Discharge Regime of the Rhine and its Tributaries in the 20th Century

International Commission for the Hydrology of the Rhine Basin

KHR
CHR

Low-water discharge on the Middle Rhine. Source: Wilfried Wiechmann, Federal Institute of Hydrology, Koblenz

The Rhine Basin

Area:	185 000 km²
Riparian states:	Italy, Switzerland, Liechtenstein, Austria, Germany, France, Belgium, Luxemburg and the Netherlands
Population:	60 million inhabitants
Alpine Rhine:	Source to Lake Constance
High Rhine:	Lake Constance to Basel
Upper Rhine:	Basel to Bingen
Middle Rhine:	Bingen to Bonn
Lower Rhine:	Bonn to D/NL border
Delta Rhine:	Lobith-mouth

Length of the Rhine: 1232 km

The Rhine – a Lifeline

Waterway for the transport of goods and people. 800 km are navigable.

Supply of industry and population with industrial and drinking water. More than 20 million people drink processed Rhine water.

Power production in storage power stations and hydraulic power stations.

Habitat for flora and fauna.

Data collection and data analysis

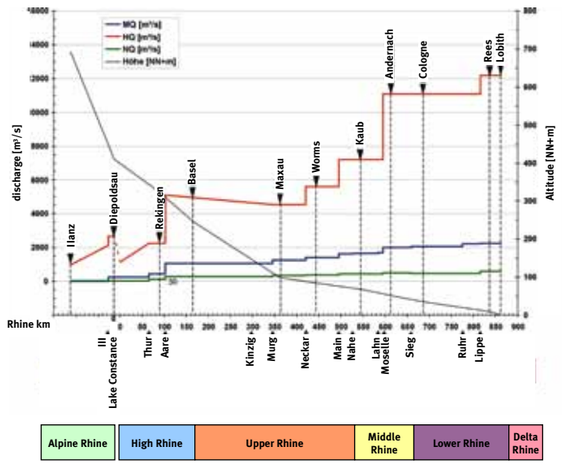
38 sub-catchments with discharge data series from 1901 to 2000, resp. 1951 - 2000 have been examined.

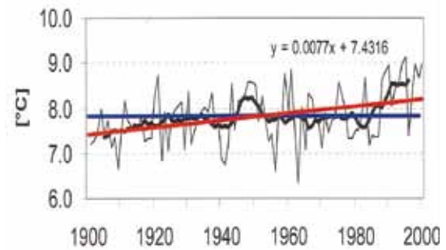
Daily areal precipitation depths of the 38 sub-basins have been ascertained.

Air temperatures and evaporation depths have been gathered in 7 sub-regions.

The anthropogenic impact on discharge has been estimated, partly quantitatively and partly qualitatively.

The hydrologic longitudinal profile of the Rhine





Lütschine, Gsteig. Source: Eric Sprokkereef

The changes

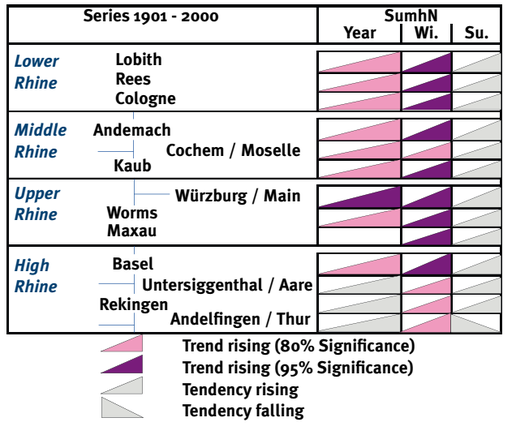
Temperature

In the 20th century, the mean annual temperature in the Rhine basin increased by 0.8°C, in the winter half year by 0.9°C and in the summer half year by 0.7°C. In some stations, a temperature rise by up to 1.4°C was ascertained.

At altitudes below 1300 m, the number of days with snow cover has decreased.

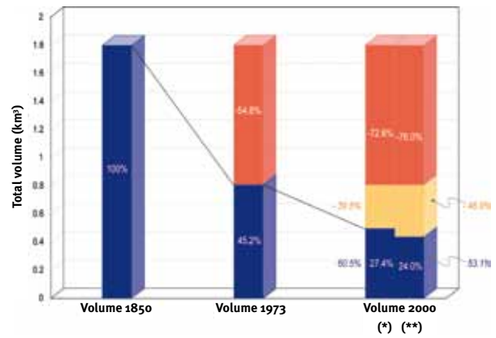
Areal precipitation

Winter precipitation has increased due to the growing number of „west weather conditions“. In summer, however, less change is noticeable.



Alpine Rhine. Source: Dietmar Walser, Hohenems

Development of glacier volume in the Ilanz region, 1850 – 2000

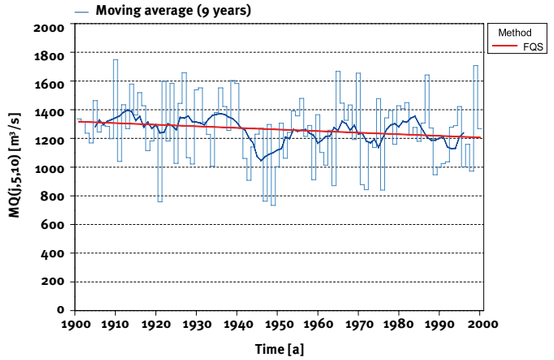


Glacier retreat

Long-term observations reveal that glacier retreat merely has a minor influence on the Rhine's discharge. Near Basel it is equivalent to approx. 1.2 % of the mean discharge in August. Smaller streams in close vicinity to glaciers may show more sensitive reactions.

Gauge Basel / Rhine

Mean summer discharges. Parameter MQ, observation period 1901-2000



Runoff

Alpine Rhine, High Rhine and Upper Rhine

The Development:

As a result of the changes in the Alpine and pre-Alpine sub-catchments, the Rhine displays redistribution dynamics between the Alps and the confluence of the Main river. Winter discharge increases significantly, while summer discharge decreases. Given that the summer season is the time of low flow and winter is the time of floods due to the climate prevailing in these regions, redistribution dynamics come along with a decrease of the variation margin of streamflow. Eventually, discharge means have only slightly changed over the year.

Deutsches Eck. Source: Federal Institute of Hydrology, Koblenz

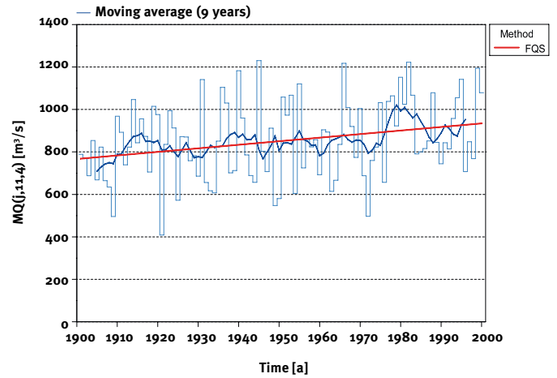
The reasons:

Due to the temperature rise in winter, more precipitation falls in the form of rain than as snow in all regions, excepting the highest altitudes. This means that no interim storage of rain takes place, but direct runoff.

Another factor contributing to the increase in winter discharge is the operation of Alpine reservoirs: the reservoir lakes are filled in early summer to allow their being used for energy production by means of hydropower in winter during low-flow. Moreover, the effects of diversions and transfer lines into or from other river catchments as well as river engineering projects (channelling, dyke control, etc.) play a major role.

Gauge Basel / Rhine

Mean winter discahrges. Parameter MQ, observation period 1901-2000



Middle and Lower Rhine

The development:
Between the confluence of the river Main and the delta estuary, the Rhine usually reaches its highest water levels in late winter. In view of clearly rising winter runoff and hardly altered summer runoff, development dynamics show an overall increase in runoff associated with a simultaneous increase in seasonal differences.

The reasons:
In this part of the Rhine basin, the overwhelming influence of the river regime, as characteristic in the Alps, does not play such a predominant role, nor is there any homogeneous use of the existing reservoirs. Instead, the winter increase in precipitation is the decisive factor. On the one hand, the latter turns out more markedly in the southern catchment, and on the other hand has a more direct impact on runoff due to higher average temperatures. On a small scale, here, too, changes in the discharge characteristics due to diversions and transfers can be documented.

Storm surge barrier Nieuwe Waterweg.
Source: www.BeeldbankVenW.nl, Rijkswaterstaat

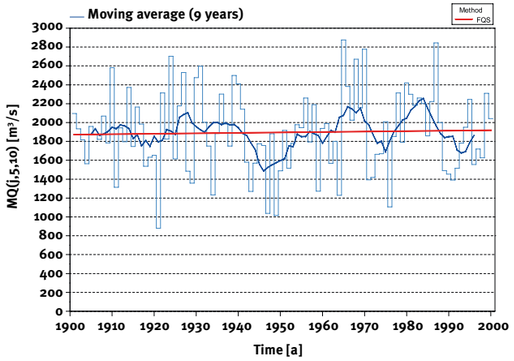
Extreme discharge situations

Flood:
In the course of the 20th century, flood peaks in most sub-regions of the Rhine basin have increased. The reason for this is not solely the rise in winter precipitation totals, but also changed precipitation characteristics, (tendency towards storm rainfalls) as well as modified peak travel times due to river engineering projects and shrinking floodplains.

Low-flow:
Due to the described increase in winter runoff, the extent of low-flow extremes significantly decreases in the course of the 20th century, especially in the southern Rhine basin. This decrease gradually disappears as the river proceeds, due to the fact that the period weaker in discharge usually takes place in the late summer or autumn months that are hardly affected by a precipitation increase, but rather by the evaporation-promoting temperature rise as more maritime climate zones are being approached. In the case of the tributaries coming from the upland regions, a trend towards an aggravation of the low-flow situation can even be observed to some extent.

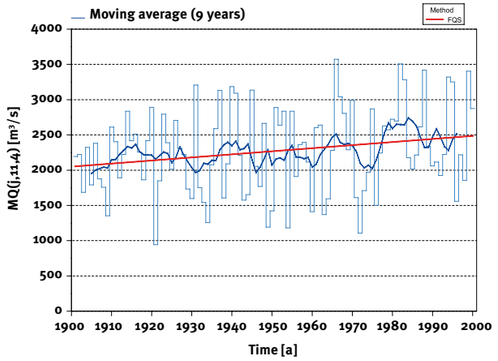
Gauge Cologne / Rhine

Mean summer discharges. Parameter MQ, observation period 1901-2000



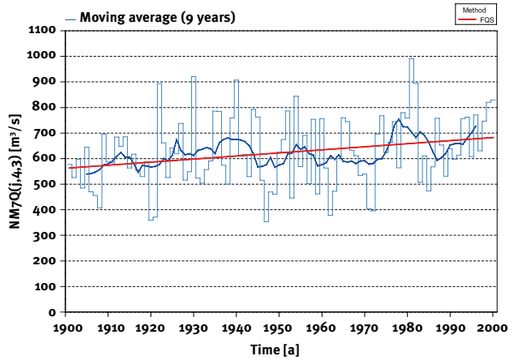
Gauge Cologne / Rhine

Mean winter discharges. Parameter MQ, observation period 1901-



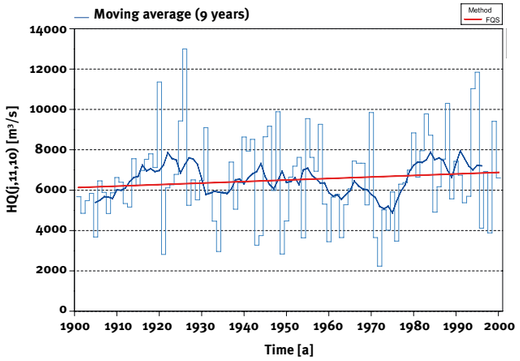
Gauge Maxau / Rhine

Low flow extremes, Parameter NM7Q, observation period 1901-2000



Gauge Lobith / Rhine

Annual flood peaks, Parameter HQ, observation period 1901-2000



Imprint

This brochure has been created by the International Commission for the Hydrology of the Rhine Basin (CHR). CHR works within the scope of the International Hydrological Programme (IHP) of UNESCO and the Hydrology and Water Resources Programme (HWRP) of WMO. It regards itself as an instrument of the institutions active in the field of hydrology and water resources management within the Rhine riparian states and supports transboundary hydrologic studies.

The information contained in this brochure is based on the CHR report I-22 „Das Abflussregime des Rheins und seiner Nebenflüsse im 20. Jahrhundert. Analyse, Veränderungen und Trends“ ISBN 978-9-70980-33-7
Further information on CHR's activities and objectives are obtainable at www.chr-khr.org. In case you should have any questions, please do not hesitate to contact:

Secretariat CHR/KHR,
P.O. Box 17
8200 AA Lelystad
Netherlands
Tel. +31 320 298 603
Fax +31 320 298 398
E-Mail info@chr-khr.org

Supervision: Eric Sprokkereef (CHR)
Text: Manfred Spreafico (University of Bern)
Jörg Uwe Belz (Federal Institute of Hydrology, Germany)
Design: Edith Oosenbrug (Federal Office for the Environment, Switzerland)
Voorheen de Toekomst, Wageningen
Print: Waanders Drukkers, Zwolle

Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

lebensministerium.at

MINISTÈRE DE L'INTÉRIEUR
ET DE L'AMÉNAGEMENT DU TERRITOIRE
Administration de la Gestion de l'Eau

Vorarlberg
Wasserwirtschaft

bfg Bundesanstalt für Gewässerkunde

HLUG

Deltares
Enabling Delta Life

ihp·hwrp germany
German
IHP/HWRP National Committee