THE USES OF RIVER WATER AND IMPACTS

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Contents

Summary

This topic writing serves as an introduction to the various topic articles dealing with River Water Uses and Impacts. Categorical listings and descriptions are made of the principal uses and major negative impacts resulting from the utilization of water from rivers and streams. Rivers are also seen as ecological systems supporting various life forms some beneficial and others detrimental to supporting human life. Examples are given from among the rivers of the world illustrating some of these uses and impacts. The uniqueness and variety of global river systems are emphasized. The concepts of support and sustainability of living systems are defined. Recommendations are made regarding procedures to ensure sustainable life support systems based on the uses of river water.

In two appendices diametrically opposite examples are given, illustrating the uses of river water and the impacts. Firstly, a major multi-national river (the Mekong), and secondly, a network of ephemeral rivers crossing semi-desert terrain and providing sustenance (western Namibia), are described.

1. Introduction

Rivers and streams form part of the hydrologic cycle, that enduring and incessant exchange of water on planet Earth from time immemorial up to the present. The hydrological cycle starts with evaporation off free-water surfaces, continues with water returned to earth by precipitation and then carries on as run-off into and over the ground surface, until it reverts back to accumulation in terrestrial water bodies and the oceans of the world. The interception of precipitation by catchment areas is followed by its conveyance as run-off along drainage areas all over the exposed land areas of the globe by means of an interconnected network of natural stream channels.

This presents humankind with one of the greatest and most useful natural phenomenon of streams and rivers, that provides civilizations with a water supply which appears to be inexhaustible in the long run. Not only are uses made of such available water, but improvisations are also devised to collect and transport the water away from the more remote sources towards the highly developed user areas. In this process various impacts are also made on the environment, that may have certain harmful effects. Spent water, after all, also has to be returned via the hydrological cycle to the original source. Harmful effects may be concentrated in this process.

2. Historical Overview

Since time immemorial, civilization centers have arisen along or close to streams and riverbanks, as well as next to estuaries, alongside coastlines and on river deltas. Ready access to water determined in a large way where towns and cities originally sprang up. Once these were established and enlarged, it often became necessary to collect water from further afield by tapping other rivers or their tributaries. Underground water sources supplement surface water supplies, but they also form part of the hydrologic cycle. Infiltration, subsurface conduction and storage follow the same general route as surface run-off - downwards along gradients under the influence of gravity - towards an eventual, even if only temporary, state of rest in the lakes or oceans of the world.

Not only does the water in the hydrological cycle follow this route of downward travel, but it takes with it solid material from the earth's surface - mud, silt, sand grains, rocks and boulders, and continuously shapes the land surface into an intricate morphology. These interconnected slopes and drainage channels cover large portions of the land's surface.

Rivers form important boundaries to neighboring tracts of land; often becoming political boundaries between countries. They also form routes of commerce and communication, linking areas of civilization by efficient water transport media, in the case of navigable rivers.

A further formative agent is ice, brought down in cold regions by glaciers or the thawing of frozen rivers, which plays an important role in breaking up and transporting solid material from the upper layers of the earth's crust. Material brought down by erosion and the tractive effort of flowing water is again deposited in lakes, reservoirs, and river mouths, forming deltas. Fertile soil is thus deposited in meander bends, alluvial fans, wetlands and dendritic delta areas, permitting humankind to settle there and raise crops for its sustenance.

The face of the land is slowly, but inexorably and continuously being changed - rivers carve out bends, known as meanders and oxbow lakes - coastlines change in the vicinity of sediment depositing estuaries - deltas form and reform. Riparian property lines would change and political boundaries may shift, as a result.

To counter the downward migration of water and the soil carried with it, and to reduce the shoaling and regime changes of rivers and streams, humanity has constructed countless reservoirs, by building many dams, has created numerous river stabilization works and has developed techniques of dredging out channels for navigation purposes. In the following sections these uses as well as their impacts will be discussed in broad terms, to be followed in the individual articles under this theme. In these writings factual information and detailed discussions on selected issues will be found.

3. Rivers as Sustainable Life Support Systems

Rivers and streams, with their immediate environments, are also ecosystems and natural life habitats. They form part of the food chain from vegetative material through invertebrate up to vertebrate animals, including humankind (bacteria, plants, fungi, crustaceans, mollusks, fish, domesticated animals and game, humans). Rivers are indeed complex life support systems, the sustainability of which depends on rather delicate balances being maintained.

Before further addressing the subject of rivers as sustainable life support systems, a few clarifying definitions may be in order. A life support system is generally considered to be that which is necessary to maintain life under adverse circumstances. For the present case, however, it may be considered that which is necessary to maintain life under all circumstances. Life, here, refers to human life, as well as life forms supporting human life.

- Examples of elementary *life support systems* might be as basic as a fresh water fountain or spring, a rainwater intercepting surface with a storage tank, a single dug well or a bored water well equipped with a windmill or other type of pump; or they may be as sophisticated as a regional water supply network for a vast metropolitan complex. A river, a lake, a ground water aquifer, a glacier, a dam with its reservoir, may also be part of such a life support system.
- *Life* is here considered a concept that is inclusive of all its forms on earth, not merely restricted to human life. The latter depends for its continued existence and support on many other life forms: plants, and animals (vertebrate and non-vertebrate) but it can also be threatened by such competitive and parasitic life forms as bacteria, viruses, fungi, mites, insects and other vectors carrying diseases such as malaria, bilharzia, yellow-fever, cholera, etc.
- *Life support* is offered by the availability of water, air, land, solar radiation and food, but also by shelter against exposure under temperature extremes, by heating and ventilation, air conditioning, waste disposal, medical services and energy. In the more restricted sense, *life support systems* have traditionally been considered to be of the non-conventional type such as used for sustaining life at high altitudes, low or high temperatures, in water and underwater environments, in underground mining and as a care for the injured, sick and elderly in various clinical situations (oxygen, drips, circulatory, dialysis and respiratory aid systems, medication, pharmaceuticals, prosthetics, etc.).
- A *system* is generally considered to be a complex interrelated and well coordinated array of components functioning together towards a definite objective, e.g. telecommunication systems, water reticulation systems, power distribution networks. In this sense a river is also a *natural system* when it comes to supporting life. A delicate balance is maintained by environmental factors such as solar radiation, oxygen transfer, plant and fish life interaction, nutrition versus eutrophication and pollution. Renewable resources, such as air, water and solar energy are necessary for creating bio-mass, the result of living processes.
- *Support* and *sustainability* are key considerations that are interrelated. Life support also implies the concept of population increase. The human life support system becomes gradually more complicated as the population numbers grow and the living area expands. New developments such as commuting, rapid transit, networks for power, telecommunications and water distribution develop. The systems become complex and also vulnerable, needing their own control and emergency services (fire control, waste disposal, security, ambulance and police services and national defense). Rivers do feature also in these aspects to a greater or lesser extent, they not only offer means of access, transport and escape, but also act as barriers requiring bridging and tunneling to be negotiated.
- *River systems* provide life support in a sustainable habitable environment, assure water supply, means of transport of commodities, removal of waste products (or their recycling) and clean energy sources, for urban complexes such as e.g. Rotterdam, New York, Cairo, Kinshasha. Rivers provide life support essentials, such as timber for homes, habitats for fish, water for crops, space for living quarters. Intermittent rivers (due to flow interruptions by ice or drought) require man-made storage reservoirs for overcoming periods of water shortage.
- *Rivers forming life support systems* are globally ubiquitous, unique, individual and at the same time may be both robust as well as tenuous: providing sustainable

services, but needing constant attention, involving their maintenance, remediation and expansion.

The above broad ideas are merely introductory and much finer details are to be found in companion articles, reference volumes and handbooks on specific subjects.

3.1. River Systems

Before dealing with the uses and impacts of rivers and streams, it is necessary to consider the wide spectrum of river systems, including their particular geomorphologic behavior, especially at their termination or mouths. This is of cardinal importance in viewing the uses and impacts made on their dependent population centers. Rivers, along their main courses, can be of various types, which will be named and examples given. Their termination can be in the form of *estuaries*, simple *river mouths*, open or closed due to sand bars, or complex *delta* formations. The ingress of *salinity* into river mouths is one important complicating factor, so is the contribution of *sediment* by the river to the termination area. These factors will affect uses such as *navigation*, *fisheries*, *water supply*, and *irrigation*.

3.2. Types of River Systems

Rivers can be of the following kinds:

- *Linear* and/or *meandering*. Examples are the Nile, the Niger and the Volga Rivers, which are characterized by *one principal stream*, with relatively minor contributing tributaries, following a gently curving course from source to mouth.

- *Dendritic*. Examples are the Amazon and the Congo Rivers, which have *many contributing tributaries*, all major rivers in their own right, that cross the watershed from all angles, resembling the branches of a tree. These main branches have their contributing subsidiary branches, and they have even smaller ramifications. The difference here is that even third or fourth degree branches are substantial streams capable of supporting navigation, but also difficult to cross by road.

- *Compound systems*: meandering, shifting, anastomosing, such as the Jamuna and the Burdekin Rivers in Bangladesh and Australia, respectively. The difference here is that the *meanders* are *unstable* and the *anabranch* channels form and reform in an arbitrary way, known as *braiding*. The Mississippi River features unstable meanders that form interstate boundaries with associated geographical problems.

3.3. Types of River Termination

- *River mouths* can be permanently open, temporarily closed, or permanently closed in rare cases. *Sand bars* that form and are removed by floods are the causes of partial closure.
- *River deltas* are formed when the sediment load is excessive for the transportation power of the river. An alluvial fan is formed which is again cut through by radiating channels forming the delta. Examples are the deltas of the Nile, Parana and

Mississippi Rivers, which are characterized by a main branch and one or more subsidiary branches in the delta. Other examples of deltas are multi-branched all of comparable magnitude, such as the deltas of the Niger, Mekong, Volga and Xi Chiang Rivers. Of these, the Volga River terminates in the Caspian Sea, the others in the open ocean, or in a gulf.

- An *estuary* is a river termination considerably wider than the main stream and singular, associated with what is known as a *drowned* coastline. Examples are the Chesapeake and Delaware Bays, the Rio De la Plata, the Amazon, the Congo and the Yangtze River mouths. A peculiarity of estuaries is the range of salinity from fresh to salt in the direction of flow, and also the well-mixed or partially stratified nature of the salinity distribution. Another complicating factor for utilizing this area commercially is the deposition of sediment. These factors affect fisheries, navigation, water supply and effluent disposal.
- *Embayments*. Some estuaries are so disproportionately wide, compared to the river itself, that the term *bay* would be more appropriate for the river termination. Examples are the Gulf of St Lawrence, the Uruguay River, the Potomac, the Rappahannock, the Patapsco Rivers, all terminating in the Chesapeake Bay. This class may also be applied to *fjords* (Norway, New Zealand).
- *Inland Draining Termination*. There are also rivers that drain inland and disappear in lakes, swamps, marshes, pans and playas. Examples are the River Jordan, the Aral Lake, the Lake Chad complex, the Okavango River (Botswana), the Etosha Pan (Namibia), and the Rift Valley in central Africa.

3.4. Inter-connections between Rivers and River Improvements

It is important also to consider artificial enhancement of river systems in the form of connecting channels, canals, cuts and improvements to water depth, bends, and width. These may be engineering works that considerably modify a river system towards some benefit by humanity.

- *Canals between rivers*, built for navigational purposes, are found in Europe, North and South America, Russia, China and Africa. They could be supplemented by dredging of certain sections of rivers for the same purpose, e.g. on the North Sea coastline of Europe, and in the Rio de la Plata Estuary in Argentina/Uruguay. Maintenance of shifting channels and deltas is also practiced (Nile Delta, Jamuna River, and Mekong Delta, for example).
- *Artificial rivers*, or ship canals, have been created for access between oceans, as well as inland waterways. Examples are the Canals of Corinth, Kiel, Welland, Suez, Panama and the Intra-Coastal Waterway, the St Lawrence Seaway and the Chesapeake and Delaware Canals. In Europe there are many smaller interconnecting canals between rivers, as well as in the United States in the Great Lakes region. Some very long inter-connecting canals are found between large river systems in Russia and China.

4. Uses of River Systems

Since time immemorial, rivers have been the locations where humanity congregated, settled and multiplied, for example in the Nile Valley, along the Tigris and Euphrates, on the Tiber and the Thames. They also form natural barriers, and therefore in some places they became international boundaries, for example parts of the Mekong, the Rio Grande, the Zambezi and the Orange Rivers.

More importantly, in the present era, river systems have the following potential uses: navigation, water power production, fish culture, water supply, habitation, recreation, industry, commerce and transport, mining, waste water disposal, international borders and harbors. The uses made will in each case depend on the local characteristics of such river systems, as well as the actual needs of the participating population.

4.1. Examples of River System Uses

The following examples are the most relevant ones:

- *Navigation*. Examples are the following: the Amazon is navigable for 2300 miles out of its 4000 mile length (main river), plus long stretches of some of the nearly thousand tributaries. Yet it only supports four million people in its seven million sq. km. drainage area, For comparison, the Nile River is navigable for 2400 miles of its 4100 mile length and supports fifteen million people in its 4.35 million sq. km. drainage area. Other navigable rivers are the Parana/Uruguay/Rio de la Plata System (which requires constant maintenance dredging of navigation channels), the Mississippi, the Ohio, the Danube and the Yangtze.
- *Hydro-electric power projects* are supported by some rivers, such as the Rhone, the Danube and the Rhine, involving dams and ship-locks for navigation purposes.
- *Fisheries* are supported by rivers such as the Columbia, Rio de la Plata and the Sacramento, for example.
- *Water supply* uses of rivers are of paramount importance in semi-arid countries, such as Bolivia and South Africa, for example the Desaguadero and the Orange/Vaal/Tugela complex, respectively.
- *Habitation area*. Examples of large urban living areas, situated next to rivers or estuaries, are Buenos Aires and Montevideo on the Rio de la Plata, London on the Thames, Paris on the Seine and Los Angeles on the river of the same name.
- *Recreation*. Apart from other uses, certain rivers have become famous as tourist venues, for example the Rhine, the Danube and the Yangtze.
- *Industry/Commerce/Transport*. Many rivers such as the Rhone, the Rhine, the Danube, the Yangtze are characterized by a linear development of highly industrialized sectors, supporting a major concentration of population of the countries they traverse.
- *Agriculture/Irrigation*. Of particular interest are the systems that developed around the Nile at both its delta, as well as at the confluence of the Blue and the White Nile branches. Another example is the Sacramento and San Joaquin River system development in the Central Valley of California.
- *Mining*. As an example of the exploitation of an ephemeral river in an arid region is cited the Kuiseb River in Namibia, which supplied the Rössing Uranium Mine for several decades with water drawn from underground aquifers.
- *Waste-water Disposal*. Unfortunately, from time immemorial, up to the present, rivers have been the convenient disposal area for domestic and even toxic industrial wastes with grave consequences for downstream users. International collaboration

has resulted in observing strict controls on waste-water disposal, and water quality maintenance, principally for international rivers. Examples are the Danube and Rhine Rivers in Europe.

- *International Borders*. Over considerable portions of their lengths, some perennial rivers also form international borders (Rio Grande, Mekong, Kunene, Zambezi, Orange, etc.) which has led to the drawing up of some bi-national or tri-partite agreements for the mutually beneficial development of their resources, for example the Parana, the Nile, the Duero, the St Lawrence, the Kunene, the Komati, and the Orange Rivers.
- *Harbors*. One of the most important uses made of certain large river systems in their improved state usually, is that of harboring ocean going traffic, for example the Port of Rotterdam is situated on the Meuse River and its extension, the canal known as the New Waterway, crossing the reclaimed Maasvlakte at the new Europoort Harbor. Another example is the Port of Antwerp which is situated on the dredged Scheldt River, tens of kilometers inland from the North Sea.

The Dutch Delta Works is an example of the extensive river improvement and flood protection programs that certain countries have brought about, in the interest of a better and safer life for their inhabitants. The St. Lawrence Seaway Project was undertaken by the United States and Canada as a connection to accommodate ocean shipping between the Atlantic Ocean and the Great Lakes system, shared by both countries.

Other examples of harbors situated on rivers or estuaries are London Docks on the Thames, Bremerhaven on the Weser River, Hamburg on the Elbe Estuary and Durban on the canalized Umbilo River in the estuary known as Port Natal, and East London Harbor in the Buffalo River mouth (South Africa).

4.2. Uses of River Deltas

River deltas as generally characterized by constant deposition of sediments in alluvial fans and underwater sand bars. In certain cases, deltas support an intensive agricultural community employing canalization and furrowing to raise staple food, for example, the Nile Delta and the Mekong Delta.

Other examples of vast river deltas are the Lena River in Siberia (undeveloped), Sao Francisco in Brazil, Burdekin in Australia, the Ganges (India and Bangladesh), the Manahadi and Godavari (India), the Indus (Pakistan), the Song Koy or Red River (Vietnam), the Irrawaddy (Myanmar) and the Orinoco (Venezuela).

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Biographical Sketch

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