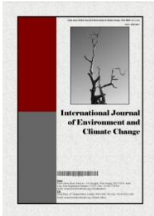

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A Review on River Revival

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The noticeable decline of flow and drying of rivers in non-monsoon period is observed by smaller hydrologic units (sub-catchments and watersheds). The flow depletion or drying of rivers is generally observed initially near the origin and then progressively in the larger hydrologic units. Rivers are losing water because of variety of possible reasons, including the installation of dams and the use of water for agriculture. But in many cases the decrease in flow is because of climate change, which is altering rainfall patterns and increasing evaporation because of higher temperatures. Reduced run-off is increasing the pressure on freshwater resources in world as well as in India, especially with more demand for water as population increases. Inspite of the fact that large sums of money have been spent on river rehabilitation across the globe, the understanding of the science of restoration is incoherent. A scientific and global intervention and approach to tackle such challenges to river management in India requires a highly effective approach, which must be process-based, predictive and must be capable of yielding the desired outcome. River restoration is one of the most prominent areas of applied water-resources science, supporting a multibillion dollar industry across many countries and helping to drive fundamental river research to address knowledge gaps that limit successful restoration. A revival strategy should identify a future prospect and long run for the river basin, the desired outcome of the strategy over the planning horizon (goals), and specific, measurable targets to be achieved over the short to medium term

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(objectives). River restoration can be supported by a combination of policies, strategies and project-level and global-level plans. Keeping this in view this paper presents some of the revival works carried out in India as well as in abroad.

Keywords: River restoration; climate change; HRV; spatial; temporal; artificial recharge.

1. INTRODUCTION

River restoration is one of the most prominent areas of applied water-resources science, supporting a multibillion dollar industry across many countries and helping to drive fundamental river research to address knowledge gaps that limit successful restoration. Mounting global concerns about water and environmental sustainability have driven the development and acceleration of river restoration practice and science. Drivers of river impairment, public interest in restoring rivers, and the need to ground restoration practice in scientific knowledge about river processes are all likely to continue to be important.

Within the last decade, different types of process-based restoration have increased in prominence, in concert with numerous calls from researchers to prioritize river function or process in restoration, rather than only river form. This has included restoration that has emphasized promoting channel-floodplain connectivity, longitudinal connectivity and partial restoration of water and sediment fluxes, and ecological productivity. The results of these process-based restoration approaches are increasingly evaluated with respect to biotic response. Simultaneously, the scope of river restoration has expanded to encompass a broader range of river types, beyond the prototypical mid order, pool-riffle meandering river. These span headwater streams in diverse settings, rivers altered by dams, large lowland rivers, and large drainage networks where restoration may involve broad, multidisciplinary efforts.

2. RECOGNIZING THE SPATIAL AND TEMPORAL VARIABILITY OF RIVER ECOSYSTEMS HAS AT LEAST THREE IMPORTANT COMPONENTS

First, it counters the notion that restoration is about recovery to a particular equilibrium state, one which is too often interpreted as a stable state. River ecosystems exhibit a natural or historical range of variability (HRV) in relevant parameters such as flow and sediment regimes, channel form, or biological communities as a result of disturbances and other changes in external forcing. Rivers respond to this variability in ways that maintain their diversity. Thus, restoration must embrace the restoration of diversity and not simply restoration of a particular river structure or form.

Second, recognition of spatial and temporal variability means that we need to rethink the role of history in informing restoration projects. It counters the idea that restoration is about going back in time to identify a particular river channel structure or form that should be restored. Rather, the role of historical enquiry is to understand how the river works and how it has been impacted upon by watershed-scale changes. This information becomes the basis for identifying the necessary conditions for ecosystem recovery, and informing potential manipulations that sustain the processes and structures needed to support particular restoration goals.

Third, recognition of spatial and temporal variability facilitates acceptance that the dynamics and diversity of rivers are important for sustainable river restoration. There should be variability in what we expect to see, and where, within a river basin. The diversity identified (and restored) will necessarily scale with the size of the basin being considered. Because rivers and the boundary conditions (climate, landscape, etc.) that force them are dynamic, any particular spatial variability is unlikely to remain fixed in time. In turn, this requires us to think critically about the kinds of metrics that we use to quantify rivers, and how these metrics respond to river restoration efforts. There is much to be gained from ecological science, which has been sensitive to the questions of spatial and temporal scale in the description of ecosystem properties.

A revival strategy should identify a future prospect and long run for the river basin, the desired outcome of the strategy over the planning horizon (goals), and specific, measurable targets to be achieved over the short to medium term (objectives). River restoration can be supported by a combination of policies, strategies and project-level and global-level plans. Uncontrolled ground water extraction is the basic cause and foremost problem of ceasing effluent discharge into the water stream.

R. Sinha et al. [1] made an effort to highlight river systems and river science in India and related major drivers and challenges and mentioned that rivers as a vital source of freshwater and the ever increasing demands for the society, there has been a pandemic deterioration of river systems globally accompanied by serious threats to biodiversity and water security. In spite of the fact that large sums of money have been spent on river rehabilitation across the globe, the understanding of the science of restoration is fragmentary. In India, most river management programmes have been primarily targeted towards water allocation and water quality and there has been no consolidated effort towards river restoration from an ecological perspective. Further, the exceptionally large expenditures incurred on flood control have not provided sustainable solutions due to the limited understanding of river processes. Even after spending more than Rs. 2,700 crores from 1950 to 1990, the flood problem and flood affected area have increased considerably in India. This however cannot be done in a reductionist discipline specific mode therefore he concluded that looking at the uncertain availability of water and the escalating future demands, it would be pertinent to consider fresh water as a ‘limited resource’. Considering the role of Himalayan river systems as a critical source of freshwater supply,he summarised that it is necessary to adopt a sustainable river management strategy. More than the issue of ‘demand and supply’, there is now a strong need, realization and effort to maintain the ‘river health’ and ‘environmental flow’ which are significantly influenced by geomorphic characteristics and biotic association of the river. Anthropogenic modifications on the Himalayan river systems, mostly driven by increased demands for fresh water, have been extensive and any efforts towards maintaining sustainable flow and river rehabilitation must address these issues to derive a longterm benefit.

Carsten Lange et al. [2] presented a model-based design for restoring the small urban river Panke located in Berlin, Germany. This new design process combines high resolution 2D hydraulic modelling with habitat modelling and river-ecological expert knowledge in a highly iterative way. Advances have been made for the habitat modelling: habitat suitability maps have been developed for fish and the habitat suitability for benthos has been assessed by including groups with different hydraulic preferences. Using the model-based design development of preference variants for the Panke which including structures such as pools, riffles, river banks, dead wood as well as aquatic vegetation was done. To account for the very detailed geometry of some structures such as dead wood, high resolution grids with edge length up to one decimeter have been generated. Furthermore flood protection has been assured. The model-based approach for the design of enhancement measures delivered valuable hints on current shortcomings in the river morphology, priorities for the creation of new habitats and quantitative information on the increase of suitable areas to be expected. In addition he analysed that relating the habitat changes to different flow rates will be helpful to estimate the temporal availability of high quality habitats after the implementation of the measures.

Devendra S. Bhargava [3] made an attempt to enlighten the stratergy for revival of Mathura’s ailing Yamuna river and made a conclusion that the pollution in the Yamuna river originates from domestic, industrial and agricultural activities apart from a totally mismanaged solid waste collection and disposal. Mass bathing in the river, open defecation and disposal of dead animals also add to the problem. The management for the collection and disposal of the city’s waste is neither effective nor scientific. The various efforts of the government have not remedied the situation for numerous reasons and technical faults. The public is equally responsible, for mainly because of ignorance, indiscipline and an unhygienic culture. The various strategies for the control of Yamuna river’s pollution were grouped into defensive and proactive approaches. The defensive strategies applied include scientific collection, treatment and disposal of all the waste waters originating in Mathura, industrial waste water’s management within the industrial campuses, improvement in the existing agricultural practices through controlled use of chemical fertilizers, insecticides and pesticides, better solid waste management strategies, construction of public conveniences at major ghats including alternatives for disposal of holy materials, and development of recreation parks and embankments, or retaining walls (serving as barrier between the town and the river) along the river banks as part of the fool proof pollution control strategy to prevent the flow of wastewater into the Yamuna river, legislative measures including the adoption of scientifically evolved effluent standards, and corruption free management of funds and a sincerely strict qualified supervision of constructional works. The pro-active strategies implemented included creation of awareness and duty amongst the Indian masses and unconcerned public, maintaining enough flow in Yamuna specially during the lean periods, enforcement of the Yamuna river's self-purifying abilities through artificial and in-stream aeration, scientific exploitation of the river's waste assimilative capacity and creation of an artificial lake for storing the flood waters and later its release into the Yamuna river during the dry flow periods. Apart from adopting the various control strategies outlined above he also summarised that there is a sincere need to punish the polluters and defaulters through a system of fines with adequate bonus to the fine collectors to keep them duty bound and honest. Creation of public awareness on the suggested lines and keeping away from persons not qualified in environmental technology will also expedite the Yamuna river cleaning.

Rajendra Singh [4] launched his experiment with "Truth". It was a unique experiment in water cycle and management in the nature's laboratory of parched desert, pioneering indeed, which led to his 'enlightenment' of community driven integrated water management establishing the harmony of water, man and nature. This discovery now forms the foundation of watershed management, successfully tested in the villages of Arwari river basin in Alwar district of Western Rajasthan. A significant achievement of the Project was the revival of the five dry rivers in the Arwari basin, – Ruparel,Arvari, Sarsa, Bhagani, Jahajwali to perennial flows through construction of 11,000 water harvesting structures and artificial recharge.

Shashank Shekhar [5] highlighted environmental flow assessment and concluded that the need of the hour is environmentally sustainable development of river resource. A process based understanding of the river ecosystem will facilitate sustainable exploitation of this resource so that humanity can enjoy the river ecosystem benefits for several generations. The environmental flow concept helps in deciding the sustainable limits to river resource development. He added that in case of the river system poor river health, river rejuvenation can also be achieved by broadly aiming at restoring assured environmental flow in the river system and the planners and policy makers should necessarily integrate the concept of environmental flow with water resources development strategy.

Rajendra Singh [6] outlined the community driven approach for artificial recharge using traditional techniques of water harvesting. He emphasized on the fact that mobilization of civil society and the community for action on natural resource management and conservation for rural uplift in India is the way to save the environment and bring prosperity to farmers in Indian villages. Traditional methods of water harvesting were employed by the local communities led by TBS to rejuvenate a local river, recharge the ground water and re-green a village. In Alwar district, 8600 small water harvesting talabs in 1086 villages were built since 1985. This resulted in rise of water level in the shallow aquifer, increase of area under single and double crop, and increase in forest cover through social forestry and agro forestry. The villagers have also formed an 'Arvari Sansad' to frame rules of water use. The efforts towards water conservation have numerous positive impacts on the communities inhabiting the area. Employment opportunities have increased and migration has reduced substantially.

S. Muhar et al. [7] presented 20 river restoration cases throughout Europe that were investigated and the effect of restoration on ecosystem services was quantified, including provisioning (agricultural products, wood, infiltrated drinking water), regulating (flooding, nutrient retention, carbon sequestration) and cultural (recreational hunting and fishing, kayaking, biodiversity conservation, appreciation of scenic landscapes) services. The results showed a clear increase of ecosystem services, which was significant over and above considerable variability, and was mainly due to cultural and regulating services.

Maged Youssef et al. [8] envisioned that negligence of rivers can be one of the most important causes for the death of a city, whereas the revival of rivers has become a must for cities targeting re-living and development. He aimed to propose an urban strategy, as a solution to revive the forgotten rivers, through creating a cultural promenade on its shore. Beirut River in Lebanon was a forgotten river that burdens Beirut city with a lack of any decent quality of life, a dead polluted space, a forgotten area fragmenting the city, which used to be the main potential gathering space for nature, tourism and investments. He investigated Beirut River through urban and ecological analyses, aiming to design an urban strategy for reviving it by creating a cultural promenade enriched with public spaces and green areas, which can most probably enhance the quality of life in the city.

First, the inductive method was used through gathering data around the chosen case study; 'Beirut River', recognizing its different changes along history. Second was the field method, the authors visited certain sites in 'Beirut River', taking live photographs, sketching, and undertaking interviews with a sample of people living near the river. Beside the interviews, a written questionnaire was distributed on this sample to recognize their point of views on the river's existing problems and the possible ways to develop it. Third was the analytical method in which he analyzed results of interviews and the questionnaire. Finally, the deductive method was applied which deducts a strategy of certain solutions to revive the forgotten rivers by creating cultural activities on its banks. He finally concluded that focusing on a forgotten river and turning it into a sustainable basin may rehabilitate its city and reform its identity.

Sachin Tiwale et al. [9] analysed the Manjra River Rejuvenation work implemented in Latur (Maharashtra) under the leadership of Art of Living and RSS Jankalyan Samiti in the summer of 2016. He evaluated the validity of an approach of widening and deepening of Manjra river to quench the thirst of Latur city by analyzing hydrology of the basin. He critically investigated the process of implementation involving gross violation of multiple rules and regulations and uncovers the lacunas and inconsistencies existing at the policy level as well as in practices governing the management of rivers. The study analysed the contribution of the project towards its intended purpose and proved that the rejuvenation of Manjra river has not contributed even a single drop to the drinking water supply of Latur city, making all the efforts futile. After such massive work lauded as success and even after witnessing a good rainfall - 21% excess than normal rainfall in Marathwada (IMD 2016), Latur city was receiving water once in a week since past nine months. Moreover, the rejuvenation work raised concerns over increasing involvement of non-government organizations (NGOs) tinkering with the sensitive river ecosystem with their questionable knowledge claims towards mitigating water scarcity and role of government agencies who are custodians of rivers silently observing this process.

Ellen Wohl et al. [10] examined the contemporary practitioners approaches for river restoration and challenges for implementing restoration, which included clearly identified objectives, holistic understanding of rivers as ecosystems, and the role of restoration as a social process. It also examined challenges for scientific understanding in river restoration. These included : how physical complexity supports biogeochemical function, stream metabolism, and stream ecosystem productivity; characterizing response curves of different river components; understanding sediment dynamics; and increasing appreciation of the importance of incorporating climate change considerations and resiliency into restoration planning. Finally, it examined changes in river restoration within the past decade, such as increasing use of stream mitigation banking; development of new tools and technologies; different types of process-based restoration, growing recognition of the importance of biological-physical feedbacks in rivers, increasing expectations of water quality improvements from restoration and more effective communication between practitioners and river scientists.

Manu Bhatnagar et al. [11] made an attempt to revive Hindon river which is a 350 km long river and is dying a slow death due to substantial water abstractions and severe pollution loads it receives from various sources along its course. The condition was manifested in degrading ecological characteristics, contaminated ground and surface water and cultural disconnect with the river. This study used the existing data which was mainly regarding water quality and integrated them into a holistic scenario considering basin level features such as the water budget of the basin, the impact of using irrigation water imported from adjacent basins, the widespread cultivation of water guzzling crops such as sugarcane, the near extinction of forest cover in the basin. The holistic scenario yielded radically different solutions for conserving the river with field observations, primary investigations and basin level statistics. The basin level conservation plan showed that the health of the river cannot be isolated from the environmental health of the basin. The detailed study was hoped to help plug information gaps and assist in its conservation with the major objective to empower sound decision by govt. and public authorities.

J. van Alphen et al. [12] summarised that present river management is largely based on restricting natural dynamics by constructive measures, like groins and fixed beds. These measures are mono-functional, disturb natural sediment transports and degenerate natural habitats. In addition they concluded that it requires large investments and maintenance costs and restoration of natural conditions means that human activities have to cope with natural dynamics and the delicate balance between natural processes, measures and natural responses of the system. This requires a thorough understanding of margins and scales (time and spatial) of natural river dynamics and the interaction with measures. Constructive measures will give way to a ‘building with nature’ philosophy, like maintenance dredging. In addition, he emphasized on online monitoring information that will supply the river managers accurate information about the status of the river system to warn them for short term critical conditions or long term developments towards critical boundaries of functions or the river system. Much of this information will be accessible through Internet. To achieve these he focused on the key factor that natural river conditions, co-operation with floodplain authorities and management bodies is inevitable and said that this will requires skills in presentation of knowledge, decision making and negotiating and highlighted that Decision support systems (DSS) are important tools for the future river manager. Finally, management actions have to be based (and sometimes enforced) on a sound legal base and maintainable policy. This will require a more active and upgraded role of surveillance in the field.

Kałuża T et al. [13] focused on changes of hydro morphological conditions in a small lowland river recorded during an experiment carried out in the Flinta River, central Poland. He proposed a solution that was a pilot project of the construction of vegetative sediment traps (plant basket hydraulic structures - PBHS). A set of three PBSH were installed in the riverbed in one row and a range of hydraulic parameters were recorded over a period of three years (six measurement sessions). Changes of sediment grain size were analysed, and the amount and size of plant debris in the plant barriers were recorded. Plant debris accumulation influencing flow hydrodynamics was detected as a result of the installation of vegetative sediment traps. Moreover, various hydro morphological processes in the river were initiated. Additional simulations based on the detected processes showed that the proposed plant basket hydraulic structures can improve the hydromorphological status of the river.

Mark Everard [14] launched a successful programme of community-based groundwater recharge in three adjacent catchments (the Arvari, Sarsa and Baghani) in semi-arid north Rajasthan, India, led by the NGO Tarun Bharat Sangh (TBS) in order to determine how successes were achieved and could be replicated. TBS-led initiatives rebuilt traditional village governance structures and participation in community-designed and maintained water harvesting structures (WHSs), which were efficient both economically and in technical design using indigenous knowledge as it enhanced seasonal groundwater recharge enabled by WHSs regenerated aquatic, farmed and natural ecosystems, underpinning a positive cycle of interdependent social and economic regeneration. Locally appropriate, integrated social and technical solutions maintaining this positive cycle have increased the quality of ecosystems and the wellbeing of local people. They used the STEEP (Social, Technological, Economic, Environmental, Political) framework to stratify outcomes, exploring principles underpinning successful local and catchment-scale regeneration and drawing out lessons transferrable to similarly water-stressed regions.

Vyas [15] enlightened various initiatives to revive a river including its pathway from Gangotri to Diamond Harbor. He analysed that the Ganga receives 6087 MLD (millions of litres per day) pollutants and this quantity is more than 80 percent of the capacity of the sewerage treatment plants (STPs) installed. Therefore, there is a need for more STPs to be constructed to clean the river. Apart from STPs, other initiatives like riverfront development will also facilitate the cleaning programme. It was believed that the new initiatives will achieve the goal and will be replicated successfully in other parts of the country and could become a role model for other states. The Madhya Pradesh government has prepared a project to establish water plants and STPs in 24 cities where the pollution level is high in the river. The government proposed to use the treated water for agriculture, industries and fire services. Two projects are being finalised--one with the KFW (German mission) and the other with ADB, costing Rs 450-500 crore and Rs 1500 crore respectively. The projects will be implemented by the town and country planning department. The government’s plan is to clean Narmada river at 14 locations, while the remaining 10 locations are situated on rivers like Betwa, Shivna, Mandakni, Parvati, etc. The projects will get loans from the financial agencies and the state government will bear 30 percent cost from their own internal sources.

Subhojit Goswami [16] worked on a seven-year-long river rejuvenation project that aimed at bringing back River Kumudavathi by recharging groundwater. 18 mini-watersheds were planned over the whole river basin that spread across two districts: Bangalore Rural and Ramanagar. A total of 278 villages, covering an area of 460 sq km, was planned to be benefitted by the project. Water pools of 20 x 20 metres and a depth of five metres have been built along the streams to sustain water even in mid-summer and improve groundwater potential in the surrounding wells. The water level, according to locals, hasn't gone down in the last three summers. Boulder checks have been laid across the stream paths not only to slow down water flow but also hold the water for more time to allow percolation, leading to increased soil moisture. Planting trees along the river course was an important part of the plan and at least 45,000 plants have been planted to control soil erosion and increase soil moisture. The plants used here were tamarind, blackberry, jackfruit, arali (sacred fig), neem, torematti, mahogany and others. These plants helped in long-term soil restoration and enhance water absorption. By planting indigenous species they opened up opportunities for villagers to pursue alternative livelihood and develop a small-scale industry around them. The results of the rejuvenation activities in eight villages were encouraging. The residents of Makankuppe, Tavarekere, Mondigere and Teppadabeguru villages, on the outskirts of Bengaluru, have witnessed improved water availability in tanks and lakes ever since the project flagged off in the spring of 2013. Now, local communities are gradually taking up the responsibility for restoration in their villages. Nine gram panchayats have also pledged their support.

Speed et al. [17] focused on challenges for modern river restoration and summarised that ad hoc or small-scale river restoration interventions are unlikely to be able to respond to these challenges. Rather, the dynamic and complex nature of river ecosystems requires a more strategic approach. This requires a systems-based approach, recognising physical, socioeconomic, political and cultural aspects of the connected river and human systems, a greater role for river restoration planning in balancing trade-offs within the basin, an adaptive approach, which tests the assumptions that underpin restoration efforts and allows for changes to goals and approaches over time. Restoration strategies need to identify and respond to the links between external drivers, catchment and river processes, river health and the provision of ecosystem services and societal priorities. River restoration can be supported by a combination of policies, strategies and project-level plans .These different instruments should be aligned and develop synergies with one another, as well as with other regulatory and planning instruments. This includes river basin, development, and conservation plans.

Yuan et al. [18] used multitemporal Landsat TM data to map and monitor land cover change in the seven-county Twin Cities Metropolitan Area of Minnesota for 1986, 1991, 1998, and 2002. The study showed an increase of urban land from 23.7% to 32.8% of the total area between 1986 and 2002, while rural cover types of agriculture, forest, and wetland decreased from 69.6% to 60.5%.

Demissie et al. [19] used Landsat data from 1973 to 2015 to assess LULC changes and their causes in Libokemkem District of South Gonder, Ethiopia. Their study showed that about 60.1% of the land experienced changes in LULC in 42 years.

Barakat et al. [20] used ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) and Sentinel-2A MSI images acquired in 2001 and 2015, respectively, for quantifying the changes in the Eastern area of Béni-Mellal province, based on the supervised classification algorithm and the normalized difference vegetation index (NDVI). The study showed that changes in land use have resulted in the increase of forest area.

De Waroux et al. [21] estimated forest changes in argan woodlands (Morocco) using aerial photographs and satellite images between 1970 and 2007. They found that forest density decreased by 44.5% during the period of study.

Hammi et al. [22] studied land cover changes in Aït Bouguemez Valley located in the middle of the Central High Atlas Mountains (Morocco) in the Azilal province, using aerial photographs dated from 1964 and Spot 5 satellite image from 2002. They found that, in the past 38 years, forest ecosystems have been affected by a relative decrease of 20.7% of the total forest area, and 8.7% for the mean canopy cover.

Xiao-Wei Jiang et al. [23] performed a study through numerical simulation technique to determine influence of depth-decaying K and porosity on groundwater age. In the study, groundwater age distribution was modeled by numerically solving the two-dimensional steady-state groundwater flow and age transport equations for simple bounded rectangular basins but with a sinusoidally-varying top boundary representing both the ground surface and the water table, i.e., the unsaturated zone is negligible. The governing equations were solved with the finite-element method implemented in COMSOL Multiphysics. The results revealed that through numerical flow and transport simulations how depth-decaying hydraulic conductivity and porosity, phenomena often neglected but widely observed, leads to simultaneous aging and rejuvenation of groundwater in basins with topography-driven water flow. He quantified that the depth decaying K leads to aging while depth-decaying leads to rejuvenation of groundwater at given locations in a drainage basin. Acting together, these factors cause aging in deeper parts and rejuvenation near the discharge zones in the unit basin. Moreover, both the size of the rejuvenated zones, and the relative age of groundwater at the lowest discharge point decrease with the decay exponent while the maximum relative age in the basin increases with the decay exponent. For more complex scenarios with nested local and regional flow systems, zones of relative rejuvenation, which were located at the interface between flow systems in the mid to lower reaches of the basin, were found to be continuous, spanning from one end to the other end of the local age system, or lenses originating from one end of the local age system but disappearing with depth. The water with maximum relative age in the basin exists at the lowest discharge point when the decay exponent is very small, but moves to the deep part of the basin and increases exponentially with the decay exponent when it exceeds 0.0008 m^{-1}. The effects of depth-decaying hydraulic conductivity and porosity were considered when interpreting ages and residence times of subsurface fluids and surface waters fed by discharge from regional basins such as springs, lakes, rivers and wetlands although this was not practiced in most past studies.

3. CONCLUSION

Finally, with this information in hand, realistic target conditions for river rehabilitation programs can be identified for each reach, framed within a catchment-based vision. Working with local/ regional river managers, a physically-meaningful framework for management strategies for river rehabilitation and conservation would then be applied. Strategic restoration requires that restoration projects be prioritized at the appropriate scale, commonly the basin-level, and over a medium to long timeframe. Prioritization undertaken at a local scale or over a short timeframe can result in significant inefficiencies. Prioritization of projects should be undertaken based on selection criteria that reflect the overall goals and objectives. These should be used to assess the range of potential restoration opportunities. The approach to prioritization needs to be tailored to the situation, taking account of the availability of information on the target river basin. Of the many approaches available, multi-criteria decision analysis is becoming increasingly popular as a method for making assessments that consider a range of factors. Sustaining river restoration outcomes require regulatory measures to be in place to protect benefits realised from river restoration and prevent them being undermined by activities within the basin, including future development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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