The Stage Zero approach – lessons from North America on restoring river, wetland and floodplain habitats

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Natural river systems support an intricate mosaic of habitats, including lakes, ponds, wet woodlands, fens, swamps, bogs and reedbeds. The complex mix of wetlands of various types and sizes offers a great range of niches for wildlife and, as such, a river and its associated floodplain can boast an outstanding diversity of species. Geomorphologists modelling the evolution of river systems – their flow, morphology and ecology – have designated this natural state as 'Stage Zero' (Figure 1). In Britain, however, changes in land-use have left such systems vanishingly rare: human modification means that most rivers now comprise a single channel, disconnected from its floodplain and adjacent wetland habitats.

Modification of floodplains dates back to deforestation during the Neolithic period, but more recent changes are the result of active reclamation of flood meadows for intensive agriculture. During the 1960s and 1970s, efforts to improve navigation and manage flood risk left most rivers deeply channelised, while surrounding floodplains were developed for infrastructure and farming, especially in the densely populated south of England. These changes, from the Neolithic to the present, have resulted in the loss of natural river function. Only 14% of English rivers were assessed as having good ecological status in 2019, and 41% of all waterbodies (rivers, lakes, estuaries and coasts) were found to have been impacted by physical modification (Environment Agency & Natural England 2021).

By the 1990s, the need to restore the physical form of rivers was being recognised, and restoration projects proliferated throughout Europe and North America (UK examples are compiled in the River Restoration Centre River Wiki: www.therrc.co.uk/eu-riverwiki). Projects have typically focused on the river itself, narrowing the channel or restoring meanders, and have more recently been driven by a natural flood management approach. This aims to use natural processes along with management techniques to slow the flow within river catchments and so reduce the risk of flooding.

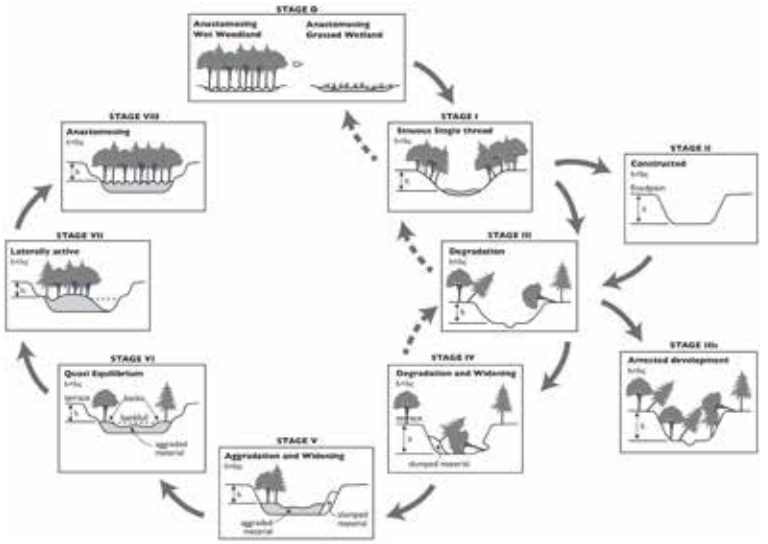


Figure 1. Stream evolution model from Cluer & Thorne (2013). The model shows how streams can evolve from multi-threaded (anastomosing) channels flowing through wetlands (Stage Zero), to single narrow channels that incise into the floodplain via erosion (degradation; stages 1–3), then to broader channels that begin to accumulate (aggradate) material as banks collapse and flow becomes weaker in places owing to the width of the channel (Stages 4–7), which can lead to the creation of and reconnection with an 'inset' floodplain. Finally, a multi-threaded system resembling Stage Zero may develop (Stage 8). Complete arrows indicate normal progression, while dashed arrows show 'short circuits', indicating places where the process may be reversed.

The widely held notion of rivers as single channels that flood adjacent land only infrequently is being challenged, with suggestions that many low-energy rivers would historically have had no discernible channel, the water instead flowing in a dynamic and evolving pattern over land and in meandering streams spread across the valley floor (Cluer & Thorne 2013). These ideas have led to the emergence in the USA of a new method – the Stage Zero approach – of restoring natural processes in river corridors, focused on rebuilding connectivity between rivers and their floodplains. By 2018, 20 projects had been implemented in river valleys (with suitable physical characteristics) in the Pacific Northwest. The intention is to 'reset' the river bed within the valley floor so that, even during periods of low rainfall water meanders through the soil and forms mobile channels over the surface.

Restoring full connectivity between an incised river – one that has been channelised and cut into its floodplain so deeply that it rarely overtops, even in flood conditions – and its former wetland-floodplain system may not be feasible everywhere. The Stage Zero approach, meanwhile, aims to restore the core processes and characteristics of natural river systems, and so develop a dynamic and self-sustaining wetland-stream complex (see Figure 2). In simple terms, a river system is 'reset' so that the riverbed is at the level of the floodplain, ensuring that water connectivity is restored across all surrounding habitats. Rather than trying to replicate a chosen moment in history, the key aim is to bring the river system to a point where natural processes can determine future change.

River restoration in the USA

The American river restoration projects use a variety of approaches, from completely (or partly) infilling an incised river so as to push water out onto the valley floor and thus allow the river system to develop anew, to using structures that mimic beaver dams in order to capture sediment and achieve the same result.

The first step for these projects is to identify an aspirational valley floor surface, based on the natural topography and slope of the river-floodplain system before it was modified (as determined by use of LIDAR and historic data) – known as the geomorphic grade line. Restoration then involves localised excavation of artificially raised areas of the floodplain, and infilling of lower areas. Planting trees and placing large woody debris across the floodplain prior to restoration helps to slow the flow, disperse water and dissipate erosive forces once the river is pushed out of its modified channel. A stream-wetland-floodplain system can then be left to develop naturally, often resulting in the formation of multi-thread river channels. For smaller streams and ditches, the modified channel is infilled and the land becomes saturated, creating wetland and marsh habitat. In the case of larger rivers, cutting an undersized replacement channel through the valley bottom, connected to the infilled original channel, reduces the initial erosive impact of water displaced from the old channel while pushing excess flows onto the floodplain.

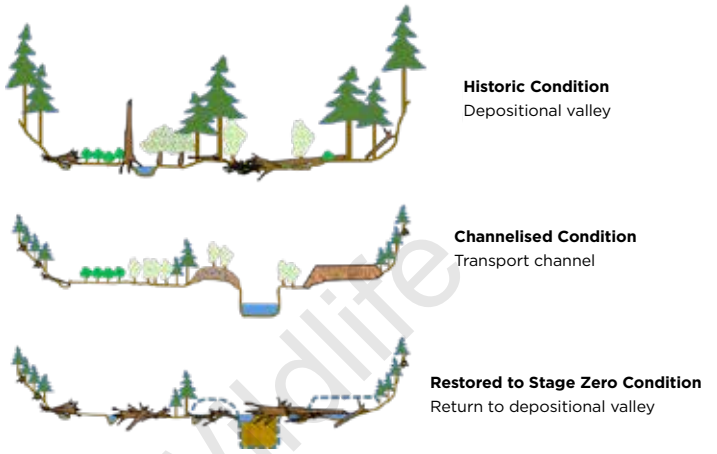


Figure 2. Illustration of natural, modified and restored river systems in the Pacific Northwest, USA. Johan Hogervorst

These projects have raised groundwater levels, increased the area and productivity of wetlands and improved habitat diversity, while the reduction in the power of stream-flow has led to a lower risk of flooding downstream, more sustained summer flows and improved water quality. A particular benefit has been greater resilience to wildfires in these wetter river valleys. For example, a restoration on the south fork of the McKenzie, Oregon, completed in 2020, escaped largely unscathed during massive wildfires in 2021, despite the majority of the surrounding forest being burned; salmon were observed spawning in the river just a few days after the fire. The return of natural stream processes has also produced numerous other benefits for the ecosystem; for instance, monitoring has shown increases in salmonid populations and in some locations the return of beavers and other wildlife.

Pre-restoration channel (left) and post-restoration 'wet meadow' (right) at Dick Creek, Oregon. Paul Powers/US Forest Service

UK case studies

Compared with the USA, the UK has a long settlement history and high population density, factors that constrain the level of possible intervention by floodplain restoration projects. Many UK rivers have suffered heavier modification than those in the USA; some have been artificially raised above their floodplains, while others have been incised into the floodplains. Nonetheless, the restoration projects in the USA have ignited the ambitions of UK catchment managers to apply the Stage Zero approach. So far, this has resulted in a series of small-scale pilots in England and Scotland, assisted by the US Forestry Service and Professor Colin Thorne, of Nottingham University.

Holnicote Estate, Exmoor

Holnicote Estate is a National Trust property in Somerset, situated partly in Exmoor National Park. Following the success of the estate's green-engineering flood management project, 'From Source to Sea', the National Trust and partners have developed their Multi-Objective Flood Management Demonstration Project through the Trust's Riverlands programme. This seeks to reverse historical drainage across the estate and carry out work in the wider River Aller catchment, including habitat restoration, grazing management and species reintroductions. The various strands of the project include:

- Implementation of Stage Zero over 5ha on the estate, in an area known as Mud Pool Meadow
- Stage Zero approach planned in the River Aller catchment
- Planting of 25,000 trees and 3km of hedgerow
- Conservation grazing across 750ha
- Creation of more than 20 new ponds
- Interrupting water runoff from roads and paths, and filling-in ditches
- Introductions of beavers into two enclosures, the first in January 2020 and the second in November 2020
- Introduction of water voles and harvest mice

The Mud Pool Meadow Stage Zero area at Holnicote Estate before restoration (a), during construction works (b), and 12 months after restoration (c). Ben Eardley/National Trust

The River Nar in 2021, post Stage Zero. Charles Rangeley-Wilson

Work at Mud Pool Meadow commenced in autumn 2019, and consisted of reprofiling or filling drainage ditches and tributary streams by cutting and filling to the geomorphic grade line (see above). In addition to drainage being reduced, hedges and trees, such as willow, were planted to intercept flow, dead wood was placed in various places across the site and vegetation was left to develop without grazing. The effect of the work was immediate and profound, with a radical change in flow as water spread across the site, reconnecting aquatic and terrestrial ecosystems. Benefits have included increases in the abundance and diversity of wildlife, recharged groundwater levels, and reductions in the extremes of low and peak flows, thereby reducing floods, drought effects and erosion. Spot testing for nitrate and phosphate just one year after restoration indicated a reduction of over 80% across the site, demonstrating that the wetlands are already effective in storing excess nutrients.

The next phase of work at Holnicote will extend the Stage Zero approach over 15ha of the main river site and 125ha of the catchment headwater and drainage-ditch network. A ten-year hydrological monitoring programme to assess water levels, as well as ongoing ecological monitoring and two PhD projects will all help to develop a clear picture of how the works have affected the functioning of the river catchment.

River Nar, Norfolk

Norfolk Rivers Trust has implemented a full floodplain reconnection trial on the River Nar, a chalk stream that was modified historically by the construction of a raised leat (an artificial channel) for milling activity. Over the past few years a breach had opened in the leat, spilling an increasing proportion of its flow across the floodplain below. The water passes through a former poplar plantation, turned willow carr, and eventually gathers in what is likely to be the original, natural pathway of the river. The leat bed was above the valley bottom, so in 2019 a new small channel was excavated in order to 'step' the river down across the floodplain. The relatively steep gradient of the floodplain and existing woodland habitat allowed the stream to evolve rapidly. By summer 2020, Norfolk Rivers

Nettleham Beck demonstration site, where a network of slightly sinuous channels and ponds were excavated to reconnect stream and floodplain. When water levels are higher wood jams in the main straightened channel force water to flow out over the floodplain (left), while the channels remain dry during periods of low flow (right). Luca Mao/University of Lincoln

Trust surveys found strong fish populations in the flooded wood, including high numbers of bullhead and some trout, and areas of newly developed wetland.

Nettleham Beck, Lincoln demonstration site

In 2017, in a project run by the University of Lincoln and the Environment Agency, a 2ha multi-channel wetland system was created along a 250m stretch of a small, groundwater-fed limestone stream. The project's primary aim was to demonstrate to farmers and landowners the relatively manageable scale of the physical change required to reconnect river channel to floodplain. The works took place on the University of Lincoln's Riseholme campus, which conducts agricultural research and training. The channel had been straightened historically, and so restoration involved creating a network of sinuous interconnected channels and ponds, as well as partly blocking the main channel with woody debris, including live willow that would establish and provide protection against bank erosion. The University of Lincoln is continuing to monitor changes in flow, water quality and macroinvertebrates, among other factors. Post-completion surveys reveal that the project has successfully created habitats that remain wetter for longer during times of low flow, which will increase resilience to periods of extended dry weather.

Identifying catchment-scale Stage Zero opportunities

In 2020, the Environment Agency's Wessex Region team, working with Dorset Wildlife Trust and the Poole Harbour Catchment Partnership, developed the Wessex Area Stage Zero Opportunity mapping project to identify feasible locations for full floodplain reconnection. The mapping is based on spatial data from four groups that together inform the likelihood of being able to restore connectivity between floodplain and river at a given location. The groups are:

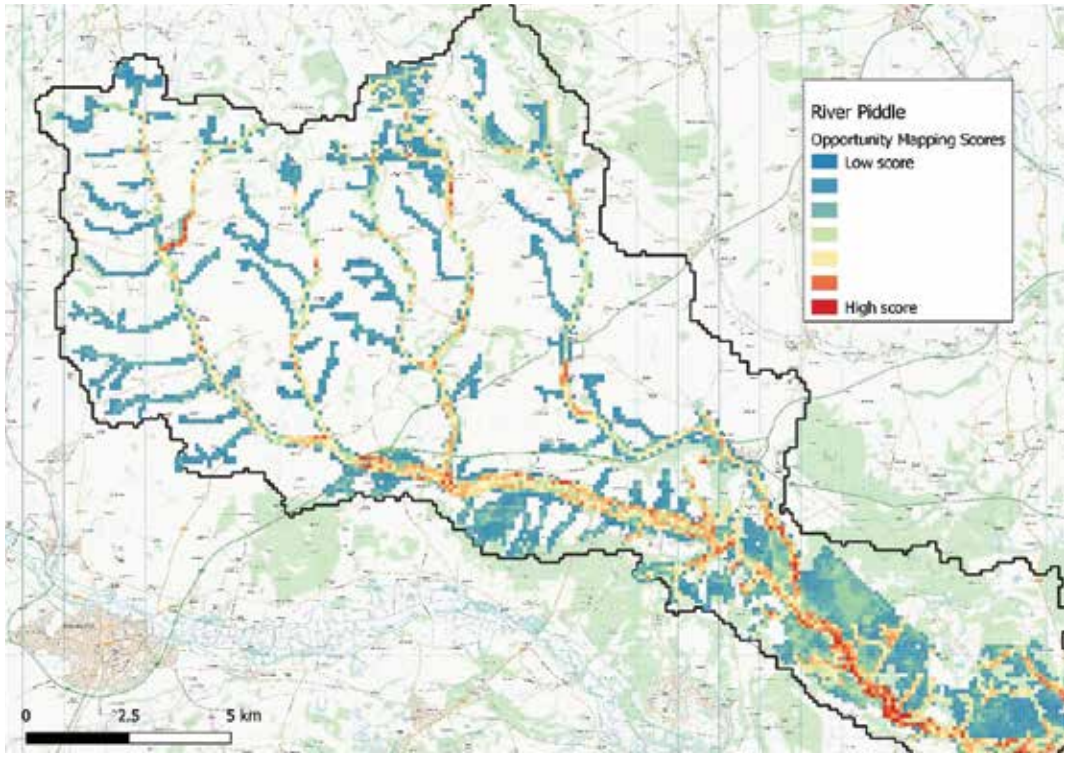
- physical and process factors (e.g. geology);
- anthropogenic factors (e.g. land-use);
- restoration factors – the extent to which the channel has been modified from its natural form;
- opportunities for and constraints on practical restoration.

It soon became apparent that the current image of a floodplain, which periodically floods from the river channel, does not reflect the true extent of the area that should be considered for restoration. For the River Piddle, for example, mapping identified that the present floodplain represents about 48% of the original valley floor prior to its modification. Identifying suitable locations for restoration is challenging, especially where developments or transport infrastructure occupy parts of the valley floor, while complex patterns of land ownership usually mean that floodplain-wide restoration would be practically difficult. The opportunity maps for selected catchments in Wessex attempt to capture these factors and aid in the selection of potential sites for full floodplain reconnection. Discussions are underway with landowners, advisors and statutory agencies over restoration of some of the locations identified through this method.

The valley bottom floor and the present floodplain (zone 3) of the River Piddle, mapped using LIDAR. Peter Stone

Future development

Pioneering work in the USA has demonstrated multiple benefits of restoring the hydrological, geomorphological and biological connectivity between wetlands, floodplains and their river channels. Restoring floodplains and wetlands lowers flood risk while improving habitat diversity, storage of water and sediment, and water quality. Despite a long history of floodplain modification in the UK, the waterways involved in pilot trials here have shown the same responses as those in the USA, suggesting that they might also produce similar benefits in terms of habitat creation and storage of water, nutrients and carbon.



Mapping scores highlighting rehabilitation opportunities across the River Piddle. Peter Stone

Stage Zero resources

The following online resources provide information on the Stage Zero approach to river restoration and examples of projects using this approach, including some that are described in the text.

Resources

Stage Zero Information Hub: www.stagezeroriverrestoration.com

Wessex Area Stage Zero mapping outputs and resources: www.wessexwater.co.uk/environment/catchment-partnerships/dorset-meeting-and-documents

Case studies

Afron Merin, Rheidol Catchment, Ceredigion: www.youtube.com/watch?v=9T55beo_efc

Allt Lorgy, River Dulnain, Spey catchment, Highland: www.youtube.com/watch?v=-ugGQaLjz9g

Holnicote Estate, Somerset: www.therrc.co.uk/blog/holnicote-natural-flood-management-project-members-site-visit

River Nar, Norfolk: www.chalkstreams.org/2020/06/11/stage-zero-on-an-english-chalk-stream

To date, application of these approaches in the UK is limited to small sites, typically headwaters or subsets of larger areas undergoing restoration. Key concerns about the feasibility of delivering floodplain-wide restoration in our overcrowded countryside relate to the complex patterns of land-use and ownership. These are yet to be resolved, but experience from Wessex indicates that opportunity mapping can help to identify potential areas for restoration and provides a useful tool during discussions with landowners. The mapping confirms that in the short term the greatest opportunities will be in headwaters or remote sites, but implementing the Stage Zero approach in these areas could help to encourage its future application over larger areas and in more complex locations. Further development of these methods continues in Oxfordshire, Devon and Cornwall, and on the Hampshire Avon and Bristol Avon catchments.

Looking forward, the reconnection and restoration of UK floodplain habitats could contribute to the government's nature recovery goals – specifically the aim to return 75% of waters to near-natural condition, as mentioned in the 25 Year Environment Plan – as well as helping rivers to attain good ecological status (The Water Environment (Water Framework Directive) Regulations 2017). The mapping tool developed for Stage Zero rehabilitation opportunities will aid in strategic planning for Local Nature Recovery Strategy mapping in Dorset through catchment and local nature partnerships. In the longer term, the success of this approach across the UK is likely to be determined by opportunities for funding, and acceptance of a new vision of what a naturally functioning river looks like.

Further reading and references

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