TECHNICAL PAPER

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NOTHING BUT THE RAIN

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NOTHING BUT THE RAIN

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ABSTRACT
In this article the phenomenon rain will be discussed with respect to roof drainage systems. To know what requirements must be taken for the design of roof drainage systems it has to be known what the rain conditions will be at the site where the drainage system will be installed. This seems obvious, but is really a very difficult question upon closer examination.

1. INTRODUCTION

Siphonic roof drainage systems are designed to create full bore flow. The pipe diameters must be chosen such that the system will operate fully siphonic at severe rain storms that take place on average once every 5 years and must, eventually with the aid of an emergency system, be able to drain a heavy 100-year storm as well.

A very difficult question is what exactly must be taken as a 5-year or 100-year storm. Rain distribution data is most of the times only available as rain intensity measurements in mm per hour and at limited sites. For a roof drainage system however the rain distribution per minute or even second can be of vital importance for it to function properly. A drizzling rain or a 5-minute heavy storm can result in the same rain intensity in mm/hour but need totally different drainage system designs.

2. THEORETICAL BACKGROUND

To design the roof drainage system optimally the rain distribution per second of a 5- and 100-year storm is necessary to determine the maximum capacity needed for the system, with and without emergency system.

Beware that this maximum capacity is not equal to the maximum amount of rain intensity since there is a storage function of the roof and water will need time to flow to the roof outlet from different distances.

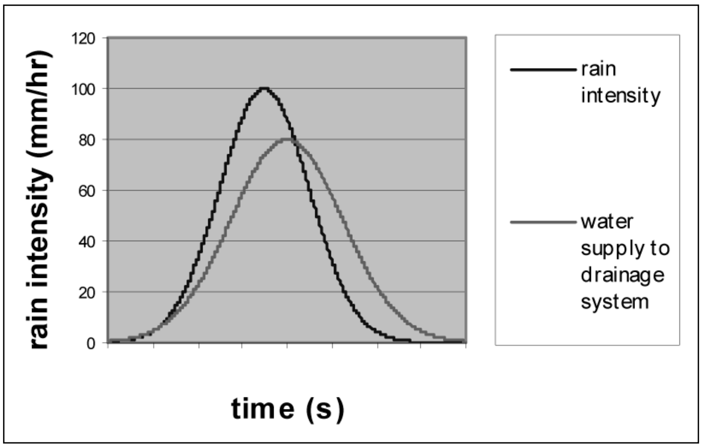


Illustration 1: water supply to drainage system is delayed and flattened out with regard to rain intensity.

For flat roofs a factor of 0,75 is used to account for this storage function.

To estimate the rain distribution and intensity at a site most often the history of rain data in the environment over the past years is taken. This data very often is presented as mm/hr or even mm/day.

For the distribution of the rain in a rain storm a design storm distribution function can be taken, which is determined for a larger area. This will only be a rough estimation since the presence of geographical influences (like hills, mountains, rivers, etc) will not be accounted for.

In developed countries the rainfall intensity frequency data has been recorded extensively for several decades. This results in statistically useful data. Rainfall intensity numbers are known for rain storms lasting eg: 5 or 10 minutes, 1, 2 or 12 hours, 1 day or 6 days with an occurrence of 10, 5 or 2 times a year to once every 1 to 100 years.

The tables with these numbers, called idf-tables (intensity/duration/frequency), are very useful for our purpose. If present we will use the 5 minute storm data occurring once every 5 years for the design of the siphonic system and that of once every 100 years for the design of the emergency system. The data can also be available in idf-curves (see illustration below) or in the form of the equation:

$$i = \frac{C \cdot T^m}{(t+d)^n}$$

with i the rainfall intensity (in mm/hr or in/hr), T the frequency (in years) and t the duration (in hours). For Indianapolis the coefficient are C = 1.5899, d = 0.725, m = 0.2271 and n = 0.8797 for durations of 1 to 36 hours and I in in/hr.

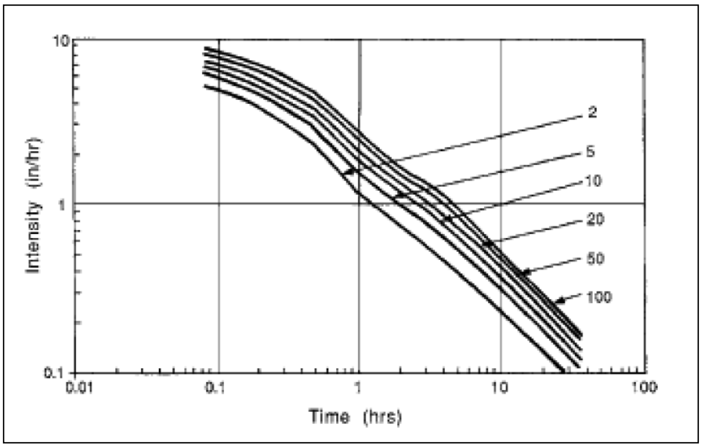


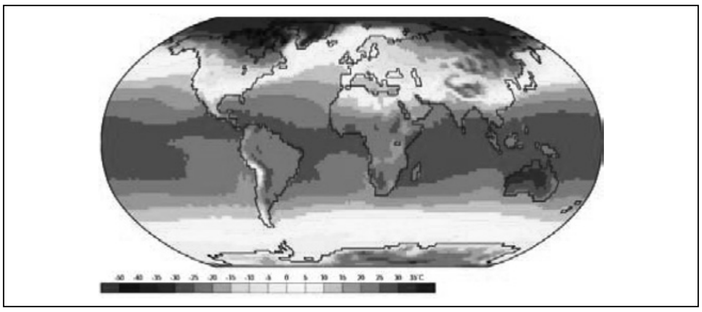
Illustration 2: example of an IDF-curve (from the Civil Engineering Handbook, second edition Ch 31 Surface Water Hydrology by Ramachandra Rao of the Purdue University, CRC press LLC, 2003).

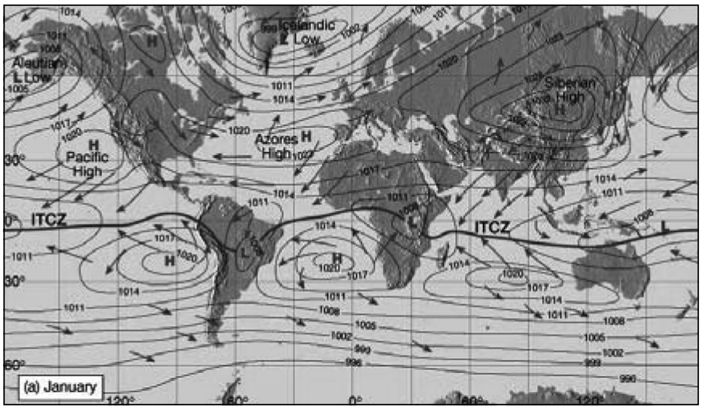
3. RAIN AND CLOUDS

Rain is precipitation of evaporated water that has condensed to droplets around dust nuclei in the air of a size so heavy that they will fall to the earth and the size and amount of these droplets appears to be such that clouds are visible in the sky before rain forms. Even the clouds have to be heavy and dark to be able to rain out. The clouds producing rain storms have the abbreviation nimb- of the latin word nimbus for rain in their name (nimbostratus and cumulonimbus). Especially the thunderclouds called cumulonimbus are linked to heavy storms with rain records.

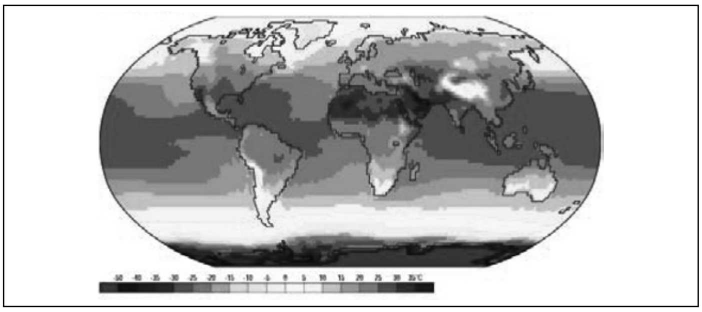
The accumulation of water droplets in cumulonimbus resulting in heavy storms depends on the presence of dust nuclei, the humidity of the air and the condensation of the water to large droplets or ice crystals. Thus for a heavy rain storm to occur it is necessary that there is a place where large masses of water are heated up to evaporate, transported to the area where the hot air is confronted with a cool front to condensate and rain out. This is more likely to happen at coastal regions where warm ocean streams are confronted with cool land masses or where warm air streams must rise and collide with a cold air front due to a mountain range.

It can be predicted from the graphs of the wind streams and temperature distribution around the globe of January and July where heavy rains are falling and where water is evaporating and transported to. Where ocean temperatures exceed land temperatures and the wind is onto the continent, rain can be expected ([rain] forests), whereas warmer land temperatures means that water is evaporating from the land and transported away by the wind (creating deserts).





Global temperature and wind distribution for january.



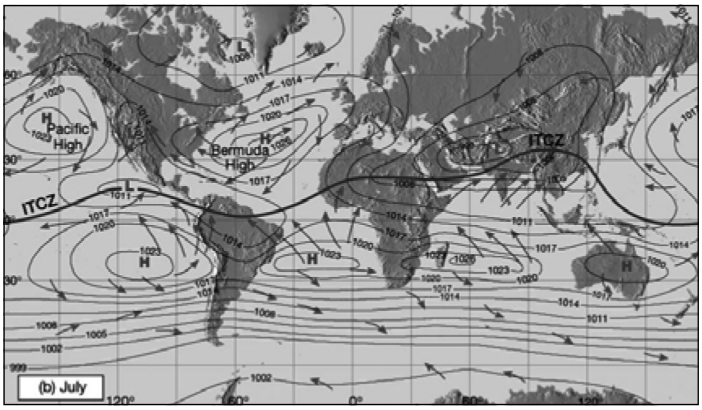


Illustration 3 to 6: global temperature and wind distribution for July. Wind distribution graphs from Kees Floor of the KNMI (royal dutch metereologic institute). Temperature distribution graphs from the Encyclopedia of the Earth.

The geographical map of the earth confirms the predictions, showing rain forests and deserts at these locations.

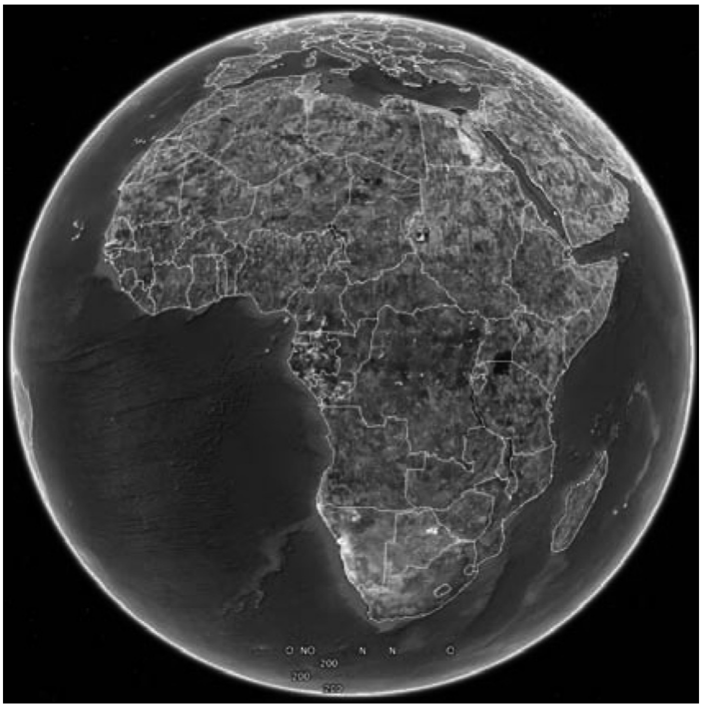


Illustration 7: Rainforests in Central Africa due to the warm jetstream from the Atlantic Ocean in January and the Sahara desert due to the relatively cold jetstream over warm land in North Africa (from Google Earth).

From these theories even the wettest places on earth can be predicted. Large temperature gradients from warm water to cold land and wind blowing onto the land will most likely give the highest rain intensity rates.

Both Choco (Colombia) and Cherrapunji (India) are known to have extremely high rain rates. Both are located in the so called inter-tropical convergence zone (ITCZ), the variable band that is situated in the vicinity of the equator and can be described as the central jet stream. Because of the warm climate the evaporation of water is very high in this zone and combined with the jet stream this is the place to form heavy cloud formations. When these clouds run into cold air fronts heavy rains can be expected. This exactly is the case in Choco and Cherrapunji. Both are located at the ITCZ in july. Cherrapunji is located at the south foot of the Himalayas. The air has to climb and is confronted with the cold air on top of the high mountains. Choco is located at the foot of the Andes near the Colombian coast and the small land mass of Panama.

The wind and temperature distribution over Europe are not that extreme. On the continent of Europe this implicates that the rain intensity will never exceed 600 l/s/ha.

4. RAIN INTENSITY DATA

Although the above theory clarifies and gives good insight in the reasons why certain places are very humid or very dry we still depend on historical data to estimate the maximum rain intensity in 5- or 100-year rain storms we use for our system designs. Therefore it is necessary to collect rain intensity data (preferably in IDF-format) to destillate the design rain intensities from.

For Germany there is the so called Kostra-Database available from the DWD (Deutsche WetterDienst) that contains data from different German regions.

For the Netherlands there is a single table, since there appears to be no significant difference within the Dutch borders for the maximum rain intensity from place to place.

In the case of a roof drainage system for the Netherlands this will lead to the following assumptions. The 5 minute storm data is similar all over the Netherlands and for the 5-year and 100-year storm 9 mm/hr and 15 mm/hr are the numbers. This can be converted to 300 and 500 l/s/ha. Exactly those illustrations are prescribed by the Dutch standards (NEN-3215 and NTR-3216) as the rain intensity to compute with for the design of the drainage and emergency systems respectively.

There is a difference in annual rainfall between places in the Netherlands and also a reasonable explanation for this. The maximum rainfall in the Netherlands is located in Apeldoorn and Vaals. Apeldoorn has the lead, which is explained by the presence of the hilly environment of the Veluwe and the “Utrechtse heuvelrug” (hilly rim of Utrecht). Vaals is located at the south side of a row of hills, where the cloudy winds coming from the Belgian Ardennes have to climb the flanks and loose their weight by raining out. Oppositely the driest place in the Netherlands, Echt, is found right at the north side of these hills, since the clouds almost never reach this side of the hills, while they have already rained out on the south side.

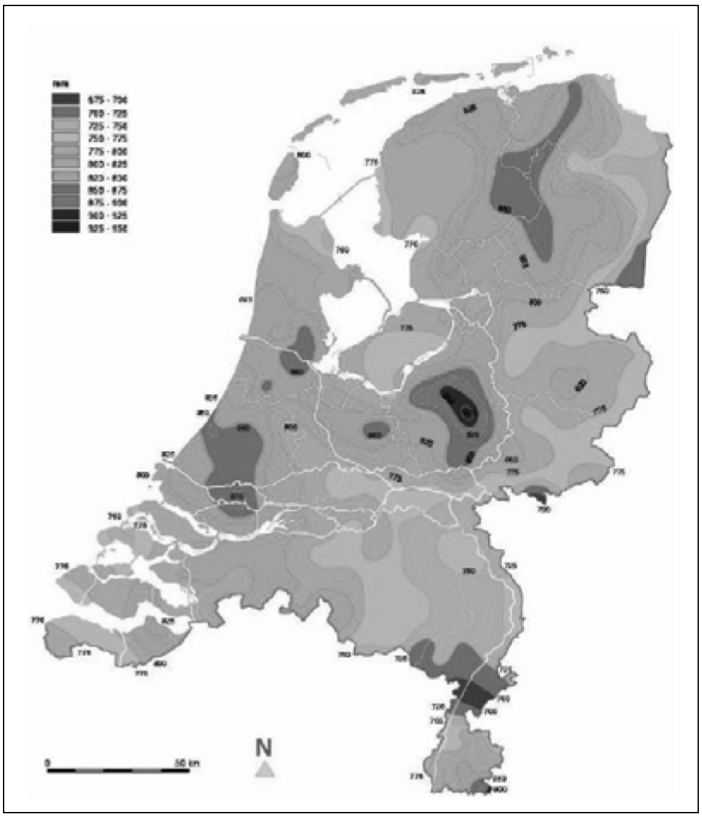


Illustration 7: annual rainfall map of the Netherlands.

5. CONCLUSIONS

In this article the development of rain storms is described. Understanding the phenomenon will give insight in the probability of the occurrence of rain storms and their intensities. For the estimated amount of rain to fall and design rain storms for a certain area still record data of this area are necessary. Usually this data is available for large areas only and do not account for geographical circumstances.

6. REFERENCES

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