(M)*	*(L)*	*(A)*
Provide a description of the characteristics of your banks sediment, including how cohesive it is.				

Reach-scale recovery potential

- Dominant bed material size
- How much energy does the reach have?

RTC and High





Moderate

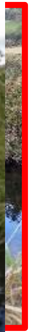
Low

Flow types

- Energy
- Tables to describe what the flow types look like and then how these should be combined to assess recovery potential

Easy to follow pictorial / tabulated guides for non-experts

Riffle	Undulating standing waves in which the crest faces upstream without breaking. These should be topographic highs on the bed and are usually located in the straight sections between bends. Often formed of tightly packed coarser sediments. Usually the steepest elements on medium energy rivers.	
Run	Surface turbulence does not produce waves but symmetrical ripples which move in a general downstream direction. They have uniform morphology though boulders may protrude through. Shallower and swifter than glides, but not as topographically defined as a riffle.	
Glide	Flow in which relative roughness is sufficiently low that very little surface turbulence occurs. These are homogeneous units, typically found in lower energy or degraded settings. Bed material tends to be finer with little variability. If the channel is dominated by glides it is likely to have a low recovery potential.	



Guide of all categories for use in the field

- Can alternate between detailed full guide and summary table as needed

1. Valley confinement				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
Confined, 'v' shaped valley where the channel is confined by a sloping valley 90 – 100% of the time.	Partly confined with narrow floodplain pockets. The floodplain locally widens but the channel remains in contact with the valley margin between 50 – 90% of the time.	Partly confined within wider floodplain pocket, where the channel is in contact with the margin 10 – 50% of the time or moderate gradient unconfined with no confinement but the floodplain has noticeable slope	Low gradient unconfined. This should be flat containing low energy rivers	Valley completely reshaped due to anthropogenic modification
2. River Type (Reference – i.e. what it would have been in its natural state)				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
- Bedrock and cascade - Plane bed - Step-pool	- Wandering - Braided - Plane-riffle - Pool-riffle	- High energy active meandering (cobble bed) - Moderate energy active meandering (cobble/gravel bed)	- Lower energy active meandering (sand/gravel bed) - Passive meandering (sand/silt bed) - Peat	Concrete or blockstone lined channel or equivalent
3. Bed Material				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
Bedrock	Boulders and cobbles	Cobbles and gravels	- Silt and mud - Sand - Fine gravels	- Concrete - Blockstone - Gabions
4. Bar Frequency				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
None - due to high energy, confined planform and bedrock dominance	Many – Bars are very common and reach has a braided, wandering planform	Some – Scattered along the reach, not just outside of bends Few – Small bars, generally inside of bends	None – No bars present within reach, and channel **not** dominated by bedrock	None due to anthropogenic controls on channel processes such as embankments or bank protection
5. Bank Grain Size				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
- Bedrock - Boulder	- Sand - Coarse river sediment in uncohesive matrix	- Silt - Coarse river sediment in cohesive matrix	- Clay - High density tree roots and vegetation (i.e. willow)	- Banks concealed by concrete or blockstone
6. Bank Erosion				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
None due to bedrock or boulder margins	High - Erosion throughout the reach, not just on the outside of bends, but straight sections as well	Moderate – Erosion at expected locations for river type, such as outside of bends	Low – Very little erosion present. Banks stable and held together by cohesive sediment, low energy and/or vegetation	None due to anthropogenic bank protection or excessive caused by livestock poaching
7. Flow Types				
(X)	**(H)**	**(M)**	**(L)**	**(A)**
- Waterfall - Cascade -	- Higher energy riffle - run units Step-pool units - May have a lot of exposed bars (i.e. wandering or braided planform)	- A mix of moderate to low riffle- run- pool and glide units.	- Low energy glides, runs and pools.	- Flume like flow - Stepped due to concrete flow

Will the river do the work?

Results

Geomorphic Variable	Resilient to change (X)	High (H)	Moderate (M)	Low (L)	Anthropogenic influence (A)
1. Valley confinement			X		
2. River Type				X	
3. Bed material size				X	
4. Bar frequency				X	
5. Bank grain size			X		
6. Bank erosion					X
7. Flow types				X	
Total			2	4	1

Overall Recovery Potential: Low

Summary of attributes:

This was a lower energy active meandering reach. There was a lot of bank slumping along the reach, but this was caused by over grazing and livestock poaching rather than by fluvial erosion. The channel was also very incised, making recovery difficult and it is likely more interventionist methods would be required here. Flows were slow and homogeneous.

Geomorphic variable	**Description**	**Recovery potential category**
Valley Confinement	Moderate gradient unconfined valley setting	**M**
River Type	Lower energy active meandering	**L**
Bed material size	Silt, mud, sand and fine gravels	**L**
Bar frequency	None	**L**
Bank grain size	Silt	**M**
Bank erosion	High, but significantly influenced by life-stock grazing and poaching causing slumping rather than fluvial action.	**A**
Flow Types	Low energy glides, runs and pools.	**L**

Overall recovery potential - Low (L) *but at the higher end of low.*

Preferred restoration option:

This channel does not appear to be straightened. It has just incised either due to being dredged or changes in hydrology and land use. The best restoration option would be to install a 2-stage channel that includes riparian planting. This would take the pressure off the channel, reducing energy during high flows and allowing a more diverse range of geomorphic units to be established. Natural deflectors could also be used to enhance this habitat.


Types of restoration and when should they be used?

- Links the recovery potential of a reach with appropriate types of restoration
- Restoration as a continuum based on effort, cost and degree of physical intervention
  - Active restoration
  - Assisted Natural Recovery
  - Natural Recovery

Natural Recovery

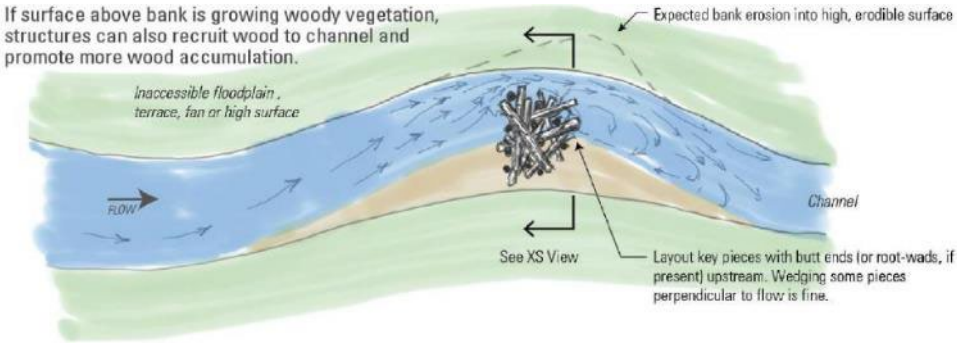
- Actions around the river to enable recovery
  - Removal of bank and bed protection
  - Breaching embankments
  - Stop maintenance
- No manual alteration of the river channel
- River gets to create the form that is suitable for that location
- Low cost
- Can be applied across large areas
- Not appropriate where rivers are incised or aggraded

Channel needs to have enough energy/sediment load to recover = high recovery potential

Assisted Natural Recovery

- Removal of pressures as in Natural Recovery and installing additional measures to enhance recovery and encourage channel adjustment
  - Engineered log jams and deflectors to encourage bank erosion
  - Sediment injections
- Good where natural recovery will take too long - measures needed to 'kick-start' recovery
- Less effort then designing and building a new channel
- Applied across large areas
- River still has the opportunity to self-heal

Channel needs help to recover within practical timescales = moderate recovery potential



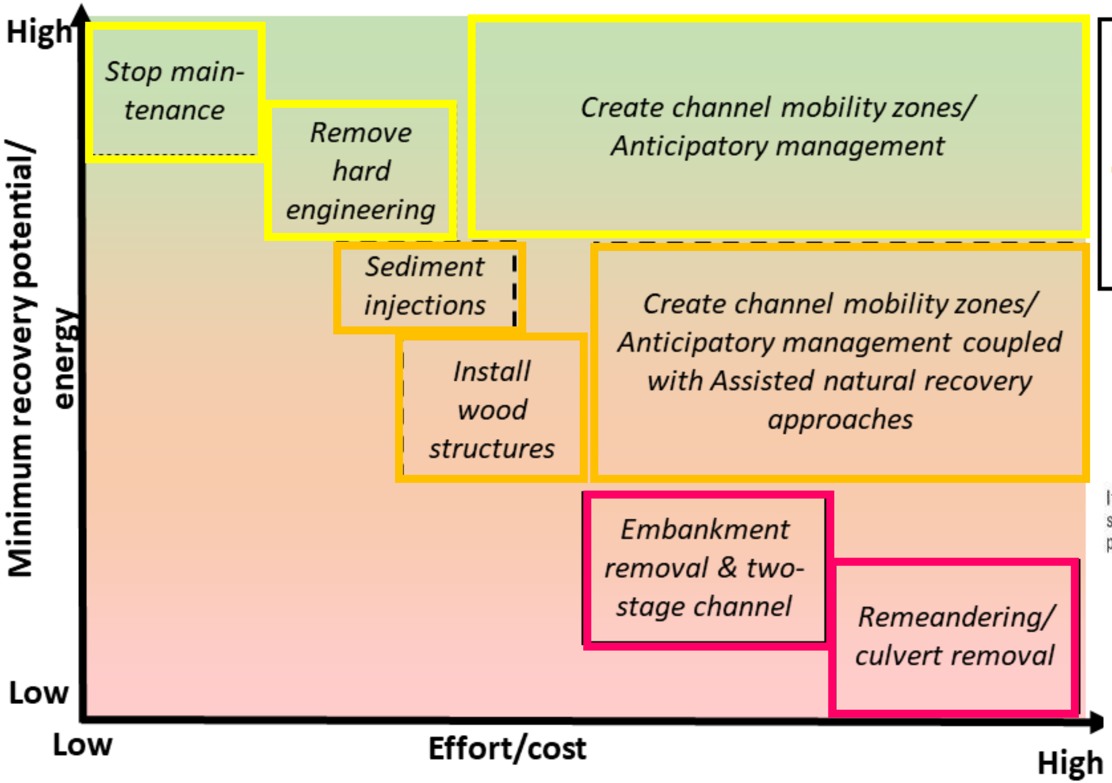
Detailed conceptual diagram of bank-attached ELJs, designed to enhance channel diversity. Sourced from Wheaton et al. 2019.

Example of habitat before (left) and after (right) following gravel augmentation in the River Tat in Norfolk. Photo credits to Adam Thurtle © Environment Agency

Active Restoration

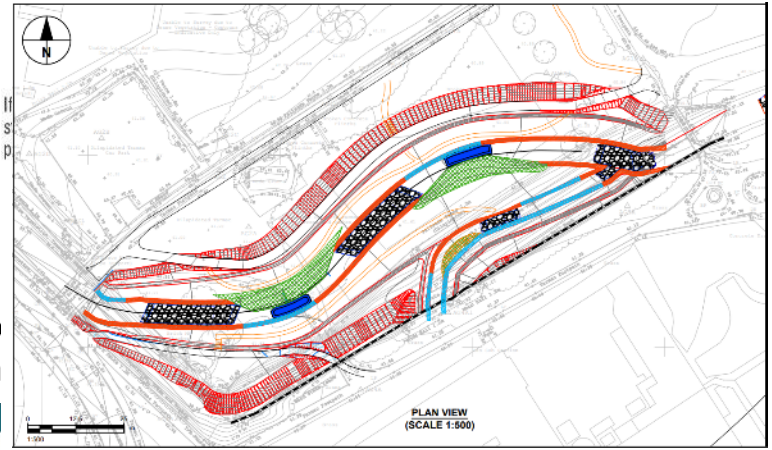
- Pressures are manually removed and a new channel is constructed
    - Remeandering and step-pool or cascade creation
    - Two-stage channel creation
    - Embankment removal
    - Daylighting culverted river
- High effort/cost to design and construct
- Necessary when close infrastructure (i.e. urban) or in sensitive locations
- Fast improvements to condition which are easy to visualise
- Can transform degraded areas

Recovery by self-healing would not be likely within practical timescales = low recovery potential and urban/constrained situations



Key

- Natural Recovery
- Assisted Natural Recovery
- Active Restoration



Riparian vegetation

Highlighting multiple benefits of riparian vegetation and the need for it to be included as part of river restoration

RIVERWOODS

Photo credit Colin McLean, Sourced from Spray 2023.

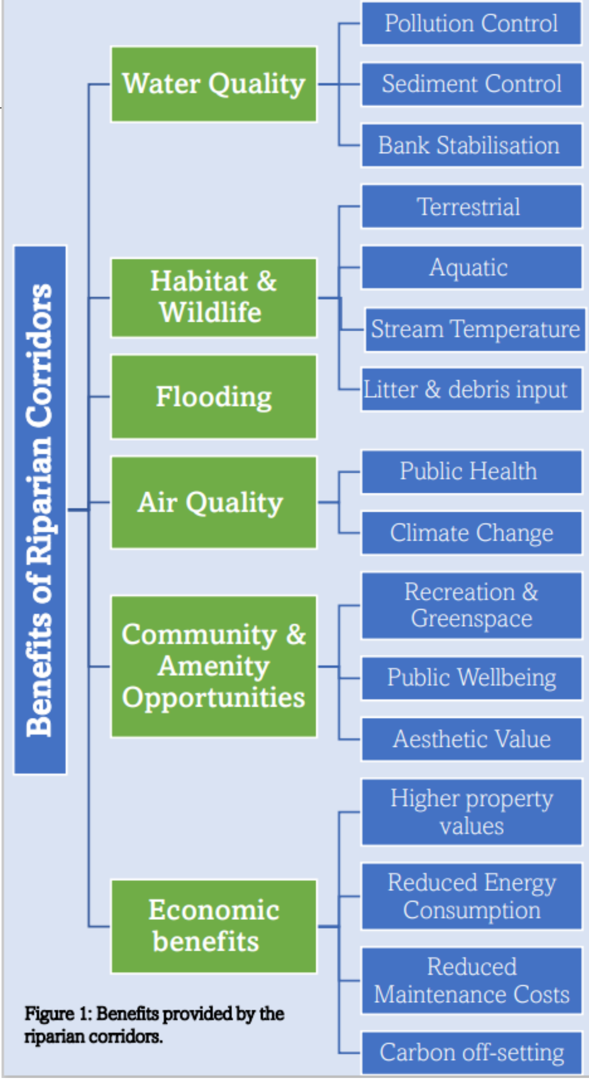


Figure 1: Benefits provided by the riparian corridors.

Water Quality

- Appropriated sized riparian buffers can prevent > 60% of bio-contaminates, pesticides & contaminates reaching rivers.
- Wooded riparian corridors can stabilise banks reducing fine sediment input and erosion risks.

Habitats and Wildlife

- Greater habitat area & connectivity as well increased protection of niche habitats.
- Controls stream temperature which is important to maintain species life cycles & delivers important nutrients through litter and debris input.

Flooding

- Riparian buffers mean flood receptors are set-back.
- Riparian buffers can reduce flood water levels,

Air Quality

- Wooded riparian buffers remove pollutants from the air & provide effective noise buffers. NHS data showed removing 1 µg/m3 of fine particulate air pollution could prevent around 50,900 cases of coronary heart disease & 16,500 strokes, over an 18 year period.
- Riparian buffers provide carbon storage & sequestration benefits removing carbon dioxide from the air and climate change mitigation.

Community & Amenity Opportunities

- Greater aesthetic value provide people with a greater sense of place as well as areas for recreation activities such dog walking, running and reading.
- Provides outdoor education opportunities, which helps children learn more & retain concepts longer.

Economic Benefits

- Increase in property value. Data from the Office of Statistics found that the price of detached houses & flats within a 100 m of green space increased by 1.9% & 0.6%, respectively.
- Shelter provided by trees could reduce energy consumption in buildings & the time and energy required to remove snow from road.
- Reduced erosion, flood protection and maintenance costs.

Examples of restoration case studies

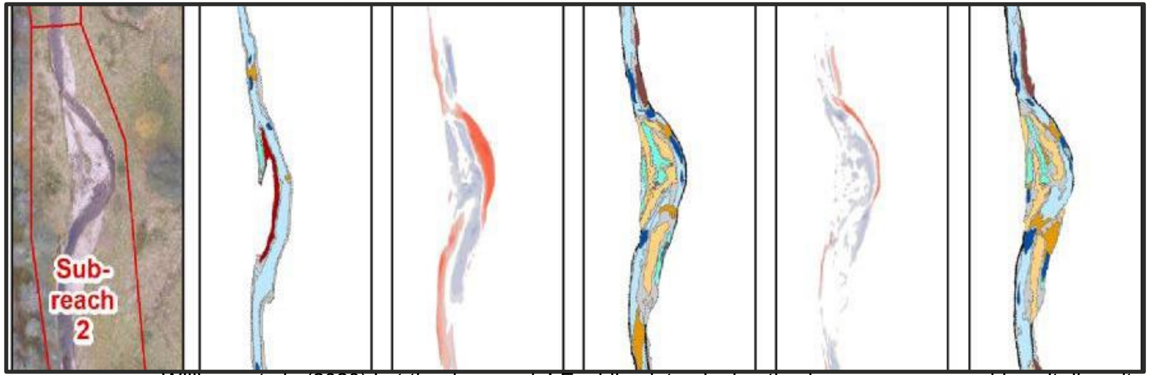
- Schemes that are already delivered, mostly within Scotland, used to test the approach
- Covered a range of locations (urban – rural), energy and types of restoration carried out
  - Recovery potential of reach
  - Type of restoration delivered (active or ANR)
  - Observed recovery / success of approach

Restoration case studies: Allt Lorgy, upper Spey

- Straightened, embanked with boulder bank protection and boulder bed check dams

→ High recovery potential

- ANR Restoration approach
  - Bank protection and embankments removed
  - Engineered log jams installed
- Rapid channel recovery seen, especially in locations where ELJs were installed
- Marked increase in channel diversity



Williams et al., (2020) Let the river erode! Enabling lateral migration increases geomorphic unit diversity, *Science for the Total Environment*, **715** (136817).

Conclusion

- Presents a hands on approach to guide when river restoration can be designed for rivers to self-heal
  - More cost effective
  - Larger scale
  - Enhance existing recovery
  - Rivers are better at creating their form than we are at designing it
- How can we provide space to support river function? i.e. channel mobility zones
- Restoring river habitats and riparian corridors have a multitude of benefits
  - Biodiversity
  - Improved flood and drought resilience
  - Reduced maintenance/dredging
  - Improved water quality and soil retention
  - Increased carbon capture

Thank you

Contact details

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