River.Space.Design.

Planning Strategies, Methods and Projects for Urban Rivers

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Planning Strategies, Methods and Projects for Urban Rivers

Second and Enlarged Edition

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Foreword

Herbert Dreiseitl

Is not every river quite extraordinary? No two rivers are identical in their morphology, limnology and atmosphere. Rivers, the veins of our landscape, are thrilling, living entities. One day a river can reflect the gentle dance of sunlight on the water; the next it is a foaming torrent, tearing away and carrying off all that stands in its way. Rivers are far more than moving water – this would be an inadmissible simplification. They are the inimitable interplay of a body of flowing water with its bed – the shaping of its banks and its surroundings. These features make each river a unique personality with its own character, recounted in legends, songs and stories since time immemorial and still familiar to us today.

Nearly all our cities and cultural spaces grew up on riverbanks, and their development and the prosperity of their inhabitants also tell a story of their relationship with the water. Trade, transport and industry flourished because of the navigability of these rivers and their significance as transport routes. For centuries, rivers were an important source of food for people settled close to their banks. Water and the shaping of water landscapes by human hand are the foundation of our cultures.

However, a river can be both a blessing and a curse! It is no coincidence that humanity's first engineering constructions were designed to regulate rivers; their purpose was always to protect settlements from the raging, destructive forces of floodwater. Conversely, it was the taming and regulation of watercourses that, in many places, made it at all possible for cultural landscapes to evolve.

Nowadays, our rivers have to a large extent been straightened and transformed into feats of engineering – their original form and the way they shape the landscape are barely perceptible. However, it is not only since the catastrophic floods of recent years, the consequences of climate change and the decline of species diversity beside and in the water that the total control and one-sided technical perception of our straitjacketed rivers have increasingly been called into question. Owing to the formulation and implementation of the EU Water Framework Directive, which aims to achieve good conditions in all European watercourses, and to the steady growth in public awareness, an increasing amount of attention is being directed towards rivers.

This is not solely a question of hydraulics and technical flood defences. The opportunities offered by rivers for recreational use are becoming more and more important as we rediscover them as places for contemplation and recuperation. With considerable improvements in water quality through better wastewater treatment and rainwater management, an urban river is no longer a city's shunned, stinking backwater; it is its fairest face and the first impression visitors gain of a town. Thus the aesthetics of a watercourse space, expressed in its morphology and the form of its banks, becomes ever more significant; the way we deal with a river is shifting from hard, technical hydraulic engineering to semi-natural biological engineering for shaping watercourses as multifunctional places for all flora, fauna and people along and in the water. In accordance with contemporary expectations, we want rivers in a good condition and well-designed – rivers that, as living organisms, are also a fount of vitality for city dwellers.

How are such aims to be achieved? Which examples are worthy of emulation and which factors are decisive in the practical implementation? These are today's burning questions in watercourse design and water space revitalisation.

It is for precisely these reasons that the appearance of such a book as *River.Space. Design*, now available in its second and enlarged edition, is long overdue. With its excellently presented content, crystal-clear structure and methodology, this book is addressed to experts and interested laymen alike. For decision-makers in politics and public administration, the interdisciplinary connections are illuminating, and planners, engineers and contractors will find valuable suggestions for their own work. Last but not least, *River. Space.Design* is a rich source for everyone with a professional interest in water, a spring from which all may drink their fill!

Let us hope that our rivers, even in a controlled form, retain the potency of their shape and ancient power to create and enliven urban landscapes for all citizens.

1

Fundamentals

Introduction

Elbe, HafenCity Hamburg. Many cities are once again rediscovering their rivers. In these new waterside landscapes and waterfronts, responses to the multifarious demands of town planning, flood protection, ecology and amenity are interwoven in the most innovative ways.

Objectives

Urban rivers and their environs have undergone a dramatic metamorphosis: having been long neglected, they are currently being developed into the most prestigious sites in town. This in its turn places a multitude of new requirements upon them, making their design disproportionately more demanding – urban riverscapes are to expected become attractive open spaces and a powerful locational factor in the economic competition between cities; the 2000 EU Water Framework Directive requires high ecological standards throughout, and at the same time urban development is exposed to extremes of weather and flooding as a consequence of climate change. All these requirements have to be met by urban water-course systems – often within the most restricted of spaces.

Impetus for action from EU directives Seen in water management terms, predictions of climate change and isolated flood and low-flow emergencies have directed attention to the necessity of adapting urban river spaces. The prognosis of longer periods of drought, more frequent heavy downpours and rising sea levels has led to the critical examination of flood protection systems and of cities' water supply and wastewater systems. The 2007 EU Flood Risk Management Directive committed member states to carry out precise evaluations of the dangers posed by flooding and to draw up management plans to improve flood protection. The resulting necessary mitigation works are bringing change to the urban environment, both above and below ground.

In parallel, the EU Water Framework Directive prioritises ecological objectives such as better water quality and watercourse structure: The Directive requires member states to 'protect, enhance and restore all bodies of surface water' [WFD, Article 4]. Extensive surveys of the status quo are now being followed by many projects to fulfil the Directive's requirements. Professional associations for water management such as the Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. [DWA 2009] are also devising their own regulatory frameworks for the design and enhancement of watercourses in the urban environment, and calling for holistic approaches to reconcile the sometimes contradictory claims upon them.

In recent years, water in the city has been attracting increasing attention from an urban planning point of view. Cities are clearly turning their faces back towards their rivers and lakes: waterside living and work environments, city beaches, port regeneration and new riverside promenades are being developed to improve the quality of urban life. Responding to the relevance of this issue, for some time now many projects to redevelop the urban riparian landscape – both the watercourse itself and its banks – have emerged and been implemented. Taken as a whole, the performance requirements for these water-courses are complex, and demand close collaboration between the various stakeholders: water management professionals, town planners, architects, landscape architects, nature conservationists and representatives of other fields. Because of the multifarious nature of urban rivers, every project quickly becomes an interdisciplinary challenge; above all the conflicting interests of safety and the search for a new closeness to water places tremendous demands on designers' capabilities.

Today, many successful redevelopment measures have been undertaken around the world and are documented in diverse professional journals, books and databases. For those now faced with designing an urban river space, knowledge of good reference projects is important, but the search is laborious and time-consuming and the results tend to be unsatisfactory because each case study is too specific to be applicable to one's own planning task. What has been lacking up to date is an overview that presents the wide diversity of design possibilities for urban river spaces in a systematic and transferable way. This book aims to fill this gap and serve as a primer and reference for designers of urban river spaces, and pursues the following primary objectives:

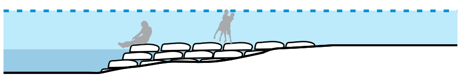
1. Create transferable knowledge From the built designs for urban river spaces that are exemplary for various reasons, the design tools were abstracted and sorted by typology. A catalogue of design strategies derived from this makes it easier for practitioners to transfer content to their own design tasks. Graphically clear presentations facilitate fast comprehension of the strategies and design tools and their spatial relevance.

2. Find an interdisciplinary language The typological order that has been devised integrates key aspects from all disciplines involved in the design of urban river spaces. This interdisciplinary presentation method and language promotes collaborative project work between landscape architects, ecologists, architects and urban planners – something of the utmost importance in the light of the complexity of designing urban river spaces.

3. Describe the processes of watercourses Rivers are constantly in motion – to say this is to make the obvious point that river spaces are subject to continuous transformation through the various water processes. Process orientation is therefore indispensable when designing river spaces, and should be reflected in the way a design is presented. Many presentations of designs for river spaces, however, concentrate on just one state or situation and thus fall short of their potential. To enable the principles of processual scenarios within watercourse systems to be understood, visual presentation forms and vivid descriptions of the water-related processes have been devised for this book.

4. Establish connections between ecology, flood protection and amenity The significance of process-oriented design for the three major thematic fields of river design in urban space – ecology, flood protection, and amenity – is made plain. Possible synergies (but also conflicts) between these three thematic foci in spatial design are revealed.

The interdisciplinary composition of the team of authors, comprised of landscape architects and hydraulic engineers, made it possible to examine the projects selected for the book from various points of view. Interviews with local experts, literature research and the team's own analyses were abstracted into design strategies, and a systematics of design tools and measures was devised. The basis of this systemisation was an analysis of watercourse processes, an understanding of which forms the basis for a conceptional categorisation and description of the various design possibilities.



D1.3
Laid stone groynes

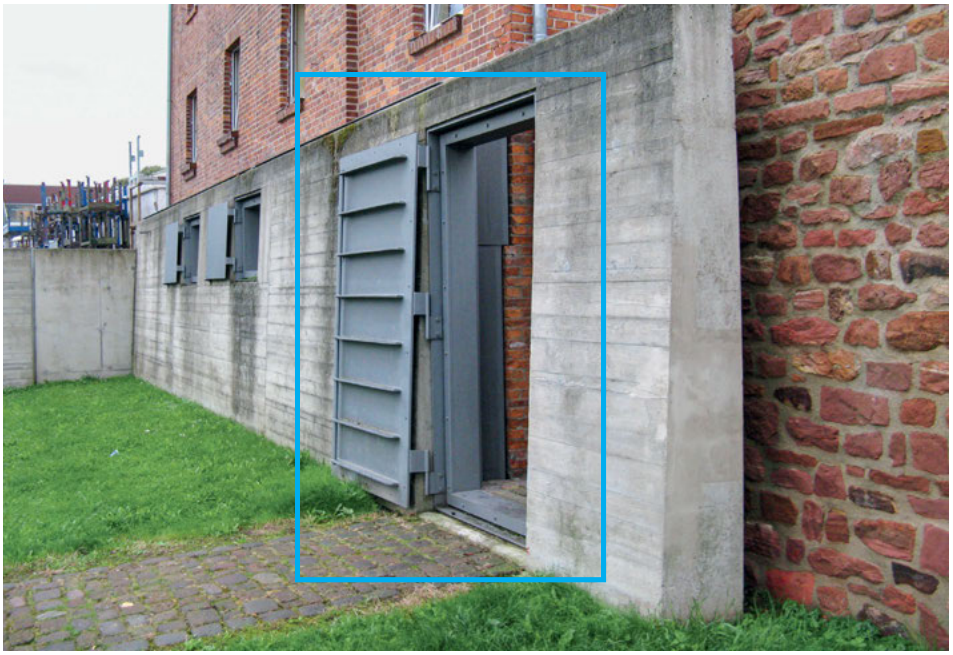
Two examples of transferable design tools from the projects examined: as part of the restoration of the River Birs in Basle, stone groynes were set across the current; in Wörth on the River Main spectacular folding floodgates were integrated in the old city wall when it was adapted as the flood protection barrier.

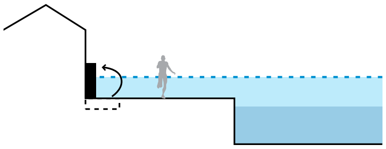
Selection of projects

Preparation for this book began with selecting examples of good practice which fulfilled predefined criteria. The selected projects address at least two of the three objectives – ecology, flood protection, and amenity; and the projects pursue an integrative approach that combines at least two of the above mentioned requirements in the sense of multiple coding so that the restricted urban space is used in different ways and public funds can be effectively employed. Projects that pursue a single objective have been included only in exceptional cases. Projects with differing intentions and characters were deliberately juxtaposed. Ecological, hydraulic or architectural objectives may have provided the initial impulse for the project. Correspondingly, the composition of the editorial team and the design languages of the projects are diverse. Contrasting the various projects, especially according to the way they addressed river processes, engenders new interdisciplinary insights and synergies.

Secondly, each project demonstrates a conscious design attempt to deal with river dynamics. The spectrum ranges from the smallest interventions in a riverside promenade to large-scale processes of altering the riverbed.

Thirdly, at least one particularly innovative design tool should be present; each project addresses an aspect that distinguishes it from other projects, or exemplifies a specific aspect not found in other projects. The overall design quality and uniqueness of the projects were not the primary selection criteria. The rivers in the various reference projects are very diverse. Consequently, not all the design tools or measures are transferable to all other projects.





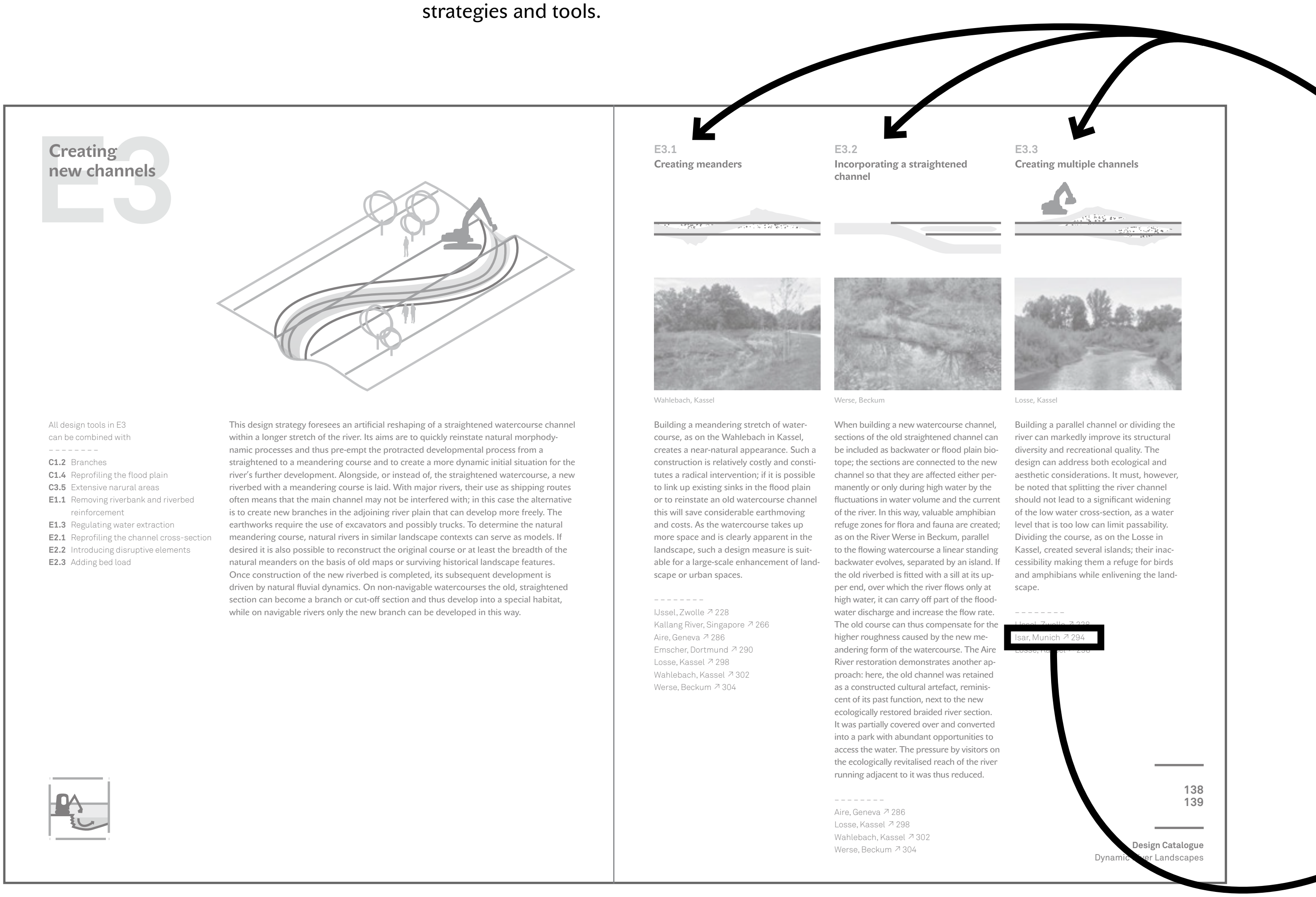
B5.3
Fold-out protection elements

The book's structure

The book is divided into three large parts:

The book begins with a fundamental description of the essentials of high-quality design of urban river spaces and the various process typologies that shape rivers, their appearance and their transformations (Part 1, Fundamentals). These fundamentals lay the theoretical foundation for the heart of the book – a catalogue of systematically organised design strategies with their respective design tools and measures. The catalogue is divided into five different 'Process Spaces' (A to E) in which the water processes in the defined spatial area of the river are variously shaped by design measures (Part 2, Design Catalogue)

The third part (Part 3, Project Catalogue) contains the projects researched as examples of best practice from which the design tools are derived. These references are fully described with illustrations and plans, and the contexts in which they came into being. The projects are grouped under the five Process Spaces, and then ordered alphabetically by the name of the river. Additionally, the appendix contains an extensive specialist glossary and an overview of all projects, as well as additional project suggestions, their design strategies and tools.



E3

Creating new channels

All design tools in E3 can be combined with

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C1.2 Branches
C1.4 Reprofiling the flood plain
C3.5 Extensive narural areas
E1.1 Removing riverbank and riverbed reinforcement
E1.3 Regulating water extraction
E2.1 Reprofiling the channel cross-section
E2.2 Introducing disruptive elements
E2.3 Adding bed load

This design strategy foresees an artificial reshaping of a straightened watercourse channel within a longer stretch of the river. Its aims are to quickly reinstate natural morphodynamic processes and thus pre-empt the protracted developmental process from a straightened to a meandering course and to create a more dynamic initial situation for the river's further development. Alongside, or instead of, the straightened watercourse, a new riverbed with a meandering course is laid. With major rivers, their use as shipping routes often means that the main channel may not be interfered with; in this case the alternative is to create new branches in the adjoining river plain that can develop more freely. The earthworks require the use of excavators and possibly trucks. To determine the natural meandering course, natural rivers in similar landscape contexts can serve as models. If desired it is also possible to reconstruct the original course or at least the breadth of the natural meanders on the basis of old maps or surviving historical landscape features. Once construction of the new riverbed is completed, its subsequent development is driven by natural fluvial dynamics. On non-navigable watercourses the old, straightened section can become a branch or cut-off section and thus develop into a special habitat, while on navigable rivers only the new branch can be developed in this way.

E3.1
Creating meanders

Wahlebach, Kassel

Building a meandering stretch of watercourse, as on the Wahlebach in Kassel, creates a near-natural appearance. Such a construction is relatively costly and constitutes a radical intervention; if it is possible to link up existing sinks in the flood plain or to reinstate an old watercourse channel this will save considerable earthmoving and costs. As the watercourse takes up more space and is clearly apparent in the landscape, such a design measure is suitable for a large-scale enhancement of landscape or urban spaces.

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IJssel, Zwolle ↗ 228
Kallang River, Singapore ↗ 266
Aire, Geneva ↗ 286
Emscher, Dortmund ↗ 290
Losse, Kassel ↗ 298
Wahlebach, Kassel ↗ 302
Werse, Beckum ↗ 304

E3.2
Incorporating a straightened channel

Werse, Beckum

When building a new watercourse channel, sections of the old straightened channel can be included as backwater or flood plain biotope; the sections are connected to the new channel so that they are affected either permanently or only during high water by the fluctuations in water volume and the current of the river. In this way, valuable amphibian refuge zones for flora and fauna are created; as on the River Werse in Beckum, parallel to the flowing watercourse a linear standing backwater evolves, separated by an island. If the old riverbed is fitted with a sill at its upper end, over which the river flows only at high water, it can carry off part of the floodwater discharge and increase the flow rate. The old course can thus compensate for the higher roughness caused by the new meandering form of the watercourse. The Aire River restoration demonstrates another approach: here, the old channel was retained as a constructed cultural artefact, reminiscent of its past function, next to the new ecologically restored braided river section. It was partially covered over and converted into a park with abundant opportunities to access the water. The pressure by visitors on the ecologically revitalised reach of the river running adjacent to it was thus reduced.

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Aire, Geneva ↗ 286
Losse, Kassel ↗ 298
Wahlebach, Kassel ↗ 302
Werse, Beckum ↗ 304

E3.3
Creating multiple channels

Losse, Kassel

Building a parallel channel or dividing the river can markedly improve its structural diversity and recreational quality. The design can address both ecological and aesthetic considerations. It must, however, be noted that splitting the river channel should not lead to a significant widening of the low water cross-section, as a water level that is too low can limit passability. Dividing the course, as on the Losse in Kassel, created several islands; their inaccessibility making them a refuge for birds and amphibians while enlivening the landscape.

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Isar, Munich ↗ 294

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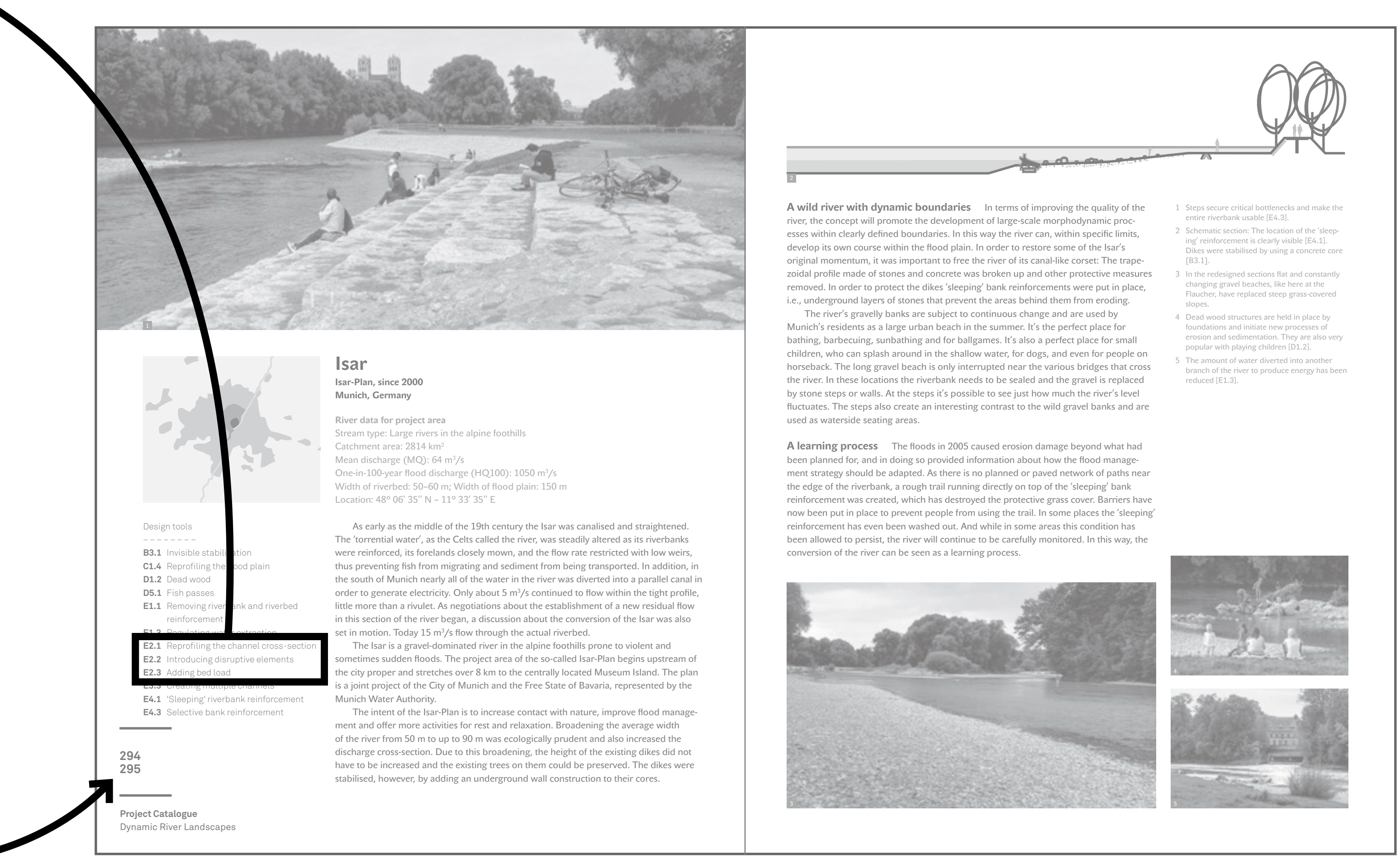
Design Catalogue
Dynamic River Landscapes

The design tools and strategies in Part 2 and the project examples in Part 3 are cross-referenced.

Connections The second and third parts are cross-referenced to be used in parallel. Several ways of reading the book are possible: in one direction, the abstracted design strategies in Part 2 can be put into tangible context by referring to the project examples in Part 3, as all the design tools are linked by references to those projects that apply them. In the other direction, the projects in Part 3 make reference to the design tools in Part 2. When the readers' attention is caught by a tangible element of a project they can follow the reference to more closely examine the respective design tool and thus ascertain whether this element is transferable to their own project.

The references are in the form of small arrows followed by a page number, directing the reader to the page in question. This linking structure makes it possible to approach the book in several different ways; any of the three parts – Fundamentals (1), Design Catalogue (2) or Project Catalogue (3) – is an appropriate starting point.



Isar

Isar-Plan, since 2000
Munich, Germany

River data for project area
Stream type: Large rivers in the alpine foothills
Catchment area: 2814 km²
Mean discharge (MQ): 64 m³/s
One-in-100-year flood discharge (HQ100): 1050 m³/s
Width of riverbed: 50–60 m; Width of flood plain: 150 m
Location: 48° 06′ 35″ N – 11° 33′ 35″ E

Design tools

- **B3.1** Invisible stabilisation
- **C1.4** Reprofiling the flood plain
- **D1.2** Dead wood
- **D5.1** Fish passes
- **E1.1** Removing riverbank and riverbed reinforcement
- **E1.3** Regulating water extraction
- **E2.1** Reprofiling the channel cross-section
- **E2.2** Introducing disruptive elements
- **E2.3** Adding bed load
- **E3.3** Creating multiple channels
- **E4.1** 'Sleeping' riverbank reinforcement
- **E4.3** Selective bank reinforcement

As early as the middle of the 19th century the Isar was canalised and straightened. The 'torrential water', as the Celts called the river, was steadily altered as its riverbanks were reinforced, its forelands closely mown, and the flow rate restricted with low weirs, thus preventing fish from migrating and sediment from being transported. In addition, in the south of Munich nearly all of the water in the river was diverted into a parallel canal in order to generate electricity. Only about 5 m³/s continued to flow within the tight profile, little more than a rivulet. As negotiations about the establishment of a new residual flow in this section of the river began, a discussion about the conversion of the Isar was also set in motion. Today 15 m³/s flow through the actual riverbed.

The Isar is a gravel-dominated river in the alpine foothills prone to violent and sometimes sudden floods. The project area of the so-called Isar-Plan begins upstream of the city proper and stretches over 8 km to the centrally located Museum Island. The plan is a joint project of the City of Munich and the Free State of Bavaria, represented by the Munich Water Authority.

The intent of the Isar-Plan is to increase contact with nature, improve flood management and offer more activities for rest and relaxation. Broadening the average width of the river from 50 m to up to 90 m was ecologically prudent and also increased the discharge cross-section. Due to this broadening, the height of the existing dikes did not have to be increased and the existing trees on them could be preserved. The dikes were stabilised, however, by adding an underground wall construction to their cores.

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Project Catalogue
Dynamic River Landscapes

A wild river with dynamic boundaries In terms of improving the quality of the river, the concept will promote the development of large-scale morphodynamic processes within clearly defined boundaries. In this way the river can, within specific limits, develop its own course within the flood plain. In order to restore some of the Isar's original momentum, it was important to free the river of its canal-like corset: The trapezoidal profile made of stones and concrete was broken up and other protective measures removed. In order to protect the dikes 'sleeping' bank reinforcements were put in place, i.e., underground layers of stones that prevent the areas behind them from eroding.

The river's gravelly banks are subject to continuous change and are used by Munich's residents as a large urban beach in the summer. It's the perfect place for bathing, barbecuing, sunbathing and for ballgames. It's also a perfect place for small children, who can splash around in the shallow water, for dogs, and even for people on horseback. The long gravel beach is only interrupted near the various bridges that cross the river. In these locations the riverbank needs to be sealed and the gravel is replaced by stone steps or walls. At the steps it's possible to see just how much the river's level fluctuates. The steps also create an interesting contrast to the wild gravel banks and are used as waterside seating areas.

A learning process The floods in 2005 caused erosion damage beyond what had been planned for, and in doing so provided information about how the flood management strategy should be adapted. As there is no planned or paved network of paths near the edge of the riverbank, a rough trail running directly on top of the 'sleeping' bank reinforcement was created, which has destroyed the protective grass cover. Barriers have now been put in place to prevent people from using the trail. In some places the 'sleeping' reinforcement has even been washed out. And while in some areas this condition has been allowed to persist, the river will continue to be carefully monitored. In this way, the conversion of the river can be seen as a learning process.

1 Steps secure critical bottlenecks and make the entire riverbank usable [E4.3].
2 Schematic section: The location of the 'sleeping' reinforcement is clearly visible [E4.1]. Dikes were stabilised by using a concrete core [B3.1].
3 In the redesigned sections flat and constantly changing gravel beaches, like here at the Flaucher, have replaced steep grass-covered slopes.
4 Dead wood structures are held in place by foundations and initiate new processes of erosion and sedimentation. They are also very popular with playing children [D1.2].
5 The amount of water diverted into another branch of the river to produce energy has been reduced [E1.3].

Prerequisites for Planning Urban River Spaces

Reshaping river spaces in towns and cities can lead to simultaneous ecological improvement, regeneration of the urban habitat, and flood mitigation. The River Birs in Basle in 1987, and after revitalisation in 2005.

If the complex task of designing urban river spaces is to be undertaken successfully, in our view three fundamental prerequisites are required: firstly, the need to take into account the multiple demands made on urban river spaces – multifunctionality; secondly, constructive collaboration between professionals responsible for the design – interdisciplinarity; and thirdly, observing the principles and in-depth knowledge of the various water processes – process orientation.

Multifunctionality

It is particularly in towns that the hybrid character of river spaces manifests itself: they are both artificial and natural at one and the same time. Urban rivers are spatially confined, artificially controlled hydraulic infrastructures. They are also important recreational spaces for city dwellers. Furthermore, they are linear ecosystems that link cities and regions to their entire catchment areas – the water from upstream regions flows through downstream regions and thus creates a feeling of community and a dependent relationship between riverside inhabitants, as changes in the upper reaches of a river always have consequences for the lower reaches.

The question to be posed about the current restoration and restructuring of river systems in towns and cities is: How can the multifarious functional demands on the design of urban water spaces be combined? How can these demands be reconciled with the natural internal dynamics within the water itself? In the past, changing the internal dynamics of watercourses caused various problems; the attitude that urban spaces close to water could only be used to their full potential when they were protected from flooding and not subject to the river dynamics led to strict limitations on the space within the direct sphere of influence of the water or even to building over the water. Together with the frequently very poor water quality in the past, the result was that water spaces vanished almost completely from the awareness and daily life of city dwellers. At the same time, many aquatic plants and animals disappeared from the technically modified rivers; weirs and ground sills presented insuperable obstacles for many species and canalisation with its hard construction methods for riverbeds and banks destroyed natural habitats. A further cause of habitat degradation is the frequently radical clearance and dredging of watercourses with the sole aim of optimising drainage and flow rate with no regard for ecological and aesthetic interests. Despite such measures, a narrow watercourse cross-section is often too small to safely discharge the volumes of runoff water which result from increased surface sealing preventing infiltration and more extreme rainfall events. The objective of urban flood protection until recently was usually to discharge the flood wave downstream as fast as possible. It is only in the past few years that a new approach has asserted itself: of keeping precipitation where it falls whenever possible through infiltration, retention and storage of rainwater, and thus moderating the effects on downstream areas.

Interplay between ecology, flood protection and amenity In this book an understanding of the internal dynamic processes of rivers serves as the starting point for all sustainable interdisciplinary projects with a view to contributing to the better integration of the many and various needs and challenges encountered in river restoration design. Three aspects dominate fulfilling this objective: more space for the water, more space for plants and animals, and more space for people. It is a matter of demonstrating the possibilities of a new synergy between what often appear to be incompatible demands. To this end, we will highlight aspects of the various design approaches and project examples which demonstrate the interplay of ecology, flood protection and amenity.

When water has plenty of space, as it does in the Flaucher urban recreational landscape on the River Isar in Munich, reconciling these demands presents no great difficulties. The model of a natural river with a strong internal dynamic and riverside flood meadows that also serves, as does the Flaucher, as an important recreational space with a direct connection to the water, can, however, only be created within urban areas in the rarest of cases due to the otherwise more typical lack of space. Addressing this, one particular focus of this book is on project examples and design approaches that combine responses to the various demands within very restricted spaces, aiming to stimulate creative and intelligent combinations, overlapping and interleaving of the various uses even when the possibilities appear limited – and even in places where the initial impetus for planning intervention was only one particular demand.

Interdisciplinarity

The future design of water spaces presents a challenge that is not to be met by one discipline alone. In the light of this it makes sense to observe and reflect upon the mutual conditionality of hydraulic, ecological, urban planning and landscape architectural decisions.

Devising a common language Often, collaboration is impeded by the lack of a common language, of basic technical knowledge of the other professional fields, and of interdisciplinary working structures. Projects are frequently prepared under the aegis of just one discipline, and the other disciplines, only brought in at a later date, are denied the opportunity to be involved in the fundamental conceptional planning decisions.

In the course of revitalising urban rivers with the aim of improving flood protection and better integrating water in the townscape as a tangible presence, there have recently been numerous interdisciplinary design competitions and projects that have stipulated close cooperation between hydrologists, landscape architects and urban planners. These projects, however, lack a systematic foundation as they focus on single cases. Nevertheless, they offer the basis for creating new planning coalitions and innovative planning structures. The composition of and collaboration within planning teams has a crucial influence on the final quality of the projects.

System comprehension as a basis This book seeks to contribute to a better understanding between professional disciplines. It is not intended to be read by just one profession but by representatives of all the professions involved in designing with water. By presenting the project examples and their design approaches from three specific points of view – ecological revitalisation, improving flood protection and integrating town planning and/or open space planning – we address the specific interests of different professional disciplines. Concurrently, presenting the cross-disciplinary nexuses stimulates better understanding of the complex demands on water space design; the basis of collaboration is served most strongly by a systematic understanding of water processes and a common language. In these respects, River.Space.Design can serve as a handbook for interdisciplinary teams and a basis for reaching mutual understanding.

The basis of interdisciplinary work on rivers is devising a shared language and an over-arching understanding of systems. This was the approach adopted for the joint creative work at the 2009 IBA laboratory on the consequences of climate change in Hamburg which also included fieldtrips.

Process orientation

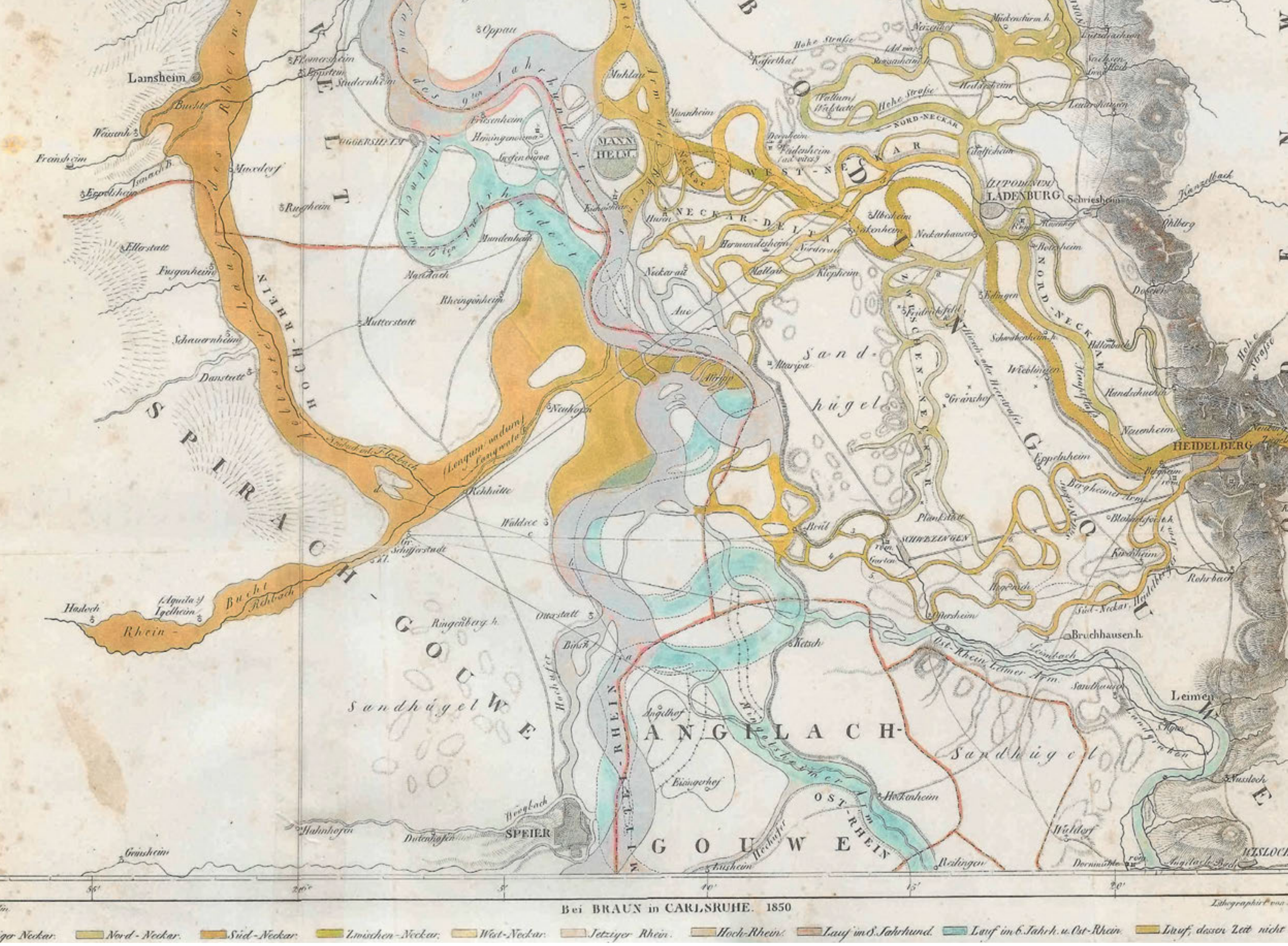
Can urban river spaces be designed without taking account of the various processes of water fluctuation and the power of water? Of course not – but glancing through publications on the design of river spaces will reveal hardly any presentations of various processual states; usually one set of water conditions (regarded by the designer as the ideal state) is shown, with no documentation or illustration of how the design responds to the changing rhythms of the water.

Designing with dynamic forces Reluctance to address processes can be found not only in the design of riverside areas; it appears to be a basic problem of all spatial design. Twenty years ago now, the American landscape architect George Hargreaves asked: 'Why are static landscapes – frozen in space and time – the norm? Maybe it's time to change that and the concept of beauty.' [Hargreaves, 1993, p. 177]. To the present day, not much has changed to dispute this insight, and most clients (but also some designers) prefer glossy presentations of a project on a sunny day with normal water levels. We consider this less than productive, and wish this book to contribute to a processual understanding of design. Two main aspects are implicit in this objective: for one, we are concerned with a better comprehension of river dynamics and for this we have devised a new systematic, to be found in the following pages; for another, we use presentation methods that can illustrate the complex temporal-spatial interplay between water dynamics and design tools. Conveying the dynamic processes is essential if one is to put across ideas on designing urban river spaces effectively.

Process-oriented work as task for the future Urban river spaces are an excellent research subject for such process orientation for in them natural processes, civil engineering systems and designed landscapes are superimposed, constantly informing and reshaping one another in response to shifting conditions such as climatic change.

The processual understanding and presentation methods devised for this book make it possible, because of their transferability, to consider every conceivable river space situation as a process and to design for it accordingly. Each project presents its own challenges, every body of water reacts differently, and every body of water has a different available space. Furthermore, it has to be accepted that the development of a project cannot be completely foreseen. Process-oriented designing means thinking and planning in terms of options, follow-up measures and responses to spontaneous developments. For many a local authority and planner, this 'evolutionary' way of designing is new; nevertheless, it is of great importance for the future.

Process orientation is an important design principle for more than river spaces; it applies to all kinds of landscape, for they are shaped by a multiplicity of cultural and natural processes: settlement growth, transport access, the changing seasons, vegetation growth, geological processes and climatic change. Our hope is that the systematic typologies and presentation methods devised for this book will offer a model for future process-oriented research and design, especially for urban landscapes.



Water Spaces and their Processes

Historical map of the channel development of the Rivers Rhine and Neckar near Mannheim. The colours indicate how the river channels have shifted over time from the 6th century until 1850.

The word ‘process’ is derived from the Latin procedere, meaning ‘to advance, to proceed’; ‘process’ is a term for the directed course of an event – it is about movement, a dynamic, and an event that observes certain rules and regularities.

‘You could not step twice into the same river’ is Heraclitus’ famous dictum. This could also be understood to mean that water and processes can never be regarded as separate. The very currents and eddies of a river at any one moment show it to be a strongly dynamic element in the landscape, and observations over a longer period reveal that the entire river space exists in a constantly advancing, continuous process of change.

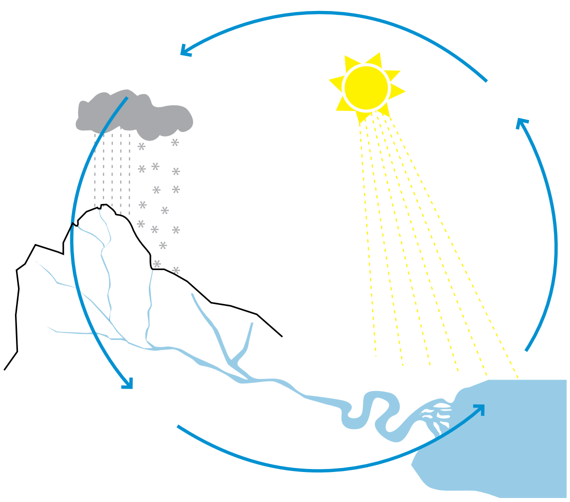
Rivers are dynamic The entire scope of a river’s dynamic is hard to comprehend at first glance; nowadays it is to a large extent deliberately restricted and thereby mostly forgotten. Even so, the forces from which it is derived are ever-present and always potent.

Mostly it is just the rise and fall of the water level which is clearly perceived by people, above all at times of extreme high or low water when changes are very noticeable. The extent to which bodies of water which are not subject to human influences are dynamic only becomes clear when observing the historical development of a watercourse over long periods. The constant shifting of the river’s course that can shape entire landscapes creates a complex, continually changing system – although the processes cover timescales that we cannot directly comprehend. The present course of a river is, seen in this light, no more than a snapshot in time of this ongoing process.

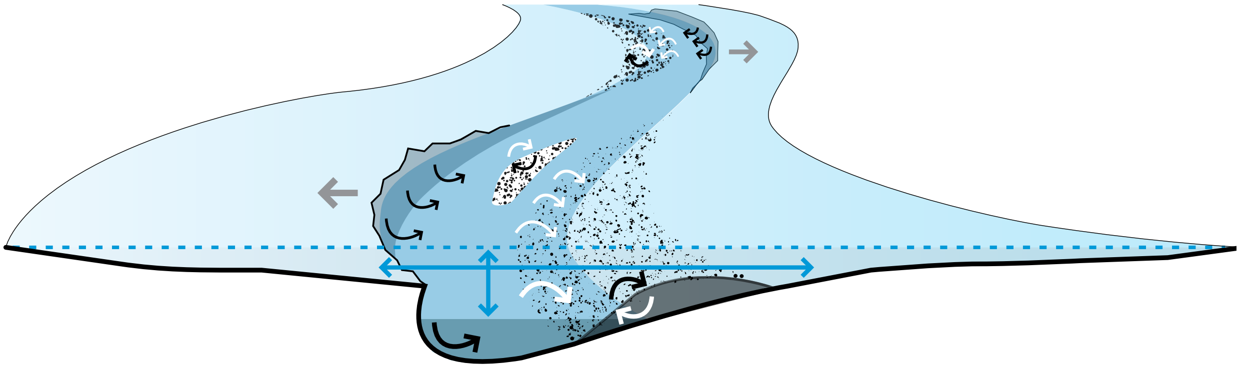
Processes and their driving forces

The source of energy driving every dynamic process is the sun. It causes water to evaporate and the vapour rises to great heights where it condenses and turns into snow or rain. The potential energy stored in this way is transferred into kinetic energy when water falls as rain and flows down hills. The steeper the gradient, the more energy can be unleashed. In contact with the earth or rock, the kinetic energy of water can erode material and thus shape the terrain. The tractive force of flowing water carries the released material downstream; in principle, through erosion and sedimentation, rivers are continually wearing down higher-lying landscapes and raising the lower-lying river spaces.

These processes are not constant and linear but occur in irregular phases: there are quieter and more dynamic phases but also sudden events such as cloudbursts and resulting flooding, through to natural disasters such as landslides or the avulsion of a loop in a river.



The energy that drives all the dynamic processes of a river and on which the natural water cycle is based is solar. When the energy-laden water meets the ground it creates a variety of river landscapes.



Types of processes

The processes that occur in flowing water are highly complex. Four spatially active processes are distinguished: vertical water level fluctuation and horizontal spread (blue arrows), sedimentation shift (circular arrows), and the changing course of a river channel (grey arrows) through erosion (black arrows) and sedimentation (white arrows).

Rivers are highly complex systems within which interconnected processes occur simultaneously: physical, chemical and biological processes exert reciprocal influences. This book focuses on the spatially operant physical processes, as they are predominant for the shaping of river spaces. Essentially, it distinguishes between two types of dynamics, each with two sub-processes:

1. Temporary flow fluctuations
Sub-process 1: vertical water level fluctuation
Sub-process 2: lateral spread of the water

2. Morphodynamic processes
Sub-process 1: sedimentation shift within the river
Sub-process 2: self-dynamic river channel development

Temporary flow fluctuations The periodical spread and withdrawal of water, caused by the discharge dynamics of the river, occupies spaces temporarily. Water fluctuations are expressed both in rising water levels and in lateral spread across a flood plain. Fluctuations in water level are completely reversible; the watercourse returns to its original state.

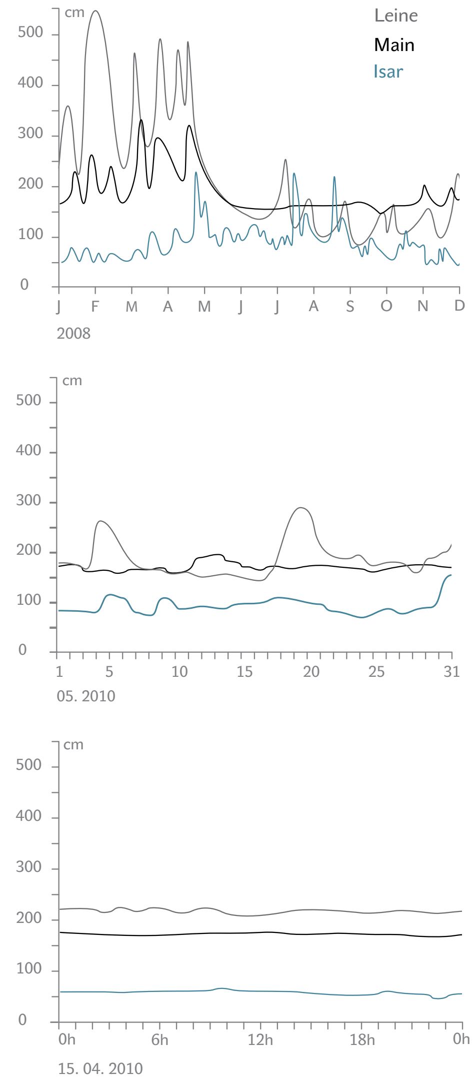
The volume of water that passes along a river varies dramatically through the year according to precipitation and snowmelt. The discharge volume differs in every river

Lateral spread of water when discharge levels rise dramatically leads to regular flooding of the river plain, as here on the River Leine near Hanover.

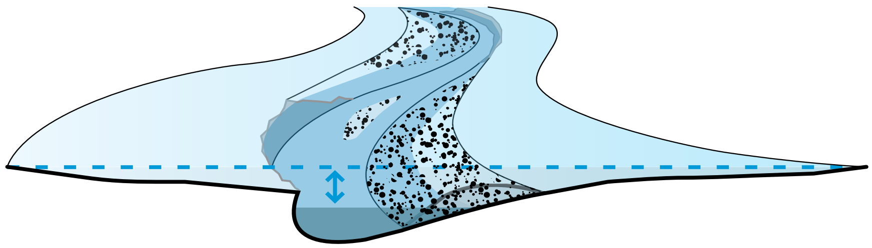
system and also at every point within a river system, depending on the extent and characteristics of the catchment area and the local climate. Heavily built-up or steep catchment areas lead to more extreme discharge peaks in the river. Heavy rain causes high water conditions that flow downstream in a wave from the rainfall location.

Sub-process 1: vertical water level fluctuations The discharge and resultant level of a river changes almost daily, although mostly it is only extreme high or low water events that are noticed. The water level in the river and during floods in the flood plain is in direct correlation to discharge from the catchment area. According to the space available and the roughness of the riverbed, the banks and the river foreland, a certain discharge rate causes a corresponding water level. This relationship can be described for single points along the watercourse as the ratio between water level and discharge. High water events are generally expressed in m^3/s – the discharge volume and not the water level.

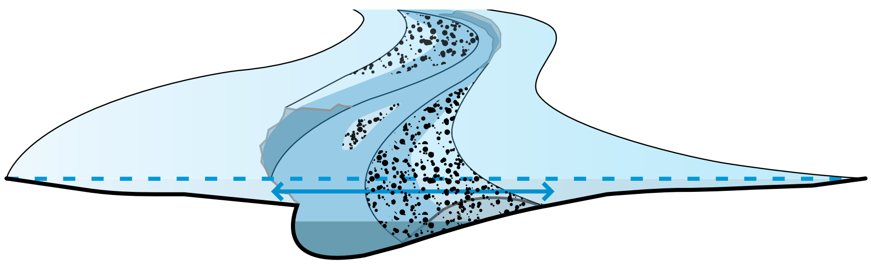
Different water levels, both low and high water, have diverse consequences for the ecosystem and human use: while high water and floods present a danger for the riverside areas and can permanently alter the composition of species in an ecosystem through the power and depth of flooding, low water can cause serious problems for shipping and power station cooling systems. Should the water level sink very low or the watercourse dry up completely, this also places tremendous strain on the ecosystem.

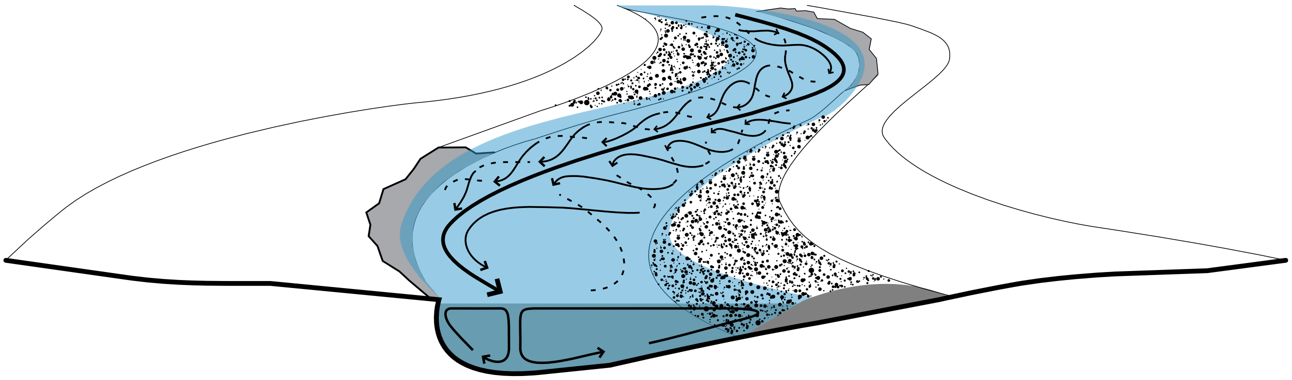


Each river has an individual flood pattern. The water level of a river changes continuously, even though generally only the extremes of flood and low water are noticed.



Sub-process 2: lateral spread of the water High water is especially conspicuous through flooding; minor rises in discharge levels can usually be contained within the river channel, but with larger high water events the river overflows its banks and covers the adjacent flood plain. This has a corrective effect: in flooding the foreland, which generally has a higher roughness, the water's energy is dissipated and its height and speed reduced. Flooding is limited, when the river is not shaped by human measures, to the valley borders. Flood protection measures such as dikes cause an artificial limitation on the spread of the water and thus the flood area.





The primary current carries water down the valley. The secondary current arises within the channel: along its central course, two contra-rotating spiral flows are created.

Morphodynamic processes The appearance of a river in the landscape represents the result of a manifold and complex morphodynamic development. The driving force is the river current, which on account of its numerous and complex sub-processes can barely be described comprehensively through scientific methodology. Exact predictions of how a river channel will develop are therefore not possible.

The primary current carries the water down the valley. Secondary current is the rotation of water around the main flow direction; this is caused by the different flow rates near the banks, where the water is slowed by friction, and in the middle of the channel, where it flows faster. A secondary flow is created that pushes the water at the sides upwards and draws it down in the middle. Two contrary spiral flows are formed. In bends of the river the outer spiral flow is concentrated and accelerated, while in the inside curve the flow is slowed down because the distance covered is shorter.

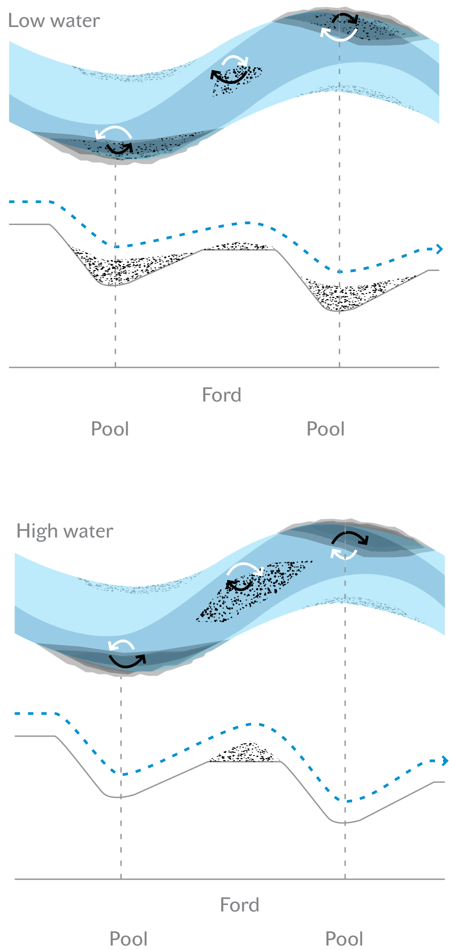
The flow of water causes erosion and sedimentation along the watercourse that subjects the river space to continuous morphological alteration. In these morphodynamic processes, that of sedimentation shift (sub-process 1) within the watercourse can be distinguished from shifts in the channel itself (sub-process 2). Sedimentation shifts in the watercourse are mainly expressed through the characteristics and structuring of the riverbed, and are to some extent reversible. With the inherent dynamic of the river channel, however, the river shifts its course and brings about irreversible restructuring across the whole river space.

Reversible sediment shift processes: migrating gravel banks in the Isar River in Munich

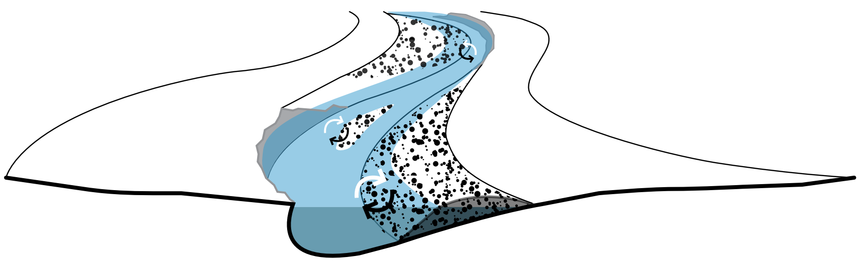
Sub-process 1: sedimentation shift within the river The slower flow on the inner curve of a river leads to the deposit of sediment; a slip-off slope is created. On the outside curve, the cut bank, the fast cylindrical flowing current erodes the bank and deepens the bed. This means that the cross section of the river bends is asymmetric; the bank on the inner bend is flat, and on the outer cut bank there is a deeper channel (pool); the secondary flow cuts a channel in the riverbed that, when the water is low, carries most of the discharge and is thus called the low water channel. As a result of centrifugal forces created by the flow vortexes, the low water channel sinuously meanders from one side of the riverbed to the other, always on the outside edge of the outer bends. In straight sections of a river the riverbed is flat which is where riffles or a ford can form through sediment accretion.

The state of the riverbed is constantly changing as a result of these dynamic processes. When discharge is low, water flow is slower and the deeper pools are filled with sediment, creating an almost level profile. When discharge is high the opposite happens: the tractive force is greater and the pools are further hollowed out. Where there are fords or riffles the flow rate is reduced, the sediment settles and the riverbed is raised. Thus the profile is further differentiated, the water is slowed by the irregularities and creates eddies. Through this alternating process of erosion and sedimentation the river as a system is self-regulating, and the longitudinal section of the riverbed varies around a relatively stable mean [Schaffernak 1950: p. 45].

Bumps and disruptive elements such as large boulders or dead wood create further variations in the flow profile along the river. These varying flow states cause small-scale erosion and sedimentation processes in which fine material settles in the quieter sections, while in sections with a faster current only coarse riverbed material can resist the flow. In this way temporary islands or sandbanks can emerge.



Reversible sediment shift processes occur in rivers. At low water the pools fill with sediment while the fords are deepened. The low water channel remains. At high water the riverbed is deepened on the outside curve, the cross section becomes more irregular, and the rate of discharge is slowed.



Sub-process 2: self-dynamic river channel development An unrestrained river is continually shifting its channel, but this shifting occurs over such long periods that it is barely perceptible. With the help of historical and geological maps and soil analyses it is possible to reconstruct the old channel runs of a river and make this development visible. The images that emerge reveal the tremendous dynamics of natural rivers.

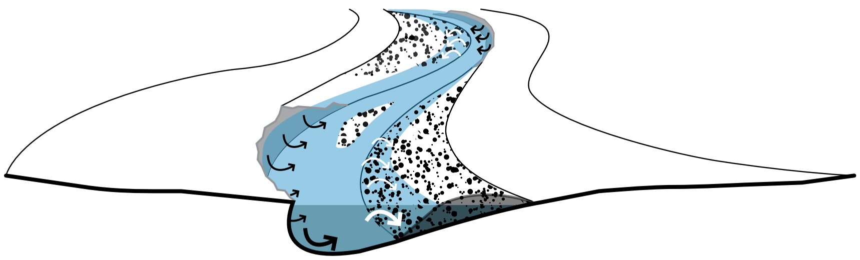
All watercourses shift through erosion and sedimentation processes. The speed of this self-dynamic river channel development depends on the malleability of the local geology and the dynamics of the water. Rivers with a steep gradient and subject to extreme high discharge events can develop markedly faster than sluggish lowland rivers or spring fed streams.

The meandering of a river is a self-reinforcing process, as the water flows faster on the cut bank on the outside of the bend and causes further erosion. The bank is literally 'eaten away' and steep edges are created. As the bank crumbles, the bend that thereby emerges shifts inexorably, both towards the edge of the valley and downstream.

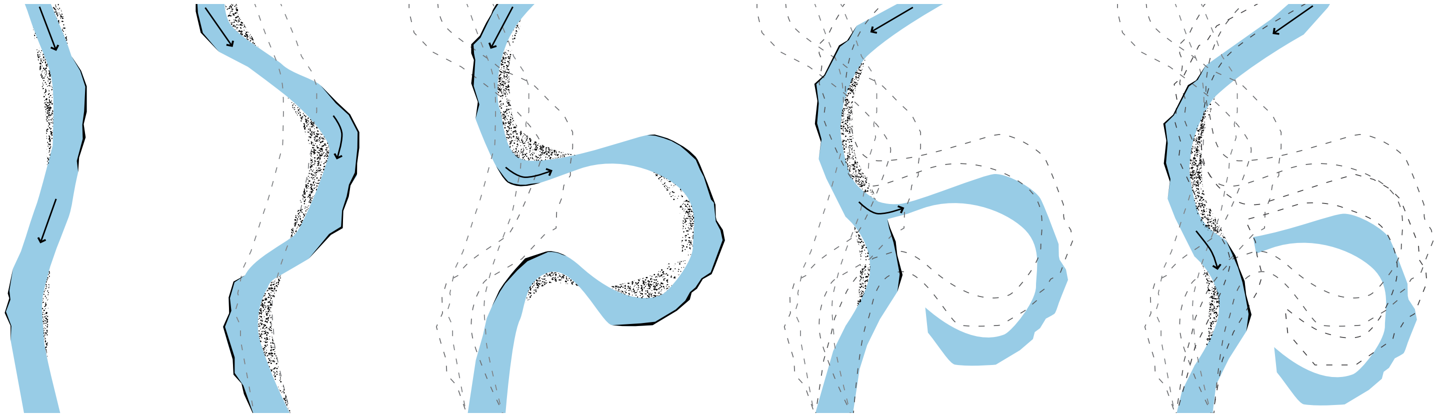
On the inside bend of the river – the slip-off slope where the flow rate is lower – sediment settles, and the course of the whole river channel shifts. The meander becomes larger and rounder, almost circular, and when the circle is nearly closed the river may break through, the loop is cut off, and the whole process begins again. The river shifts in a sinuously pendular movement downstream. The abandoned loop becomes an oxbow lake that slowly dries out and is only filled when the river floods. This development can be gradual or sudden as in the case of a meander avulsion.

The meandering forms that emerge slow down the river discharge rate and make the river longer. This morphodynamic process of river channel shift also contributes to the self-regulation of the system. For example, it protects the system from the eventuality that the form of the river itself is destroyed by flooding or that the stream channel cut deepens without restraints.

Within the riparian corridor, these dynamic processes are the source of enormous diversity for a variety of habitats for flora and fauna. The oxbows develop into areas of still water directly adjacent to the 'active' river. The dynamic processes of renewal give rise to special temporary habitats such as sand or gravel banks or crumbling riverbanks. Within the river, a wide diversity of flow and sediment types is created.



Erosion on the outer bank of a river bend and sedimentation on the slip-off slope create ever-widening meanders that gradually move downstream. After an avulsion, oxbows are left that only contain water when flooded.



Water landscapes as an expression of spatiotemporal processes

Even though in principle the same processes occur in every river, no two rivers are identical. As exactly the same conditions can never be found in two places, each river is essentially unique. It follows that the design measures for each project must be precisely attuned to the individual river in question.

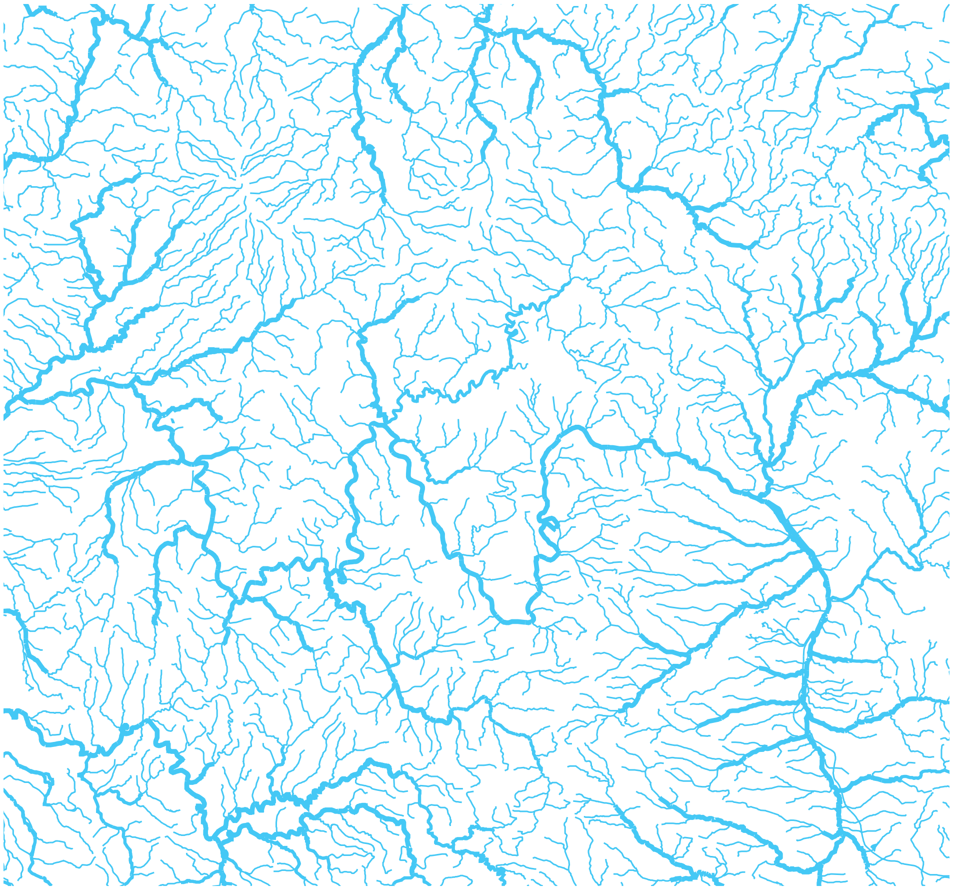
River systems cover the surface of the Earth like a dense tracery of veins. Determined by topography, they comprise a branched system in which all the water of an area conjoins in ever-larger water channels. One speaks of catchment areas, between which ridges in the landscape act as watershed divides. According to whether they divide springs or areas with heavy rainfall, built-up areas or woodland, the volume and rhythms of the discharged water vary enormously.

Interplay between water and landscape Each river forms the surrounding landscape in diverse ways, and conversely the surrounding environment exerts influence on the shape of the river through many factors. The land forming power of water arises from the close interplay of topography, geology, climatic conditions and the above mentioned erosive and accumulative activity of the current. Every river changes over various timescales and to various spatial extents; water landscapes are thus expressions of complex spatiotemporal processes.

These formative processes arise from water as a transport medium, which through the power of its current, shifts soil and stone within the catchment area. The eroded material is ground down smaller as it travels downstream; depending on the gradient and the resulting flow rate, the transported material becomes finer on its journey from the steep headwaters in upland and mountain regions to the slow-flowing lowland reaches. Varying dynamics mean that different water landscapes are created along the upper, middle and lower reaches of a river. In the upper reaches, constant abrasion of material creates steep river valleys that cut deep into the ground. The degree of erosion is in direct

Meanders of a river on the North German Plain – the River Leine near Hanover

River channels pervade the landscape like a dense tracery of veins.

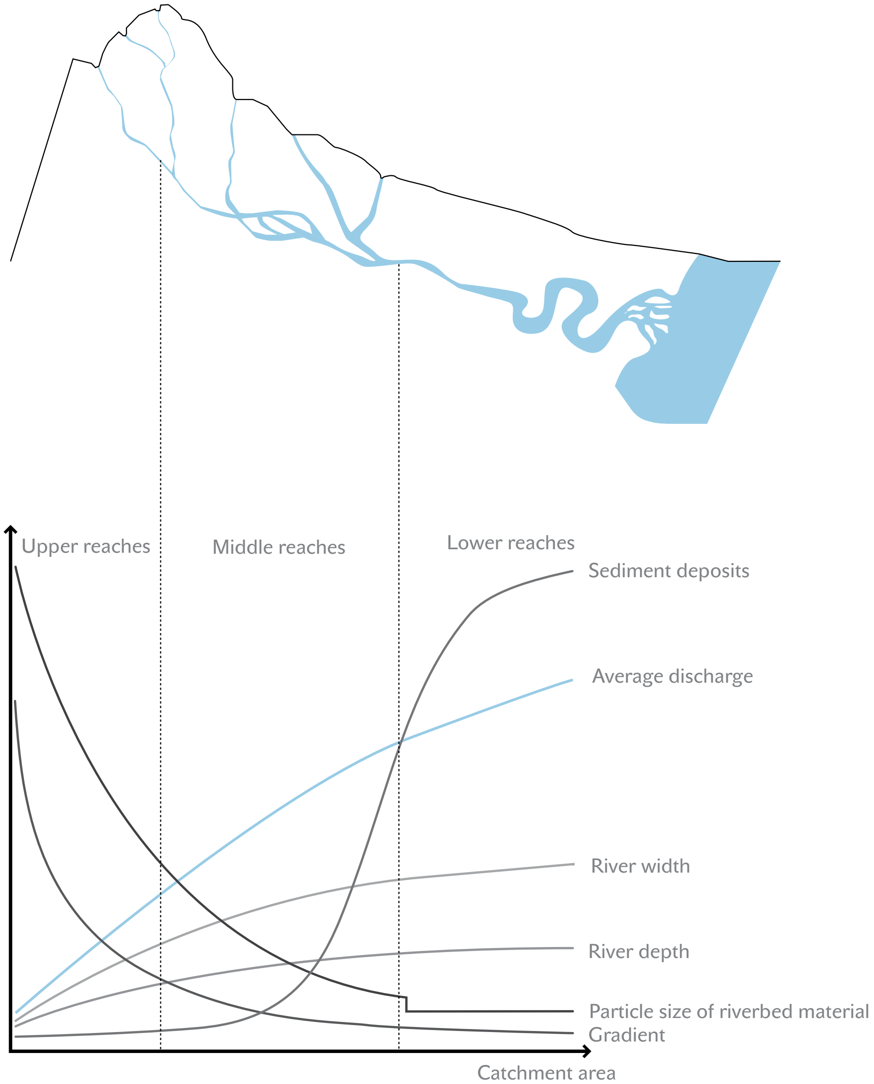


relation to the geology of the local substratum and the discharge dynamics; because of the steep gradient no significant meanders are created. In areas where large amounts of sediment settle at once, such as plains at the foot of hills, the river can divide into several parallel branches. Material from upstream is transported to the middle reaches and some of it, along with locally eroded material, is carried on further downstream. In this way rivers are created that develop a relatively stable depth through their bed-load balance. Here, and in the lowlands of the lower reaches, one can observe marked meanderings of a river caused by slow discharge and heavy sediment deposits.

River sedimentation shapes the landscape In the lowland and delta areas of rivers, one can expect ongoing elevation of the land by deposited alluvial sediment. Varying flow conditions cause uneven rises in the flood plain areas: when the river overflows its banks the heavy sediments are deposited close to the river first – gravel and sands. These accumulate directly adjacent to the water as elevated rises, which are seldom submerged and on which the oldest human settlements along larger rivers are often to be found. During flooding the river current behind these rises is much calmer and finer sediments – clay and silts – settle and create clay soils on which the historically long uninhabited marshland landscapes developed. These were lower-lying than the sandy rises and could only be settled and farmed through major drainage construction and dike construction. A good example of such zoning is the Altes Land on the River Elbe near Hamburg. Its oldest settlements lie on the narrow riparian hill rises along the Elbe, from whence the lower-lying marshland could only be made productive by drainage and construction of 'Marschhufendörfer' villages, while the lowest marshland, furthest from the Elbe, has not been settled to this day and is used only for extensive farming.

The elevation of land levels is particularly pronounced when the sea level rises and backs up the river discharge. The river water comes to a virtual standstill, sediments are deposited, and the riverbed and banks are built up. In delta areas the bed load carried downstream can create new land out to sea. As large quantities of bed load are deposited when the flow is backed up, and impede and divert the main channels of the river, areas of new and divergent branching of the main channel occurs creating extensive delta landscapes with several parallel and interlacing water channels.

One special case is that of inland deltas which occur when a river is influenced by the tidal flow and ebb of the nearby sea. Back from the coast, sediment is deposited where the river discharge is brought to a temporary halt by the flood tide and the current divides. The cities of Bremen and Hamburg were founded on these distinctive branchings of a river channel. This brief outline of the spatiotemporal dynamic of river processes makes it plain that the processes are in principle the same but the diverse characteristics of each location lead to a situation whereby no two river landscapes are alike.



Diverse conditions influence water processes, leading to different landscape and river types in the upper, middle and lower reaches.

Designing Water Spaces

The River Isar in Munich was given a new appearance through creative handling of the transitions from water to land. The river's limits were shifted back at some points to allow natural beaches to reinstate themselves. Necessary bank reinforcements were shaped as steps to sit on.

The primary purpose of this book is to develop, by systematising of the innumerable existent water spaces, a readily comprehensible catalogue from which transferable knowledge can be extracted for future design tasks. The determinant factor of such a catalogue is the way it reveals common principles that apply to all conceivable water spaces. Through intense study, particularly of the processes that occur in bodies of water, we came to the conclusion that the determination of the river's limits, the way in which those limits are set, is the decisive factor. The spatial character of a river emerges from delineating and restricting the two types of processes described above: variations in discharge and morphodynamic processes. Every anthropomorphically influenced river in an urban space has these two types of limits! It follows that designing for urban river spaces always addresses the limits of these two river processes.

Water spaces and their limits

The spatiotemporal processes that unfold in a natural river present a daunting challenge for using the water spaces as human habitat. Uncontrolled shifting of the riverbed and the amount of space appropriated by high-discharge rivers endanger the settled and cultivated cultural landscape and have always challenged human beings to test their shaping powers as 'Lords and Masters of Nature' [Blackbourn, 2007, p. 37] against the dynamics of rivers and to set limits on rivers' processes. We describe these limits in this part of the book as 'process limits'. The importance of setting limits on naturally occurring processes was described by Schaffernak in 1950 in his book on fluvial engineering: 'Rivers run wild when left to their own devices. [...] Agriculture is damaged by the destruction of cultivated land when a river breaks its banks, from flooding and changes to the groundwater level; shipping suffers from awkward shifts in the main channel and variations in water depth, and constructing hydroelectric plants is more expensive because their successful use is only possible on regulated watercourses.' [Schaffernak, 1950, p. 5)

The kinds of process limits that people have placed on river dynamics have, however, changed considerably in the course of time. In the pre-industrial era, coping with rivers was typically through small-scale measures to set the process limits, strongly oriented on the various dynamics of a river in the various landscape spaces and based on close familiarity with the habits of the river in question. As far back as the early middle ages, there were minor diversions and impoundments of watercourses to feed a mill or create defensive structures. Dikes and ditches were also constructed and the first breakthroughs in meander zones were made to divert water from endangered locations [Strobl, Zunic, 2006, p. 81]. On the River Rhine from the 12th century onwards, a whole range of terms appeared to describe the various types of main and subsidiary river branches, islands, narrow streams, oxbows and the different forms of flood meadows along the riparian corridor with a differentiated vocabulary [Blackbourn, 2007, p. 75]. The dynamics of the river were not markedly influenced by small-scale, uncoordinated measures, but attempts to redefine the process limits at a few points shifted the dynamics of the river further downstream so dramatically that the danger here was exacerbated – a situation that Blackbourn calls 'hydrological leapfrog' [Blackbourn, 2007, p. 77].

Large-scale canalisation in the 19th century With industrialisation, rivers gained in importance as transportation routes and river valleys were correspondingly more densely settled. In the early 19th century, improved technical capabilities led to large-scale canalising of rivers and regularisation of the major river valleys: fundamental interventions such as straightening meanders to improve navigability, land reclamation and flood protection, along with the construction of large weirs.

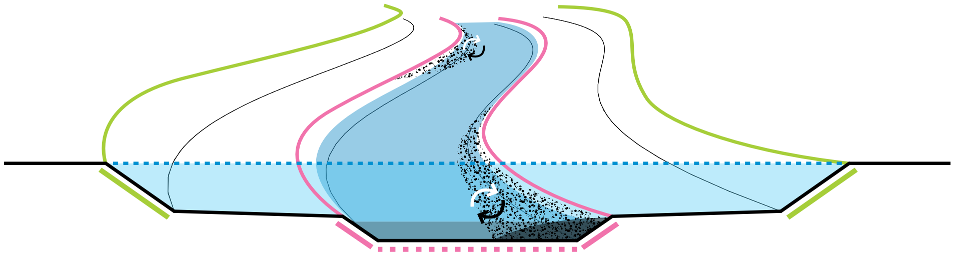
One very well-known engineer from this era was Johann Gottfried Tulla, revered as the 'Tamer of the Rhine' for his straightening of the river, whose first plans were submitted in 1809. These engineering works, which he called the 'Rheinrektifikation' (Rhine correction), were founded on the conviction that 'no current, no river, not even the Rhine, needs more than one riverbed.' [Tümmers, 1999, p. 145]. The straightening of the Rhine, involving breakthroughs of meanders and the removal of over 2000 islands, was the largest engineering project of the age, shortening the river between Basle and Worms by almost a quarter of its length, from 345 to 273 km and improving navigability immensely. Additionally, groynes and dredging made the river navigable all year round. In the course of industrialisation, setting process limits attained a completely new dimension in terms of scale and of durability. Not only at isolated points but along their entire length, rivers were forced into strong, continuous containments by sealing and securing the banks between dikes and reinforcements and the riverbed with groynes, weirs and ground sills. These changes to the process limits led to dramatic shifts in rivers' dynamics: because of the faster water flow, erosion of the banks and bed increased markedly.

As a result, the river cut ever deeper into the land, leading to sinking groundwater levels in the surrounding areas. Technical interventions made further sealing measures necessary; for instance, the entire riverbed on some sections of smaller branches was completely sealed. Dikes were constructed ever closer to the river. Although Tulla assumed that the Rhine would find a new equilibrium in its new bed and did not foresee the need for a comprehensive system of dikes, they became indispensible in the course of his 'corrections'. Through the modern age, then, rivers became technically shaped civil engineering works. Today, only about one third of the original flood meadows along the rivers of Germany are flooded by major high water events. Along the Rivers Rhine, Elbe, Danube and Oder, the proportion is no more than 10 to 20 per cent [Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2009, p. 4]. Ever more stable and higher dikes improve flood protection at particular locations but also create barriers in the landscape. Straightening rivers and cutting off backwaters stimulates faster water discharge. Simultaneously, however, the water retention capacity is reduced and the danger of flooding thereby aggravated.

These lateral limitations on rivers are exacerbated by technical alterations to the river channel profile itself. Cross-current constructions such as barrages, falls and canalisation through pipes impair ecological permeability, that is, they present insuperable obstacles to the movement of most species. Sealed riverbanks and smooth riverbeds offer no habitats, and the loss of flood meadows means a scarcity of space for the metamorphic stages of water and riverbank inhabitants.

New objectives The findings of the survey carried out in the course of devising the EU Water Framework Directive show that 21 per cent of all the rivers and streams in Germany are still close to their natural state. The overwhelming majority of them lie outside conurbations [Umweltbundesamt, 2010]. Rivers in urban areas have been subject to the most radical alterations and represent the focus of this book, being dramatically

The photograph shows the River Wiese near Basle. Ground sills and the hard-surface trapezoid cross section have put the river in a straightjacket.



The classic trapezoidal cross section of a canalised river

Flood limit
Limit of the self-dynamic river channel development
Riverbed seal

reshaped by the human hand both in their spatial structures and in their dynamics. Restoration of a river to its natural state is, because of tight spatial restrictions and the danger of flooding, usually neither feasible nor sensible. So what room for manoeuvre do we have for the shaping of process limits to achieve multifunctionality with regard to ecology, flood protection and amenity? What constructions or spatial solutions are suitable for the various types of rivers and the various local conditions? It is only when one is thoroughly familiar with the process limits that one can also modify them and sound out the corresponding scope for design interventions.

Types of limits

In order to systematically collate and present the design possibilities for urban river spaces, this book defines two different process limits, corresponding to the two types of process dynamics explained in the 'Types of processes' section: temporary fluctuations in discharge, which affect the lateral spread of the water, and the morphodynamic processes that alter a river channel's course. Accordingly, we define these two process limits as:
1. the flood limit
2. the limit of the self-dynamic river channel development

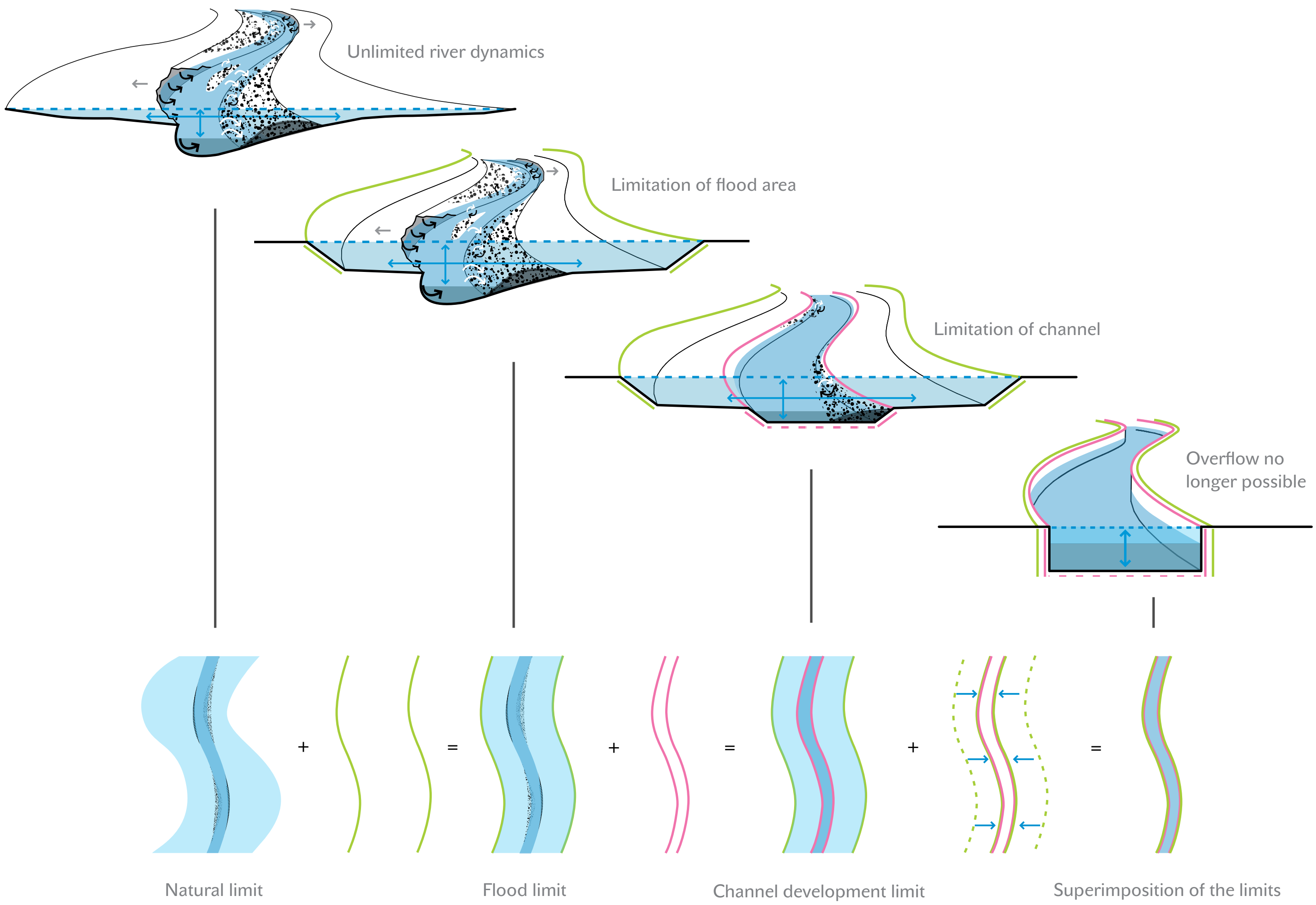
Flood limit The lateral spread of water from a river is possible up to a defined flood limit; the illustrations in this book mark this process limit as a green line, which could represent a dike or a flood wall.

Within this limit, vertical fluctuations in the water level and lateral spread of the water surface happen. Beyond this line such occurrences are no longer taken into account; flooding would be a catastrophe. The limit is marked in the landscape as a dike, embankment wall or the natural edge of the river valley.

The limit is always a relative limit, as it relates to a defined high water level; as high water events are never completely predictable, theoretically a level can occur that overflows all defence systems and thus the flood limit. The height of the green line for a defined protection level is calculated based on flood probability statistics or recurrence intervals. The risk that flooding exceeds this limit can, for example, lie at the height of a statistically defined one-in-100-year flood (HQ100) – a flood that could theoretically occur only once every 100 years. In densely built-up areas and places particularly vulnerable to flooding, such as Rotterdam in the Netherlands, there are ring dikes that are built to meet the possibility of a one-in-10 000-year flood. In terms of design and construction, this line represents a decisive interface as in front of and behind it fundamentally different preconditions for potential uses prevail and thus planning, construction and life patterns are also completely different.

The limit of the flood area delineated by the green line, however, does not represent a particular protected status but the respectively defined protection level. It runs a little below the crest of the dike or flood wall, as a margin of safety for waves and wind pressure is calculated into the height of this crest, known as freeboard.

Limit of self-dynamic river channel development The second process limit introduced in this book is that of the self-dynamic river channel development, marked as a red line in the illustrations. Unlike in the space defined by the first process limit, erosion



On most rivers natural processes have been either restricted or are completely controlled. The flood limits (green line), set for instance by a dike, delineate the flood area. The limitation of the self-dynamic river channel development (red line) through, for example, embankment walls or low weirs curtails any shifting of the channel.

and sedimentation processes occur within the area it delineates – the form of the river can change through its own dynamic and channel migration is possible.

Often, this limit lies directly on the riverbank, so that the river can appropriate no more space through its own dynamic; the river is fixed in its course and the limit of a self-dynamic channel development is identical with that of the river itself. Frequently, the entire riverbed is also sealed and the river is thus physically constrained within a corset. If the limits of the channel development lie in the river flood plain, however, visible erosion and sedimentation processes are possible.