Hydrology, hydraulics and hydrotechnics

A few words about rivers in context of SimCity 4

Kamil B. vel kbieniu7

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Introduction

This document is meant to be a kind of a brief guide into hydrology and hydrotechnics for SimCity players. I tried to make a summary of most important features of river engineering that might be found useful for more experienced and realism-oriented players. Being such a wide topic, there are many simplifications that are meant to make the guide more understoodable for the most of the community. Even though the document is quite significant in volume as for a game tutorial, so I divided it into several chapters.

All information in this document is based on books, internet sources, as well as my own university education and own experience. I tried to do my best, but if you manage to spot any kind of mistakes, feel free to share your comments.

Also, feel free to share the document itself, the best with the link to the origin webpage.

An attachment to this document is a step-by-step tutorial how to build an earth dam in SimCity 4.

The original version has been published at sc4devotion forum:
http://sc4devotion.com/forums/index.php?topic=18372.0

I. Catchment basins – worth keeping in mind when terraforming.

This chapter consider some land shaping tips and basic ideas on catchments basins. It might be especially helpful for people who are terraforming their regions.

When terraforming our regions we tend to concentrate on mountainous landforms, i.e.: mountain peaks, hills, cliffs or plateaus, while in the same time neglecting valleys and lower parts of the terrain reducing them just to "something boring that is between" the aforementioned shapes. And that may lead to unwitting mistakes and errors that make our land unrealistic and in need for later corrections. The most common issue is creating a large amount of little areas that have lower elevation than anything around them.

Look at the region below. For the first moment it might seem quite fine: we've got mountains, rivers and plains. But if you look closely, you will spot several of such areas (marked with red circle).

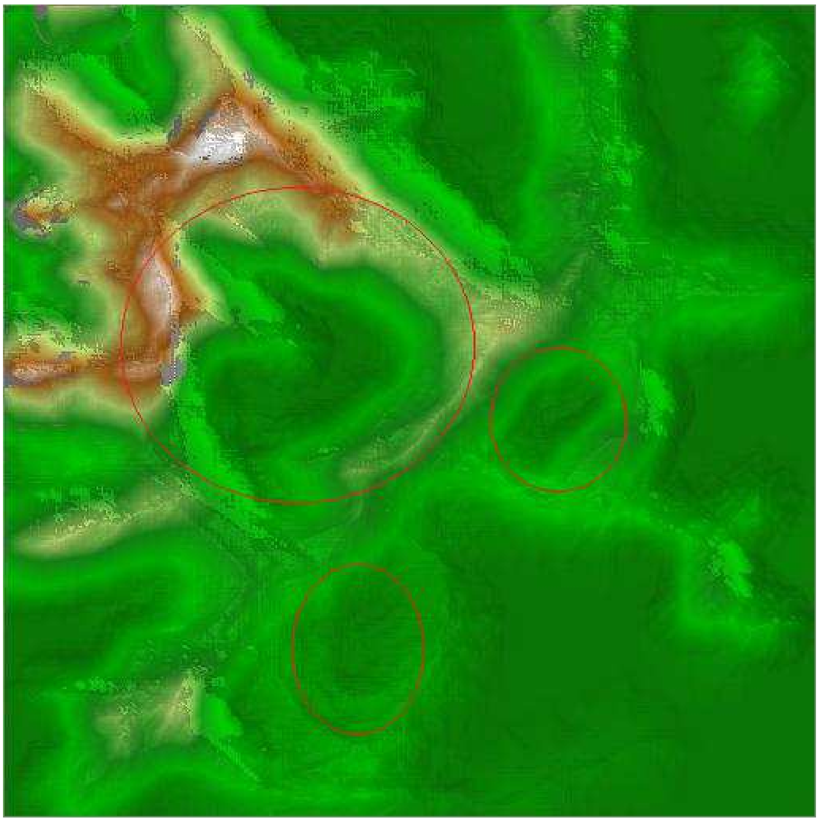

Fig.1 *A terrain shape with enclosed basins.*

Why it is so important? If we concentrate only on creating hills or trying to plan how to lay our future towns or roads, that makes no big trouble. But if we later try to model a small stretch of a river or a creek, then the problem begins. Imagine a rainfall (even though bare SimCity 4 doesn't have it) and water droplets landing in the proximity. Each of them will follow the slope and go as low as possible. If they reach such area, water has no further direction to escape and this lower zone will soon become a lake.

Fig.2 *A valley high in the mountains. Arrows show how surface water flows down. Now imagine that there is no exit from this area.*

Water is everywhere (unless we're building on a desert). Each point of our region could be exposed to a rainfall and from each point there should be a constant way downstream, so the water flows further and further right down to the sea. That's why - in my opinion - it's much better to terraform our regions not concentrating on mountain ranges and uplands at first, but on catchment basins.

But what is a catchment basin?

*A **catchment basin** or a **drainage basin** is an extent or an area of land where all surface water from rain, melting snow, or ice flows to a single point at a lower elevation (usually the exit of the basin, where the waters join another body of water, such as a river, lake, reservoir, estuary, wetland, sea, or ocean).*

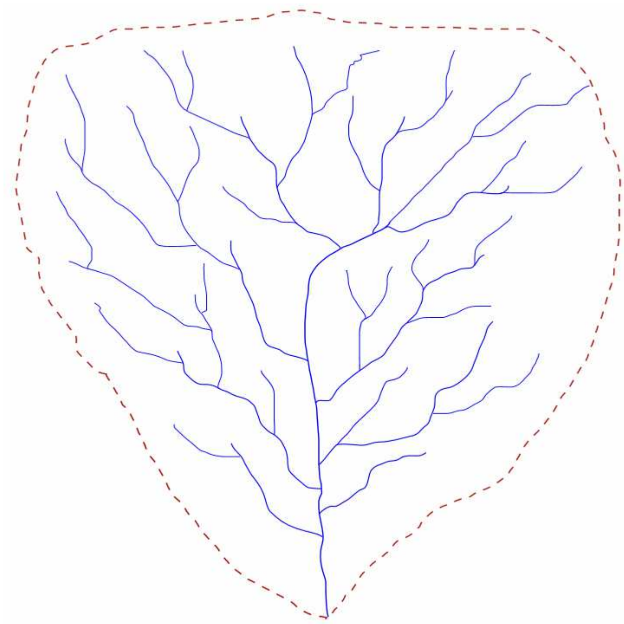

Fig.3 *A schema of a catchment basin. Source: Wikipedia [W1]*

It is very important to know and feel what a catchment basin is. Look at the region below. Pick a random point on it and try to guess: if you pour a glass of water on a surface at this particular point, which way would the water flow? Then pick another one and now try to guess: which area water will reach this point from? Does the concept seem to be more clear now?

Fig.4 *May I have a glass of water, please?*

Remember – it should apply to no matter which point you choose, the entire region should be drained (it means that water will find its way down to the very end). This is a crucial rule for "planning" our river network… yes, you've red it correctly – not just one river, but *a* ***network*****.** Don't draw just one line from the sea up to its springs – **consider it as it was a hierarchical network**!

Now I'm pretty sure that you're asking: **how to terraform with this rule**? To be honest... I do not have one good idea. What I would advise is to perform this kind of analysis of "how the water will flow?" somewhere during your terraforming. You may start with "drawing" the main mountain ridges and main landforms and after that try to "dig" into those mountains creating continuous valleys.

Ok, so we have our entire region properly drained down to one big river. What will happen with the water then? Of course, it would go further downstream… further and further, merging with other rivers, draining bigger and bigger areas. It might run into a zone with higher elevation than itself and form a gorge then, eventually reaching its final target, a sea or an ocean… But not necessarily…

Fig.5 *Gorge of Dunajec river in Pieniny on Polish-Slovakian border. Note very narrow valley and steep slopes. Author: Jerzy Opioła, source Wikipedia [W2]*

Sometimes, especially in dry regions, rivers don't reach the ocean. They are enclosed in a big no-outflow area, where there is no further way down, just like in our little no-outflow circles from the beginning. In such situation the water is coming and coming, filling up the lowest possible spot and forming a lake. The lake gets bigger and bigger until its surface became large enough so the amount of water evaporated from it equals the amount of water that is coming from the rivers. Real life examples of such enclosed systems are Great Basin with Great Salt Lake in the western US or Jordan Valley and Dead Sea in the Middle East. And that's why those water bodies are so salty – water evaporates leaving all dissolved minerals at scene.

Fig.6 *Great Basin, USA. Water from this area flows neither to Pacific nor to Atlantic Ocean, evaporating instead. Author: Kmusser, source: Wikipedia [W3]*

A little bit of hydrology. How it varies between regions?

Water is in a constant movement. It falls down from the sky during rainfalls or snowfalls. Some of it stops on the plants, the rest reaches the land. It might flow down on the surface (runoff) finding a river, infiltrate the soil and reach underground aquifer layers (layers that contain water) or evaporate back to the air.

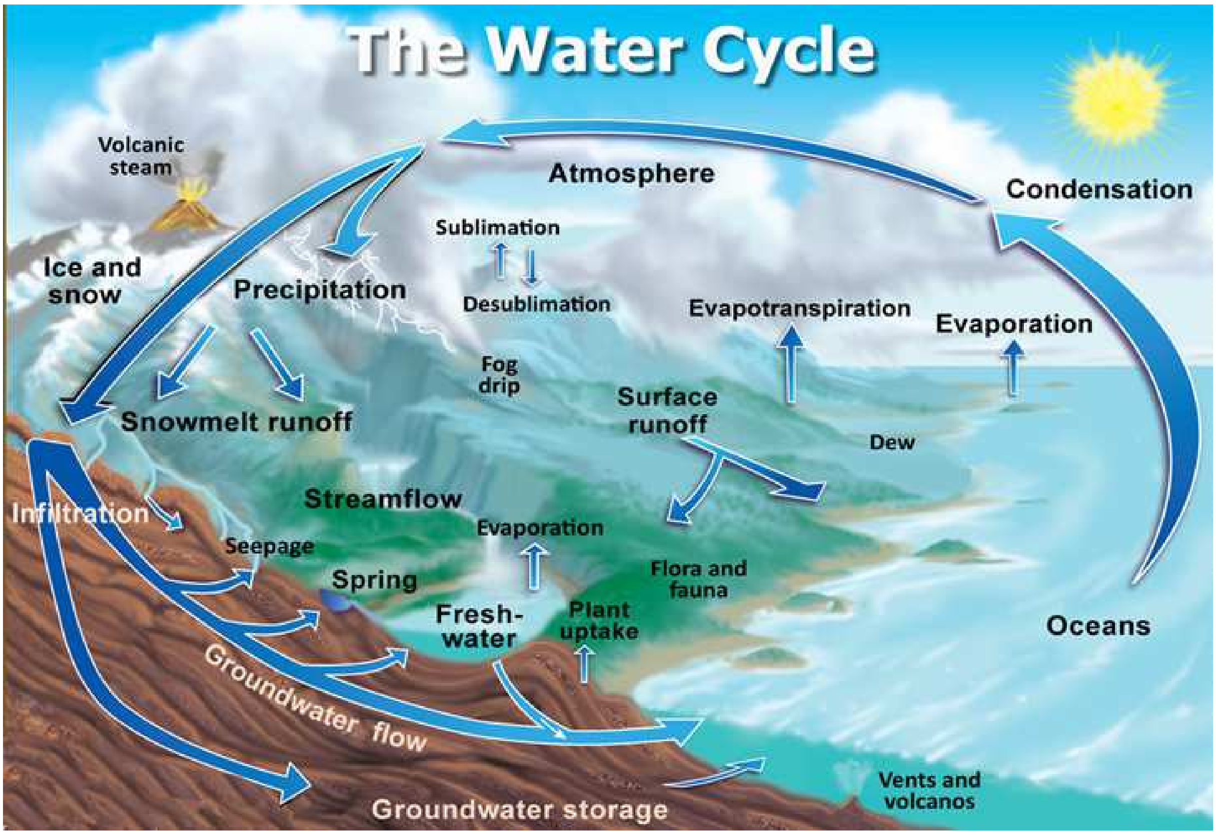

Fig.7 *Water cycle explained… or at least depicted.*

You probably remember this graph from school, don’t you? You might feel like being back in a classroom, but I hope I haven’t make you bored too much.

We can divide and distinguish catchment basins in many ways, but let’s concentrate just on one division:

a) **mountainous catchment** – usually has steep slopes and low-permeable soils (meaning that water has problem to filtrate into the ground). It’s caused by bedrock layers on the surface or placed relatively shallow what means that almost entire water is running on the surface and it does it very quickly. What is more, in higher altitudes the annual amount of rainfall or snowfall (called *annual precipitation*) is usually higher than in lowlands. Those two factors cause mountainous regions to have very dense river networks with – let’s simplify it – more rivers and wider rivers produced. However, floods are more quick-occurring and rapid (within hours after a rainfall) and dry seasons more perceptible.

b) **lowland-type catchment** – in lowlands slopes are much more gentle (or almost flat), so the velocity of water in rivers is much lower. The ground is usually made of easily-permeable soils, so water has possibility to infiltrate the land and be stored underground. That effects in less water reaching rivers and lowlands seem to have less of them, with several large rivers travelling across the continent (like Donau, Rhone, Wisła and Volga in Europe or Mississippi in the US) that are the most visible ones. Floods last for longer and many of them is caused by ice melting during springtime (in areas of world where the snow falls), as well as dry seasons do not necessarily force rivers to dry out.

c) **mixed catchment** – might have characteristics that are a mix of aforementioned ones.

Below is a map showing amounts of rain- and snowfall across Europe. Note that higher values are present in mountainous areas and in the proximity of the ocean.

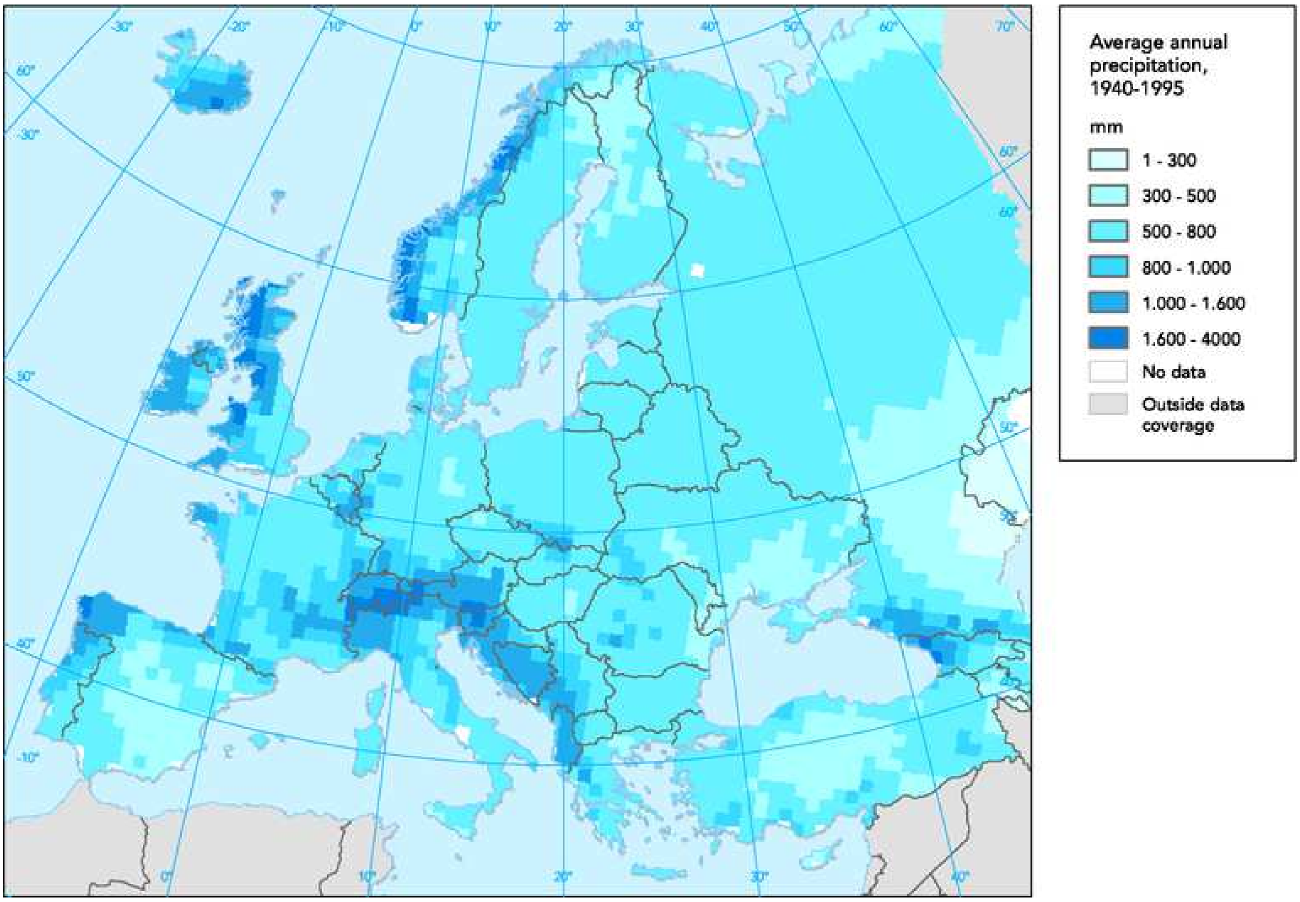

Fig.8 *Annual precipitation across Europe. Source: European Environment Agency [E1].*

An interesting phenomena is a rain shadow. It occurs when wet air runs into a barrier (area of higher elevations) and creates a rainfall. The air travels further, but now is drier and the area behind the barrier gets less rain. It could be very significant, helping deserts to form (like Atacama Desert in South America being situated between two mountain chains of the Andes and the Chilean Coast Range), but even small (few hundred meters high) mountains or highlands can create such shadow. Look up at the map of precipitation across Europe, and note what happens in central Spain, Scandinavia or eastern England.

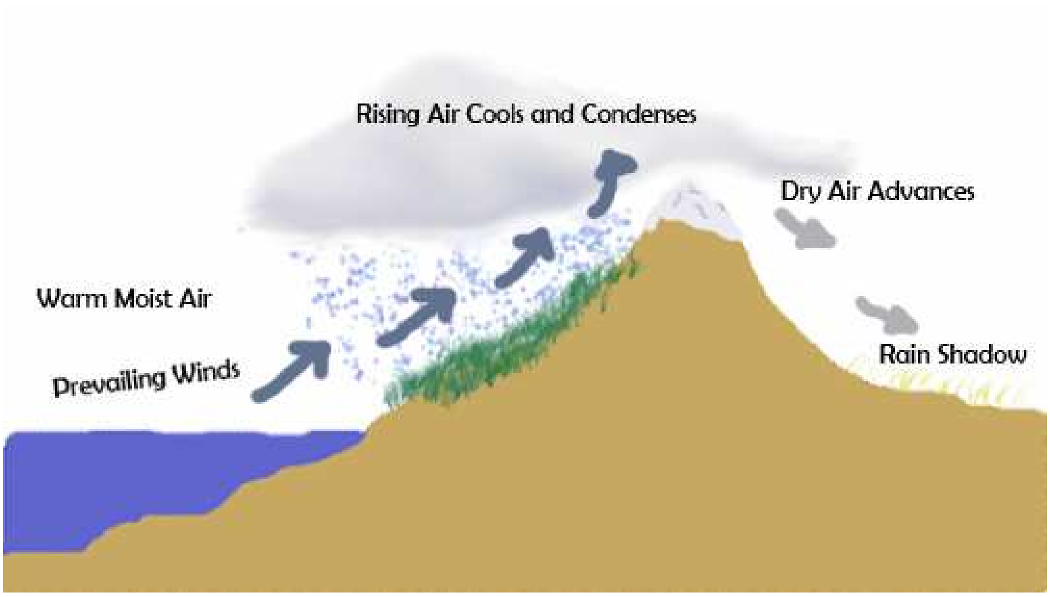

Fig.9 *Rain shadow explained. Source: Wikipedia*

By the way, in drier regions some rivers may even temporarily dry out! And it doesn't need to be on Sahara. The photo below shows a dry river during summertime near Montpellier, southern France.


Fig.10 *What can you tell judging on sediment type? Source: own work.*

Watercourse

Rivers collect water from a catchment basin and transport it to areas with lower altitude. What is very important, they also carry **sediments** (sometimes called as **debris**) such as rocks, gravel, sand and thinner particles.

Sediment transport is crucial – it comes into the watercourse because of erosion. Surrounding terrain is destroyed (by water or with help of wind, sun or frost – and that's a main power of constant shaping of Earth's surface) and produced particles are being carried downstream. The faster the water runs, the bigger particles it may carry. If it slows down too much, those rocks, gravel or sand stop and are accumulated forming new forms (like alluvial plains or islands).

<u>One river has many faces</u>

Rivers are not homogenous in their entire length. We can divide them into several sections that vary a lot one from another:

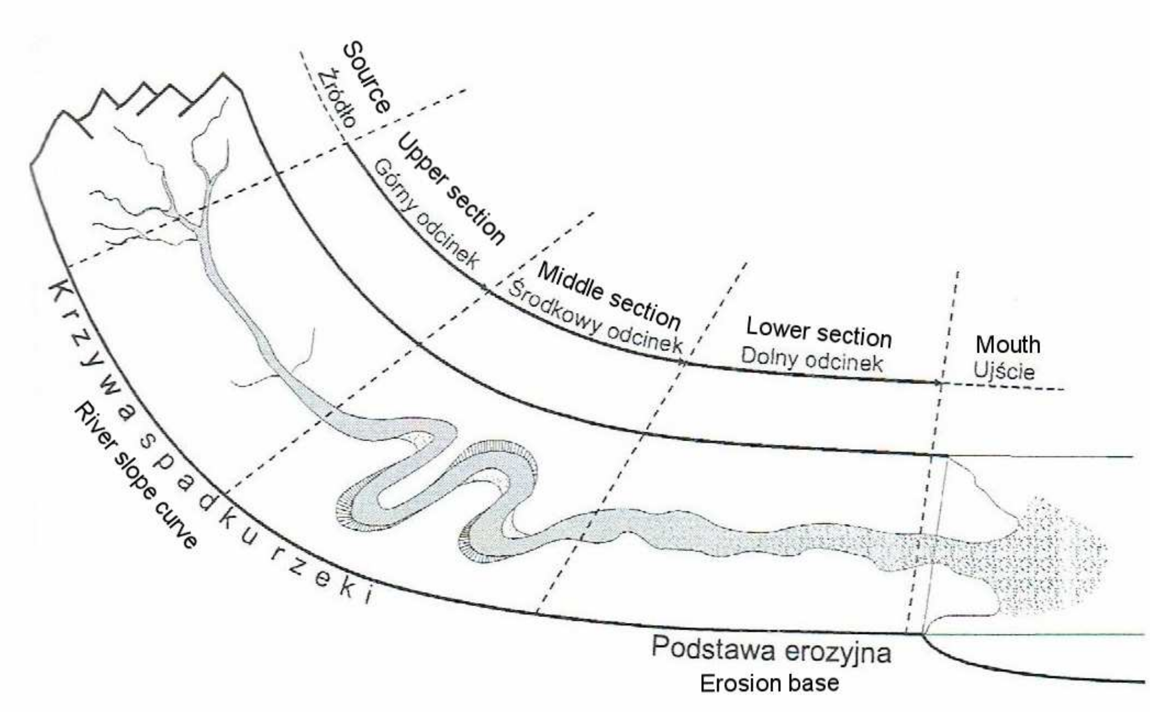

Fig.11 *River sections along its course. Source: [E2]*

Springs or **sources** – it might be a single-point source where underground water (from aquifer geological layers) leaks out on the surface (so called seepage), it might be an area that collects all surface water flowing on it, a glacier, a lake or it even swamps. Sometimes it might be an underground river that runs through caves and corridors inside the bedrock and finally reach out the open-air.

Upper (mountainous) section - characterized by steep slopes . Steep slopes means the water is running faster, so it has more energy and thus ability to erode surrounding terrain and carry all the material downstream, even boulders and rocks. The river bed is mostly built from rocks, gravel or it's even a bare bedrock. The course of a river is mostly straight (it's not meandering).

Middle section (mountains and highlands) – slopes are more gentle, the water slows down and has no such energy as previously, so larger debris (like boulders and bigger particles of gravel) stopped upstream and build the river bed and banks. In this section a river may develop meanders.

Lower section (highlands and lowlands) – slopes and differences in height are really small, the water runs very slowly and has very little energy to carry the material (unless during floods). River bed is built mostly with sand, dust, silks or very fine (thin) gravel. In this section accumulation of material occurs more than erosion, meanders and islands are a common thing.

Mouth – a point where a river reaches the sea, ocean or lake. It might have a form of an estuary (a wide and triangle-shaped basin-like), a delta (network of many parallel running channels) or a combination of both ones.

Above-mentioned division may help us with shaping the layout and appearance of a river (using a huge variety of MMPs). Let's see it on several examples:

A mountainous creek or a river will mostly have banks and bed covered with rocks and gravel. As the effect of bed erosion, many rapids, whirlpools, disorders etc. are present. Sometimes bedrock might be visible. There's almost no vegetation directly on banks.

Fig.12 *Białka river, Poland. Author: Łukasz Goryl, source: Wikipedia [W4].*

Fig.13 *A SimCity counterpart – two mountainous rivers merging. Note that the channel is mostly built from boulders, rocks and gravel.*

If we move downstream (for example to highlands or to large and almost-flat mountain valleys), slopes are no longer so steep and water runs slower. Thus, rocks and gravel are still present in the river, but more of thin particles are accumulated as well. Some vegetation grows on the banks. The river has some curvature, creating a sinusoidal-like course or meanders sometimes.

Fig.14 *Raba river near Dobczyce, Poland. Author: Piotr Matyga, source: Wikipedia [W5].*

Fig.15 *A SimCity counterpart – Jaworzyna river in Galand. The flow is more gentle and the banks consist mostly of sand, but gravel and rocks are still present.*

In the lowest areas, slopes and thus the velocity of water are very low. There are practically no rocks and no coarse gravel, mostly sand. Banks are mostly covered by vegetation and the course is curvy, with well-visible meanders. In wider rivers islands or other forms of material deposits are often present.

Fig.16 *A SimCity counterpart – Parszęta river near Raszkowo, Galand. A lowland river, having neither gravel nor stones on its banks.*

<u>Even inside one river there might be different forms</u>

Even if we analyze just a small (a hundred meters long or so) stretch, the river is not completely homogenous. Its curving motion implies several phenomenon.

When flowing through a curve, water has different velocity throughout its cross section. It runs faster in outer part (thus eroding the outer bank) and slower in inner part (thus disposing carried material). That's why you may often spot wide gravel deposits, sandbanks and beaches on inner banks.

Fig.17 *A river in Bieszczady Mountains, Poland. Depositing material on the inner bank, while on the outer bank its limited by bedrock. Source: own work.*

Fig.18 *A SimCity counterpart – try to make wider sand deposits on inner banks.*

The same forces cause meanders to form in flatlands (where slope is very gentle and ground sensitive to erosion) and make them grow larger and larger, often being eventually cut through and forming an oxbow lake (an oxbow lake is a cut-off and croissant-shaped part of old river channel).

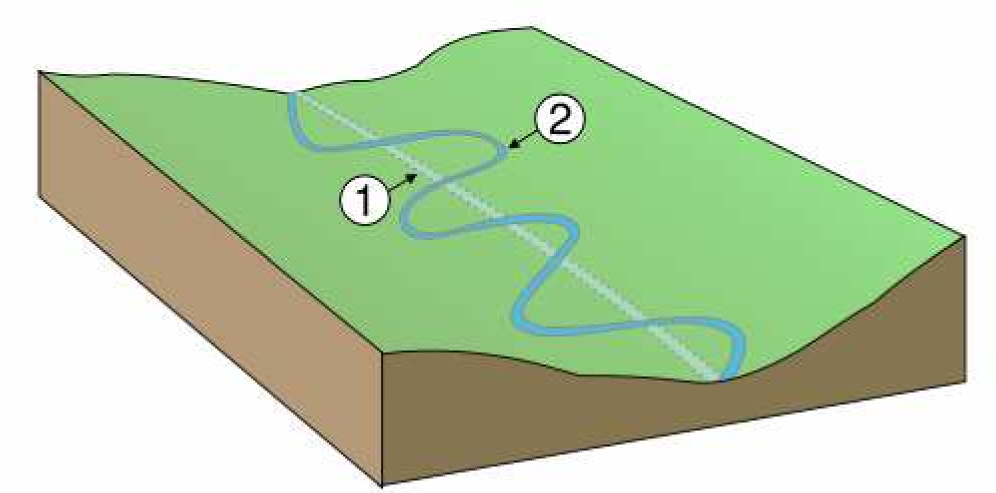

Fig.19 *Meanders: 1-before, 2-after. Author: MesserWoland, source: Wikipedia [W6].*

Fig.20 *Meanders on Rio Cauto in Cuba. Source: wikipedia [W7].*

Fig.21 *A SimCity counterpart – Wirta river near Kolbrów. Although not so spectacular and seeming to be partially geometrized, meanders are visible.*

Fig.22 *A SimCity counterpart – Amazon River. Author: Korver [S1].*

Local differences in velocity also cause island forming. If, for some reason, the main current inside the river split on two (leaving an area with lower speed in the middle of the river) bigger particles of material will be deposited in this place creating an island. It might be also caused by an obstacle, like a big rock or bridge pillars making some kind of a “shadow” behind them. Thanks to the same mechanism, rivers may create a lot of islands, forming a beautiful multi-branch braid-like layouts.

Fig.23 *Islands and multiple branches forming a braid-like layout of Wisła river near Warsaw, Poland. Source: Google Maps.*

Fig.24 *A pile of gravel stored behind a pillar of a bridge. Source: own work.*

Fig.25 *Tagliamento near Saint Peter in the community Ragogna, Italy.*
Author: Johann Jaritz, source: Wikipedia [W8]

Fig.26 *A SimCity counterpart – sandy islands on Wirta River, Galand. Some islands might be even covered with vegetation*

Mountainous torrents, creeks and rivers keep their course rather straight because of steep slopes and usually more resistant grounds. However, you may also spot different forms like riffles or some kind of in-water “ponds”.

Fig.27 *A SimCity counterpart – a torrent in Smreczyny Mountains, Galand. Note the stones in the water and many rapids.*

You'll never flow alone

As we have already said – rivers create networks and they can be hierarchized. We may pick one main river that flows through the whole catchment basin (i.e. down to the sea) and has its tributaries… which also have their own tributaries… which also have their tributaries and so on. A river starts in its sources and, as it flows downstream and merge with their tributaries, it has bigger and bigger *flow rates* (volume of water flowing through a particular point per a unit of time, for example m3/s) and – what is probably the most important from SimCity point of view – grows wider. There's no point in trying to put specific rules about what width should a river in SimCity have. However, I can give you a hint. In mountainous regions, river networks are usually denser and rivers wider (compared to their length), than it is in lowlands and plains. It's because higher amount of rainfall and less permeable soils.

"Technical" note about river merging. A tributary should point the same direction as the main river. Obvious, but sometimes might be forgotten…


Fig.28 *A SimCity counterpart – Wirta and Olszyna rivers merging near Olsza, Galand.*

Water and humans

Water has always been a very important thing for humans. Not mentioning the need for drinking water, it has always been shaping how the settlement and development look like.

Many towns and cities were established just by the rivers because of several reasons:
- **access to waterways** that used to be the fastest and most efficient way to travel and it is still today in many countries (like in the Netherlands or Germany);
- fertile soils on floodplains of big rivers - let's just say that the first biggest human civilizations started along Nile in Egypt, Ganges in India or Euphrates and Tigris in ancient Mesopotamia;
- **easier access in mountainous areas** – just imagine – if you walk along a river, you don't need to climb any mountain. They were first paths into mountain regions.

Below there are several examples from real world:

Fig.29 *City of Toruń, Poland. One of the most important cities in medieval Poland has been located just by Wisła river. Source: Google Maps.*

Fig.30 *Grenoble, France. The city is located at the merging point of two rivers: Isère and Drac that make a wide and flat valley. Easy-accessible, despite being surrounded by the Alps. Source: Google Maps.*

Fig.31 *A mountainous village stretched along a stream in southern Poland. Source: Google Maps.*

Briefly, what can we take to SimCity?

- many medieval (but of course not only!) towns were located by the rivers, especially on nearby hills or inside "triangles" made by two merging rivers;
- a very wide rive is a very big barrier – thus giant bridges that were hard to build are located in the proximity of big cities and shaping the entire route layouts in the region;
- wider river valleys are usually built from alluvial soils (material that was carried there by the river itself during large floods) that are very fertile, so they might be extensively used for agriculture and lead to dense development;
- in mountain areas villages are concentrated and spread along streams (that often need some hydrotechnical regulations to ensure protection against erosion and flooding).

Worth notifying is the fact that river banks, as well as wetlands, are very important environmental areas and characterized by a large biodiversity. Thus, many natural preserves are located along rivers, large estuary areas and deltas or swamps.

Fig.32 *National Park "Ujście Warty", where Warta river merges with Odra (Oder). Located by the Polish-German border. Source: https://www.pnujsciewarty.gov.pl*

Drinking water supply.

Have you ever thought about where the water in your tap comes from? There might be several places:

a) **surface water intakes** – located in the rivers or lakes. Often special structures are built to facilitate it, like dams (raising the water level and storing it), weirs (raising the water level) and many others;
b) **underground water intakes** – located in aquifer ground layers and taken by wells… or some more technically sophisticated installations. Hint: on the top of a mountains or a hill it might be rather not efficient to locate such intake. Underground water also flows down;
c) **desalination plants** – we know those facilities from SimCity 3000, remember them? In such plants sea water is used to remove salt from it. A brilliant idea, there is quite a plenty of water in the oceans, if used widely, it might satisfy all our needs for potable water, right? Well… not quite really… Desalination process requires large amount of energy making it very expensive, so only in several countries it is used widely, like Israel, Australia or Saudi Arabia. It is a reasonable source in very dry regions where there is a significant lack of fresh water and enough power available (the best, if there is lot of energy from the Sun to engage solar panels to produce electricity).

So, we’ve just taken our water, what to do next? Before it can reach out taps, firstly it needs to be purified. It is done in water purification plants where it is controlled, treated and once again controlled. Then, by a broad network of pipelines, it is carried to our homes.

By the way, do you know what are the water towers for? Water inside pipelines is transported under pressure. To create that pressure, one can pump up the water to a high container, so it fills the network with help of gravity forces.

We use fresh water to eat, drink and produce things in factories, but then we also produce wastewater. For years rivers were not only a source, but also a place where to dump all of what we don’t want any longer (unfortunately it is still a practice in many places around the world). Of course it wasn’t (and still isn’t) a good thing for the environment… and ourselves… So, how should it look like?

Wastewater from homes, offices, industry and agriculture is transported by separate pipes to wastewater treatment plants. Here it is processed and cleaned to a level that allows to return it back to rivers without harming the environment. Briefly speaking, there are plenty of instruments, devices and methods like sand filters, large sedimentation tanks and even bacteria used for this process.

By the way, wastewater pipes are usually not working under pressure but their content flows down with help of gravity, so such treatment plants should be located in the lowest part of the catchment basin (usually just by the river where we are going to dump the cleaned wastewater back).

The never-ending battle

So, we now know that humans tend to settle along rivers and streams. However, among benefits, there are also risks. Floods or erosion can be destructive and life-threatening, so engineers throughout ages tried to conquer the power of water.

There are plenty of solutions and type of structures to increase the security and use the benefits of rivers. Below few of them are listed. Unfortunately, they are rather hard to implement in SimCity.

River regulation – natural rivers have very different and non-geometrical channels. For reasons of flood protection or to facilitate water traffic, river channels are often modified and receives geometrical and regular shapes (including their cross-sections and course) by appropriate ground works. Compare two photos shown below. On the left there is a natural river and on the right a modified one.

Fig.33 *Natural and modified river. Source: Google Earth.*

Levees (or *dykes* or *floodbanks*) are usually earthen constructions that go along rivers. They protect surrounding terrain from being flooded. In built-up areas might be located just by the river channel, but usually they are in distances of several dozen or several hundred meters from it.

Fig.34 *A broken levee by Sacramento river, USA. Source: Wikipedia [W9].*

Channel protection – such as stone mattresses, grass and low-vegetation seeding or other type of bank stabilization that prevents from erosion which might be destructive for surrounding terrain.

Fig.35 *Bank protection on River Dinin, Ireland. Source: Inland Fisheries Ireland [E3].*

Fig.36 *A SimCity counterpart – partially protected banks and boulevard in Szlachtowa, Galand.*

Boulevards and heavy embankments – totally modified artificial channels, usually made of concrete or bricks. Used inside densely built-up areas, like villages or towns located directly by the river. Although it is tragic for ecological continuity in a watercourse, it gives the highest protection level for surrounding terrain, as it eliminates erosion and helps the water to flow faster (and therefore, because of rules of fluid mechanics, increase the capacity of the channel) and drastically lowers the risk of flood.

Dams and weirs – used for storing water (dams) and raising its level (dams and weirs), allowing to control it in specific sections of a river. The difference between a dam and a weir is that weir is usually not higher than few meters and have no devices to control how high is the water level upstream. More about it in the next chapter.

Fig.37 *Heavy embankments in Krościenko nad Dunajcem, Poland. Source: own work.*

Dams and reservoir

There are many different Hydrotechnical structures, but no doubt that the most impressive among them are dams and associated reservoirs. So, let's take a closer look at them.

Fig.38 *Goczałkowice Reservoir, Poland. Author: Andrzej Otrębski. Source: Wikipedia [W11].*

Let's begin with reservoirs. Obviously their task is to store water, but the reason for storing might vary:

a) flood protection – during floods, amount of water flowing in the rivers is extremely high. By storing part of it in one safe place we reduce the amount of water travelling downstream and thus protect the area that lays below the reservoir. When the flood is gone and the situation in the river is safe, we can then slowly release the volume of water that was stored. Special kind of reservoirs are dry reservoirs, that are filled with water only during flooding (usually have no steerable devices) and stay empty for the rest of the time;

b) water supply – by having huge amount of water stored in one place, we can take it to serve as a source of drinking water for people or for industrial/agricultural purposes. Such source is far less sensitive to changes in amount of water in rivers (annual fluctuations of inflow);

c) protection against draught – just like in the previous point, if we have enough water stored in one place, we can release it downstream, so there is more water flowing below the reservoir, that it comes to it from upstream. By doing this, we can protect the habitats, other water supply points located downstream or maintain waterways serviceable;

d) production of energy – we not only store the water, but also raise its level. This difference in heights allows to produce energy (if water is directed trough turbines);

e) recreation – although usually not a main purpose of constructing billions-euro-worth structures, its often their secondary function. However, if a reservoir is a source of drinking water, recreation (including bathing, yachting and other activities) might be forbidden.

Fig.39 *Dobczyce Lake, Poland – an artificial reservoir closed by an earthen dam. Created as a drinking water supply for Kraków. Source: Wikipedia [W10].*

Where a dam and a reservoir should be located?
- in the end of a long valley which shape would allow to store as much water as possible with no need to build extremely high dams;
- where there is enough water coming from upstream to collect (the area of catchment basin is sufficient enough) and where it would really increase flood protection level (for example, there is a large tributary river between the reservoir and a city that we want to protect – the reservoir would not affect floods coming from its tributary and its protective effect would be lower);
- where number of buildings to flood and people to move is as low as possible;
- in a place that is narrow and have steep slopes – as it is much more expensive to build a wider structure than a taller one. What is more, if the valley is narrow than elsewhere, it usually means that rocks and grounds in this place are more resistant (they haven't eroded so much) and would be a better place for foundations of a giant structure.

It's much easier to locate a reservoir in mountainous regions. In lowlands it is also possible, but usually it's hard to find an area where there is enough height difference between the valley and surrounding terrain. Dams would need to be very long in such situations (often not only a main "front" dam is needed, but also side dams too).

Now let’s look closer at the dams themselves. We can distinguish two types of them:

a) concrete dams – made of concrete or reinforced concrete. Usually located in narrower places, where big height is needed (but not necessarily). Generally arc-shaped, because such layout allows better distribution of forces acting on the structure. Of course nice arcs in SimCity are not possible, but that’s another story;

b) earthen dams – made of earth (rocks, gravel, sand, clays, whatever is in the proximity of construction site). Its waterward surface is usually covered with concrete slabs or asphalt layer to increase stability, protect from mechanical impacts and prevent water from filtrating through the structure. Their dry side could be stabilized with rocks and boulders or seeded with grass, creating a structure that nicely fits in the landscape.

Fig.40 *A concrete dam in Solina, Poland. Source: own work.*

Fig.41 *An earth dam in Świnna Poręba, Poland. Image taken before the reservoir has been filled with water. You can see the protection of the inner side of the dam with concrete layers and rocks. Author: Gambitek. Source: Wikipedia [W12].*

Fig.42 *A SimCity counterpart – a concrete dam on La Truyère river. Author: Badsim [S2].*

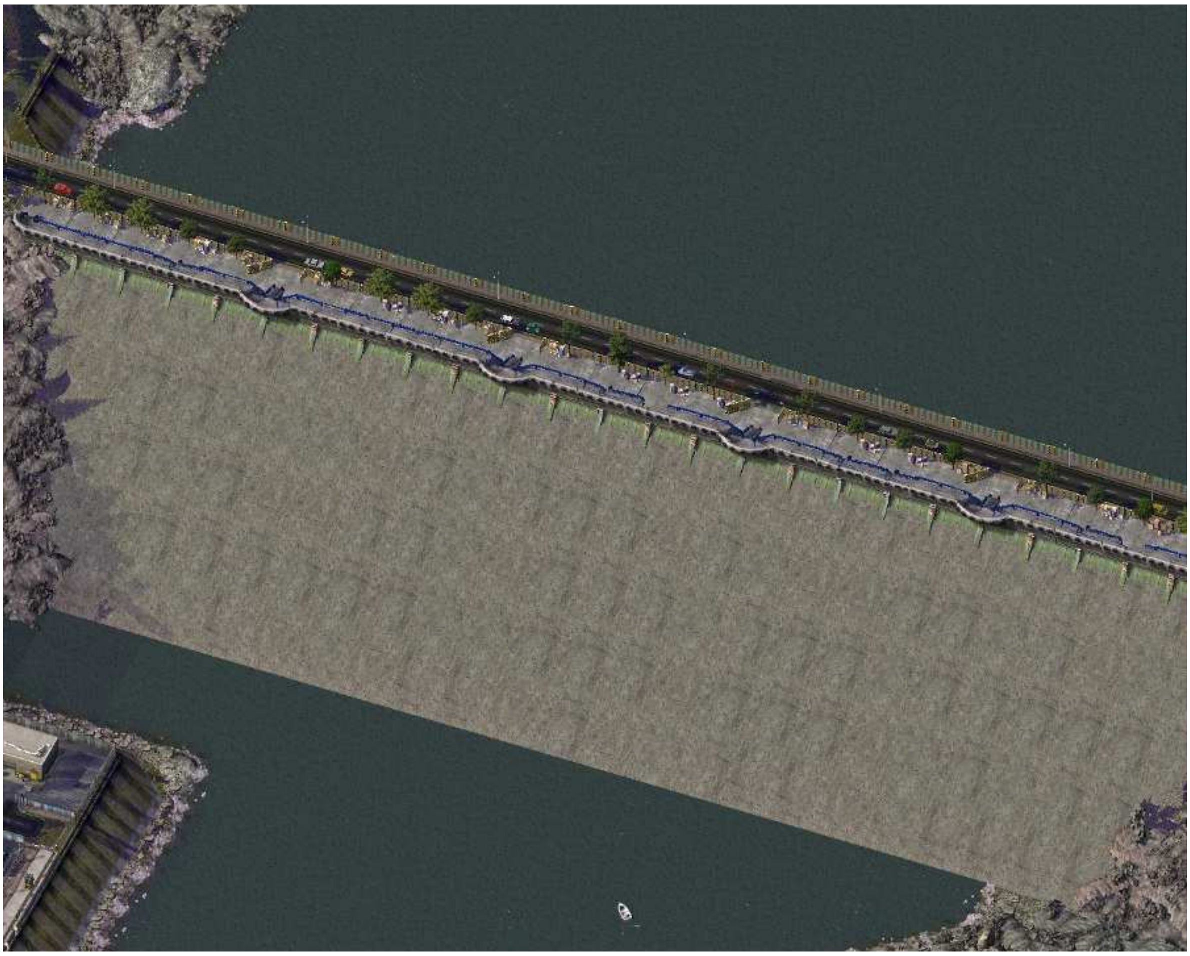

Fig.43 *A SimCity counterpart – a concrete dam on Bassenthwaite Reservoir near Grasmere. Author: Vizoria [S3].*

Fig.44 *A SimCity counterpart – an earthen dam on Wirta river, Galand.*

Every dam has two devices on it. These are culverts (underground pipes that are located in the bottom) and a spillway (an open-air channel - kind of “waterfall”). During regular work, the main route for the water to flow through are the culverts. Spillways (or overflows) have only one task, which is to carry water during floods. It is necessary to have an open-air outflow, because closed pipes do not have enough capacity. In fact, rules for designing say that during a flood around 80% of water need to go through a spillway, while only 20% through culverts. Both devices could have steerable closings, so it is possible to regulate how much water we stop.

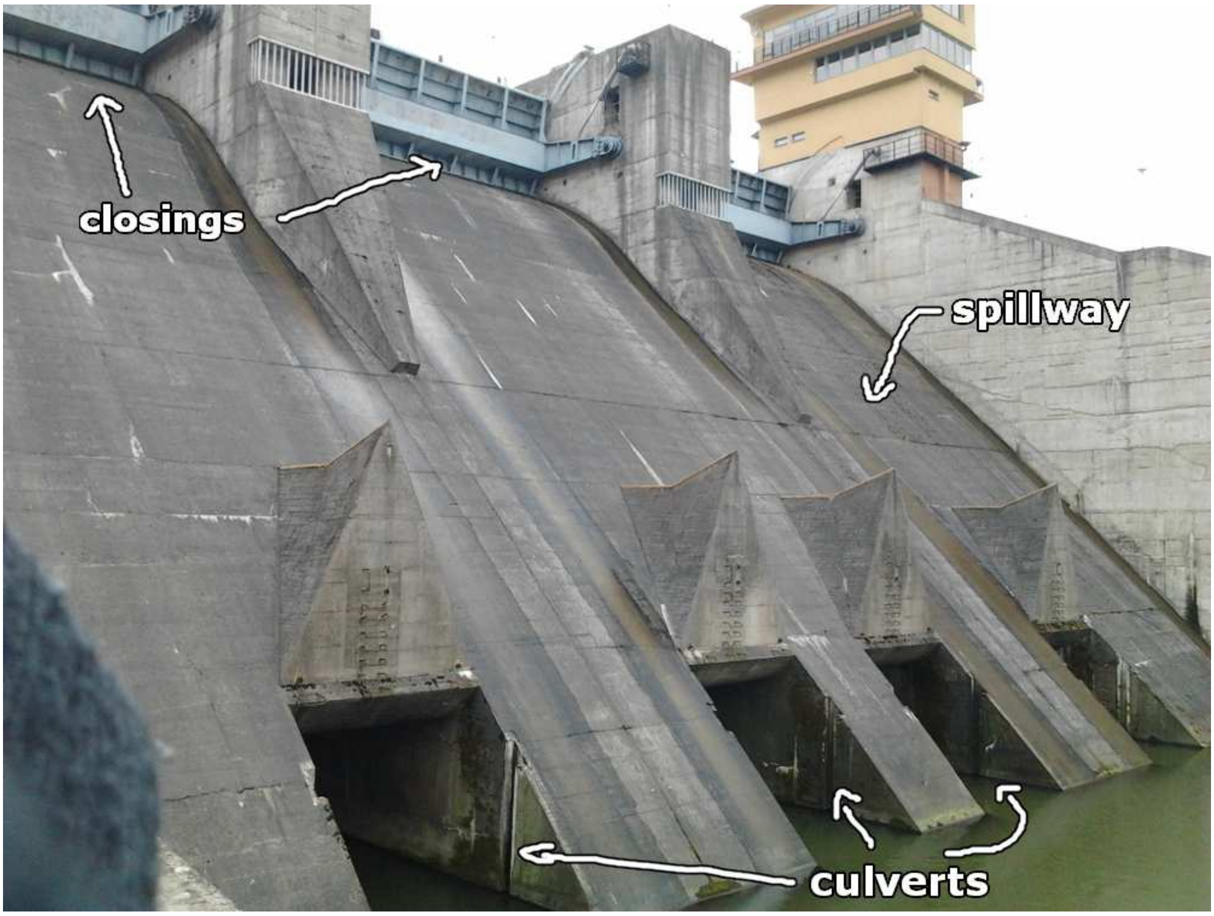

Fig.45 *A concrete section with spillway and culverts on an earthen dam in Dobczyce, Poland. Culverts often are located in one section with spillway, but that's not necessary – they can be placed in various places, including under the dam or drilled trough the bedrock on the side slope. Source: own work.*

By the way, during floods the amount of water increases astronomically. A real-life example: in Dobczyce (Poland) average rate of flow is 10,6 m3/s (during dry seasons it is around 1,25m3/s), but during severe floods it might reach more than 1000 m3/s.

Spillways are sometimes confused as used for production of energy, but that's not true. Their only task is to carry water during floods. In fact, electricity is produced in turbines that are usually mounted in separate culverts in a different part of the dam.

Sometimes there is a road located on the crest (top of the dam). However, they are usually not major roads, just minor ones. Locating a highway on the same construction is not the best idea, as a wide road would require bigger dimensions of the dam, vibrations coming from intensive traffic might be harmful to the structure and traffic accidents might became a danger to the environment (and sometimes to a drinking water supply) if some hazardous material carried by vehicles get into the water.

Special type of power facility is a pumped-storage power plant. It consist of two reservoirs – one located "normally" on the watercourse and the other one on a higher elevation (for example on a top of a nearby hill). Those two are connected with pipes that allow pumping and dropping the water up or down between them. It is used as a large-scale storage of energy. During periods of lower need for electricity consumption (like during the nighttime) the water is pumped from the lower reservoir to the upper one. During times with higher need for energy (like in the evenings, when the usage reaches its peaks) the water is discharged back down powering the turbines and producing electricity.

Fig.46 *Pumped-storage power plant in Porąbka-Żar, Poland. Upper reservoir on the top of a mountain, the lower reservoir visible in the background. Author: Ongrys. Source: Wikipedia [W13].*

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