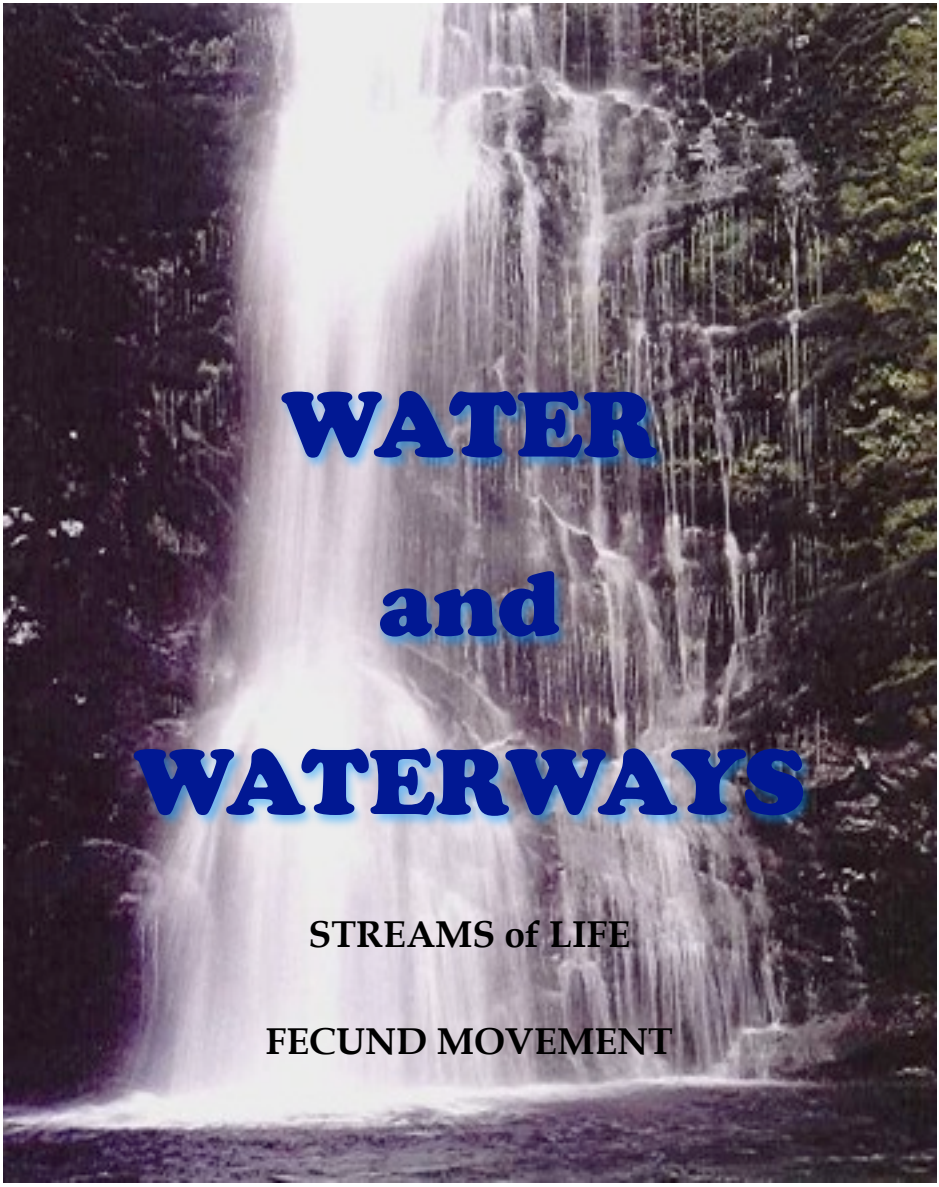

REGENERATING VEINS of the EARTH

GARY WILLIAMS

Water & Soil engineer - Biodynamic farmer - Permaculture activist - Natural philosopher

Gary and his partner Emily live on a small farm where there is a wide diversity of farming and forestry activities, from home gardens and orchards to staple crops, animal grazing, firewood and plantation forests, and wilderness. Their stewardship of this land is guided by the principles of permaculture and the practices and methods of organic and biodynamic agriculture. They like to experiment and share their land, and have a bio-filtered swimming pool and an eco-building farm stay for short-term use.

Gary is a teacher of permaculture and provides advise and design assistance to people and communities seeking a more resilient and sustaining way of living, which reflects the nature of their place.

Gary works from home as a professional engineer in the field of water and soil resources. His academic qualifications are: Bachelor of Engineering, Bachelor of Science (Physics) and Master of Commerce.

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>
> "Patterns of Exchange — A Study in Human Understanding" 1988, 401 pages.
>
> "Out of the Helix — Essays on Cultural Transformation" 2006, 275 pages.

This pamphlet is about the dynamics of water flowing in the landscape, and its relationships with all of life.

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Water is essential for life, and people are attracted to waterways, living beside rivers and streams, lakes and wetlands, and along the coast. Life is most abundant at these margins of water, land and air, but it is also hazardous, with risks from floods and erosion, to the predation of other creatures and disease organisms.

Life is full of opportunities and risks, and the more abundant and creative life is, the greater the opportunities and the uncertainties. There is always tension in life, between growth and maturity, productivity and resilience, creativity and stability, enterprise and security. This balancing of energies is reflected in the movement of water.

Life mimics the spiraling flow pattern of water, with its vortex form of inward, converging and concentrating movement, and outward, diverging and expansionary movement.

A way of life of health and vitality requires this dynamic, with its oscillations of opposing energies.

Waterways are the ribbons of flow that both divide and connect the landscape. Shaped by

the land and shaping the land through an interplay of give and take processes.

The state of water in our environment and the health of the rivers and streams that flow through it, is a potent indicator of our way of life, and the relationship we have with our environment.

The straightening and confinement of our rivers and streams, the draining of wetlands, the pollution from our discarded 'wastes', the over-use of water from surface and ground waters, and the removal of forests from waterway margins, floodplains and high country watersheds, is a reflection of our culture of control and exploitation. Of taking without giving back. Of a lack of respect for life as a whole and the place where we live.

A productive and resilient humanity requires a cultural shift, to a worldview of connection, where interactions are mutually beneficial, and interdependence is based on respect and responsibility, for the land and water we share.

WATER & WATERWAYS

WATER

BASIS OF LIFE

The Gaia hypothesis is: where there is life there is water. Water is a fundamental requirement of life, the necessary facilitator of living processes. All the exchanges of life require the presence of water, at least when they take place at (normal) ambient pressures and temperatures.

At its simplest, life can be understood as a synergy between water and carbon. The movement patterns of water, with its interweaving spirals and vortex dynamics provides the connectivity, while the multiple bonding ability of carbon allows the formation of very long and complex molecules, as carbon-based chains and rings, to which a wide array of elements can be attached.

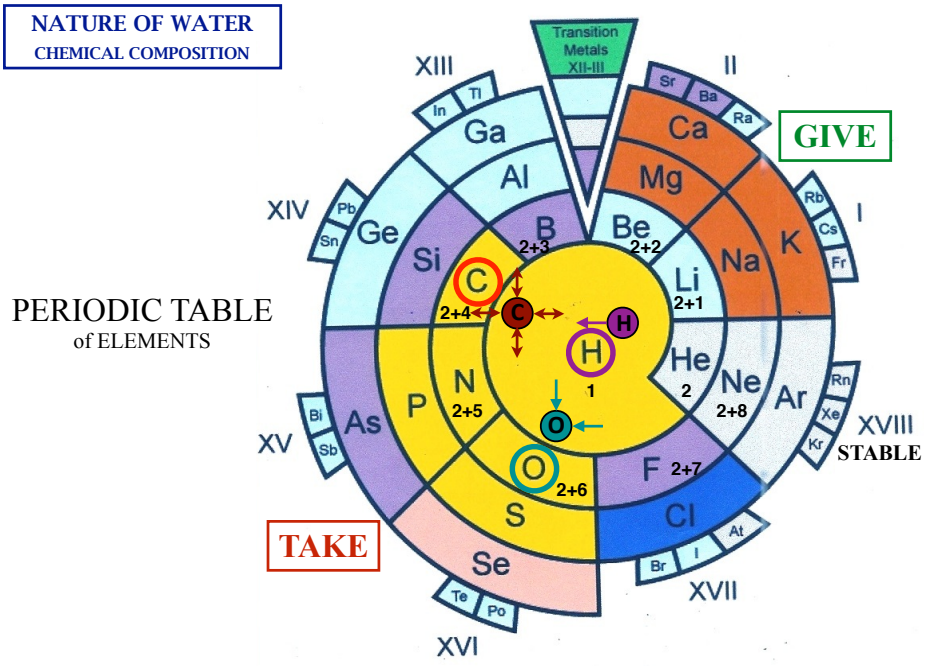
Carbon is the simplest element with an ability to form multiple bonds, being midway between elements that can easily give electrical energy (+ cations) and those that can easily receive (— anions).

Water is a simple molecule, made up of the most basic element, hydrogen, and the simplest element with two bonding gaps, oxygen, giving H_2O. Hydrogen with a single positive proton can, though, both share its single negative electron, and share another electron to complete its energy field. This 'bipolar' uniqueness allows weak connections between water molecules along with the strong chemical bond of the electron sharing of two hydrogen atoms with an oxygen atom (see Figure 1).

All the unusual properties of liquid water arise from this weak bonding between water molecules.

The weak bonds give rise to molecular clusters and water shaping and covering around elements in liquid water, including around complex organic molecules. This facilitates the exchanges and fitting together of organic compounds, the dissolving and transporting of these compounds, and hence the distribution of nutrients throughout the networks of life and ecosystems. The heat required to change the state of water, from solid to liquid and gas, because of the weak bonds, makes it very effective at transferring heat and moderating temperatures. It is the main driver of local and global climates.

Spiral pattern Periodic Table (Figure 1)



Water is a basic feedstock of life, with plants forming carbohydrates from water and carbon dioxide, through photosynthesis. The atmosphere provides a medium for the fast and effective transfer of these basic ingredients of organic life.

Air and water are the great transporting and mixing media of life on planet Earth, that allow plants to thrive, while being fixed in one place. Air blankets the Earth as an atmosphere of gases, which circulate through the heat of the sun and climate processes. Water circulates through the processes of the hydrological cycle — as water vapour in the air, as liquid water on and under the surface of the Earth, and as solid ice or snow at high latitudes and altitudes.

The biomass of life fits within and makes use of the geo-physical processes of the Earth — of the movement of gases in the atmospheric, the flow of air and water in porous soils on land, and the circulating waters of the oceans.

Air and water are both energised and purified by these circulatory processes, and these processes and the nature of air and water can be adversely affected by the pollution of toxins and the excessive loading from waste dumping. There is also an essential inter-connection between these physical processes and the ecological systems and networks of life. The nature of the air and the complex circulations of water on the planet arise from, and are dependent on, living processes and eco-systems.

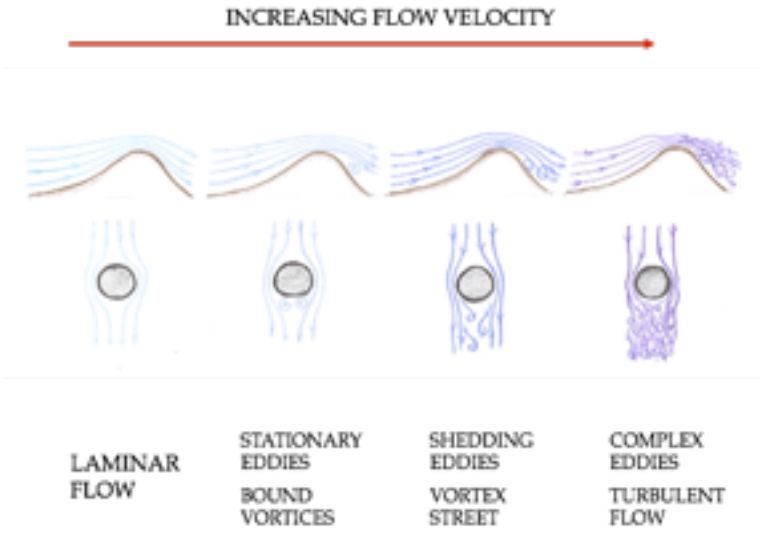
Water can have many ionic states, and form molecular links and networks that reflect the substances in it. Water is the universal solvent and the essential facilitator of life. After hydrogen it is the most common molecule in the universe, and mediates physical and biological processes, from the birth of stars to the birth of humans.

PATTERNS OF WATER

Liquid water flows in complex spiraling patterns, with the interweaving of converging and diverging streamlines. The characteristic form of water flow is the vortex, made up of interconnected expanding and contracting flows. The more vortex formation that takes place in a body of water the greater its creative vitality, and hence ability to transport and connect.

The vortex pattern changes as the velocity of the water flow increases (see Figure 2). At slow velocities water flows in a uniform stream-lined way, as laminar flow, where the lines of flow are generally parallel and flow velocities are relatively uniform throughout the flowing body of water. As the velocity increases vortex or eddy cells form and can remain stationary in the lee of protrusions or obstructions. Then these eddies are shed as a train of linked rotating eddies, of a 'vortex street'. At higher velocities again the flow breaks up into a fully turbulent flow of highly interwoven eddies and vortices.

Transitions in Flow Patterns (Figure 2)



As the flow velocity increases there is a changing degree of individuality and continuity and of eddy size and complexity. There are streamlines of spirally flow and eddies of varying discreteness and boundary complexity. The flow looks chaotic, but it is just too highly patterned for us to perceive, or recognise. Everywhere the flow is continuous, as one body of water, with all the vortices and streamlines forming an integrated whole, with no gaps or void spaces.

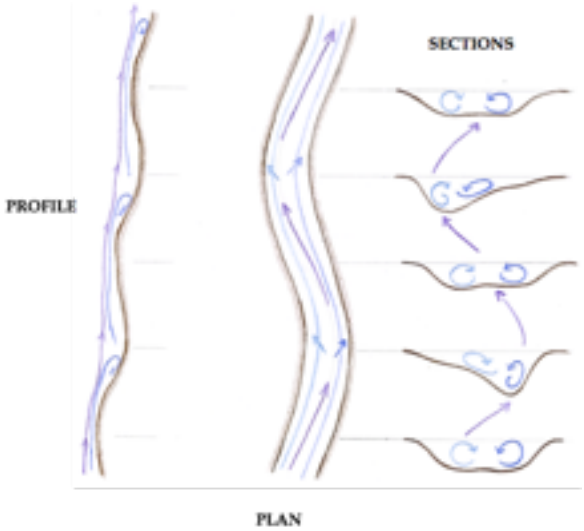
The patterns of flow thus alter as flow velocity increases, with abrupt transitions from laminar flow, through stationary and shedding eddies to full turbulent flow. At the same time, there is a larger pattern to the flow forms that characterises the bigger picture of the transitions and the differing flow behaviour, with their spiral-form similarities and infolding repetition.

As water spirals down waterways in a pulsating way, there are two main flow spirals, which interweave in a side-by-side way, expanding and contracting as the waterway bends one way then the other (see Figure 3) The interwoven converging and diverging spirals of this flow give rise to a range of eddies and vortices that form and re-form in a continuous dance of discreteness and connection — spirals being neither fully closed nor fully open. The pattern depends on the flow and the form of the waterway channel(s). The flow accelerates and decelerates as it goes from more uniform flow to sudden bursts, and it is these flow variations that provides the energy to move sediments and other materials.

It is the sideways action of the spiraling flow that moves the bed material lining waterway channels, causing bank erosion and bar deposition, and this in turn gives rise to channel migration. This sediment movement is episodic as flood events pass down the river channel, and the continual erosion and deposition moves the sediments in pulses, with accumulation and then removal taking place within the river channel and across the floodplain. There are discrete bars from bend to bend, and pulses of sediment movement within a continual transport of bed material downstream.

The channel migration, through the erosion and deposition of the sediment movement, is similarly step-wise or episodic, while giving rise to a progressive movement across the floodplain. There are distinct pools and riffles in the channel form and alternating bends, while the migrating channel maintains a self-similar form over time.

Spiral Flow along a Waterway (Figure 3)



There are distinct pools and riffles in the channel form and alternating bends, while the migrating channel maintains a self-similar form over time. A waterway channel maintains a twisting meander form and an oscillating cross-sectional asymmetry from bend to bend, but the overall form can change suddenly as river conditions alter, for instance from a single meandering channel to a braided form of many interweaving channels. Again there is continuity of form and endless variety of individualised expression.

Nutrients accumulate and dissipate, through breakdown, interaction and exchanges with groundwater under and alongside the waterway channels, and through surface runoff.

This absorption and release of nutrients takes place in a similar oscillating way, with the direction of movement depending on temperature gradients, which vary as the relative temperature of the water and land changes. Again there is a continuity to the process and sudden transitions as waterway conditions change and because of climatic variations – over the short and longer term.

This interaction of water and land gives rise to watersheds, which display the same characteristics of repetitions and transitions, with a fractal repeating shape from the functional dynamics of water and its patterns of movement.

POLLUTION

The cheap energy that fossil fuels provided has been used to build an industry and urbanisation that spews vast amounts of concentrated wastes and toxic materials into waterways and the oceans. This water pollution is most obvious locally, but there are global impacts through the circulations of rivers, the oceans and the atmosphere, as there is with the pollution of the air.

The vitality, purity and availability of water is directly affected by the loss of forests and the degradation of soils by agriculture — which also affects the air, locally and globally. The loss of riparian vegetation and habitats along the margins of rivers and streams affects the health and stability of the waterways, altering the transport of sediments and nutrients, and their exchanges across floodplains and with groundwater.

The pollution and degradation of water and air has been so intense and extensive that it has affected global systems of circulation and exchange, altering the water, carbon and nutrient cycles of life on Earth.

Toxic waste streams can be treated by various industrial interventions, and mixed and diluted before discharge to the natural environment. Loading and the concentration of harmful substances is the critical factor in pollution, but in the end it is natural systems, mainly the reducing microbes, that will transform the 'wastes' and make them available for re-use again.

Maintaining healthy and robust eco-systems is essential for the effective processing and re-use of our output 'waste' streams.

WATERWAY HEALTH

The well-being of any organism or community of creatures arises from being an integral and responsive part of a healthy diverse ecosystem, where exchanges of multiple types and frequencies maintain a living system that is robust, self-balancing and self-healing. These life systems are nested within each other, having some unique identity while being multiply connected.

Ecological health is, thus, a complex dynamic, which involves death and decay as much as growth and fruitfulness. There are open cycles (spirals) of growth, productivity, maturity and decay, as life forms interact, to give interwoven vortices of regeneration and degeneration. Health involves an expansiveness of productive growth and expression, alongside contractive reserves, storages and alternative pathways of resilience and repair.

Ecosystem health is about the diversity of exchanges and the rate at which nutrients or information is exchanged throughout the whole system. These exchanges, though, form a complex pulsing of different energies and resonance patterns — of growth and decay, productivity and repair, individuality and connection.

Nature creates complexity and diversity out of simple processes, and there is a basic polarity of positive and negative in the forces of matter and processes of life. Understood most crudely there is a duality: of chemical and electrical + and —, of the H^+ and OH^- of water, of acidic and alkaline, of oxidation and reduction processes, of masculine and feminine. These polarities can be used to sense and monitor the state of organisms or ecosystems, but it is the balance or harmony between the varying energies that is important for health. The basic polarities are woven into vast arrays of complex exchanging systems and entities, where there is a fluctuating balance of dynamics, a meta-stability that allows creative growth and responses to hazardous impacts. The patterns of flow and interaction of water provide us with insights about this essential nature of life on Earth.

WATERWAY SYSTEMS

WATERWAY DYNAMICS

Waterways both divide and integrate the landscape, draining all of the land and in doing so generating margins and boundaries. Rainfall infiltrates into the ground and runs off to waterways as overland flow and as seepage flows through the ground. It collects in hollows and swales and then drains to small rivulets, creeks and streams, as a network of waterways builds up. Every piece of land is connected by a drainage network, and this network forms a complex web of margins along all the channels from the smallest creek to wide rivers. There is a pattern of branching waterways that is repeated at different scales throughout any catchment or regional landscape.

This complex branching pattern of waterways, that reaches from the receiving oceans to the farthermost headwater points of the river watersheds, provides a transporting and re-cycling system over and within the land. As part of the hydrologic cycle (see Figure 4), waterways collect the water that falls on the land and returns it to the seas and oceans. In flowing downhill, this water collects and transports materials, with sediments moved through erosion and deposition and nutrients dissolved in the water.

These waterway systems are the veins of the Earth, collecting together the water that falls on the land and carrying it back to the sea, along with nutrients and sediments. Waterways are the connecting pathways and pulsing carriers of the recycling and renewal systems that water and drain the land and shape the landscape. These waterways are most essentially streams of flowing liquid water, and water is the medium of life.

Life is attracted to, and is most abundant and complex, alongside waterways. Even in their physical expression, rivers have a responsiveness and dynamic very similar to living systems.

Hydrological Cycle (Figure 4)

Waterways are part of a complex re-cycling, of water, soil and debris materials, minerals and organic nutrients. There is a continual inter-change throughout the system, with variable flows of sudden floods and much longer periods of recessional flows and dry period low flows. The transport of sediments in particular, but also nutrients, mostly takes place during the short period of flood events, as episodic movements over short distances. As part of the downstream movement, there is a continual give-and-take, of erosion and deposition, of exchanges with groundwater and to and from the river floodplains.

At the largest planetary scale, there is an evaporation of water back to the atmosphere from the oceans and the large tropical rainforests of Africa and South America. But at every scale there is evaporation and plant transpiration to the atmosphere, and rainfall back to the earth (within the oceans and over the land). The hydrological cycle has cycles within cycles of evapo-transpiration and rainfall, like the eddies within eddies of flowing water or circulating air. Rain is carried over the land

through a convective heating and cooling, as occurs generally in the tropics over the cycle of day and night, or by the winds generated by the atmospheric circulation of the revolving Earth.

The atmosphere carries the rain to the land, providing clean, oxygenated and ionised water, and this brings a renewal to the land, like arteries do for the cells of the body. The waterways, like veins, collect the runoff, with its sediment load, and return the nutrient and sediment enriched water back to the oceans.

Rivers are, then, open exchanging systems, where there is continual re-cycling and renewal (see Figure 5). There are complex shifting margins, and at those margins energy and information is exchanged through inter-dependent and interwoven processes. This continual mixing gives rise to a dynamic meta-stability, through a multi-level feedback dependence within these processes, and the health of the river environment depends on the diversity of this variable environment and its constant renewal.

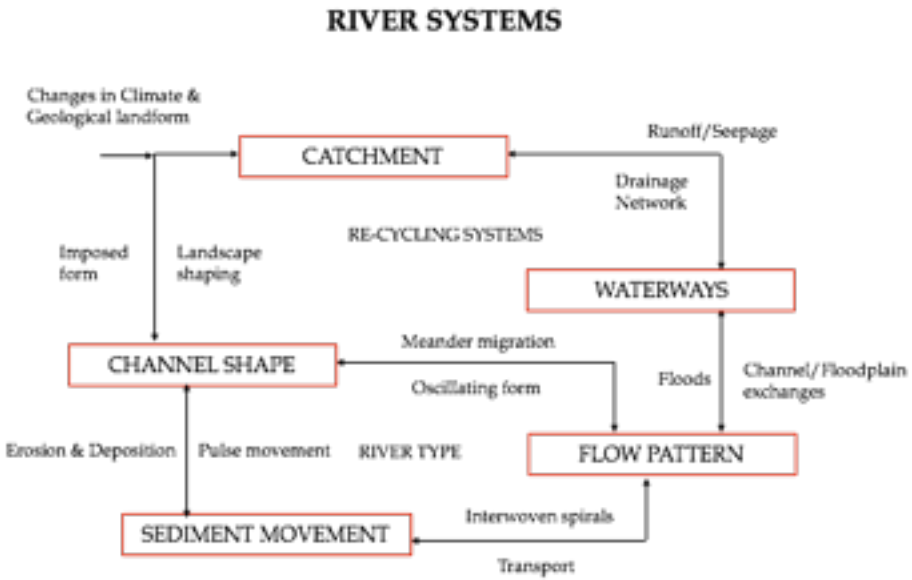
As energy and information exchanging systems they are like living organisms and share a similar dynamic to ecological systems. Rivers, even through their physical processes, have the form and sparkle of life.

The flow pattern of interwoven spirals of convergence and divergence gives rise to repeating patterns at all scales. There are eddies within eddies, recycling spirals within recycling spirals. At the same time, there is a 'step' dynamic of transitions or quantum jumps, of deceleration and acceleration busts, pool/riffle sequences, oscillating meanders or braids, and reach long waves of channel degradation and aggradation.

Waterways both form and are formed by the wider landscape, and their character depends on the nature and intensity of the influencing forces of climate and catchment setting. They are a reflection of their watersheds, and the state or condition of rivers is a potent and visible indicator of the health of the landscape and its eco-systems. Understanding the larger patterns of the

watershed, with its geology, vegetation cover and climate regime, enhances our understanding of rivers, and vice-versa.

Landscape & Waterways — Interconnectivity (Figure 5)

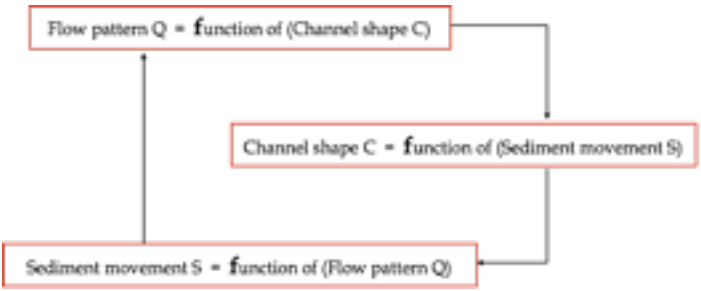


The interconnections of river systems go both ways, with each aspect both affecting and being affected through the linkages or feedback interactions.

The self-similarity of river channels, that form and re-form to a characteristic pattern from flood to flood, arises from an interconnection or feedback loop between flow pattern, sediment transport and channel shape. The river moves, but the meander form stays the same. Flow pattern is a function of channel shape. Channel shape is a function of the erosion and deposition processes of sediment transport. Sediment movement is a function of the flow pattern (see Figure 6). There is a feedback loop connecting all aspects of the river behaviour, that gives both a dynamic variability (and creativity) and a stability of repeating self-similarity. Change the flood regime by a hydro-power development and the downstream sediment transport and

channel migration will be affected. Alter the channel shape through river management works, and the flow pattern and sediment transport behaviour will change.

Functional relationships of Waterways (Figure 6)



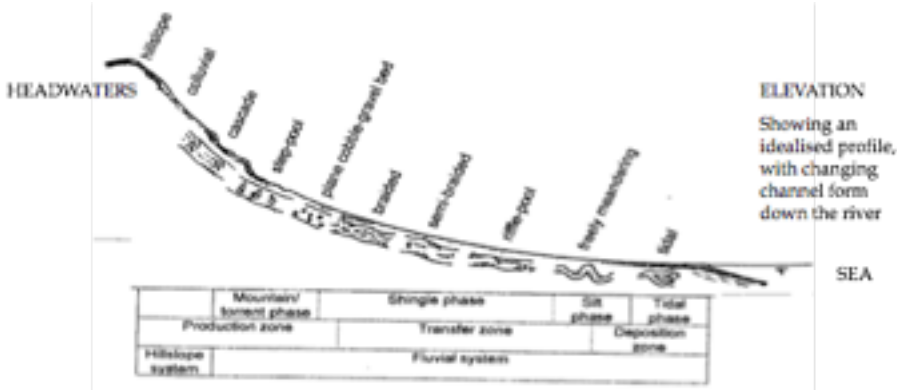
There is the same inter-relationships along the coast from wave energy, between wave pattern, sediment movement and coastal shape.

WATERWAY CHARACTER

There are, undoubtedly, difficulties in defining the natural character of rivers and streams, because they are very dynamic and changeable natural systems, highly responsive to the many influences of climate and landscape, and to the human modifications of these influences. The natural character of any reach of a river or stream, in its physical expression, depends on the intensity of the flow forces, the supply of sediments to the reach, and the resistance of the channel bed and banks. It is not a stable state, more a dynamic balance of forces. Thus, waterway reaches that have been modified by catchment and riparian changes can still have a natural character, through a specific expression of river system processes. The channel dynamic and form will be different to what it was, but it will be a form and dynamic that occurs along waterways naturally, but with the formative influences differing in strength or intensity.

The natural character of a river changes along the river, from the headwaters to the sea, and when characterising a river this is done by reaches (see Figure 7). It is a given reach that can be characterised, not a river or waterway system. The nature, character and responses of a river change from reach to reach, as the forces and processes at work change, and a given character can only be defined for a reach where there is a similarity of river processes along it.

Changing reach character along a River (Figure 7)



The ecology of a river reach depends on the physical character and conditions, but there is a complex inter-play between the biology of flora and fauna along waterways and their physical nature, while the physical processes and ecological relationships of aquatic and terrestrial habitats form an inter-dependent and inter-connected system. Most noticeable are the interactive effects of vegetation in rivers, with river margins providing diverse vegetative habitats, and vegetation affecting the channel form through island colonisation and channel splitting. The primary energy input of a forest stream is the leaf litter, while the primary energy input to an open river channel is from in-stream algae and macrophytes. This gives rise to very different eco-systems, which in turn impact on the channel form.

Thus from steep forested headwaters to wide flat marshy alluvial plains, rivers change their form, and over time they change with climatic variations and changes in the intensity of floods. These changes alter the ecology of the river, which in turn feeds back and alters the physical processes and form of the river.

At one end there are mountain brooks – steep shaded waterways of pools and drops over and around a bed of gravel, cobbles and boulders. The water flows in a side to side stepping pattern through the pools and drops and around the boulders and carved out baserock. There is little change in the bed or movement of the boulders, except in extreme events. The power of the water is absorbed in the turbulence caused by the very rough and highly complex bed form. Here the water retains or even increases its oxygen level, is mineralised but with low nutrient levels. The shading and cooling effect of forest vegetation along the waterway maintains cooler and less varying temperatures of the water, the air over the water and the soils beside the waterway. This affects the viability and productivity of aquatic insect life and the exchange of nutrients between the stream water and adjacent groundwater. The primary energy input to the river ecology is litter from the overhanging trees, and this directly feeds bacteria and fungi and supports a high diversity of invertebrate insects.

At the other end there are flat graded and slow flowing channels within wide alluvial plains and saline estuaries of sluggish tidal flow with beds of sand and silts. The river channels have a uniformly meandering form, with no obvious pool and riffle zones, but there is a variation in depth from bend to bend with reversing channel section asymmetry. The whole of the river bed is mobilised during significant flood events, with channel material streaming from the eroding outer bank of one bend to the inner side beach of another bend. The power of the water is mainly absorbed in the movement of the channel sediments, with only minor turbulence losses from obstructions and variations in channel form. Within the estuarine reaches, there are continual in

and out flows of the tidal exchange and the silt material present means that the water is never clear, and has a high load of fine sediments and nutrients. Here aquatic plants predominate, and the primary energy input is from in-stream algae and water weeds. Under low flows, the bright sunlight, high temperatures and enriched nature of the water can generate extensive algae blooms.

Between these extremes there are a wide range of channel forms as flows and sediment/nutrient loads vary, and in-stream, riparian and floodplain life varies in concert. The character and nature of waterways change in response to, or in refection of the changing landscape and environment.

A comprehensive characterisation of waterways would extend beyond a determination in terms of the physical features of river or stream reaches, and along with physical form would include the hydrological regime, the riparian (and floodplain) vegetation and habitats, and the aquatic life and habitats (of invertebrates and fish).

RIVER RESTORATION

There has been much international debate, and more than a little controversy, about what is natural character and what does river restoration mean. If a river is to be restored to its natural state, what is this state, and how do people then continue to live on floodplains and beside rivers? There have also been many river restoration failures, often because a preconceived idea about river naturalness has been imposed on river reaches that have a quite different character.

To have natural character, a waterway reach does not have to be in some presumed 'natural state'. This is the same confusion that arises in river restoration, of some presumed 'natural state' to restore a reach to, without having regard to its natural character, and the nature of the dynamic processes at work along the reach. A river reach can only be 'restored' to what suits the existing or present nature of the reach, given its riparian and catchment

conditions and the influences of the prevailing climate. Conversely, a river retains its natural character whatever the changes in catchment or climatic influences, albeit a different natural character than it had previously.

Retaining natural character is a matter of providing sufficient space for the river to express the character it has along any given reach, given the vegetation present and the colonising and growth character of that vegetation. It relates to the dynamics of the river system, and changes over time, and over geological eras. It is not the retaining of a fixed state, or a conversion to some supposed 'natural state'.

WATERSHED MANAGEMENT

IMPACTS on WATERWAYS

Our interactions with waterways, as with the natural world in general, is mounded by our cultural values and beliefs, by a worldview that is about control and dominance. Civilised life, of urban living and settled agriculture, has been developed from a worldview of control, where there is a perpetual struggle against the forces of nature to wrestle a living from it.

In the urban industrial lifestyle of the modern developed world, rivers are mostly seen in terms of water resources and services. The principal services being to provide channels to contain flood waters and pass them as fast as possible downstream and through to the sea; and as waste disposal conduits to dilute and transport away our 'wastes'.

Given these aims, it is hardly surprising that the techniques of management then result in straightened waterways with fewer and sharper margins, less or more uniform waterside vegetation and restricted or completely prevented waterway-to-floodplain exchanges. All of which degrades the waterway environment by

constraining and/or modifying waterway processes and thereby altering and suppressing the ecology and life of waterways

Our cities and landscapes are divided by very artificial and rigidly defined sharp boundaries, with a linear layout of separate and distinct parcels of land, recorded as mathematical units. Property title boundaries go in straight lines from one survey point to another, without regard to the features and form of the landscape.

Similarly, our process technology involves a rigid control of separate elements combined together in complicated ad hoc ways to suit a specific goal or output. There is little built-in redundancy or internal self-governing. Control is imposed on the system through continuous monitoring and a constant manipulation of externally supplied inputs and energy.

The modern human world has become very disconnected from the realities of life on Earth, with its multiple cocoons of artificiality. Thus, when we have to deal with natural systems, like forests, wetlands and rivers, there is often a failure of understanding — and of imagination. And hence a severe disjunction between the tools and techniques we use and the character and responses of these geo-eco-systems. In so many ways, we have come to live very differently to the ways of our world.

Policy functions are separated from operational functions, service delivery is compartmentalised into separate competing business units, and objectives are separated and become the responsibility of different departments. Problems are dealt with one at a time, and signed off when a specific solution is identified for each problem. The aim is for a continuity of economic activities, where there are no surprises and business can continue as usual. Except 'as usual' means maximising short term gains and doing so continuously through constant growth.

Instead of seeing ourselves as part of nature, and thinking and acting in a way that mimics the patterns and processes of nature,

we have developed a singularly extreme and rigid approach. Socially our lives have become dis-connected and lack a common guiding rhythm and purpose, as we engage in a frantic whirl of often mindless activities, with no aim or direction other than to maximise a singular purpose. Whatever it is we are doing there has to be more of it, whatever we have got we must have more. Everything must be controlled and regulated to make us safe and secure, but every possibility must be developed and all things must be freely available. The overriding goal is economic expansion, with investments being determined by the pursuit of financial gain, making money. All the other consequences in the real inter-connected world are subsidiary at best, if not ignored or deliberately dismissed.

It is not possible to determine the health and vitality of rivers and streams by economic analysis. The common measure of economics, of monetary prices, requires a dumbing down of all values to relative trade or exchange ratios. They are not even a measure of utility or value, of usefulness or beneficial value. They are just a representation of the relative willingness to pay for goods and services that are made available and exchangeable within a given market.

The natural world, which is being ever more confined and destroyed by human activities, has a very different rhythm and dynamic. Natural systems have a highly complex dynamic of connectivity and inter-dependence, with an indeterminacy and creativity that gives rise to a fluctuating meta-stability between order and chaos. Life flourished within this dynamic tension.

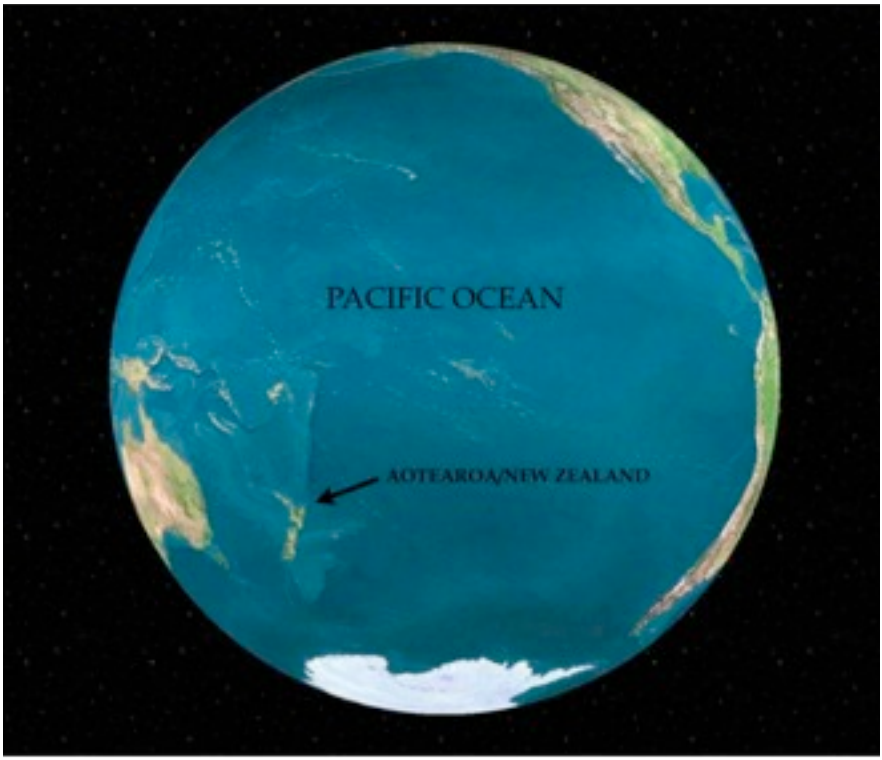
The diversity and complexity of life means that context is fundamental to the understanding of a place or waterway, and for effective interactions. The behaviour and responses of a waterway or river reach depends on the specific nature or character of that reach, within the wider context of its watershed and local climate.

Effective and mutually beneficial management of watersheds thus depends on the nature of the locality, and the formative influences of climate and landscape processes.

AOTEAROA/NEW ZEALAND ENVIRONMENT

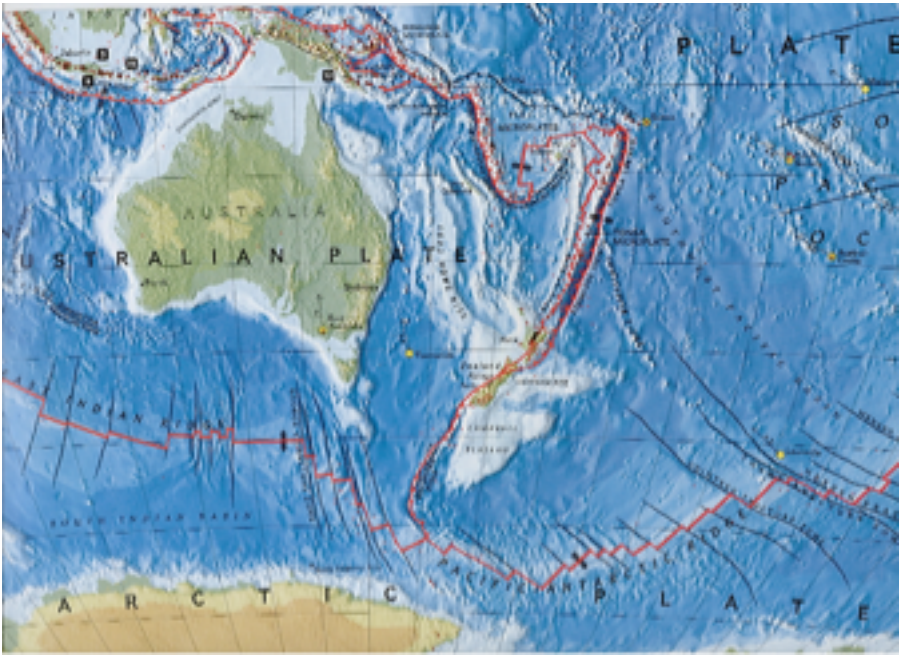
Aotearoa/New Zealand (A/NZ) is a very isolated landmass in the south-west of the Pacific Ocean (see Figure 8). This ocean is the largest on Earth, and covers nearly half the globe. A/NZ is a continent, but much of the continental landmass is beneath the ocean surface, and the present land area consists of two large mountainous islands and scattered small islands, near and far from the two large islands.

Aotearoa/New Zealand Location (Figure 8)



It lies on the tectonic boundary of the Pacific "ring of fire", with uplifted mountains, volcanoes and geothermal areas, and the continental landmass has been pushed and shoved, raised and sunk, over long periods of geological time (see Figure 9). It has a mountainous backbone along the line of this boundary, with rapidly uplifted and shattered base rocks, and steep gravel-bearing rivers that have a short run from the mountains to the sea. It has a southern mid-latitude oceanic location, where the mountain ranges cut across the westerly circulation of anti-cyclones and depressions of these latitudes, giving rise to high intensity rainfalls and strong winds.

Geophysical map of south-west Pacific Ocean (Figure 9)



(The tectonic plate boundaries shown - in red)

The oceanic climate is highly variable, with an unstable seasonal pattern, and longer term variations from the oscillations of large global circulations, southern oceans circulations (around Antarctica) and circulations around the South Pacific. The back

and forth movement of a convergence zone of two large circulations gives rise to decades long variations in the A/NZ climate. The diverse landscape and climatic regions of A/NZ are affected at different times and in different ways through the pulsating dynamic of these natural oscillations.

As well as the seasonal variations from its mid-latitude position, every year the seasons are different and there is wide variations in climatic conditions from week to week, and even day to day. It is a high intensity climate with much variability, on a rugged, mountainous and geologically active landscape — a high energy place.

Flood flows are generated very rapidly, and give rise to sudden but brief flooding of floodplains, under natural conditions. The relatively high flood flows and steep grade of rivers in A/NZ give rise to powerful highly turbulent flows that move large amounts of sediments and debris over short periods of time. However, the short duration of these floods suddenly truncates sediment transport and channel movement, and this can leave sharp hook embayments and other channel irregularities in the bed of watercourses following flood events. The steep landscape of weak fault-broken and weathered base rocks gives rise to high watershed input of sediments, even with the natural forest cover of A/NZ. As a result, the alluvial (self-forming) channels of these rivers are highly mobile and change rapidly, even over human life spans.

The landscape and environment have changed substantially in recent geological times. During the last glacial age, A/NZ was mostly covered by open grasslands and scrublands, with forests on the margins and ice-fields along the higher mountain ranges. From around 15,000 years ago, there was a progressive covering and diversifying of forests, with the warmer climate and greater rainfall of the present inter-glacial period.

The isolation of A/NZ gave rise to unique and highly diversified temperate climate rain-forests, with its own soil life and a fauna

based on highly speciated birds, lizards and snails, and grasslands with a profusion of small flowering plants. The geological submergence of A/NZ meant that mammals had been eliminated from the ecology. Lowland podocarp forests, in particular, are highly diversified, as multi-layered forests with a complex mosaic of species and interactions between plant and soil life. These A/NZ forests have adapted to a high energy regime, with intense rain and strong winds, on steep erodible land, and have high resilience to climatic extremes.

In summary, the tectonic location of A/NZ, with its earthquake, volcanic and land uplift and subduction activity, has given rise to a very active landscape, with steep and fractured mountain ranges and fast-flowing and very mobile rivers. Its oceanic location gives rise to a highly variable climate, and its mid-latitude position means that global climate changes have a very pronounced effect on its local climate.

The nature of the A/NZ landscape then gives rise to many different regional climatic regimes on the two main islands of A/NZ, from subtropical conditions in the north to cold temperate in the south.

A general zoning of regional climates is shown on the 'Aotearoa/New Zealand — Climate Regions' map (of Figure 10). This excludes mountainous areas and is a very coarse scale mapping, but provides an overall guide to the larger scale diversity of A/NZ regional climates. The storm intensity and flooding phase of any given region, from the climatic oscillations that affect A/NZ, is critical to the approach taken to watershed and waterway management. Interventions during a quiescent phase will be very different to those during a flood intense phase — as the waterway systems will be responding very differently giving rise to different channel dynamics.

In general, the Bay of Plenty will have a quiescent phase when the Interdecadal Pacific Oscillation (IPO) is in its positive (westerly predominant) phase, while the South Island West Coast

will be in a flood intense phase. The converse holds when the IPO is in its negative (northeast predominant) phase, with the Bay of Plenty experiencing a period of intense flooding.

Generalised Regional Climates (Figure 10)

NEW ZEALAND RIVER MANAGEMENT

Significant habitation by people, which affected the environment, is very recent in Aotearoa/New Zealand. Polynesian migrations less than 1000 years ago brought the cultivation of sub-tropical vegetables, and the use of fire for cultivation, clearing and hunting. The hunting of large ground birds and the use of fire, along with climate changes, led to the conversion of large areas of forest to grassland, especially in the South Island, and the extinction of many large birds, including all of the flightless moa. The introduction of rats and dogs also led to the extermination of many small birds and invertebrates.

In the last 200 years, European exploration and settlement has had a much larger effect, especially in the North Island, and given rise to a very mixed up ecology, from introduced species and altered ecosystems. There has been the introduction, both by association and deliberately, of a vast array of plants and animals from all around the world, including grazing and predator mammals, game birds, freshwater fish, insects and many viral, bacterial and fungal organisms. At the same time, the large lowland and coastal wetlands were drained for farming use, with over 90% of all wetland areas being drained. Most of the lowland forests have been cut and burnt for pastoral farming, including on steep hill country, with forest cutting for timber taking place up into steep range land.

The landscape of A/NZ has, then, been highly modified from lowland plains to rugged hill country by extensive pastoral monocultures, with much of the countryside being uniform short grass 'green deserts'.

Apart from the remaining native forests on the steep mountain and range land of the main axial ranges of A/NZ and some volcanic mountains, the environment has been highly modified by a range of human activities, if most significantly by pastoral agriculture. Many invasive species of plants have been

introduced, and introduced mammals, both domestic and wild, have profoundly altered ecological relationships, and the health of present ecosystems.

Alongside the large-scale impacts on watershed vegetation and erosion processes, there have been a whole host of direct and intentional interventions in waterways and river systems. Many of these interventions have been to use land and water as economic resources, and then to protect productive assets from flooding and erosion.

Rivers and waterways have been confined and their movement restrained for flood and erosion mitigation purposes, as well as being modified or dammed for hydro-electric power, despite the high energy regime and sediment transport loads of most NZ rivers. At the same time, the introduction of invasive species that rapidly colonise waterways has profoundly altered the riparian vegetation and vegetative regime of rivers where the native forest cover has been removed.

The lower reaches of most rivers in A/NZ, including nearly all the larger rivers, are managed, and there are many flood and erosion mitigation schemes throughout A/NZ. The main aim of many of these schemes was the protection or development of agricultural land.

The generally localised urbanisation along rivers and low population density, has meant that river management has been carried out using relatively inexpensive low strength methods. There has been a general reliance on vegetation alongside the river channel, and willows, in particular, have been used to manage bank erosion. Infertile varieties of willows have been used, but willows grow rapidly from cuttings, and snagged material can quickly spread willow vegetation across river channels.

Willows have been planted along waterways from the early days of European colonisation, and many waterways have become choked with willows due to their rapid growth and spread in the

A/NZ environment. The use of willows for river management, while widespread, is very much a two-edged sword. A periodic alternation between the clearing of willows from channels for flood capacity and the planting of willows along banks for erosion protection, is not uncommon.

Rivers are dynamic systems with continual losses and regrowth of vegetation in and along their margins. Besides willows, many other rapidly colonising species that have been introduced, including gorse, broom, lupin, pampas grass, tree lucerne and a range of acacia species from Australia. These introduced species have established and spread rapidly along A/NZ waterways. This has changed the vegetative makeup of A/NZ rivers, altering the way they behave and migrate in flood events. Native vegetation is much less invasive, and generally establishes slowly by seed, and not by vegetative propagation.

At the same time that river channels were being modified in these ways, the clearing of forests, especially from the rolling to steep hill land that makes up a large proportion of the A/NZ landmass, has markedly affected watershed conditions and the supply of sediment and debris to and down waterways. Large flood events in early European times were very heavily laden with debris, and in the denuded catchments soil debris flows could form during intense rainfalls on saturated soils. A sequence of blockages from debris and sediment flows and then bursting flows down waterways gave rise to higher and more severe flood flows than runoff alone.

Initial flood management was mostly by earth stopbanks along river channels. Machinery was used to remove vegetation from channels, and reshape the channels of shallow gravel-bed rivers. Extensive use was made of gravel extraction from river beds for commercial uses in construction and road making. In many instances this resulted in entrenched waterways and unnaturally distorted channels that have given rise to ongoing management difficulties.

Severe storms caused widespread catchment erosion and very extensive sediment deposition as well as flooding around A/NZ in the 1930s. In response, the NZ Parliament passed the "Soil Conservation and Rivers Control Act" in 1941, during World War II. After the war, major flood mitigation schemes were constructed along the lowland reaches of rivers, along with soil conservation measures in the pastoral hill country. The increasing availability of machines, and of increasing power and sophistication, gave rise to two major trends in river management.

Firstly, there was much more intervention in rivers, with the straightening of channels and the reshaping of the active gravel-bed areas of rivers, using draglines and bulldozers. This did result in the clearing from river beds of the invasive introduced vegetation, although the disturbed river beds facilitated a rapid re-colonisation, giving rise to repeated channel clearing. This activity also induced very significant alterations to the channel form and the pattern of low flow channels, braiding and flood overflow channels. At the same time, more substantial and higher stopbanks were constructed alongside river channels. Generally, these flood defenses were close to the edge of main channels or the gravel bed area as present at the time of construction.

Later, quarried rock was used to construct rock protection works along river banks, generally as a solid lining of the bank, using hydraulic excavators. This resulted in fixed river banks that prevented any further channel migration. However, a rock lining on one side of a river could aggravate erosion on the other side, as the river channel moved and flood flows were more sharply deflected across to the other side. The increasing use of rock works gave rise to more constrained channels, which increased bed scour and bank erosion pressures, hence generating the need for further rock works.

Vegetated margins were still widely used, and some intermediate strengthening measures were developed. This included fences of driven piles joined by two or three cables to form a flow retarding measure, without blocking off the flood flows within the vegetated berm land. The river edge of the vegetation was also strengthened by sets of permeable groynes spaced along the river bank. These permeable groynes could be made of different materials, but involved tied-together pile structures spaced at regular intervals along the river edge and oriented in a downstream direction. They deflected the main body of floodwaters away from the river bank, as small deflections, while still allowing a flow of floodwaters through the groynes and vegetation along the river margin.

The combination of highly mobile and powerful rivers with a low habitation density, but economic reliance on agricultural produce, has given rise to a particular approach to the management of rivers in New Zealand. Although it has involved hard edge protection works, in many cases rivers have been managed through a flexible edge of vegetation, generally willows that are easily propagated but also spread easily. This then required relatively frequent interventions of channel clearing and reshaping, and the reinstatement or strengthening of margin vegetation.

Each river system has, though, its own history of modifications, and there are on-going and cumulative effects from past alterations of channel form, flow patterns and sediment delivery. These past changes affect the present river conditions, and hence potential future modifications and adjustments to river management practices. The in-channel and margin vegetation has a particularly significant impact on channel form and roughness, and changes in vegetation extent and density can alter the type and planform of river reaches. The vegetative status of a river reach is, thus, critical to river management, and management options.

AOTEAROA RIVER MANAGEMENT

The starting point of a reassessment of past practices of river management was a better understanding of geomorphological processes, and how river systems are formed and altered over space and time. In simple terms, rivers expend the energy they have from water flowing downhill on moving material, given form and friction energy losses from changing channel shape and vegetative interference. The movement of sediments, from catchment inputs and channel re-working, is thus an inherent associate of hydraulic (flood) flows, and hence also of the alteration and migration of channels.

River management to contain flood flows or to reduce erosion losses (of land or assets) directly affects channel width and form, and hence impacts on sediment transport, as well as flood levels and velocities. The relationship between flow containment, altered channel form and the scouring and deposition processes that move channel bed materials, was a fundamental principle of the review of management practices I undertook in the late 1980s.

The aim was to work with the processes of nature, and not against them, and thereby achieve a more effective and cost efficient management of rivers over the longer term. The aim of engineering design is to select options that have the least overall cost in the long term (of many decades), where costs may be evaluated over a range of management objectives, and not just financial or budgetary costs.

The main outcomes were to give rivers more space to move with flexible vegetative margins and to use a diversity of techniques selected to suit the specifics of any given site or waterway reach. This depended on an understanding of the wider and longer-term watershed processes, the legacy of past events and human interventions and the current dynamics at the reaches of interest.

Repeat aerial photography provided a means for assessing channel form and rates of change, and these changes could be related to the magnitude and frequency of floods and historical

variations in the intensity of flood flows. Comparisons of multi-decadal records of aerial photographs showed similarities of channel form over time, with characteristic forms along given river reaches. Particular channel forms displayed a self-similar pattern, with the width and radius of curvature of channel meanders remaining the same as channels moved and were reformed by flood events.

What was also notable was the repetition of these patterns of change over time in concert with the intensity of flood events. The nature of the channel would change as the hydrologic regime shifted from a quiescent period to one of more frequent and larger floods and then back again, but the shape and width of channels and their general meander form would remain the same, for a given regime, although differently located.

These patterns of channel form and behaviour indicated that a river reach had a characteristic way of behaving within a range of variation. Determining the characteristic form of a river reach and its variability over time then provided the basis for an assessment of the space required for the river to maintain its natural processes associated with flood flows and sediment transport. From this a clear channel area could be determined along with zones of riparian vegetation on each side. This provided a defined area for the re-working processes of bed material transport, while allowing for channel migration and expansion, but with some containment of flood flows and erosion pressures.

A range of alternative scenarios and management practices were assessed. The options were summarised in three possibilities, as shown in Figure 11 below. This is a diagrammatic representation of the main alternatives considered in the studies, and used for community consultation and explanations of the alternatives. The studies showed that the approach with a defined active channel area within wide vegetation buffers that allow channel migration and a give-and-take at the channel edges, would be the

most cost effective in the longer term, while maintaining an environmentally diverse river corridor. This approach was seen as an intermediate alternative, between a heavy control that fixed the channel edge, and a retreat that provided a wide river corridor, but one that would become densely vegetated. The main problem with a wider set back and minimal intervention option was that recently introduced (non-native) species would rapidly colonise the space and choke flood flows. Not only would the willows introduced by past vegetation management spread, but also self-seeding gorse, broom, tree lucerne and other invasive pioneers would colonise the river corridor. In time there would be breakouts from this enlarged area because of the deflection effects of the vegetation, with an anabranching of long, separated channels through the vegetation and beyond.

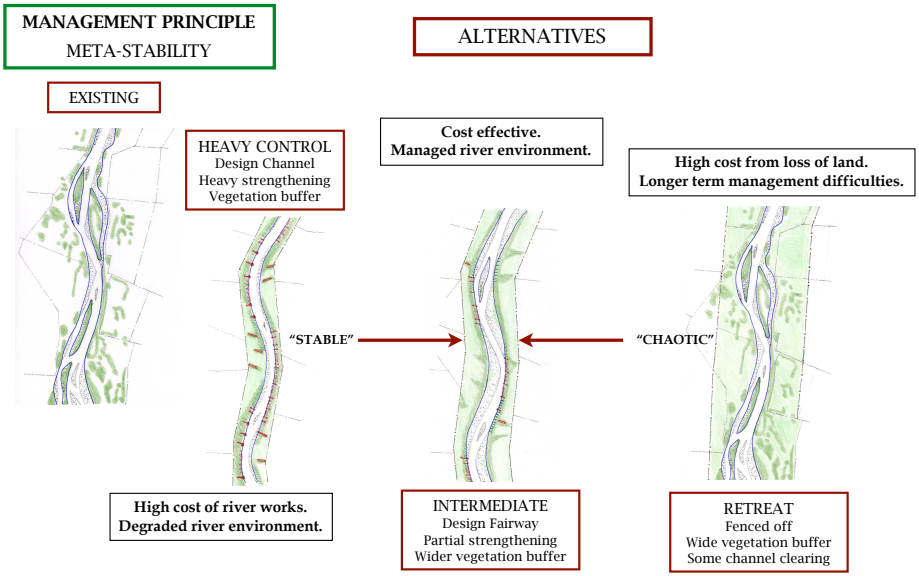
Essentially, the approach taken involves a systemic balancing of: on the one hand, the human occupation of floodplain land, with the risks of flooding, land loss and damage to assets this entails; and on the other, the space required by rivers for the natural processes that transport water, sediments, debris and nutrients, given the impacts that introduced vegetation is having on these processes.

The 'intermediate' approach that was developed in this way was a compromise, given the altered river conditions from past interventions, the confinement of the natural spread of flood waters and the vigorous growth of river channel vegetation. The 'heavy control' approach was expensive, and required continual repairs and maintenance because of the extent and rate of river adjustments to the works, while a 'retreat' option required the retirement of productive land and the management of large areas of vegetation.

The objective was to obtain better environmental and economic outcomes, by maintaining a more natural waterway that is managed in a way that recognises and works with waterway processes. This objective was, however, constrained in its

implementation by many factors, including: the availability of river-side land, costs and economic impacts, funding arrangements, the presence of introduced invasive plants, the use of willows for river edge management, natural bed and bank controls that deflected and disturbed channel forms and meander patterns, artificial controls at important assets, and changes in upstream or watershed conditions.

Generalised Management Alternatives for Gravel-bed Rivers (Figure 11)



This approach has been implemented along river reaches throughout A/NZ, mostly where there is an existing management scheme from past river management. It does assume a continuing commitment to management interventions, especially of the waterside vegetation.

LIVING with WATERWAYS

An integrated and responsive approach to the management of waterways in A/NZ requires a cultural shift. An understanding of water and waterways that recognises its life-giving energies, and the need for a respectful and responsive relationship, as creatures of this world, dependent on the health and well-being of living systems and the physical processes that maintain life on planet Earth.

Water can not be boxed in as separate entities and contained by rigid structures. It is the role of water to cross boundaries and exchange information and nutrients. The use and management of water has to be undertaken communally, as a common shared life-bearing medium. A sharing of power and decision-making at a community or hapu level should be embedded in our relationships with the natural world, and our management (or interaction with) water most challenges this sharing and decision-making. The social constructs of ownership and its exchange (by conquest, gift or purchase), the emphasis on competition or cooperation and our communal decision-making processes all affect the impacts we have on water and waterways, and hence their health.

The exchanges mediated by water allow connection and hence responses, and a responsive sensitivity engenders responsibility. A society or community that valued all its members and supported their health and creativity would function like a highly responsive and healthy ecosystem. Observing the patterns of water and the functions it performs provides an understanding about life and our social systems. The dynamic sharing of water, with its inward and outward flows of spiraling vortices, provides a template for the sharing of social power for the benefit of all people and the diverse groups and communities that make up a complex society.

Providing space for the natural dynamics of waterway processes allows a diversity of form and character, from the main stream to wild margins, side flows, edge eddying and overflows spilling into wetlands, ponds and floodplains.

A relationship with water based on its diversity, connective power and exchange capacity, would provide us with the physical, mental, and spiritual space to be creative individuals and communities.

How we relate to and treat the waterways of our place is how we relate to and treat ourselves.

Gary Williams Summer 2022

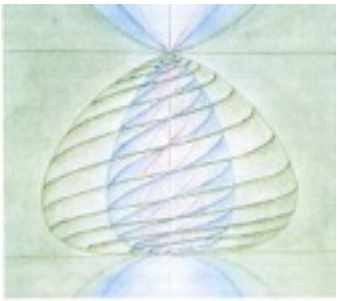
Otaki, Aotearoa/New Zealand

www.waterscape.co.nz

Love Life, Love Water.

Healthy waterways means healthy people.

With thanks to the margin-dwellers who care about the health of our waterways and their life-giving energies.



WATERWAY MANAGEMENT

THAT IS

RESPECTFUL & RESPONSIVE

VITALISING & NUTRIENT RECYCLING

CREATIVE & DIVERSE

VALUING WATER AS NATURE INTENDED