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Floods in Norway

Lars Andreas Roald

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Sammendrag: Rapporten beskriver historiske flommer som har rammet i alle deler av det norske fastlandet fra 1340-årene til 2014. Den beskriver naturlige og menneskeskapte årsaker, flomskade og hvordan samfunnet har håndtert skadeflommer under pågående hendelser og ved kartlegging, varsling, forbygninger og annen aktivitet. Forventete endringer i flomhendelser i Norge som følge av framtidige klimaendringer belyses ved eksempler på historiske flommer.

Emneord: Flom i Norge, naturlige og menneskeskapte årsaker, flomskade, flomhåndtering og følger av klimaendring

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FLOODS IN NORWAY

Sammendrag

Norge rammes årlig av flom et eller annet sted i de norske vassdragene. Denne rapporten beskriver historiske flommer som har rammet Norge fra 1340-årene til 2014. I kapittel 2 defineres hva vi legger i begrepet flom og oppgir navn på gamle flommer som har vært så ødeleggende ar de har fått egne navn. I kapittelet beskrives også sammenhengen mellom flom og norsk topografi og oppsummerer vannbalansen i Norge. Kapittel 3 beskriver Flommene har ulike årsaker. Dette gjennomgås i kapittel 3. Menneskelige aktiviteter påvirker flomforholdene. Arealbruksendringer kan føre til endringer i jordbruket og i urbane områder. Kraftutbygging fører også til endrete flomforhold. Dette oppsummeres i kapittel 4. Hvor flommer oppstår er avhengig av de dominerende værtypene. Kapittel 5 gir en oversikt over de flomskapende værtypene som rammer i ulike landsdeler. Store flommer tar sjelden mange liv, men er den typen naturskade som påfører samfunnet de største økonomiske tapene. Kapittel 6 beskriver hvordan staten har kompensert flomofre i gammel tid gjennom avtaksforretninger til dagens ordning gjennom forsikringsbransjens naturskadepool og statens naturskadefond. Når en storflom rammer trer ulike beredskapsinstitusjoner i aktivitet. Kapittel 7 gir en oversikt over denne aktiviteten, forteller om flomforbygning og om Hydraprosjektet. Kapittel 8 presenterer metoder for flomberegning og modellering og flomvarsling. Kapittel 9 forteller om hvilke endringer som kan forventes i flommene som følge av klimaendringer.

Kapittel 10 er en omfattende referansefil som inneholder referanser til litteratur om flom i Norge.

Rapporten består fire Appendicer. Mesteparten av stasjoner og steder som lider av flomskade er navngitt med sine norske navn.

Appendix A sammenfatter navnene på norske administrative distriktene med på engelsk.

Appendix B, C and D beskriver flommene i de seks flomregionene: East and South Norway (B), West Norway (C) og Mid- og North Norway (D). Beskrivelsene i hvert Appendix består av tre deler.

1

Del 1 består av en beskrivelse av regionen og inneholder også kart utvalgte stasjoner på Østlandet, Vestlandet, Midt-Norge and Nord-Norge. Størrelsen på hvert nedbørfelt varier betydelig mellom regionene og er årsak til en noe forskjellig struktur på inndelingen av de ulike landsdelene.

2

For hver region presenteres historiske flommer fra tiden før observasjonene presentert i tabellform. De lange flomseriene plottes og vises grafisk. For hver serie oppgis feltegenskapene og de 10 største årlige flommene vises i tabellform.

Appendix B presenterer resultatene fra de åtte hovedvassdragene på Østlandet ie Trysilelv, Vrangselv, Haldensvassdraget, Mosselva, Glomma, Drammensvassdraget, Numedalslågen, Skienselv

og 11 elver på Sørlandet ie Kragerøvassdraget til Vegårdselv, Nidelva, Tovdalselva, Otra, Søgneelv, Mandalselv, Audna, Lygna, Kvina, Fedaelv og Sira.

Appendix C presenterer resultatene fra 53 elver på Vestlandet ie elver på Jæren, 4 elver i Ryfylke, 4 elver i Sunnhordaland, 8 elver i Hardanger, 8 elver i Nordhordaland, Voss and Gulen, 13 elver i Sogn, 5 elver i Sunnfjord and 7 elver i Nordfjord.

Appendix D presenterer resultatene fra 28 elver i Midt-Norge ie 16 elver i Møre og Romsdal, 12 elver i Trøndelag og 45 elver i Nord-Norge ie 24 elver Nordland, 11 elver i Troms og 10 elver Finnmark.

3

Del 3 inneholder beskrivelser flommene in hver region. De største flommene opptrer gjerne i flere elver og kan finne sted samtidig i flere regioner. Rapporten inneholder samlebeskrivelser av 50 store flommer på Østlandet, 28 store flommer på Sørlandet, 76 store flommer på Vestlandet 28 store flommer i Midt-Norge and 32 flommer i Nord-Norge.

Rapporten inneholder grafer som viser døgnnedbør og vannføringer. For nyere flommer er det kart som viser fordelingen av nedbør, snøens vannekvivalent, grunnvann og markvannsfordelingen. Værtypen under flomhendelsen er vist ifølge den tyske værklassifiseringen Grosswetterlagen og den britiske Lamb/Jenkinsson klassifikasjonen. Der det foreligger opplysninger om flomskade er også dette gjengitt for mange store flommer.

Summary

Norway suffers annually from floods somewhere in the Norwegian river network. The report describes historical floods in mainland Norway from the 1340's to 2014. Chapter 2 defines the concept of a flood, names some notable floods in the past, show the link between the occurrence of floods and the Norwegian topography and summarise the water balance of Norway. Chapter 3 summarises the different types of floods and their causes. Human activities modify the the occurrence some notable floods and magnitude of floods. The link between land use changes and floods and between hydropower development are described in Chapter 4. The occurrence of and timing of floods in Norway are dependent of the exposure of each catchment to the underlaying weather types. This is described in Chapter 5. Floods have been the dominant cause for economic losses caused by natural event in Norway, but they rarely cause large losses of lives compared to losses caused by severe storm, storm floods, avalanches, landslides or rock falls. Chapter 6 describes how the state has compensated flood victims in the past and presently. When a severe flood occurs, a large number of public and private organisations participate in mitigating the flood damage. After a severe flood, a lot of work is done in building flood walls and securing the affected areas against future floods. Floods mitigation and prevention is discussed in Chapter 7. After the large flood "Vesleofsen" a major research program "Hydra" examined aspect of handling large floods. This is also summarised in Chapter 7. Chapter 8 discusses methods for estimating flood magnitudes and for flood forecasting and warning. Recently some trends towards a shift in the occurrence of floods are appearing. Snow fall floods appear less frequently while events caused by intense rainfall in urban areas causing local losses at times exceeding the losses caused by the snowmelt floods. These changes are linked to Climate change. Chapter 9 of the report summarises the finding of Climate change modelling in Norway.

Chapter 10 comprise an extensive list of references to floods in Norway.

The report comprises 4 Appendices. Appendix A summarises the names of the administrative districts in English. Otherwise the names used in the Appendixes are the Norwegian names.

Appendix B, C and D describes floods in a part of Norway Most of the data series and locations suffering from the floods are named with their Norwegian names.

Appendix B, C and D describes the floods in the six mainland regions: East and South Norway (B), West Norway (C) and Mid- and North Norway (D). The descriptions in each Appendix comprise three parts.

1

Part 1 comprises a description of the region and includes also maps of selected stations at Østlandet, Vestlandet, Mid-Norge and Nord. The size of the catchments varies considerably between the regions.

2

Appendix B presents results from one or more station in each large river in current district. The report present data from the eight major water courses at at Østlandet ie Trysilelv, Vrangselv Haldensvassdraget, Mosselva, Glomma, Drammensvassdraget, Numedalslågen, Skienselv and 11 rivers at Sørlandet ie Kragerøvassdraget to Vegårdselv, Nidelva, Tovdalselv, Otra, Søgneelv, Mandalselv, Audna, Lygna, Kvina, Fedaelv and Sira.

Appendix C present results from 53 rivers at Vestlandet ie 5 rivers in Jæren, 4 rivers in Ryfylke, 4 rivers in Sunnhordaland, 8 in Hardanger 8 rivers in Nordhordaland, Voss and Gulen, 13 rivers in Sogn, 5 rivers in Sunnfjord and 7 rivers in Nordfjord.
Appendix D present results from 28 Rivers in Mid-Norway ie 16 rivers in Møre and Romsdal, 12 rivers in Trøndelag, and 45 rivers in Nord-Norge ie 24 rivers in Nordland, 11 rivers in Troms and 10 rivers in Finnmark.

The results include: Historical floods prior to the observed series are presented in separate tables. Graphs showing observed long-term flood series. Catchment characteristics and the 10 largest floods in long-term series are presented in tabular form for all stations within the current region.

3

Part 3 presents a number of the largest floods in each region. Most large floods occur simultaneously in several rivers or even in two or more regions at the same time.
The report comprises detailed description of 50 large flood events at Østlandet, 28 flood events at Sørlandet, 76 flood events at Vestlandet 28 flood events at Mid-Norway and 32 flood events in North-Norway.

The report includes graphs shoving daily runoff and precipitation. Maps of the precipitation, snow water equivalent, ground water and soil moisture distribution are also shown for some recent floods. The weather types according to the German Grosswetterlagen and Lambs indices are shown for many flood events after 1890. The flood damages are also presented where the information is available.

Preface

The book *Det regne så det søyde og tora slog - Flom i Norge* by Lars A. Roald describes causes of large floods in Norway, flood damages, a number of large historical floods, flood forecasting and possible consequences of future climate changes for the occurrence of floods. The descriptions are in a popular form intended for a general audience and are richly illustrated with photos of various flood events. The text quotes many anecdotes from the large events drawn from various sources. The book is written entirely in Norwegian, but the information about the floods is also of interest for historians, hydrologists and climate researcher in other European countries. Actual data of precipitation, water levels and discharges are kept at a minimum, and very few graphs of data have been shown in the book.

The earliest observed water levels date back to 1675 in Norway. From 1603 damages caused by some large floods have been examined at many farms by commissions comprising of a tax collector or local judges and farmers from neighbour farms. The damages have been described in reports as a basis for reducing the taxation for some years. Large floods have been described in newspapers and in local history books from the year 1789 onwards.

This report presents the ten largest floods at nearly 500 past and present gauging stations on the Norwegian mainland until 2014. The information includes meteorological causes, graphs showing the discharge, precipitation, snow water equivalent, soil moisture and ground water surplus depending on what is available of data in addition to compensations caused by the flood damages.

This report is a result of the Hydra project after the large flood *Vesleofsen* in June 1995. The material is underlying a new national Norwegian flood database, Flomhendelser.no, which contains far more information that could be included in the book. The current report: Large floods in Norway present historical floods with the observations in graphical form.

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Table of contents

1. Introduction

Norway suffers annually from floods somewhere in the Norwegian river network, causing damages to the natural conditions as well as to values created by human activities. These floods can cause substantial economic damages, but they do not normally cause a large loss of lives. This report describes the occurrence of floods in Norway and discusses the causes of the floods in various parts of the country.

The report comprises nine Chapters. Chapter 1 gives a comprehensive overview over most aspects of floods in Norway. Chapter 2 defines some basic hydrological concepts and describes how the various hydrological and meteorological components of the water balance are distributed in Norway. Chapter 3 discuss the various causes of floods in Norway. Human activities can increase or decrease the potential for large floods. This is discussed in Chapter 4. The occurrence of floods caused by snowmelt and rainfall. Rainfall events are linked to a number of modes of the atmospheric circulation. Chapter 5 discuss some classification systems for weather types. Most of the floods in Norway can be linked to two or three typical weather types. Chapter 6 discuss flood damages, and how flood damages victims have been compensated in the past and presently. When a large flood occurs, many emergency organisations is participating in rescue work and in reducing the damages. Chapter 7 gives an overview of this, based on information from some of the large spring floods at Østlandet. The Chapter discuss briefly also measures to reduce damages of future floods. Chapter 8 discuss briefly flood estimation, flood zone mapping and flood forecasting. Climate change projections indicates that the flood regime may change in a warmer climate. Chapter 9 discusses past variations in the occurrence of floods, and projections of floods in the future. Followed by a comprehensive Reference list. The report has four appendices: Appendix A present translation of Norwegian regional geographical names, Appendix B Floods in East and South Norway, Appendix C Floods in West Norway and Appendix D Floods in Mid- and North Norway.

2. Floods, precipitation and runoff in Norway

2.1 What is a flood?

When the water level in rivers or lakes starts flowing over a defined level or over the riverbanks and starts causing damages, there is a flood. The Norwegian word is "*flom*", and it is derived from the old norse word: "*flaumr"*. There is a balance in Norwegian rivers between the inflow caused by meltwater, rainfall and inflow from the groundwater storage and the capacity of the river to transport the inflow further downstream. The inflow varies considerably over time. If the inflow is large enough, the water will flow out of the riverbed, causing inundations and damages near the river. The river channel can shift because of erosion or sedimentation, and the river can shift to new channels during severe floods. The streambed will usually adapt to the large floods in districts where large floods occurs frequently. In inland districts as in the mountain valleys in East Norway with less precipitation, large floods occur less frequently. Rivers and brooks are not able to adapt to rare floods. Heavy rainfall, often in combination with heavy snowmelt, can cause small brooks to grow to torrential streams in steep mountain slopes. These floods can cause multiple landslides in the hills, while the flood plains on the bottom of the valleys are inundated. The best example of these floods is *Storofsen* occurring in 1789.

Some of the most severe floods in Norway are known by names. Best known is *Storofsen*, *Ofsen* or *Skriusommaren* - the disastrous flood, which occurred in July 1789 in East Norway. Large floods in 1675 and in 1773 in River Glomma are known as *Storfloden*. Prior to the Black Death, a major flood caused large changes at Vågåmo in River Otta. This flood occurred in either 1342 or 1348 and is named *Digerofsen*. A major ice run flood in River Glomma with tributaries at Storelvdal is known as *Storisgangen*. The extreme flood in West Norway in December 1743 is known as *Storeflaumen* in Hardanger. The extreme flood in South Norway in June 1860 is known as *Ofsen*, *Storflaumen or Stor-Elvvoksten*. A large flood at Jæren and Agder in 1898 is known as *Storflodi*. A large flood in 1938 in East Norway is locally known as *Storflåmen*. A rain flood in July 1941 at Stryn in West Norway is known as *Fløda*. The severe flood in East Norway in June 1995 is known as *Vesleofsen*. The floods in June 2011 and in May 2013 in River Glomma and River Gudbrandsdalslågen are both known as *Pinseflommen or the Whit-Sunday flood*. Archaeological excavations have found evidence of an even larger flood in the mid part of Gudbrandsdalen. This flood occurred probably at 100- 200 BC, which is called *Gammelofsen* (Gundersen & Loktu, 2012).

The Norwegian Meteorological Institute has assigned names to extreme weather events since 12 October 1995 starting with the storm Agnar in Mid-Norway to Nordland. Names are only given to events with a high potential for causing severe damages. Most of the named extreme weathers are storms, causing wind damages and storm surges on the coast. Some of these events have caused severe floods, and these names have occasionally been used for the floods. The extreme weather *Kristin* caused floods and landslides in the Bergen district 14 September 2005, and *Loke* caused similar floods and slides in West Norway two months later. The rainstorm *Frida* occurred in 6-7 August 2012 and caused severe damages in the Drammen district.

2.2 Norwegian link between topography and floods in Norway

The Norwegian mainland extends from 58°N to 71°N and from 5°E to 31°E. The country has a more than 2000 km long coast facing the North Sea in the south, the Norwegian Sea in the west and the Barents Sea in the northeast. Long mountain ridges are running parallel with the coast in West Norway. Long inland valleys are running from northeast to northwest from the Oslofjord. Some of the largest rivers in Norway flow through these valleys. Long valleys extend from the coast towards north to northwest. Another mountain range runs near the border to Sweden and Finland in Nordland and Troms. Most of Finnmarksvidda is quite low lying.

Norway is situated in the temperate climate zone as a result of the exposure to the North Atlantic Current moving temperate ocean currents to the Norwegian coast. Mild air masses carries abundant precipitation from the Atlantic Ocean and the North Sea causing heavy precipitation causing frequently floods on the windward side of the mountain ranges and rain shadow on the leeward side. Basins on the south coast and the inland districts in southeast are exposed to weather systems moving in from southeast to southwest. Coastal basins facing the North Sea and Norwegian Sea have floods caused by polar front cyclones moving in a sector between southwest and northwest. Floods in Finnmark are mostly caused by snowmelt, usually occurring when warm air is flowing in from south-southeast over Finland.

2.3 The water balance in Norway

The annual runoff varies considerably between different parts of Norway because of the differences in exposure to different weather systems. Figure 2.6 show the distribution of the annual runoff for the normal period 1961-1990 given in mm/year (Source: Klima i Norge 2100). The annual discharge each year were estimated from the precipitation subtracted the annual evapotranspiration and corrected for annually changes in the snow reservoir and groundwater storage.

The water balance (1971-2000) can be summarised as:

Precipitation:	1600 mm
Evapotranspiration:	500 mm
Runoff:	1100 mm

The variability of the runoff:

Wettest:	5400 mm at Ålfotbreen in Nordfjord
Driest:	<350 mm in small streams near the valley floor in Skjåk, Lom, Vågå and Lesja in Oppland and locally at Junkerdal in Nordland.

2.3.1 Precipitation

When humid air approaches the coast, it is lifted orographically, causing precipitation either as snow or as rain depending on the air temperature. Most of the precipitation falls on the windward side of the mountain ranges, with more or less pronounced rain shadow in the inner mountain valleys on the leeward side. The annual precipitation in Norway is shown in Figure 2.1. The annual precipitation at the most maritime district in Norway, near Ålfoten glacier, where an average of 5400 mm may fall in a year, while the driest locations in the valleys east of the mountain divide may receive less than 300 mm annually.

Atmospheric rivers can cause almost continuous rainfall lasting a month or more. In October 1983 a total rainfall of 1180 mm was observed at Brekke in outer Sogn. The autumn 2000 was very wet at the southern part of Østlandet and in southern Sweden. Lows forming repeatedly over southern Britain moved fronts across Sørlandet and along the Oslo fjord. Similar events have caused extreme weather across Britain in the summer 2007 and 2014 with the polar front getting stuck for a long time.

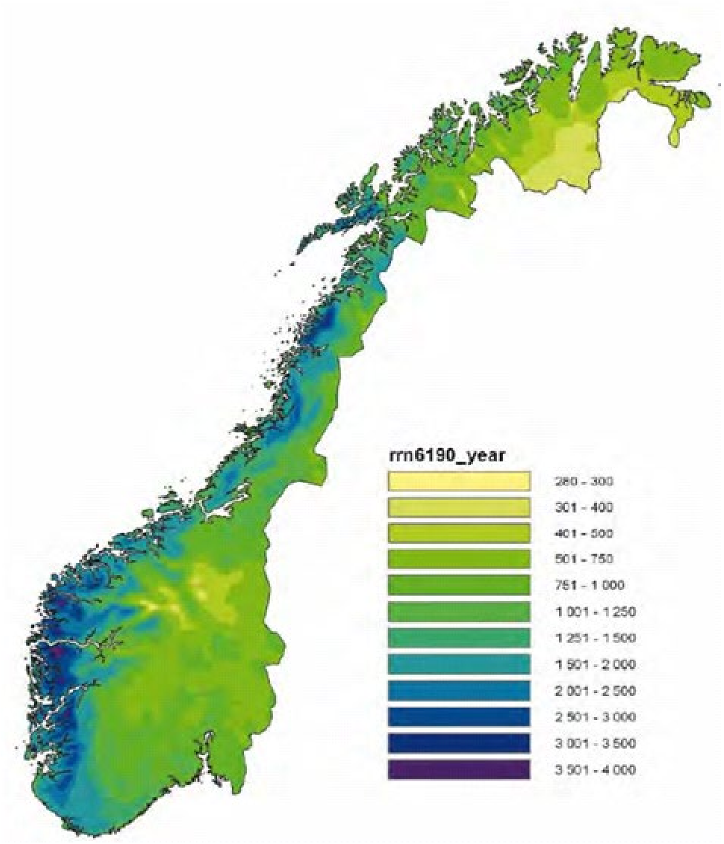


Figure 2.1 Annual precipitation in Norway 1961-1990. (Source: Klima i Norge 2100)

Traditionally, the precipitation was observed once or twice a day at met stations operated by the Norwegian Meteorological Institute. The largest amount of rainfall observed within a day (from 8:00 hrs on the previous data to 8:00 hrs on the present day) were 229,6 mm observed 26 November 1940 at Indre Matre at Kvinnherad in Sunnhordaland. From the 24 to 27 November was a total rainfall of 480 mm observed at the station. A total of 156 and 155 mm fell at Samnanger in Hordaland 10-11 October 1953. This is said to have fallen within a 24 hours period. A one-day rainfall of 100 - 200 mm is not uncommon within the coastal maximum precipitation zone in West and North Norway south of the Lofoten Islands, especially from October to January. A thunderstorm lasting four hours produced a rainfall of 173 mm at Mykland in Aust-Agder 27 August 1939. The severe weather in Telemark 29 June 1927 produced a one-day rainfall of 134 mm at Rjukan. A one-day rainfall of 139 mm was observed at Sandar in Vestfold 25 August 1950. Heavy rainfall can occur in the inland. A local rainstorm produced a one-day rainfall of 125,5 mm at Folldal 28 June 1935. Most of this rainfall fell in two hours. Another rainstorm produced 116 mm in a day 24 August 1940. Private observations indicate even higher intensities in the nearby Gaula basin, but these observations have not been verified. Another event 16 August 2011 produced a large flood at Holtålen in the upper Gaula basin. The maximum one-day rainfall was 111 mm, observed at Håsjøen- Solgløtt at Rørosvidda further east.

Local rainstorms have caused severe local damages at developed areas. Short-term rainfall is a major challenge for small catchments like urban areas. The term is defined as heavy precipitation lasting shorter than 24 hours.

A network was set up in the late 1960s observing rainfall several times a day for examining floods in urban catchments. The early network was instrumented with tilting bucket pluviographs (Pluvius). The instrument tilted for ea ch 0,2 mm, and the time resolution was minutes. Recently another instrument Weighting gauge (Geonor) has been included in the gauge network operated by the Meteorological Institute. This instrument in operating with hourly values.

Short term rainfall data have been analysed by Førland et al (2015). They have mapped the highest observed values for each county for durations ranging from minute to 12 hours for data from the Pluvius network and from hourly values from the Geonor network.

The IVF (Intensity-Duration-Frequency)- statistics estimates the probability (return period) of rainfall intensities of durations from 1 minute to 24 hours. The estimates are given for returperiods of 2, 5, 10, 20, 25, 50, 100 and 200 years. The corresponding rainfall intensities are both given in the unit (l/s ha) and (mm). Figure 2.2 show an example of the IVF- statistics for the station 18701 Oslo Blindern (1968-2014).

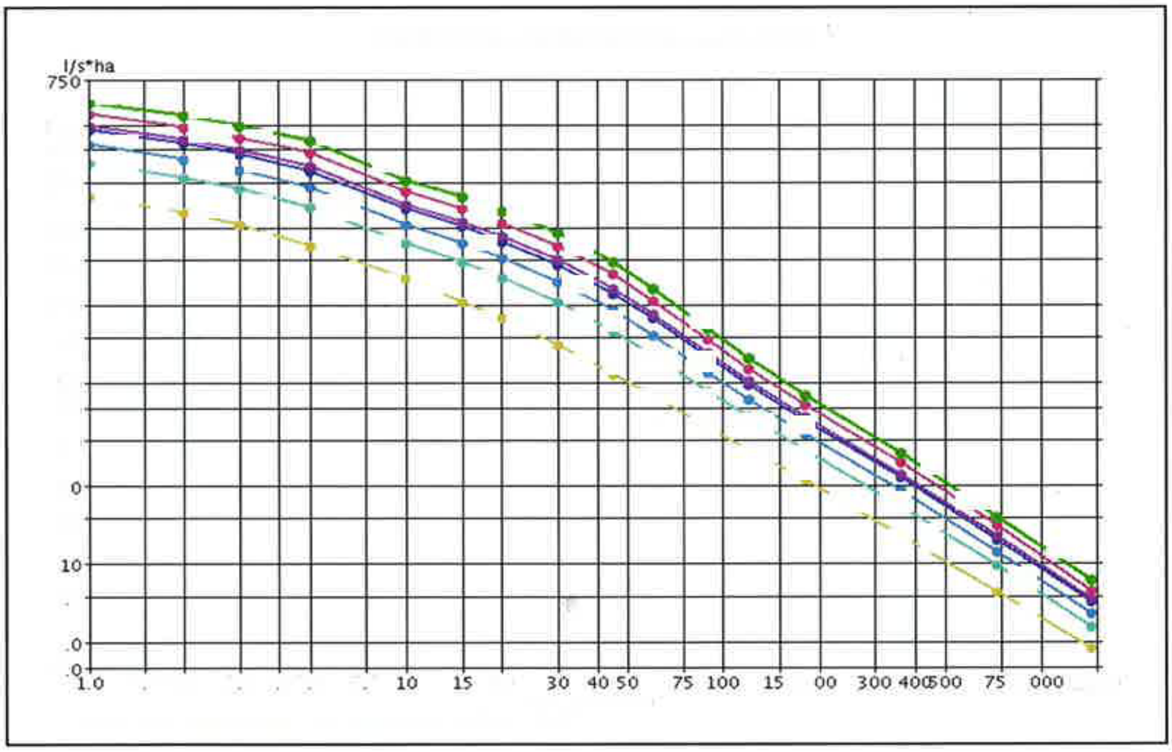


Figure 2.2. show an example of IVF statistics for the station 18701 Blindern(1968-2014) Source Mamen & Iden (2020).

The highest observed precipitation at different durations are available from Norsk klimasenter for all counties in Norway.

2.3.2 Water levels

The water levels or stages are observed at all the gauging stations in the Hydrometric network of Norway. The levels of past floods outside the network are also known at a number of locations. The flood levels were cut into rock faces or marked on trees or buildings next to the river. Some of these levels have later been shown on flood stones. The oldest known flood level in Norway is from River Glomma at Elverum in 1675.

The water levels were originally noted once a day by observers on the staff gauges. The oldest continuous series was observed from 1824 to 1827 (Schive, 1828) in River Vorma at Minne near the outlet of Lake Mjøsa. The measurements were resumed from the autumn 1846 at several locations in Rivers Glomma and Vorma. The purpose of these early measurement was to provide data for deciding between use of steamship traffic through a system of weirs and locks or to base the new public transport on railways. The railway was chosen from Kristiania to Eidsvoll as the best solution in combination with steamships from Eidsvoll to the towns around Lake Mjøsa, Hamar, Lillehammer and from 1860 Gjøvik. Annual flood levels in Lake Mjøsa at Hamar are shown in Figure 2.3. Water levels observed prior to 1876 were observed in the unit feet and inches.

Some flood levels were also marked on flood marks next to River Drammenselv, the second largest river in Norway. The earliest continues series starts in 1853. There was a number of flood marks next to the branch Snarumselv/ Hallingdalselv from the 1860 flood. Most of these flood marks, have disappeared because of construction of nearby roads.

Similar observations were made in River Skienselv, starting in 1851. Annual flood levels observed at Lake Norsjø, upstream Skien is shown in Figure 2.4. The Skiens Canal was constructed to provide transport using steamships to Notodden and on a series of lakes to Dalen further west in Telemark. Some data exist from Rivers Toke, Vegårdselv, Nidelv, Tovdalselv and Otra from the second part of the 19th Century. The series in River Nidelv starts in 1874.

The water levels have been observed from 1896 at a few stations in Vest-Agder and Rogaland. The earliest flood level in River Vosso at Lake Vangsvatn is marked on the wall of the church at Voss, dating back to 1604. The longest continuous data series at Vestlandet has been observed at Bulken in River Vosso, starting in 1892. The water levels have been observed occasionally from 1864 in Lake Vangsvatn, but the earlier data has several gaps. Twelve floods are known prior to 1892, the earliest is Storflaumen in 1743. Several of the floods in the 19th Century exceeded the largest flood in the 20th Century, which occurred in 1918.

Some early observations exist from 1883 in River Lærdalselv. Long-term series started in River Årøelv in 1899, in Rivers Gaular and Jølstra in 1902. The longest series in Nordfjord started in 1900 at Lake Breimsvatn, Lovatn and Hornindalsvatn, and in Oldevatn and Strynsvatn in 1902.

The observations in River Gaula at Haga bru started in 1902. Several floods are known from the late 17th Century, but the actual water levels are unknown. The earliest observations in Nidelva at Lake Selbusjøen started in 1859. The flood levels are known for several floods, the earliest and largest occurred in 1707, as shown on a new flood stone next to the lake.

A number of long-term series was started in late 1916 or in 1917, especially in western and northern Norway. The earliest observations in North Norway started in 1908 in Troms and in 1912 in Finnmark.

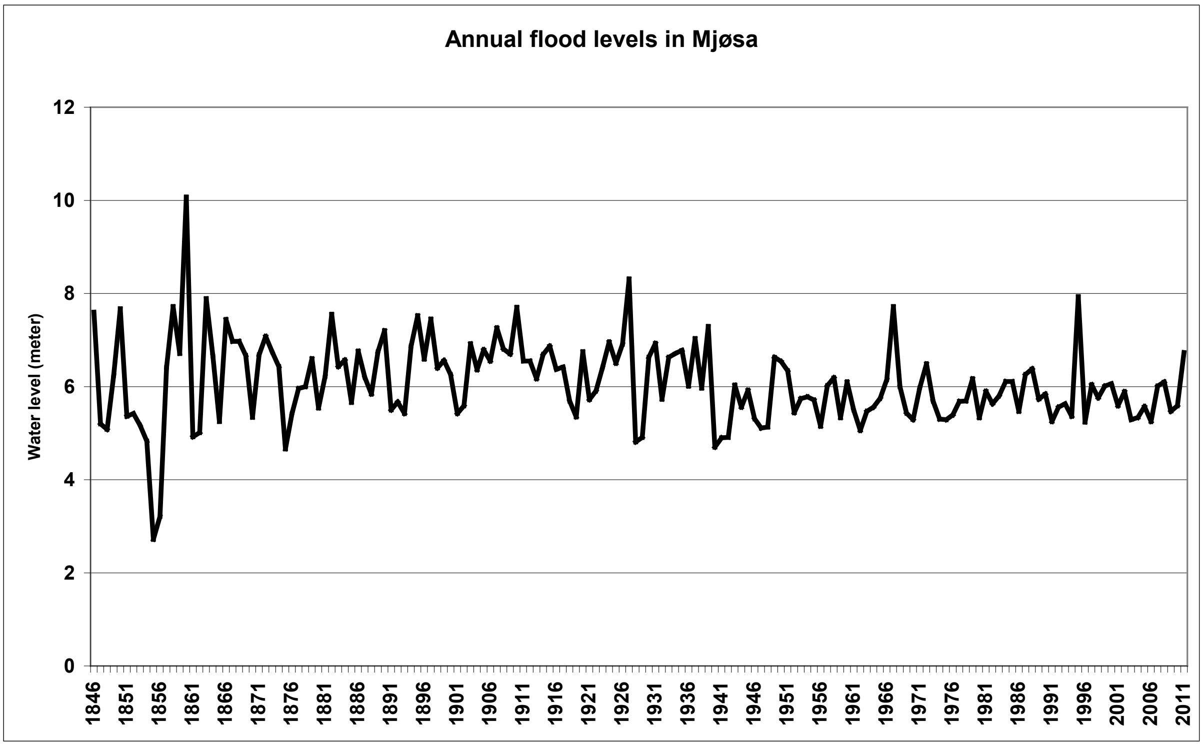


Figure 2.3 Annual flood levels in Lake Mjøsa 1847-2011. The flood levels from 1789 and 1827 are also known. The flood in 1789 peaked at level 10,10 meters, 3 cm higher than i 1860.

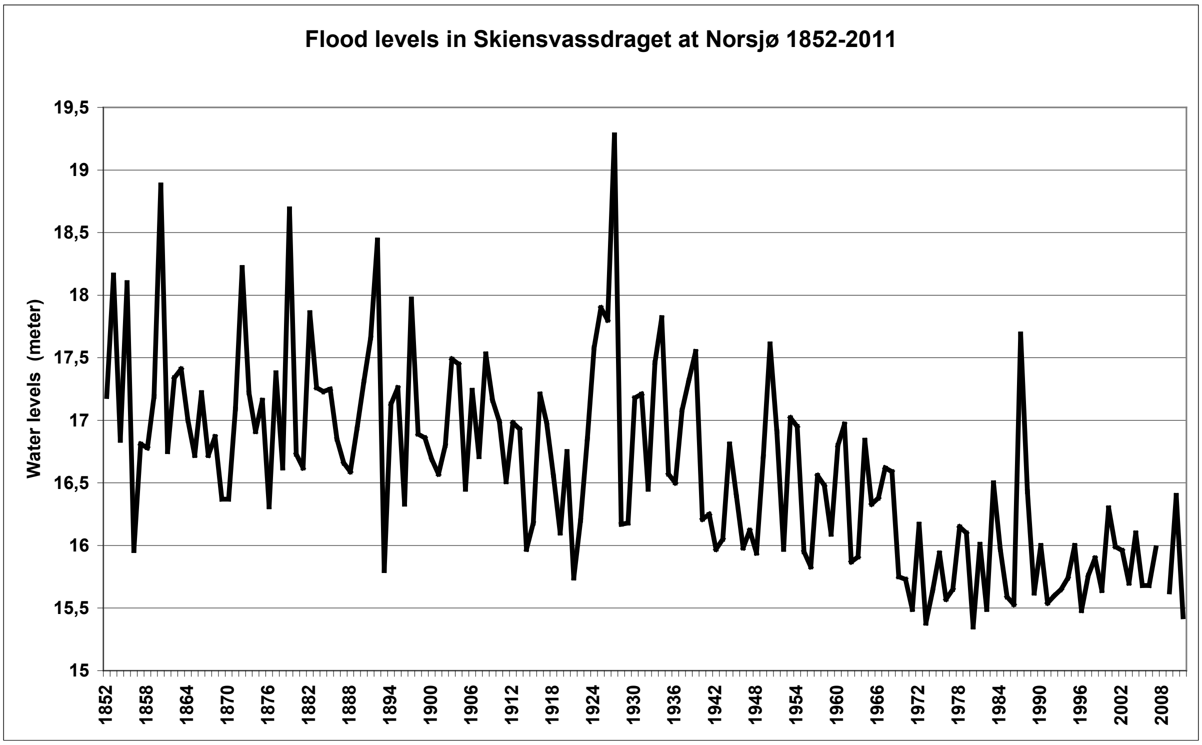


Figure 2.4 Annual flood peaks at Lake Norsjø in Skiensvassdraget. The reduction in the magnitude of the floods is caused by extensive hydropower regulations from 1909 and in the late 1950s.

The levels of large floods are also known at a number of locations outside the gauging station network.

Some stations were equipped with chart recorders (limnigraphs) before the 1930s. These recorders produced graphs, which were digitized manually. The water level was observed for some years at punching chart recorders producing 5 minutes values at a number of stations operated by the research program PRA4.2 "*Program for rensing av avløpsvann*". The station network has later been equipped with other types of data recorders and high time resolution data is now an integral part of the hydrological database.

2.3.3 Discharge

The water volume flowing past a point in the river within a fixed time step is called the discharge. It is usually given in the unit m^3/sec. While the water level can be read directly from a staff gauge, determined from the level of a float in a well linked to a chart recorder or data logger or measured indirectly using pressure sensors, the discharge requires more elaborate measurement procedures. The traditional method was to measure the water velocity over a cross-section across the river near a gauging station. The velocity is measured at several depths at a number of verticals, using a current meter. The first current meter came into use in Norway in the late 1850s, but the earliest estimates of the discharge were based on measurement of the surface velocity using floats. Now instruments based on the Doppler principle, are used as a supplement to the user of current meters. The discharge is measured in torrential and shallow streams by releasing a known amount of salt to the river and measure the conductivity of the water as the wave passes the site of the measurement. Other tracers can also be used.

The gauging stations have mostly been sited at locations, where there is a stable relationship between the water level or stage and the discharge. This relationship is called the stage-discharge curve or the rating curve. The rating curve is based on simultaneous measurements of the stage and the discharge over as much of the range of stages occurring at the station as possible. The relationship can be expressed mathematically as:

$$q = \text{const} \, (h + \Delta h)^{\text{eksp}}$$

where q is the discharge, h the stage and const, Δh and eksp are constants which must be estimated based on the observed stages and discharges. The rating curve of a station, Gryta, which is equipped with a V-shaped weir in a small stream near Oslo is shown in Figure 2.5. The figure shows also the measurements used in determining the constants.

The simple relationship cannot be fitted to all stations. For stations with a more complex hydraulic control, the rating curve comprises of a number of segments, each valid within a range of stages, and each with a separate set of constants. A general problem with the establishment of rating curves is that good measurements on high and extra low stages may be lacking. The weir at stations such as Gryta has known hydraulic properties, which reduces the uncertainty in the determination of the discharge during floods. This is, however, not the case for most stations, and causes considerably uncertainty in the estimate of the floods at stations lacking observations of the discharge at high stages. The discharge is estimated from the measurements of the water levels and the rating curve.

The use of a multi-segment rating curve is not valid at locations near the junction of a main river and a major tributary, because of backwater effects. The discharge can however be estimated by the "two-scale"- method. This is currently in use at the gauging station Ertesekken in River Vorma upstream the junction with River Glomma.

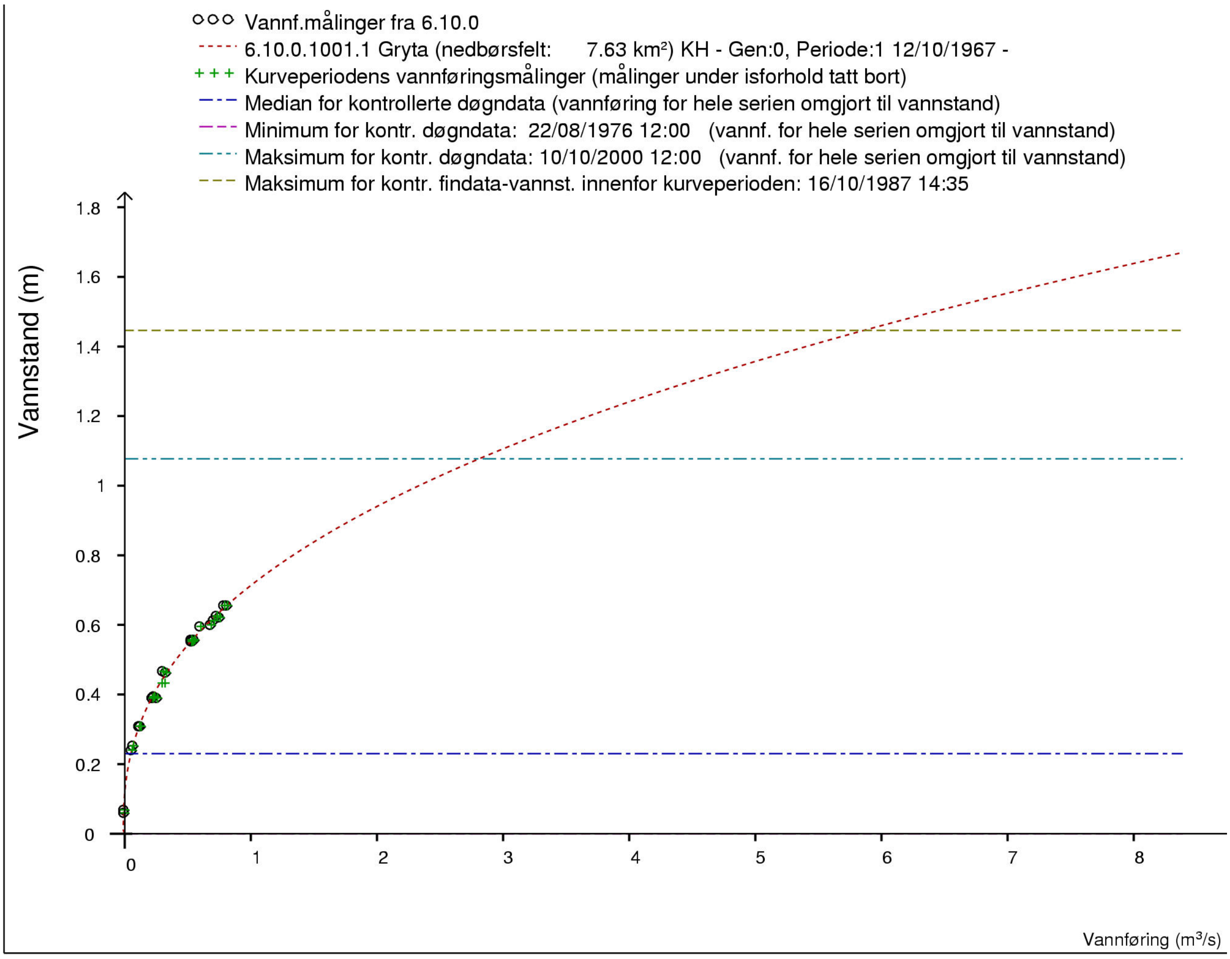


Figure 2.5 Rating curve for the gauging station 6.10 Gryta in Oslo

Knowledge and good forecasts of the actual water levels are vital for the local population and for the emergency services during a major flood. The discharge is usually fairly constant along a reach of a stream unless a tributary add water to the river. The water level varies however, considerably along long river reachrs, depending on the properties of the river channel. Flood frequency analysis is therefore based on discharge rather than water levels. The shape of rating curves shows that an increase in the stage at low levels lead to a moderate increase in the discharge, while at high levels, a moderate increase in the stage results in a large increase in the discharge.

The use of rating curves is based on the assumption that the condition of the controlling section at the station is constant. If sand or gravel accumulates in the controlling section, or the section of the river or the riverbank is eroded, the relationship between stage and discharge may change. This can happen during a flood. It is then necessary to establish a new rating curve, valid from the time of the assumed shift in the hydraulic control. This may happen several times during the life of a long-term gauging station. The discharge may then be estimated from a number of rating curves each valid for a limited period.

The relationship can be temporarily changed because of growth of vegetation or occurrence of ice in the controlling section. This will normally cause higher water levels at the same discharge as when ice of vegetation is not present. Backwater caused by vegetation is only present in a small number of small lowland rivers, but backwater because of ice is quite frequent at many stations in the winter. In Norway, the observed water level is adjusted to the water level corresponding to the estimated discharge under ice-free conditions. The discharge is estimated from direct measurements through the ice as well as measurements from nearby stations not affected by backwater from ice. This procedure is called "isreduksjon". The estimated discharge is quite uncertain, but the discharge is usually low when ice dams occur. This uncertainty does not affect the estimation of the floods.

The water level was originally observed once a day. The discharge was estimated from the rating curve and was considered as the average value of that day. Later most stations have been provided with recording instruments, observing the water levels several times per day usually at a fixed time resolution. The discharge may vary considerably within 24 hours, especially in smaller basins. Based on high time resolution data, more accurate estimate of the daily mean flood can be made. This introduces some uncertainty when using both data from the period of once-a day observations, together with the later daily averages in flood analysis. This is less of a problem in the largest basins such as Rivers Glomma or Drammenselva where the daily variation usually is small even during floods. For small basins, especially without lakes, the difference can be considerable. The difference is most extreme in small urban basins where the difference may be more than 20-fold between the peak and the daily average.

The annual daily floods estimated near the outlet of River Glomma at Sarpsfoss are shown in Figure 2.6. This series is a composite series based on data from a number of gauging stations from 1846 to 1851, observations at Sarpsfossen from 1851 to 1905, and discharge data from the upstream station Langnes from 1901 to 1964 and from Solbergfoss from 1964.

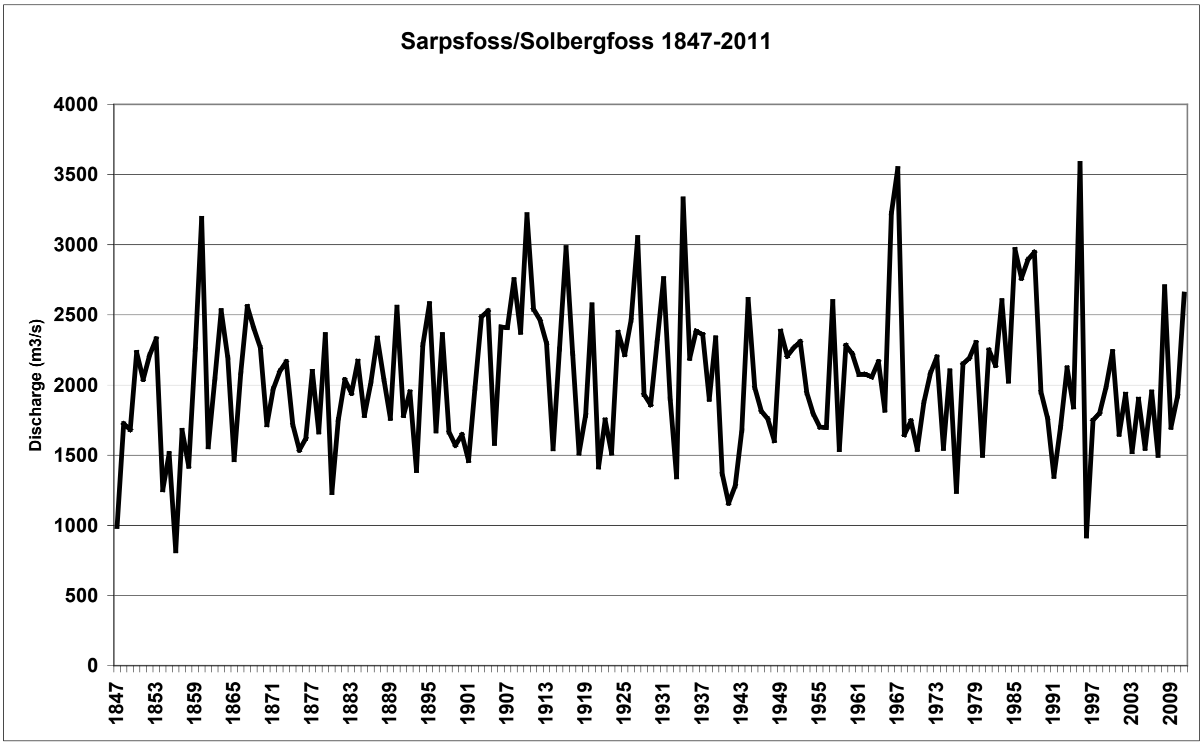


Figure 2.6 The annual flood in River Glomma near the outlet near Sarpsborg

2.4 Magnitude of floods observed in Norway

The magnitude of a flood given in m^3/sec depends strongly on the basin area upstream the station. A large percentage of lakes upstream the station tends to reduce the floods compared to floods in basins with few if any lakes. If a part of the basin is covered by impervious surfaces, the flood peaks will increase, and the floods will come faster. For a comparison of floods in streams with a different basin area, it is common to divide the discharge by the area. This is called specific discharge and is often given in the unit l/sec km^2. In urban hydrology the unit l/sec ha is more frequently used. The specific discharge may also be given as the depth of water from the upstream basin for a given time step, usually as mm/day. A runoff volume of 1 l/sec km^2 over a day correspond to a water depth of 0,864 mm/day.

The highest observed specific runoff was near 11.000 l/ km^2. This was observed over a time step of five minutes in a small urban research basin in Oslo. The basin area was only 0,96 ha, and 95 % of the basin was covered by impervious surfaces. This was a peak value, and the daily average in such basins may amount to only a few percentages of the peak. The largest floods in large basins such as River Glomma has a specific runoff less than 100 l/sec km^2 near the outlet. The basin area is 41.000 km^2. In natural basins with an area ranging from 10 to a few hundred km^2 at Sørlandet, Vestlandet and in Nordland the largest floods have peaked at 1000 to 3000 l/s km^2. Medium sized basins such as Lalm in River Otta have a basin area of 3942 km^2. The peak during the extreme flood in 1789, *Storofsen*, has been estimated to 1799 m^3/sec or 431 l/s km^2 (Søgnen, 1942). Beldring et al (1989) assumes that the daily average was 1650 m^3/s or 420 l/s km^2. River Gaula in Trøndelag has a basin area of 3062 km^2. The flood observed in August 1940 was 3060 m^3/s or 1000 l/s km^2. The station had been equipped with a chart recorder earlier in the 1930s, but the charts from 1940 are missing. The observation was evidently once a day reading. This observation seems to be an exact observation of the peak value rather than the once a day reading taken at the same time each day. The daily average has later been estimated to 2140 m^3/sec or 702 l/sec km^2.

3 What causes floods in Norway?

3.1 Snowmelt floods

Most of Norway is covered by some snowfall in the winter. Large spring floods occur mostly in the inland and mountainous part of Østlandet. Some large snowmelt floods occurred in 1792, 1860, 1879, 1910, 1916, 1966, 1967, 1995, 2011 and 2013 in South Norway. Snowmelt floods are also dominant in North Norway. The largest snowmelt floods occur also in in Finnmark where the largest flood on record occurred in 1920. The distribution of the snowfall within each catchment varies from year to year. The snowmelt starts usually in the lower part of the catchment and moves gradually uphill as the temperature increases depending on the steepness of the terrain. The air temperature decreases with altitude by 0,6 degrees per 100 meter in saturated air and by 1 degree per 100 meter in dry air. Large basins such as the Glomma basin covers both large low-lying areas, low- mountain and alpine areas. Floods occur often several times in such basins. There is a typical flood from the lowlands in March/April “Lavlandsflommen”, flood from the mountain slopes “Liflommen” in May/June and a late mountain flood in late June/July “Fjellflommen”. In glacier streams, the flood often culminates in August. A cold spell in the spring delays the melting from the upper part of alpine rivers. The large floods in 1967 and 1995 could have been more severe had it not been for cold spells in the uppermost parts of the catchments of Jotunheimen. Some typical mountain floods occurred in 1944 and 1958.

Snowmelt intensities are dependent on the energy transport from the atmosphere. The energy transport is dependent on solar radiation, rain falling on the snow and transport of wind transport of dry and sensible heat. The most effective process is the transport of saturated humidity, typically occurring in west Norway near the coastal glaciers such at Folgefonni, Ålfoten, Jostedalsbreen and Svartisen glacier. Solar radiation causes also snowmelt floods. The contribution from short and long-wave solar radiation are more typical in the inland. The contribution from dry heat contribute less, and melting caused by rainfall least of all.

Snowmelt floods last typically several days. They develop gradually, often starting in a part of the catchment, gradually extending to larger part as more tributaries contribute to the flood in the main river. The discharge varies throughout the day during the melting. The highest value each day occurs usually in the evening.

In rivers on the outer coast, snowfall events often occur several times with melting in between. Late autumn and early winter floods are common in these rivers. Early autumn snowfalls occur frequently at Vestlandet, succeeded by quickly rising temperatures and intense snowmelt. This is quite common in Rivers Valldøla, Driva, Øksendalselva and Surna at Møre and Romsdal and in coastal rivers in Trøndelag and Nordland counties.

Frontal snowfall can occasionally cause heavy snowfall at Sørlandet in some years. Sørlandet suffered from such events in 1937, 1970 and 2008.

The start and the duration of the snowmelt flood in a basin are dependent on the steepness of the terrain. The air temperature decreases with altitude by 0,6° per 100 meter in saturated air and 1° per 100 meter in dry air. Large basins such as River Glomma cover both large low-lying areas, low mountain areas and alpine areas. Floods occur often several times during the melting season in such basins. There is typically a flood from the lowlands in March/April, a flood from the mountain slopes and low mountains in May/June and from the most alpine part in late June or in July in Glomma. A cold spring delays the melting in the low-lying part of the basin. An abrupt increase in temperature possible in combination with rainfall causes snowmelt over most of the basins causes the large spring floods in these large basins. Large snowmelt floods can occur when the lowland flood is delayed, and the melting occurs simultaneously in most of the catchment. After the large spring or summer floods in Gudbrandsdalen a lot of snow 1967 and in 1995 remained in Jotunheimen. This snow contributed to later smaller floods in River Gudbrandsdalslågen later in the year.

Snowmelt floods usually last several days. They develop gradually, as the melting increases. Snowmelt floods occurs often only in parts of the catchments unless the melting coincides in the lower and the upper parts of the catchment. Floods occurring in the lower part of a large catchment is known as the "lavlandsflommen" or the lowland flood. Floods occurring in the upper slopes is known as the "liflom" and floods occurring in the alpine part of the catchment is known as "fjellflommen" or the mountain flood. The discharge varies throughout the day. The highest value each day occurs usually in the evening when the temperature has started to decrease. Snowmelt floods caused by high temperatures in dry weather usually show a sinusoidal distribution of the runoff through each day.

Snowmelt floods occurs simultaneously over large regions, typically in southeast Norway, and occasionally also in the inland basins in Trøndelag and further north. Snowmelt is the dominant cause of floods in the large inland basins of the two northernmost counties in Norway, Troms and Finnmark. These floods can start as an ice run flood.

Low-lying basins near the coast from Oslofjorden to Vesterålen have no typical spring flood period. Many floods in these basins occur occasionally in the late autumn or early winter. Many autumn floods occur after a spell of autumn snowfall, followed by mild weather and heavy frontal rainfall.

The spring flood occurs normally from April to May in inland rivers in the lowland at Østlandet. In River Glomma the spring flood normally occurs from May to June. This is also the case in the main rivers in Glåmdalen and Østerdalen, in Trysilelva, in Gudbrandsdalen, in Drammenselva, Numedalslågen and in Skienselva. Spring floods occur usually in June and July in the alpine districts such as Jotunheimen, except in glacier streams where the flood peaks from July to August. The larger rivers running towards the south coast, such as Nidelva, Tovdalselva and Otra have also spring floods in May and June, but rainfall floods are also frequent at other times of the year. The spring flood occurs normally in rivers flowing from Hardangervidda to Sørfjorden in Hardanger in May to early July. Spring floods occurs simultaneously in rivers draining to the east, such as River Drammenselv, Numedalslågen and Skienselv. In the inner districts of Møre og Romsdal and the major streams in Trøndelag such as Rauma, Driva, Orkla, Gaula, Nidelva, Stjørdalselva and Verdalselva the spring flood usually occurs in May or June.

In Rivers Vefsna, Rana and in rivers draining mountainous areas in Nordland, the largest annual flood usually occurs in May or June. The extreme flood occurring 17 Mai 2010 was the result of extreme snowmelt caused by severe Foehn wind caused by intense rainfall in Sweden. The annual flood occurs usually in June but can occur in May or early July in the large rivers in inland Troms and Finnmark. Because the Finnmarksvidda mountain plain is quite flat, the snowmelt floods tend to be quite concentrated and can exceed the largest floods at Østlandet.

3.2 Rainfall floods

Most floods in Norway are caused by rainfall, possibly in combination with snowmelt. Many large autumn or early winter floods from Rogaland to South Troms occur after a spell of cold weather with abundant snowfall in the mountains. Strong and mild winds from west-southwest cause the temperature to increase abruptly in the mountains. Intense snowmelt may be in combination with heavy rainfall causes many small streams to flood. This weather type can also cause slush avalanches, with a high potential of causing fatalities. One example of this occurred 9 February 1928 in Hordaland and Sogn, see Figure 5.2.

The largest rainfall floods at Østlandet occur in the summer or early autumn when the rainfall covers large areas. This is linked to southeast weather types, see Figure 5.4. The timing of the flood in different part of the basin is also of crucial importance. The large Glomma basin comprises two main branches, the main river to the east and the more alpine part of the basin to the west. Downstream the confluence of these two branches at Vormsund is the town of Lillestrøm. This district is densely populated. If the flood waves coincide from the eastern and the western branch, a devastating flood will be the result. This happened in 1789, but not in 1860 when the flood in the eastern branch was less extreme. The floods in 1967 and 1995 occurred at a time when there was a large snow reservoir remaining in the most alpine part of the basin. The temperature was not high enough to cause large snowmelt in the alpine areas, which produced smaller mountain floods later in the summer, when the main flood was over. Local rain showers can also cause severe damages, especially it they occur in densely populated areas. Large rainfall floods have occurred somewhere in Norway in 40 of the last 118 years between the 13th and 16th August.

Long-term rainfall produces most of the largest floods at Vestlandet, such as the floods in November 1906 Sogn og Fjordane and Sunnmøre, October 1918 in Voss, November 1940 at Vestlandet etc. Long-term winter rainfall has also caused floods in coastal basins at Fosen in Trøndelag such as the floods in late January in 1932 and 2006. Warm air masses from southeast in combination with heavy precipitation cause large floods in coastal basins in Nordland in the late autumn or early winter. Large rainfall floods in the autumn can penetrate to Salangselva in the southern part of Troms, as well as in coastal basins to Tromsø.

3.3 Ice run floods

Ice form in many Norwegian rivers during the winter: The physical processes for building up the ice cover in a river, causing ice jams and ice runs, is described in Asvall (2010). When water freezes, super-cooled water forms which may move down in the water volume. Where the water is prevented from flowing freely by rocks etc can the super-cooled water stick to these obstructions and form ice barrages raising the water level. This will cause the surface water velocity to decrease. Ice on the surface can then form. A series on ice dams can form more or less regular in steep rivers, creating a staircase like profile. The water may later cut through the bottom ice and start flowing again near the riverbed. Increasing temperatures and winter rainfall can cause ice dams to breach and start an ice run. Drifting ice can accumulate at a constriction or a bend of the river channel, forming an ice plug. These ice plugs can dam the stream, causing inundation and deposition of ice on the flood plain adjacent to the river. These ice plugs are most common when the ice forms in the autumn or early winter. Dropping temperatures will cause the ice as well as water to re-freeze, causing the ice jam to last a long time.

When the temperatures rise in the spring, open water first appear in the rapids, gradually spreading as the temperature increases. If the slope of the river is small, open water appears near the riverbanks. The ice breaks up as the discharge is increasing. When the discharge is sufficiently large, the ice start will move downstream. Initially large pieces will move, but the ice will break up gradually in smaller pieces. Drifting ice may stop at obstructions in the river channel until the water level increases enough to flow over the river-bank and deposit ice on the flood plain, causing damages to farmland.

Ice runs and ice plugs have frequently caused damage near many rivers at Østlandet, Nord-Møre, Trøndelag and in the spring in Finnmark. Several of the largest spring floods in Glomma started with ices runs, either in tributaries or in the main river, such as the floods in 1675, 1683,1717, 1927, 1928, 1934, 1959, 1966 and 1967 (Devik et al, 1929; Asvall, 2010). A number of severe ice runs occurred at Koppangsøyene at Storelvdal 1827-1828, 1925-1931, where the tributary Imsa had ice runs in 1828, 1856, 1897 and 1910. The water level was higher at the village of Otta in Gudbrandsdalen in the winter 1996 than during *Vesleofsen* in 1995 because the river channel was filled up with bottom ice resulting from a cold and dry winter. Large ice run floods have occurred in Surna, Driva, Orkla and Gaula in 1850, 1859, 1866, 1880, 1881 and 1882. The flood level at Holtålen in Gaula during the ice jam in 25 December 1881 was reported to be as high as the level of the large rainfall flood 16 August 2011. Ice runs are also common in Namsen and in the larger rivers in Finnmark. Some of the larger floods in Tana and Neiden start with ice runs.

3.4 Floods caused by slides

Some large clay slides have caused dams to form. These dams can cause widespread inundation upstream the dam, later resulting in dam failures and floods. Clay slides are often the results of various human activities in the basin. Some clay slides have however occurred after heavy rainfall and floods. A large clay slide, Løkenfallet, caused a 19 meters tall dam to form in 1794 in River Rømua a few years after *Storofsen*. A 9 km long lake formed upstream the dam. Another clay slide occurred at the farm Thesen into River Vorma in 1795. The dam caused the level in Lake Mjøsa to increase by 8 meters. A third clay slide at Holum into River Leira near Kråkfoss caused the river to rise 12,5 meter forming a 6 km long lake upstream. The army and road construction workers succeeded in digging through the dams in River Rømua and River Vorma, a task that required 132 and 111 days in the two rivers. The dam in River Leira failed in 1883, and the resulting flood destroyed all bridges over the river before the confluence with River Nitelva near Lake Øyeren. Several slides during *Storofsen* in 1789 have caused damming with subsequent dam failures. The water levels were observed for some years at punching limnigraphs producing five minutes values at the stations operated by the research program PRA4.2 “Program for rensing av avløpsvann”.

The worst natural disaster in Norway, the *Kvasshyllan slide*, seems to have occurred during a flood in River Gaula, resulting in the loss of more than 500 lives, and the destruction of 48 farms and at least three churches in September 1345 (Skálholt-annalene; Helland & Steen, 1885; Basberg et al, 1996; Rokoengen et al, 2001; Furseth, 2006).

The disaster in the summer 1789 was also known as *Skriusommaren* in Gudbrandsdalen. River Gudbrandsdalslågen was blocked by a rockfall at Rosten near the border between Sel and Dovre in 1789. The subsequent dam break caused severe flooding at Selsmyrene resulting in almost total damage on some large farms. It is highly likely that Gudbrandsdalslågen was dammed by slides occurring downstream Fåvang with a subsequent dam break. The flood wave deposited large masses of gravel, sand and debris below Fåberg. During Storofsen slides from the north side of river Otta in Skjåk. This moved River Otta towards the south side killing 2 men and creating the area where the village Bismo later was developed (Berg, 1936).

The 250 slides occurring at Tinn in early June 1927 was a mixture of avalanches and landslides. The large mountain slides from Ramnefjell in Loen occurred after heavy rainfall in 1905, 1936 and 1950. Tjellefonna fell into Langfjorden in Romsdal 22 February 1756, after a rainstorm lasting eight days. This slide may have developed over time resulting from earlier rainstorms occurring in 1650 and 1743.

Several rivers at Vestlandet, Møre og Romsdal and in Nord-Norge have been dammed by avalanches or landslides, with subsequent dam breaks and flooding. Extreme avalanches at Vestlandet have caused severe loss of lives 1679, 1755 and 1850 at Sunnmøre, 1858 in Romsdal, widespread 1868, 1928 in Hordaland and in Trøndelag and Møre og Romsdal near River Driva. Some of these events were caused by polar lows, other by slush avalanches, which have caused local floods and fatalities.

3.5 Jøkullhlaup - floods from glacier dammed lakes

Some glacier streams have large floods caused by water bursting out from lakes dammed by a glacier. Such glacial outburst floods or jøkullhlaups tend to occur for a number of years but can cause severe floods. Jøkullhlaups are known to have occurred i River Mjølkedøla to Vinstra (Liestøl,1956; Klæboe, 1938a), Folgefonni, Hardangerjøkulen to Simadalen, Jostefonn towards Vetlefjordsdalen, Jostedalsbreen toward Jostedalen and toward Olden, Illstigbreen toward Muldal at Tafjord, Østerdalsisen at Rana, Blåmannsisen towards Sisovatn and Koppangsbreen in Lyngen. These floods occur mostly in periods when the glaciers are becoming thinner, allowing water from glacier dammed lake to escape under the ice. Some of the larger jøkullhlaups came from Lake Demmevatn towards River Sima in 1893, 1937 and 1938, from Lake Brimkjelen in Tunsbergdalen in 1926, 1937 and 1938 and from Lake Svartisvatn towards River Rana 1946-1955. Vetlefjorddalen at Tjugum in Sogn suffered severe damage from a flood occurring 18-19 July 1820 (Urtegaard, 1991). The flood started as a jøkullhlaup from Lake Skadalsvann, which previously was blocked by an arm of the Jostefonn glacier. A jøkullhlaup occurred also for the first time from Blåmannsisen glacier in 2001. The glacier dammed a lake forcing the outflow to flow over a threshold forming the water divide towards Sweden. Thinning of the glacier caused water to break through flowing into a Norwegian hydropower reservoir on the other side of the glacier (Engeset et al 2001). Other outburst occurred in 2005, 2007 and 2009, and happens now almost every year. Recently several jøkullhlaups have occurred at Koppangen in Troms.

3.6 The link between floods and conditions in the ground

The response of a basin to input of water from melting snow or rainfall is dependent on the content of soil moisture and ground water. A river will often respond with a small flood after a prolonged period of dry weather. Subsequent rainfall causes larger floods after the ground has been saturated, even if the new amount of water influx is less or equal to the first event, ending the drought.

If a layer of frozen soil is present in the ground, water cannot infiltrate through the frozen layer. Rainfall on frozen ground causes many winter floods in the coastal districts of Vestlandet and Nordland. These floods cause damages to buildings unless the basement is above the ground.

When a layer of frozen soil is covered by surface layers of unfrozen and saturated soil, this can cause severe landslides in steep terrain. This was the case in the summer 1789 in Gudbrandsdalen, when the summer was locally known as Skriusommaren. Some of the slides at Vestlandet in December 1743 resulted from ice layers in the ground.

3.7 The effect of lakes

The inflow from rivers into to lakes is attenuated as the flood wave passes through the lake. The outflow from a lake is equal to the inflow minus the increase in the volume of the lake in a given time step. The outflow is determined by the water level and the rating curve at the outlet. The volume is determined from the stage-volume curve and the water level in the lake. The water level of the lake will increase as long as the inflow is larger than the outflow. When a flood wave flows into a lake, the outflow is usually lower, and the water level will rise as water is stored in the lake. As the water level increases, the outflow capacity is also increasing until it exceeds the inflow. The water level will then start to sink, causing the outflow to decrease. As long as the outflow is larger than the inflow, stored water will be released from the lake. A lake will therefore cause the flood in the downstream river to be delayed, and the peak to be reduced in magnitude. This effect can be calculated if the rating curve of the outlet and the stage-volume curve is known (Søgnen, 1942).

The attenuation of floods is considerable in the major rivers such as Glomma, Drammensvassdraget and Skienselv with large lakes. Lake Øyeren in River Glomma has a narrow outlet at Mørkfoss. The water level rose almost 17 meter above the usual level in the winter during *Storofsen* in 1789. The length of the lake is usually 36 kilometer. The length of the lake was extended 54 kilometers to Rotnes in Nittedal in 1789. There is a couple of small waterfalls in the main river upstream Fetsund. Backwater from Lake Øyeren caused the waterfalls at Bingsfossen and Rånåsfoss to almost disappear. The outlet at Mørkfoss was modified from 1857 to 1869. It was estimated that the peak of the floods in 1850 and 1860 would have been reduced by 3,6 meters had the modification been operating during these floods (Sætren, 1904).

Rivers with few in any lakes respond quickly to heavy rainfall, and can have large floods, such as River Gaula in Sør-Trøndelag. Tributaries flowing through steep terrain to the large rivers in the major valleys in the inland can flood severely even when the flood in the main river is moderate, such as River Finna, Veikleå and Moksa in Gudbrandsdalen.

3.8 Backwater and bifurcations

When a major flood is on, the water level in the main river can cause backwater into tributaries. One example of this is where River Vorma joins River Glomma at Vormsund. The backwater from Glomma can penetrate to Sundfossen in Vorma and even affect the water levels in Lake Mjøsa. Backwater from River Glomma can also penetrate to Lake Storsjøen in Odal, which then serves as a detention storage for the flood in the main river. Further upstream at Nor in Grue backwater from River Glomma has flooded into Lake Nugguren.

Backwater from Glomma at Kongsvinger can penetrate into Lake Vingersjø. When the water level is sufficiently high, part of the flood will flow into River Vrangselv and into River Klara in Sweden. (Pettersson, 2001).

4 Floods and human activities

4.1 Land use changes

The land use has changed considerably over time in Norway.

- Large quantities of timber were cut in coastal basins and exported to the Netherlands and Britain in the 17th Century. The deforestation caused large floods in 1609 and 1627 after the forests had been removed in the Lake Engsetvatn basin at Sunnmøre. The floods did almost destroy the large farm Tenfjord.
- Mining industry required large amount of timber. The government defined a large zone called "*Circumferensen*" around the large copper and silver mines at Røros and Kongsberg. The mining companies had monopoly on all timber form the forests owned by the Crown within this zone. The mountain district around Røros was completely denuded of trees. Even to-day the forests have not been re-established in this district. The amount of timber required in the mines was so large that the Crown granted the mining companies permit to utilise the timber in privately owned forests. The consequence of the deforestation was that the floods in River Glomma at Østerdalen became more severe, and the farmhouses were gradually moved away from the flood plain. The floods in Numedalslågen have not increased, even if the utilisation of timber was as high as in the Glomma basin. The re-growth was probably sufficient to compensate for the increased utilisation of the forests.
- The standing tree volume has doubled since the 1920s. Better management of the forests and the disappearance of extensive grazing as well as the effect of warmer climate, is responsible for this. The height of the tree-limit in the mountain forests is also increasing. More forests tend to reduce the magnitude of the floods.
- Vegetation on the riverbank tends to hinder erosion and flood damages. Farmers have locally removed this vegetation to extend their fields closer to the rivers. Some of the damages seen along Rivers Glomma and Vorma are caused by this activity (Schive, 1828).
- Many main roads were constructed on the flood plain next to the river, cutting of areas, which may be inundated by large floods.
- Construction of access roads to recreation areas or for forestry in steep terrain can cause increased risk of flood damages and landslides if the drainage through culverts has too low capacity. Lack of maintenance of culverts and flood protection works can also cause floods.
- Canalisation of riverbeds to facilitate shipping on Norwegian rivers as on the European mainland is now only present in a few rivers at Østlandet. The construction of dikes along flood prone rivers can cause severe damages if the dikes are overtopped or fails for other reasons.
- Towns and built up areas are growing. The infiltration of water into the ground decreases as more impervious surfaces are constructed. The runoff is diverted through underground pipes or flow on the surface. Basements will fill up if the urban drainage system is inadequate. Streets and metro- and train lines may flood as the surface water

is flowing in new directions. Water supply and sewer systems may fail during a flood. The floods in urban areas are generally faster and have much higher peaks than in a rural basin. Floods in urban areas cause far more damages than floods in rural areas.
- Floods can cause severe damages, but ongoing floods have also resulted in flood tourism especially in the River Glomma basin. During the large flood in Lake Øyeren in May 1910, the railway sold 15 000 tickets to peoples from Kristiania/Oslo who wanted to see the ravages at Lillestrøm. Ministers and Members of the Parliament as well as other citicens have visited the sites ravaged by other floods. During such events it may be necessary to prevent looting.

4.2 Effects of hydropower regulations

Most of the large rivers in Norway are utilised for hydropower production. The effect of the regulation is dependent on the reservoir capacity compared to the annual discharge. The reservoir capacity of River Glomma is 3600 Mm^3 which correspond to 16 percent of the annal discharge, while other large rivers such as River Dramselv, River Numedalslågen, River Skienselv, River Nidelv and River Otra have a reservoir capacity of 30 to 55 percent of the annual inflow (Tingvoll,1999). While Vesleofsen caused severe damages in 1995, the other rivers escaped from severe damages because of the larger reservoir capacity of the reservoir compared to the inflow. The long-term annual flood series drops gradually over time as more hydropower developments as more hydropower developments takes place in the larger water courses.

Regulations will also lead to redistribution of the inflow over the year. Water is stored in the reservoir during the melting period in the spring and early summer and utilised for power production at in the autumn and winter. Long-term series in heavily regulated rivers show a marked decline in the flood peaks after regulation has taken place. The long-term series at Norsjø at Skien shown in Figure 2.3 at page 11 demonstrates the reduction in flood magnitudes as large upstream reservoirs start to operate.

Some hydropower schemes include diversion of rivers from one basin to another. If no diversion is present in a regulated basin, the same volume of water will pass through the power station and through the spillways as it would in the river under natural conditions in a year. The seasonality of the flow can however change considerably, as shown in Figure 4.1 in River Måna downstream the large Møsvatn reservoir. The regulated discharge is close to the natural in the late summer and autumn when the reservoir is filling up. Heavy inflow on a full reservoir can easily cause floods in the river channel because of release of water through the spillways or bypass tunnels. Long-term flood series show a general decrease in flood magnitudes in strongly regulated rivers as shown in Figure 4.2. The low flow tends to increase in the regulated rivers.

When water is diverted from a basin, the discharge and the floods will decrease. This is shown in Figure 4.3 for River Eira at Eikesdalen, where a part of the basin have been diverted to the Aursjø reservoir for the Aura power plant at Sunndalsøra in 1958, and another part have been diverted to the Grytten power station at River Rauma.

The exception is in case the reservoir us used as a multi-year reservoir. In that case, the regulated outflow in a given year can differ from the natural case as for the large Blåsjø reservoir in Rogaland.

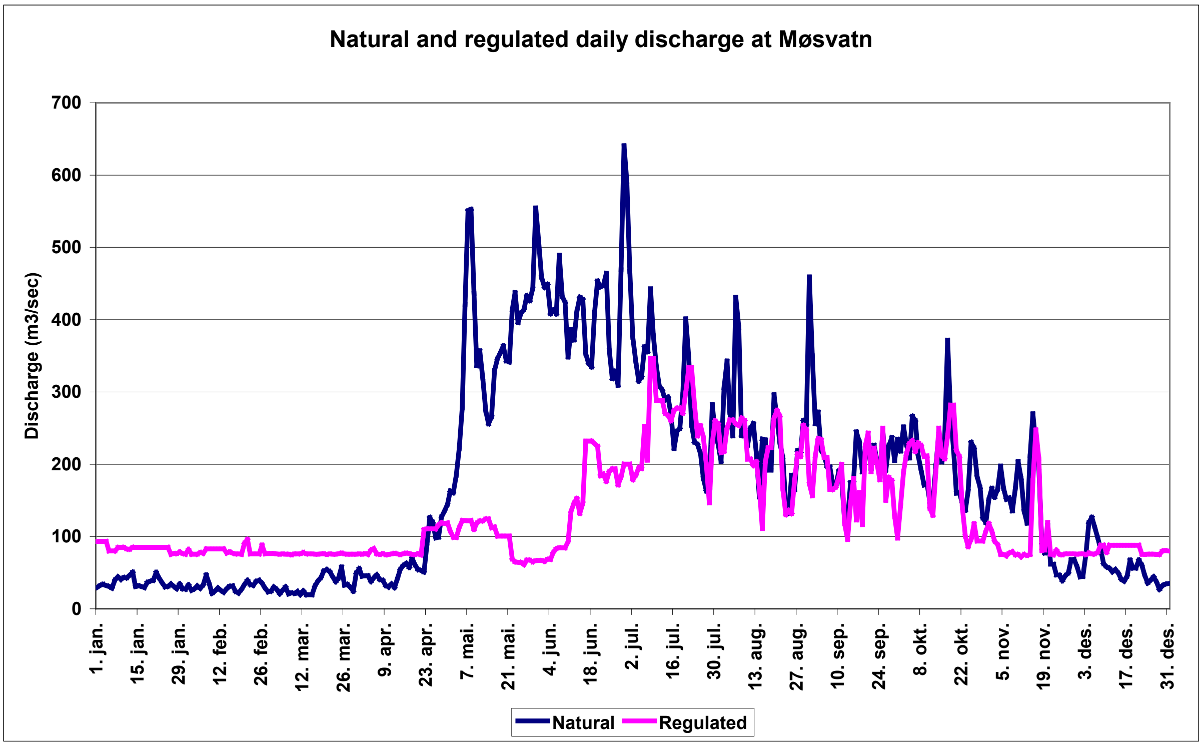


Figure 4.1. *The highest daily discharge every day through the year based on data from Lake Møsvatn in Telemark for the years 1909-2010. The huge reservoir Møsvatn redistributes the outflow over the year by storing water in the snowmelt season and releasing water in the winter for power production. The regulated discharge is close to the natural in the late summer and autumn, when the reservoir is filling up. Heavy inflow on a full reservoir can easily cause floods in the river channel because of release of water through the spillways or bypass tunnels.*

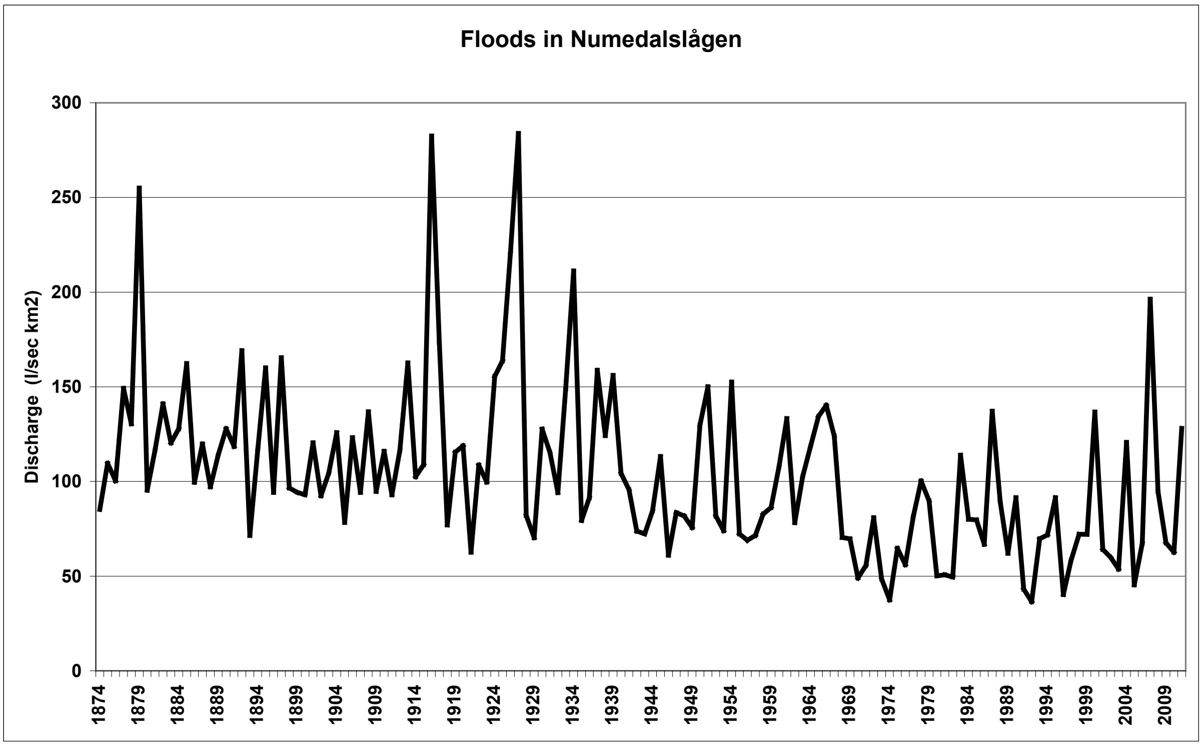


Figure 4.2. Annual floods in River Numedalslågen 1874-2011. The series is a composite of data from Labro, Bommestad, Kongsberg and Skollenborg. The basin areas vary between these stations, and the composite curve is therefore shown as specific runoff. The basin was strongly regulated by large reservoirs in Tunnhovd- and Pålsbufjord in the 1920s, causing the reduction in the floods.

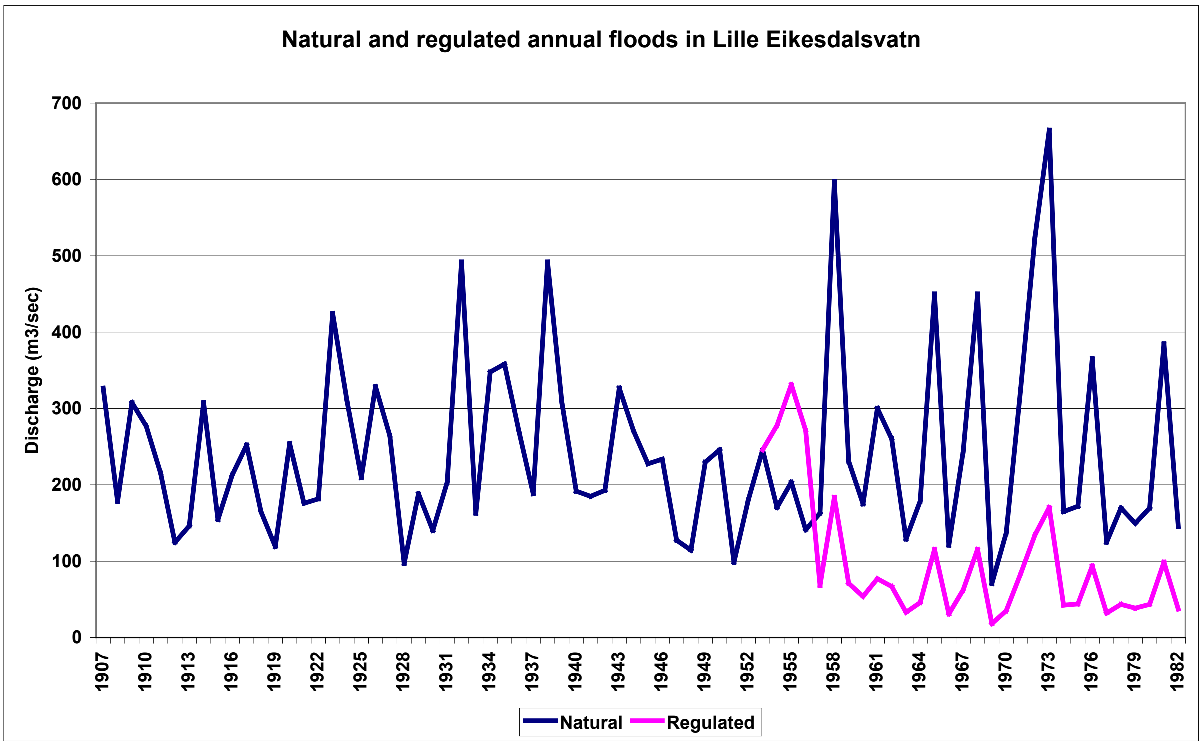


Figure 4.3 A major part of the basin of River Eira was diverted in 1958 to the Aursjø reservoir, reducing the annual flood in the outlet of Lake Eikesdalsvatn.

5 Floods and storm trajectories

5.1 Classification of weather types

The occurrence of floods in different parts in Norway depend on the exposure of each catchment to different weather systems. Van Bebber (1882) classified trajectories of storms reaching Europe from the Atlantic into five major classes with a number of subclasses. The trajectory, which has caused most flood disasters in Central Europe is known as the Vb-tief or Vb-zug in his terminology.

Several classification systems have been developed for daily weather types, based on the location of cyclones and anticyclones. The classification was originally based on manual identification of the weather type using daily weather maps. These methods have been improved using objective classification instead of the old subjective methods. The classification scheme was usually focussed on a limited geographical part of Europe, such as a country. The German "*Grosswetterlagen*" (Hess & Brezowsky, 1952) operate with 30 different weather types. This classification is focussed on the weather in Germany. A similar classification was developed by Lamb (1972) focusing on the weather in Great Britain and starting in 1861. Both classification schemes were originally manually based but are now based on numerical analysis of re-analysed weather maps going back to 1871.

The link between floods and storm trajectories in Norway was discussed in Johnson (1861). Halvorsen (1942) studied the link between the distribution of precipitation and storm trajectories from southwest and south. Evjen (1953) studied the number and direction of cyclones over Norway and the Norwegian Sea. Johansen (1973) applied a classification scheme of weather types in West Norway. Andersen (1973) compared the distribution of monthly precipitation to the classification of Johansen. Kanestrøm & Smits (1988) studied the regional distribution of precipitation in Trøndelag, and Kanestrøm & Mamen (1988) studied the distribution of heavy precipitation in North Norway. Nitter (1998) has classified weather types based on a method by Iver Lund for the period 1881-1993. The method describes 36 weather types.

Large floods in Norway are usually caused by a combination of several factors. Large rainfall floods can however be identified from long-term records of daily rainfall and discharge. The date of each flood peak can be obtained from daily flow data for all floods above some threshold values. The date of the heaviest rainfall can independently be determined from daily precipitation values at one or more meteorological station. By comparing the dates of flood and the precipitation peaks, a number of rainfall floods can be identified at a number of stations. The rainfall will usually peak one or two days before the flood peak. By comparing the time of rainfall peaks with one or more daily weather classifications, the weather type causing each flood can be obtained. By applying this method to all rainfall-generated events at a station, the weather type, which most frequently has caused floods in a given basin, can be identified.

This method has been applied to data from 62 Norwegian flow series (Roald, 2008). The discharge and rainfall data were from 1895 to 2006. Two different weather classifications were used. The German "Grosswetterlagen" (Hess and Brezowsky, 1952) and the Lamb-Jenkinson indices (Lamb, 1972) are both extended back to 1871 on a daily resolution, which make it possible to examine the circulation linked to early floods. The results are shown in Figure 5.1 based on "Grosswetterlagen".

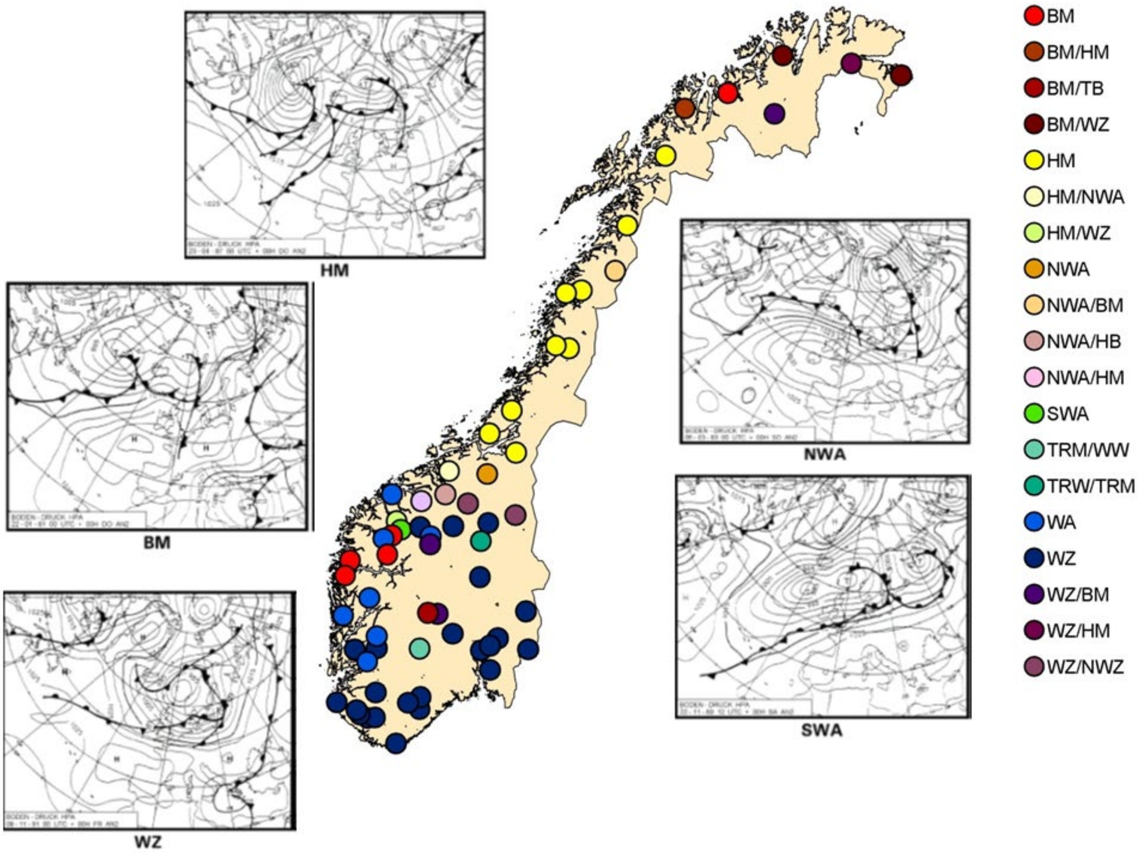


Figure 5.1. The most frequent flood generating weather type at 62 gauging stations in Norway

Note the strong concentration of floods linked to the same dominant weather type in different parts of Norway. Floods in the southeast and near the south coast are most frequently caused by weather type WZ. This weather type is linked to cyclonic weather as well as in Germany. The type WA is linked to westerlies in Germany partly anticyclonic and occurs in Norway further north at Vestlandet, with the exception of basins near the Sognefjord when an anticyclonic ridge extends from Germany to Britain. The most common flood generating weather type from Trøndelag to south Troms is exclusively a weather type characterised by an anticyclone over Germany, with humid air masses flowing in from the Atlantic. The classification of floods in Nord-Troms and Finnmark are less useful since the classification schemes are focused on the weather in Germany.

One weakness with this study is that it is focusing on the most frequent flood generating weather type. As it will be shown below, some of the most hazardous weather types occur so rarely that they will fail to appear in this analysis.

Figure 5.1 show that most of the rainstorms occurring at Sørlandet and in coastal districts near the Oslofjord are caused by lows over or near Britain, setting up transport of warm and humid air from southwest. Floods in the inland are mostly caused by polar front lows from west, although the largest and most rare floods are caused by the south-easterly weather type.

5.2 Polar front (extra-tropical) depressions

The polar front is the boundary between warm subtropical air masses in the southern North Atlantic, and cold polar air-masses to the north. Most extra-tropical cyclones grow from waves on the polar front. When these cyclones form two fronts develop; a warm front on the eastern side and a cold front further west on the northern hemisphere. The warm front moves into cold air ahead of the front, while the cold front moves into the warm air behind the warm front. The cold front moves faster than the warm front, and as it overtakes the warm front gradually lifting the warm air as a tongue over the occluded front at the ground.

The difference in temperatures implies the presence of a large amount of potential energy, causing the depression to intensify and the wind to increase. As warm and humid air is lifted over the warm front, rain will fall out usually with moderate intensities. The stability in a cold front is lower, and the vertical velocity is higher, causing showers, which can be far more intense than the rain ahead of the warm front.

Most floods occurring at Vestlandet, Nordland and Sør-Troms are caused by polar front lows. The activity along the polar front reaches a maximum between October and January. This coincide frequently with anticyclones located over Great Britain or over the European mainland, with strong westerlies from the Norwegian Sea further north and a depression close to Iceland in the west. Figure 5.2 show the weather map of a polar front low causing intense rainfall on the coast of Nordland 11 January 2002.

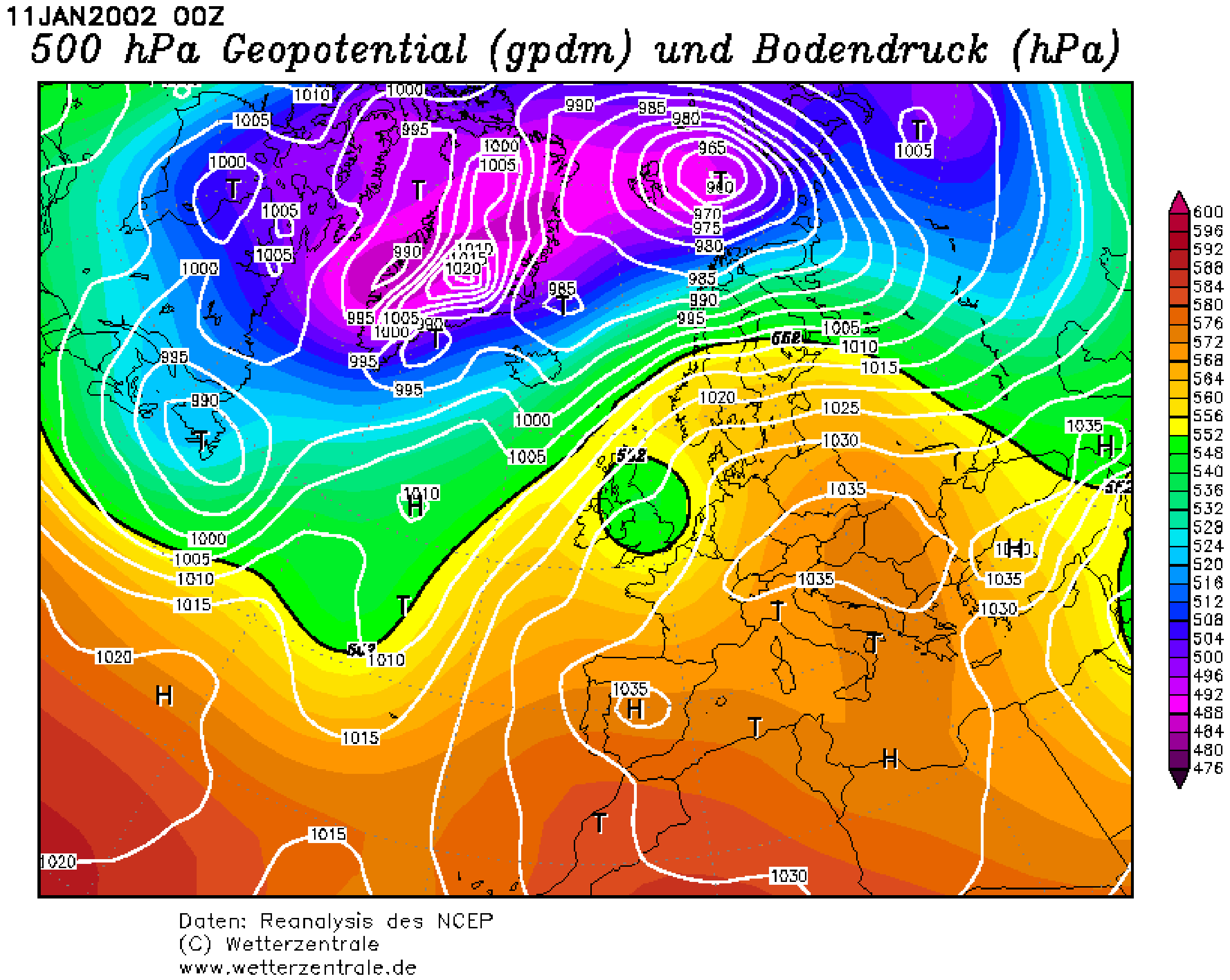


Figure 5.2 Weather map of a polar front rainstorm causing severe floods in maritime rivers in Nordland in January 2002. (Source: www.wetterzentrale.de)

5.3 South-westerly weather types

Some years fronts may stream towards the northwest coast of the continents of the northern hemisphere lasting one or more months. This transport of warm and humid air can extend from the hurricane belt in the tropical or subtropical Atlantic, Pacific and Indian oceans. These transports can cause heavy floods on the west coasts and have been described as atmospheric rivers (Lavers et al., 2011). It has caused some of the largest floods known in California and is also causing long duration floods in northwest Europe. This weather type has caused long duration rainfall at the western or southern coast of Norway in the autumn/early winter of 1975, 1983, 2000 and 2013. Some of these events has remnants of tropical cyclones embedded in the stream from southwest.

Tropical cyclones occur typically from July to November in the tropical part of North Atlantic. Tropical hurricanes and storms can some years turn towards northwest Europe before or after they reach the east coast of North America. As these cyclones moves over cooler water, they will gradually lose their tropical properties and joining an extra-tropical polar front cyclone. These cyclones have typically a tongue of warm and humid air above the front, which can cause heavy rainfall and intense melting on glaciers when reaching the Norwegian coast. These cyclones can reach the coast of Norway somewhere between Agder and Lofoten. The heavy rainfall tends to fall near the coast, but they rarely penetrate far inland. Hurricane remnants reaching West or North Norway tend to follow a trajectory north of Scotland. Other hurricane remnants cross over the southern part of Ireland and England. They can move into the North Sea, causing local flooding in rivers at the south coast of Norway a day or two later.

The remnants of hurricane *Faith* reached West Norway 6-7 September 1966 causing local windstorms and heavy rainfall. More than 150 mm rain fell at several stations, most 242 mm at Hovlandsdal in Sunnfjord over two days. This caused a large flood in rivers from Ryfylke to Nordfiord. The flood was most extreme in glacier streams on the western flank of Folgefonni and in Fjærland. The cyclone crossed over Norway at Nordøyan in Trøndelag, over Sweden and Finland and ended north of Novaja Zemlya in Russia.

Remnants of tropical hurricanes have reached the coast of Nordland several times. Remnants of hurricane *Beth* and the tropical storm *Chloe* reached the Svartisen glacier 20 and 26 August 1971 both with 120 mm rainfall, causing large floods in the glacial streams.

Remnants of hurricane *Charlie* caused severe damages in Ireland in August 1986. A few days later up to 110 mm fell on the coast of Aust-Agder. The Boscastle flood in Cornwall in England was partly caused by Hurricane *Alex* in early August 2004 (Golding, 2005). Some days later, the remnant caused local rainfall floods on the south coast of Norway. Remnants of Hurricane *Frances,* which caused severe damages in Florida, flooded the basement of the house owned by Hells Angels in Trondheim in August 2004. Their motor bikes were taken by the flood. Five days later the remnants of Hurricane *Karl* caused extensive damages at Sunnmøre and a week later the remnants of the tropical storm *Lisa* caused rainfall and minor floods near the south and southwest coast.

The activity of the hurricane season was record high in 2005 when several of the hurricanes moved towards northwest Europe as shown in Figure 5.3. Hurricanes Maria and *Nate* came together towards the west coast of Norway and caused heavy rainfall and landslides 14 September 2005 (Extreme weather *Kristin*). The transport from southwest continued for more than two months. Remnants of two hurricanes, Ophelia and Wilma passed between the west coast of Norway and Iceland, causing very mild weather at the west coast. The warm and humid air caused another large rainstorm and flood 14 November (Extreme weather *Loke*) without the remnants of a tropical cyclone embedded. The rainfall intensities were as high as those of *Kristin*, and the consequences of the flood were quite similar.

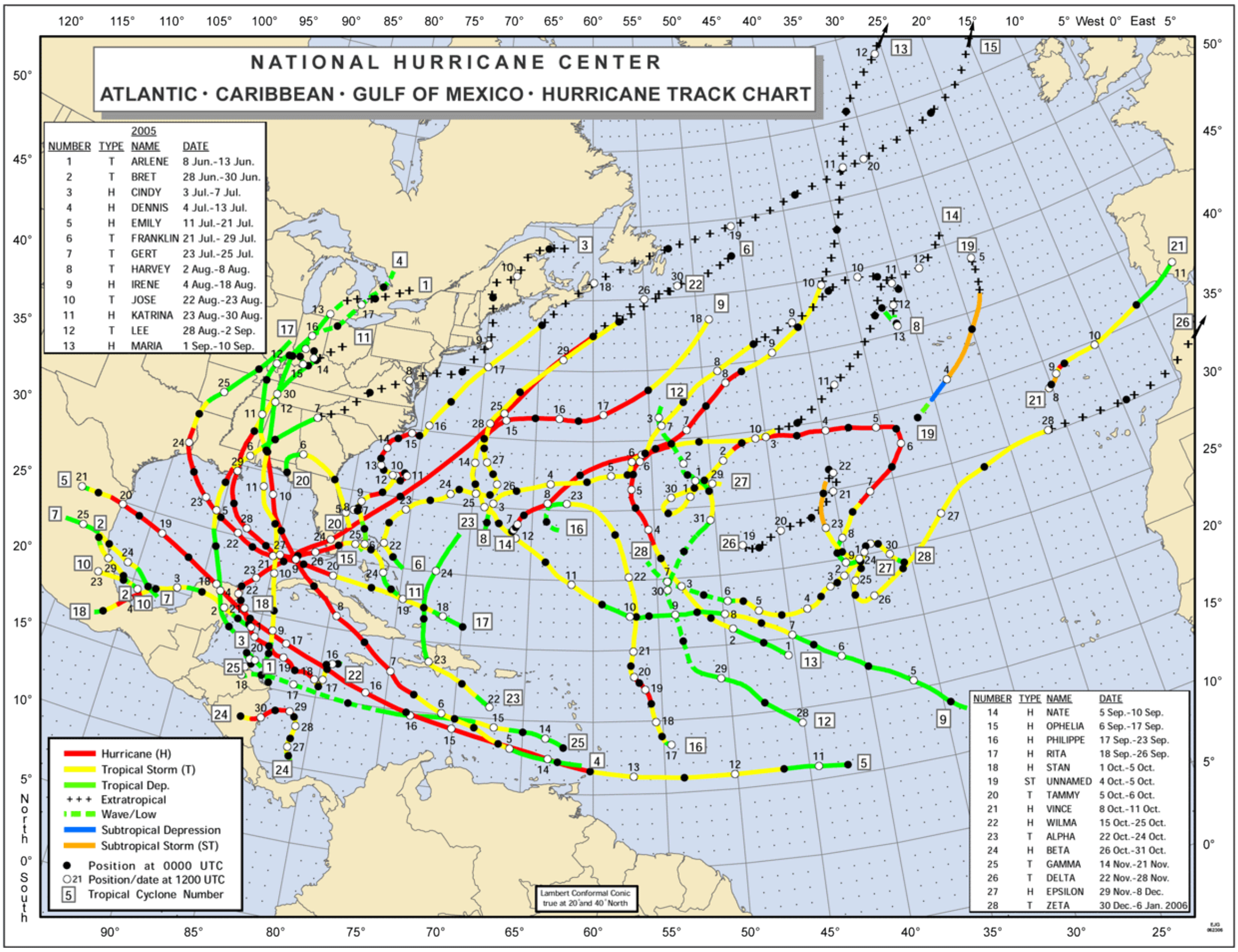


Figure 5.3 Trajectories of the tropical cyclones in the north Atlantic 2005. Source: National Hurricane Center).

5.4 South-easterly weather types (Vb-low)

Many of the most disastrous floods in Central- Europe are caused by a weather type, which is known as the “Vb-tief or Vb-Zug” in Van Bebbers' terminology (Van Bebber, 1882). These large floods occur in major rivers such as the Rhine, the Elbe, the Oder and the Danube and in their tributaries.

The Vb-tief is linked to blocking anti-cyclones in the North Atlantic Ocean, typical near Iceland, and over northeast Europe, typical near Finland. Very warm air is present in the east. A depression is often present in the Norwegian Sea near the coast of Norway forcing cool maritime air masses southward. Depressions can move in from the Atlantic Ocean south of the blocking anti-cyclone, typically from the Bay of Biscay towards southeast over southern France and into the Mediterranean. The low will accumulate heat and humidity over the sea and will then move over northern Italy and into the Balkans where it turn around the eastern flank of the Alps and start moving in north-northwest direction. The depression can link up with the depression from the Norwegian Sea, forming a trough orientated from southeast to northwest. A sharp frontal zone will separate the hot and humid air streaming northward on the eastern side of the front and the cool air streaming southward further west. This front is characterised by severe thunderstorms and very heavy rainfall, especially if the front is more or less stationary over a few days. The most intense Vb-lows occur usually in July-August, but they can occur in other months as well.

Most Vb-tief affect Central Europe, but they will occasionally penetrate to Scandinavia. Intense rainfall events caused by Vb-events are most frequent in southern Sweden, but the weather type has caused some of the most disastrous floods in east Norway, such as Storofsen in 1789 (Kington, 1979; Østmoe, 1985). The Vb-tief is quite rare in Norway, and the weather type does rarely occur in several subsequent years such as 16 May 2010 (in Nordland), 10-14 June 2011 in Glomma/Gudbrandsdalen, 25 July 2012 in Målselv and 22-23 May 2013 in Glomma/Gudbrandsdalen. The weather map shown in Figure 5.4 show the typical Vb-type weather pattern, which caused the severe flood in Gudbrandsdalen in May 2013. The weather type has also occurred at the peak of other large snowmelt floods causing intense melting because of high temperatures. This happened in late May 1879 causing widespread flood at Østlandet as well as in some inner fiord rivers at Vestlandet, 20 May 1966 and 30-31 May 1967 in the eastern branch of River Glomma.

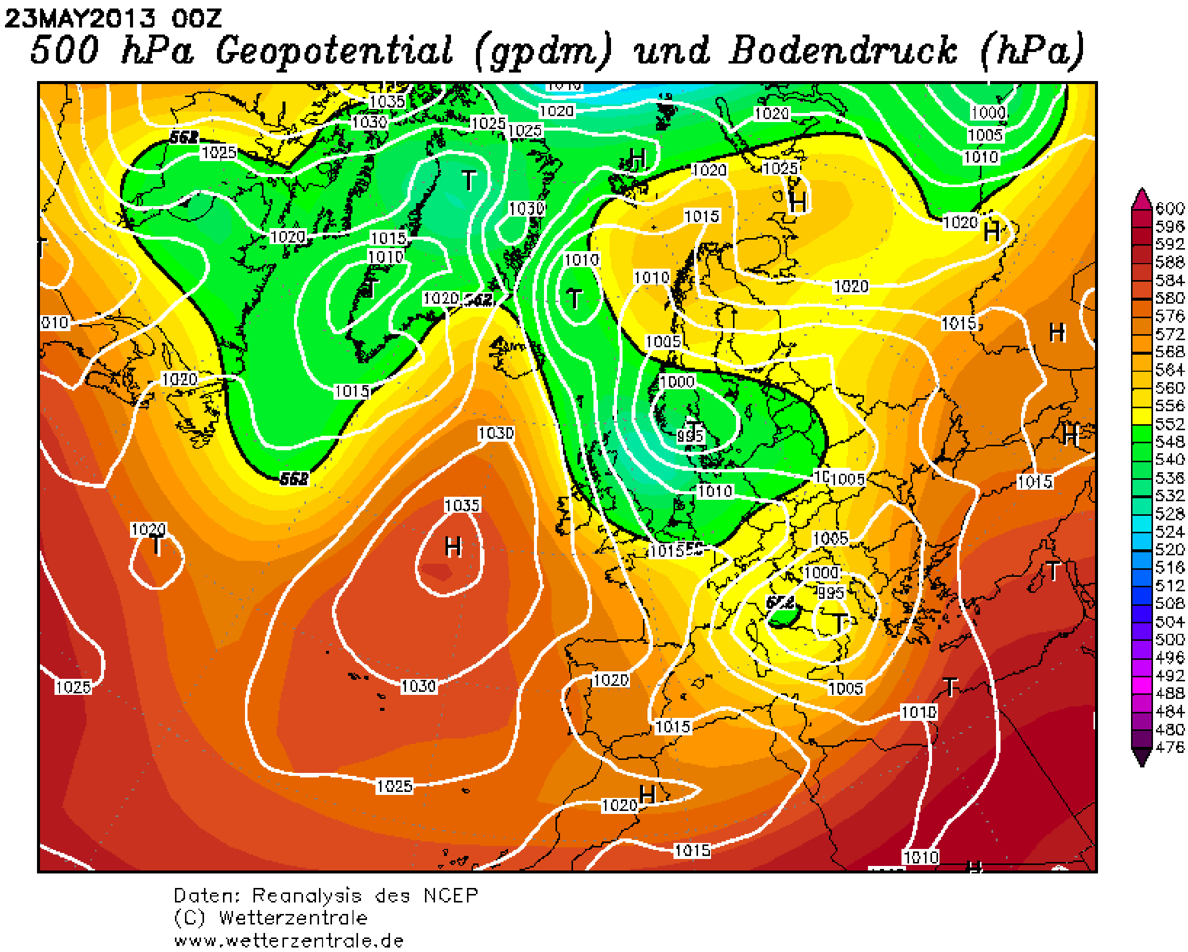


Figure 5.4 Reanalysed weather map 23 May 2013 show that the severe flood in Gudbrandsdalen was caused by a Vb-type low. (Source: www.wetterzentrale.de)

Rainfall moving in from southeast does not always start in the Mediterranean but can move in from the Baltic or other east European countries. These events are characterised by high temperatures in the east. The peak of some of the larger spring floods occurred when warm air combined with rainfall penetrated from southeast.

Warm air masses can occasionally penetrate from the Mediterranean over France, Belgium, the Netherlands and the North Sea towards Western Norway. This occurred 14-15 July 1979, causing heavy rainfall in the mountains of Ryfylke and extensive flooding in Jostedalen.

5.5 Arctic outbreaks and polar low

A special type of depression occurs in the north when very cold air masses moves southwards from the Arctic Sea. These depressions are smaller in extension than the extra-tropical polar front depressions. They occur where very cold air moves over comparative warm ocean water. The difference in temperature between the hPA level of the atmosphere and the sea surface to form a polar low is around 43°C. As tropical cyclones these lows are instability lows rather than linked to fronts.

The polar lows occur mostly in the coldest part of the winter. They are most common in the Barentz Sea but can occasionally reach the coast of Nordland and Vestland. These lows do not produce large floods, but they can cause very heavy snowfall in the coastal mountains. Some of the worst avalanche years have been caused by snowfall from polar lows, such as in February 1679 and February-March 1718 at Nordfjord and Sunnmøre, February 1755 at Sunnmøre, February 1858 in Romsdal and February 1860 from Nordfjord to Trøndelag. These avalanches can cause many fatalities. Occasionally warm air and heavy rainfall can succeed a polar low. This can cause severe slush avalanches as in 1868 in Stryn and in 1928 in Hordaland, outer Sogn and Sunnfiord.

6 Flood damages

6.1 Overview of flood damages in Norway

Large floods do not usually cause many fatalities in Norway. The major floods develop slowly, usually giving potential flood victims time to evacuate from the exposed part of the flood plain. Among the few events, which have taken many lives, are the large flood and landslide in River Gaula in 1345, "Storofsen" in 1789 and "Storflaumen" in 1860. The fatalities occurred primarily from landslides with the exception of the event in 1345 when most people perished after the failure of a dam created by a major landslide. The type of natural disasters, which otherwise has taken most lives in the past, was the large storms on the coast killing many fishermen. Avalanches, mountain slides and clay slides have also taken far more lives than floods alone. Although floods alone do not take many lives, it is causing the largest economical losses of all types of natural disasters occurring in East Norway. Storm damages causes greater losses than floods in the coastal districts in West and North Norway.

The large spring floods occur mostly in the large basins in east and mid Norway where farming is most widespread on the flood plains. These floods tend to occur after the spring farming have been completed. Inundation tends to cause large losses in seed grains as well as in fertilisers. When water is flooding into the fields, channels can be eroded, leading to severe loss of the soil. Deep layers of sand or gravel can by deposited in the fields, causing the spring farming to start a second time.

Farm buildings can be inundated or taken by the flood. The farmers can lose farm equipment, farm animals and crops when the storage buildings were destroyed. It has been necessary to use rowing between the buildings in boats during some large floods near River Glomma. There are descriptions of cattle sheds with dead cattle hanging inside floating in the rivers. Rainfall floods in the late summer or early autumn have occasionally destroyed the crops stored in the barns. Sawmills and grinding mills were highly vulnerable to floods, and many were lost during the largest floods.

The Norwegian rivers were traditionally used for floating timber from the forests to the sawmills for the timber and the paper industry. The timber was contained in the river by timber booms, but these could fail during large floods. Floating timber damaged or destroyed bridges and other constructions near the rivers. Owners of the timber contained by failing booms could suffer severe economic losses when the timber disappeared further downstream. Escaping timber could accumulate in the fields on the flood plains, requiring a considerable effort to clear away.

Many floods cause severe damage to the railway lines by undermining the railway bed, destroying bridges and even station buildings at some locations. The traffic had to stop when parts of the line or station areas were inundated. Avalanches, rock falls and landslides cause also damages to the railway. Similar damage occurs on the roads. Large floods such as the flood in 1860 destroyed 114 bridges in one county alone. Intensive summer showers can cause small streams to flood, causing the traffic on the roads and railway lines to stop. Too small culverts can cause this type of failure. During large floods in 1918 and 1940 In Rivers Glomma and Gaula almost all main roads between Oslo and Trondheim as well as both railway lines was cut, forcing travellers to make long detours via Sweden or through the mountain roads further west.

Large floods have also caused severe damages on the telegraph- and telephone network in the past because of breaks in the lines and flooding of the telegraph and telephone buildings. New technology has made the telecom network less vulnerable to flood damages. The electricity supply may also fail, because of damages to the network or inundation of transformer kiosks.

Much industry is located at cities near the main rivers. When a flood occurs, it is necessary to evacuate valuable machinery to a safe level, as well as removing raw material and the finished products from the water. The production may stop for a while leading to lost production. The workers can be laid off, losing their income during the break in production if they are not employed in flood protection or evacuation work.

The most severe damages occur in densely populated areas. The cost of local floods in urban areas exceeds by far the cost of floods in rural districts in most years. Floodwater penetrates the basement and even the ground floor of many private houses near the main rivers or large lakes. Sand and gravel accumulate and damage furniture, as well as the floors and walls. The freshwater supply may fail, and the sewer may overflow, causing the damages in the houses even more severe. Many shops store their goods in the basement and suffer large losses unless the merchandise is removed prior to the flood. Shops suffers from losses while closing during a flood. Even if the shop is dry, customers may have difficulties getting to the shop.

When the access roads to the towns or villages are closed, problems may occur by providing fresh food to the inhabitants. Failing electricity supply will cause home freezers to stop working, causing frozen food to be lost.

6.2 Damage reports and tax deduction

The Danish-Norwegian State was quite poor in the 17th and 18th Century. The State was unable to compensate victims of most natural disasters. Some funds were collected after large disastrous floods in Gudbrandsdalen in 1760 and after Storofsen in 1789. The amount collected was small compared to the losses the flood victims had suffered. A procedure was introduced around 1600 for mapping the flood damages. The loss of production was assessed as a basis for granting a deduction of the tax for some years, until the damages could be repaired. A commission or court documented the damages at each farm, which had suffered from the flood. The tax collector, the local judge or the local police chief headed the commission. Five or six local farmers serving as jurors in the local court, were also appointed as members. This commission answered typically eight questions, describing in detail the damages. The report was examined by the tax collector. Some collectors were quite keen to ensure that the State would not lose its income and proposed therefore to increase the tax on neighbour farms which had not suffered damages. The reports were assessed by the county governor, who gave his recommendations before he sent the assessment to "Rentekammeret" which served as the Ministry of Finance in Copenhagen. "Rentekammeret" could change the size of the deduction as well as the number of years for which it was granted or refuse to accept the deduction all together. If the deduction was approved, a royal decree was granted for some years

New assessments could be made to determine whether the damages could be rectified. An assessment report after Storofsen at the farm Gaupar in Lom is given below.

Example of a deduction report after Storofsen in Bøverdalen in Lom. The court was constituted 10 November 1789 at the farm Gaupar in the parish Lom at the request of the farmer Tron Olsen to determine the damages at the farm caused by the recent flood. The court comprised five jurors: Tosten Agneberg, Johannes Hage, Ole Øy, Hans Øverbøe and Gabriel Qvamme. The court examined the damages to the farm caused by slides and floods. They assessed the damages and summarized their findings in answering eight questions:

1. The accident occurred 21th and 22th July this year.

2. The farmland comprised of 4,8 hectares of which 2,0 hectares was totally damaged caused by riverbank failure and erosion leaving only rocks. The remaining farmland suffered from repeated floods.

3. The grassland comprised 42,0 hectares of which 32,0 hectares was severely damaged. The rest of the grassland could be restored.

4. Two farm buildings were destroyed by the flood. Eighteen other buildings suffered some damages. The damages to the farm buildings were assessed to 432 Rdlr. A bridge was also taken' and the local sawmill was damaged. The total share of damages to the farm Gaupar amounts to 575 Rdlr.

5. No lives were lost at the Gaupar farm, either humans or farm animals.

6. Prior to the flood, 12 barrels of rye and barley was sown annually, producing 6 or 7 times crops in good years. Now only 7 barrels could be sown, producing only 6 or 7 times crops in good years.

7. The farm could support 8 or 9 horses, 50 cattle and 150 sheep or goats prior to the flood. Now the farm can support only 3 horses, 30 cattle and 60 goats or sheep.

8. The court assessed the value of the farm 1.800 Rdlr prior to the flood. The value was assessed to no more than 800 Rdlr after the flood. The total loss at the farm was thus assessed to 1.000 rdlr.

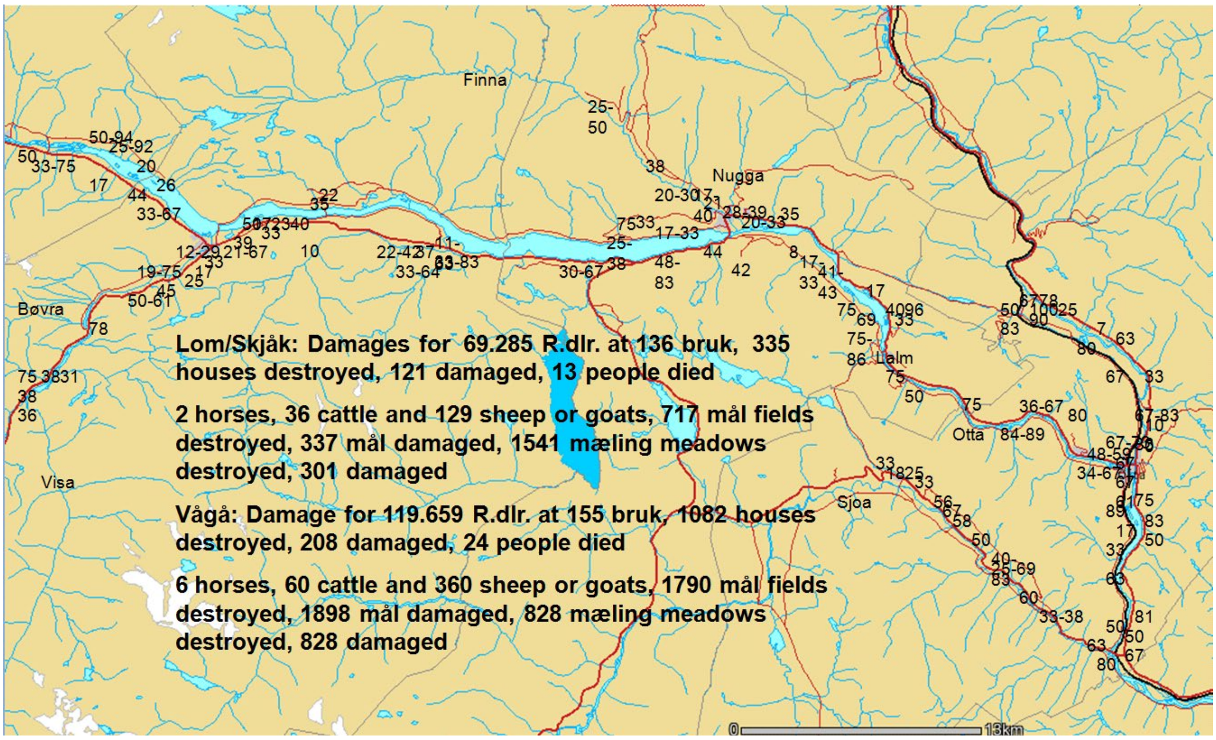


Figure 6.1. *Percentage reduction in tax at farms in Sel, Vågå and Lom in the Upper Gudbrandsdal after Storofsen in 1789. Similar maps can be produced for selected floods in other districts.*

Damage reports from floods up to 1813 were returned from the Danish archives to Riksarkivet after World War II. Riksen (1965) have written a catalogue of the damage report prior to 1813 and have written extracts of most of the reports after the large flood in West Norway in December 1743 and after Storofsen in July 1789. More than 1500 farms and smallholdings suffered damages i 1789, and the Riksen Archive refers approx. 1000 of these reports. The reports after 1814 are collected in "Lensmannsberetningene" from the during of the Union with Sweden. These reports have been stored in the various "Statsarkiv". Norway has suffered from many severe events since 1789. The damages were taxed by two local men headed by the local "lensmann". In Appendix B are examples of the taxation after the severe floods in 1860, 1927 and 1995.

6.3 Present practices for compensation of damages caused by floods or other natural disasters.

The current law regulating the compensation for natural damages caused natural disasters dates back to 25. March 1994 and was a result of experiences from "The New Year Hurricane of 1. January 1992" and "Vesleofsen in 1995".

The causes covered by the compensations are: 1). Storm and storm surge, 2.) Floods, 3.) Flood slide, 4.) Avalanches, 5.) Precipitation and snow, 6.) Ice runs and other causes. The law is managed by the board of the Natural Peril Fund under the Ministry of Agriculture. The Natural Peril Fund compensates damages to non-insureably properties. The Norwegian Natural Perils Pool compensates damages to properties which can be insured against fires. The database NASK provides information on number of compensated damages or the sum of compensations for selected periods and months.

Damages to the infrastructure are covered by the road authorities, Jernbaneverket, the telecom companies and the electricity supply companies as well as the county and municipality affected by the event. Damage to farmland is normally not covered by the insurance pool or by the Natural Peril Fund. This requires a separate causes and natural damages at insurance, which is usually not used by the farmers.

Figure 6.2 show the compensations for four categories of natural damages for every Norwegian county 1980-2014. The graph show that floods were the dominant cause of flood damages at Østlandet, while storms were the dominant cause in Vestlandet and Nord Norge.

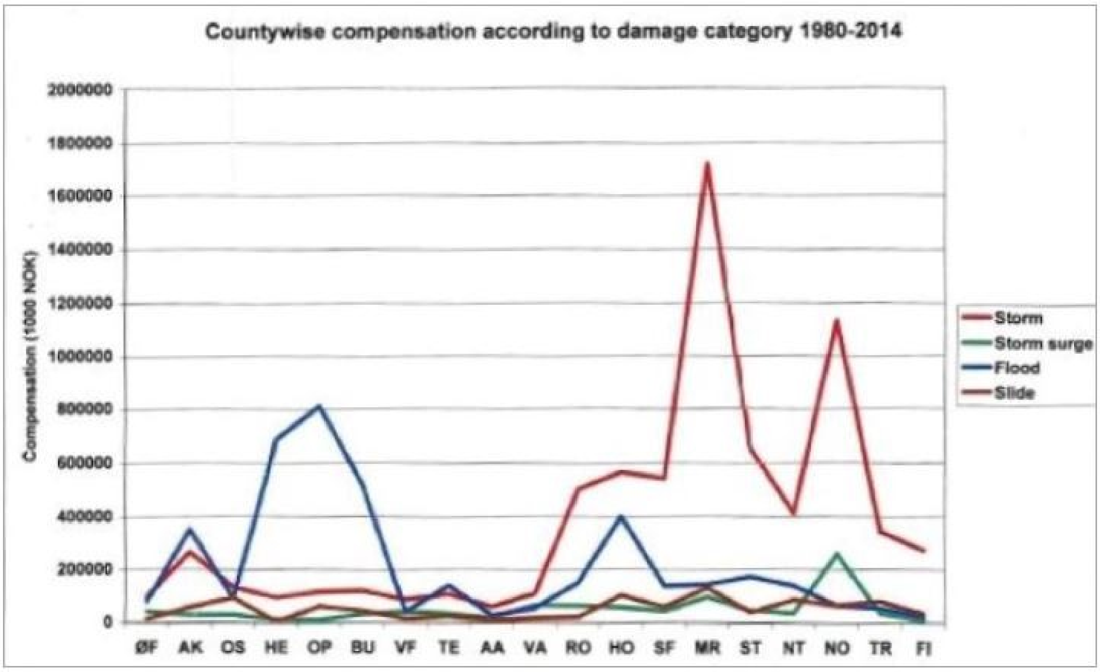


Figure 6.2 Compensations granted for five categories of natural disasters each of the old Norwegian counties 1980-2014. Floods is the most expensive damage category of the counties from Østfold to Buskerud. Storms or storm surges are the most expensive category for the counties to the West and North. The southernmost counties from Telemark to Agder have no dominant type of natural disaster.

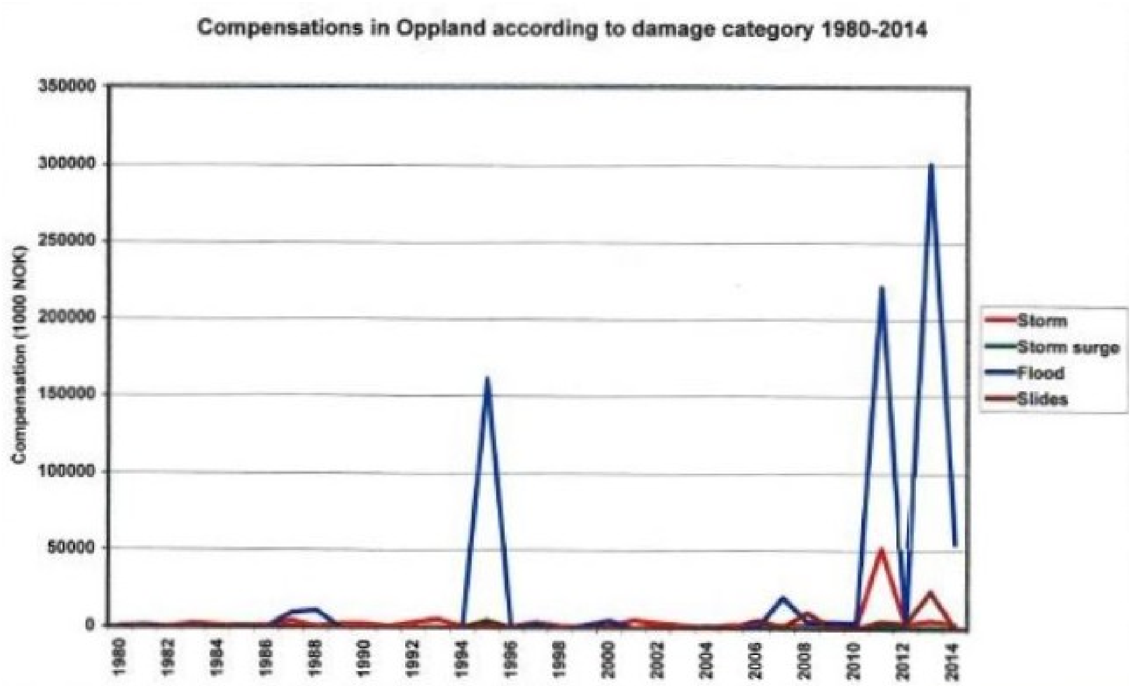
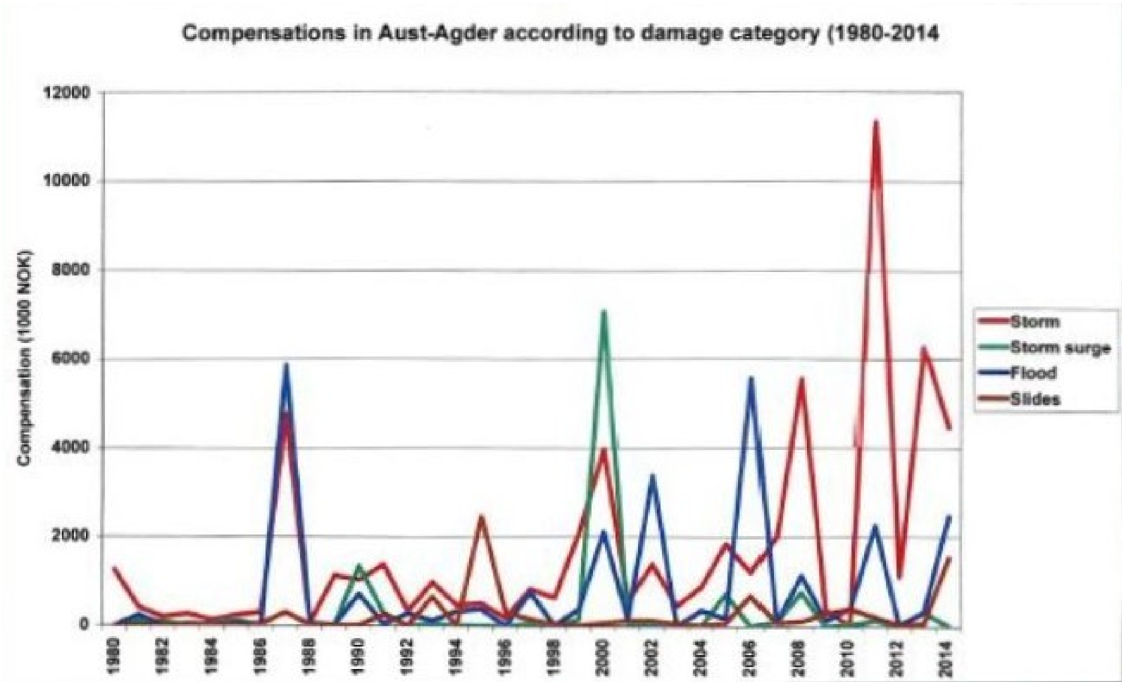


Figure 6.3 The compensations granted to a county varies considerably from year to year depending on the type of damages. In inland counties such as Oppland or Hedmark, the floods were totally dominant in three months in 1980- 2014.



Figur 6.4 The compensations granted to a county (Agder) on the south coast without one dominant cause of month with natural damages.

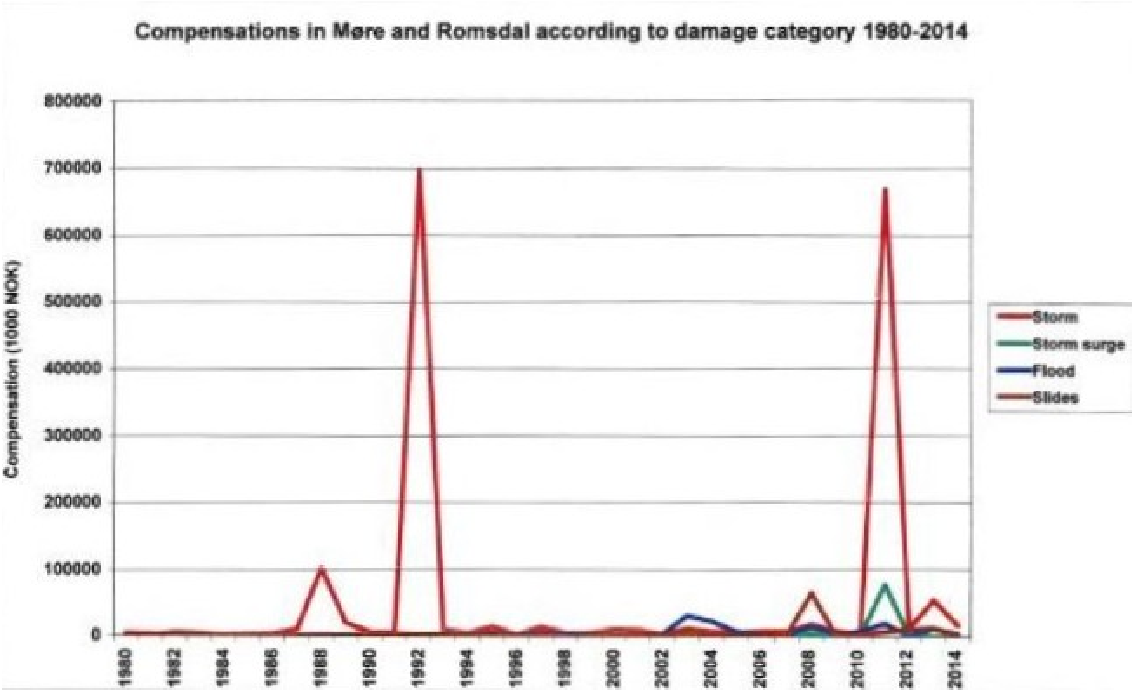


Figure 6.5 Compensation for months with storm damages on the west coast (Møre and Romsdal).

7. Flood mitigation

7.1 Handling of a flood by the emergency authorities

The first services involved when a flood is expected are the forecasting services of the Meteorological institute and NVE. The hydropower companies can prepare for a large spring flood by reducing the water levels of the reservoirs provided that the warning is given sufficiently early. NVE can grant permission for the companies to deviate from the mandatory operationally rules. During the 1995-flood water was temporary stored in Lake Mjøsa, allowing the faster flood wave in River Glomma to pass the confluence with River Vorma. NVE provides data on the water levels and discharges, as well as projections of the expected development during the flood in co-operation with the hydropower companies.

The major co-ordinating organisation during the flood is the Police. The municipalities play a major role in handling the situation for the population, dealing with evacuation, food supply, technical infrastructure such as sanitation and fresh water supply. The Town engineer has an important role in the day-to-day work during the crisis as well as the Fire department. When several neighbour municipalities are affected, a joint disaster office have been organised, such as in Skedsmo and Fet during some large floods. The county is also involved through Fylkesberedskapsrådet.

The home guard (Heimevernet) is notified and helps with construction with dikes, filling sandbags and with controlling traffic and prevention of looting. The Army has also contributed during some large floods. Some 7000 soldiers and civilians participated during Vesleofsen in 1995. The Army provided boats to facilitate communication within inundated districts. The Air force provided helicopters.

The Civil defence (Sivilforsvaret) and non-governmental organizations such as Norsk Folkehjelp, Red Cross etc. provide services to accommodate flood victims and for medical services.

The road (Veivesenet) and railway authorities (Jernbaneverket) are responsible for keeping as much as possible of the roads and railway lines open, and to repair damages, when it is possible. The local power companies are working on securing transformer stations and other constructions in danger of being inundated, and to re-supply the population in districts without electricity. The Telecom companies are important for handling the situation, as loss of communication will make the co-ordination very difficult.

A committee of Ministers was formed during Vesleofsen in order to provide the emergency services whatever support was needed from the Government.

7.2 Measures to reduce the damage of future floods

The traditional way of preventing flood damages has been to construct flood protection works along river reaches where inundation of the flood plain occurs. These dikes have been constructed to withstand a flood with a return period of 200 years. Culverts are constructed to transport flood water under roads and railways towards the main river. Maintenance of these constructions is crucial to avoid flood damages.

Kvam in Gudbrandsdalen suffered badly from the spring flood 7 May 1934, flooding the village and breaking the railway line. The damages were quickly repaired, and the next severe flood ravaged Gudbrandsdalen in 1938, but did not cause additional damages at Kvam. This flood caused severe damages at Vågåmo and elsewhere in Gudbrandsdalen. The total cost in Gudbrandsdalen was estimated to 1 million kr (1938). The worst damages were caused by River Finna. Unfortunately, the protection works was not maintained, and later floods ravaged Kvam badly in 2011 and 2013.

A belt of trees on the riverbank serves also to reduce the damages of floods by preventing erosion of the riverbank and the water velocity on the flood plain.

When reservoirs are constructed in a catchment, the effect of the operation is that the magnitude of most floods is reduced. If the reservoir is already full when a flood occurs, the downstream flood can be larger than under natural conditions.

River Glomma has two main branches where the flood in the eastern branch occurs before the flood in the western branch. The reason for this is that the snowmelt occurs later in the alpine part of Gudbrandsdalen. The outflow of Lake Mjøsa is also delayed and the peak is reduced because of the large volume of the lake. The largest floods downstream occur when the flood coincides in the two branches such as during *Storofsen* in 1789. During *Vesleofsen* in 1995 water was stored in Lake Mjøsa some days, allowing the faster flood peak to pass the junction at Vormsund, before the accumulated water in Mjøsa was released.

Experiences from large floods in Germany have led to the removal of flood protection works along the upper Danube, where the river is now allowed to inundate its natural flood plain. This is not as easy along the more constricted Rhine, where one solution is to construct polders, ie reservoirs next to the river, which will fill up during the first phase of a flood and will release the water afterwards.

Some measures intend to reduce floods in urban areas. These floods are often intense with a short duration. Surface water is presently diverted through gutter and pipes in the ground together with the wastewater. By delaying the outflow from urban areas, the capacity of the drainage system will suffice to handle more floods. This can be achieved by infiltrating water from the roofs into the ground instead of into the gutters. Use of green roofs and water gardens will also serve to reduce these floods (Braskerud, 2014) . The identification and establishment of channels in the cities where urban floods may pass on the surface without causing severe damages is also an important measure. Maintenance of the gutters and pipes are also of crucial importance.

The most important measure to prevent flood damages is to avoid development at locations, which are highly vulnerable to inundations. Flood zone maps are a very important tool in planning of new developments and is produced by NVE . The development of the roads and railways in inland valleys has resulted in location of many villages or small town around railway stations where tributaries are joining the main river. Locations such as Tretten, Ringebu and Kvam and Vågåmo in Gudbrandsdalen and Rjukan in Tinn have suffered damages from floods and slides many times. The tributaries are steep with flash floods and slides. It is unfortunately not possible to avoid new developments on such locations. The developers should select technical solutions, which reduces flood damages when the next flood occurs.

7.3 The handling of a large flood – The HYDRA PROJECT

Damage from the 1995 floods has been estimated to NOK 1.8 billion. Seven hundred people were evacuated from their homes. Some 17 000 farms were affected. 140 sq. km of farmland was inundated 199 km of main roads were blocked and 470 km of railways were blocked as a result of the flood. The Norwegian research programme on floods – HYDRA- was set up after the flood focusing on how human activity affects flood conditions in river basins. After the 1995 flood, the Government appointed a commission for reducing society’s vulnerability to floods. The commission submitted its report in August 1996 “Tiltak mot flom” (Measure against floods), Norwegian Official Report (NOU) 1996 16. Prior to the flood in 1995, The Norwegian Water Resources and Energy Directorate initiated a research programme on floods– HYDRA. The working hypothesis of the HYDRA is that the sum of all human interventions in thr form of Land use, hydropower regulations, flood protections measures, may have increased the risk of flooding. The findings of the program has been published in a separate series and in a final report with the title: “Flommen kommer” or”Living with Floods”.

8 Flood estimation, flood zone mapping and flood forecasting.

8.1 “Living memory"

It is surprising how quickly people tend to forget the damages caused by large floods. After three year, much is forgotten except among those directly affected by a severe flood. New developments have been planned on the flood plain below the levels of recent floods, which should have been considered in the planning process. This seems to be quite common in most countries in Europe (Pfister, 2011).

Concepts such as return period of a flood prove difficult for many people to understand. At a meeting in a town which had suffered badly an old woman said “Now I can go home and sleep safely, because now it is 200 years to the next large flood” after being informed that the two floods of 1966 and 1967 both had a return period of 100 years.

8.2 Terminology

We start to define basic terminology that is used in statistics in general and in flood frequency analysis in particular.
The ***cumulative distribution function (CDF)*** $F_X(x)$ evaluated at x is the probability that X will be equal or smaller than a specific value x. In extreme value statistics we want to estimate the probability that an extreme event will be equal or smaller than a specific value within one year. It could be the probability that a flood will be equal or smaller than10 m^3/s or that the 1-hour precipitation will be smaller than a specified amount (e.g. 30 mm). F will always be between 0 and 1.

The ***probability density function (PDF)*** is the derivative of the *CDF* and describes how the probability mass is distributed. The cdf is thus the integral of the pdf. The *PDF* has often a bell-shaped curve, and the area under the curve is one.

The term ***return period*** (T), is used to describe the rarity of a flood event. Given an infinite series of annual maximum flood values, the return period is the average time interval a specific flood level or discharge is exceeded. The term ‘return period’ has led to the misunderstanding that a particular flood magnitude is exceeded at regular intervals, or that it refers to fixed times for the next occurrence. In contrary, the waiting time between flood exceedances has a high standard deviation and cannot be used do estimate the waiting time for the next large flood. The return period is also difficult to interpret in a non-stationary climate.

An alternative interpretation is to relate the return period to ***annual exceedance probability (AEP)*** denoted by G, and the ***CDF*** F. The relationship between G and T is given as: $G = 1/T$, and the relationship between F and G is given by $F = 1-G$. Thus a 100-years flood has an *AEP* of 1/100 = 0.01, and F = 1-0.01 = 0.99. The exceedance probabilities of a flood with return period T within a time period of n years can be calculated as $EP = 1 – (1- 1/T)^n$ and is listed in Table 8.1 for n = 10, 50 and 100 and *T* = 10, 100, 1000 and 10000. The table show that the probability that a 100-year flood should occur within a random 100-years period is 0.63. The *AEP* is also straight-forward to use in non-stationary settings and easily allows us to calculate exceedance probabilities in a changing climate.

Table 8.1 The probability for a flood of a given annual exceedance probability or return period should occur within a random 10, 50 or 100 years period.

Annual exceedance probability	Return period (years)	Length of record (years)		
		10	**50**	**100**
0,1	10	0.65	0.99	1.00
0,01	100	0.10	0.40	0.63
0,001	1000	0.1	0.05	0.10
0,0001	10000	0.001	0.005	0.001

8.2.1 Methods for design flood estimation

Estimates of design floods characterized by a return period or annual exceedance probability is used for reducing the impacts of large floods in the society. The Norwegian dam safety regulations (Lovdata 2010), requires that dam safety should be evaluated for floods with 500 or 1,000 years return periods, depending on an individual dam safety class. According to building regulations (TEK17 2017), buildings and infrastructure should resist or be protected from floods with 20, 200, or 1,000 years *return* periods, depending on the consequences of flooding. Flood inundation maps used for land use planning are also based on design flood estimates.

It is therefore a need to estimate the flood sizes of specific return periods that are translated to *AEP*, or *CDF*. For locations with sufficient flood observations we can use single site flood frequency analysis, and for locations with no or very few observations, we need to use regional flood frequency analysis. A third way to estimate design flood is to derive the CDF by combining the distribution of precipitation extremes with a precipitation-runoff model.

8.3 Flood frequency analysis for daily floods

The national database of streamflow data has the longest records for daily data. It has therefore been a tradition to perform flood frequency analysis on daily data and thereafter transfer them to peak floods. Below the approaches recommended for daily floods are summarized. The approach depends on the availability of local data.

8.3.1 Flood frequency analysis at ungauged sites

Regional flood frequency analysis is to estimate the design flood at sites with no or very few observations. Following the results from the most recent analysis in Norway (Engeland et al, 2020), this challenge is split into two sub-problems: (i) estimation of the index flood, (ii) estimation of the growth curve. Below we will briefly describe the approach recommended for Norway (se Engeland et al, 2020 for details).

Index flood

The median annual maximum flood is used as the index flood. The regression equation was estimated using the log-transformed index flood q_{ind} (l/s/km^2) as the dependent variable. Based on a Bayesian stepwise regression analysis, the following model was identified for the

(eq.8 .1)

where Q_N is mean annual runoff (l/s/km^2) for the period 1961-1990 (Beldring et al, 2002), E_L is length of the main river (km), A_{SE} is effective lake precentage, T_{Feb} and T_{Mar} is average February and March temperature for the pe-riod from 1961-1990 from SeNorge 2.0 and W_{Mai} is average sum of snow melt an rain for the period 1961-1990 for SeNorge 2.0.

This equation shows that catchments with the larges average runoff has also have the largest median floods. Further, the median flood decreases with river length and lake area, since both factor contribute to an attenuation of floods peaks. The contribution from mean temperatures in February and March is challenging to explain since these two variables are strongly correlated.

The pie-chart in Figure 8.1 shows the explained variance for each component of the regression equation. We see that climatological properties explain 56 % of the variation in median flood, where the mean annual runoff dominates with 46 % explained variance. 24% of the variation is explained by the river length and effective lake percentage.

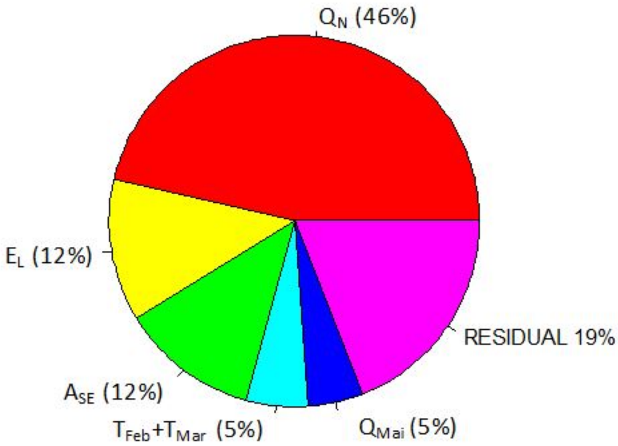


Figure eq 8.2. Explained variance attributed to the variables included in the regression equation for the index flood.

Cross-validation of the model on an independent data set not used for estimate has a RMSE of 0.276, indicating that with a 95% probability the true index flood will be inside the estimate */1.72.

Growth curve

The Generalized extreme value (GEV) distribution was used for estimating the regional growth curve.

$$F(x) = \begin{cases} exp\left\{-\left[1 + k\left(\frac{x-m}{\alpha}\right)\right]^{-1/k}\right\} & k \neq 0 \\ exp\left\{-exp\left(-\frac{x-m}{\alpha}\right)\right\} & k = 0 \end{cases}$$ (eq 8.2)

Where *m* is a location parameter, α a scale parameter and *k* a shape parameter.

Since the median flood is already estimated, the location parameter *m* was calculated as:

$$m = \begin{cases} q_{ind} - \alpha \frac{(ln2)^{-k}-1}{k} & k \neq 0 \\ q_{ind} + \alpha ln\big(ln(2)\big) & k = 0 \end{cases}$$ (eq 8.3)

Regression type models are established for the scale and shape parameters in the GEV distribution. The scale parameter was parameterized to depend on the index-flood and can be calculated as:

$$\alpha = q_{ind} exp\begin{pmatrix} -1.562 - 0.00361 * A_{BRE} + 0.00227 * A_{SKOG} \\ +0.000238 * H_{10} + 0.00157 * P_{Jul} - 0.000580 * W_{Jun} \end{pmatrix}$$ (eq 8.4)

Where A_{BRE} (%) is the percentage of the catchment area covered by glacier, A_{SKOG} (%) is the percentage of the catchment area covered by forest H_{10} is the elevation at the 10% percentile of the hypsometric curve, P_{Jul} (mm) is the mean precipitation in July from SeNorge 2.0, W_{Jun} is the sum of snow melt and rain in June. We see that the scale parameter increases with increasing forest cover, 10 % elevation and Precipitation in July, whereas it decreases with glacier cover and the sum of snow melt and rain in June. This indicates that the scale parameter is larger for catchment dominated by rain floods than for catchments dominated by snow melt floods.

The shape parameter was restricted to take values between -0.5 and 0.5 and is estimated as:

$$k = -\frac{1}{2} + \frac{1}{1+exp\left(-0.111+0.0173*A_{SE}+5.79*10^{-5}*E_{TL,net}\right)}.$$ (eq 8.5)

where $E_{TL,net}$ (m) is the total length of all rivers except lakes, within the catchment.

The shape parameter decreases with increasing lake percentage and net river length. This is explained by the attenuation of flood peaks by these two characteristics.

The largest uncertainty source in this regional model for flood estimates is the regression equation for the median flood. The average uncertainty increases gradually from */1.72 towards */1.87 when moving from the 2-years-flood to the 1000-years-flood (*/1.78 for 50-years-flood, */1.80 for 100-years-flood and */1.82 for 200-years-flood).

This model is implemented in the interactive map-based tool NEVINA (nevina.nve.no) where the user can select a point in the river network. The application extracts the upstream catchment area and calculate the relevant catchment properties that are necessary to estimate the design flood. The calculations can be exported as pdf-reports and shapefiles.

8.3.2 Flood frequency analysis at sites with < 10 years of data

The largest contribution to uncertainty originates from the estimate of the index flood in equation 8.1. To decrease the estimation uncertainty at locations with one to 10 year with annual maximum flood data, its is recommended to estimate the index flood as a weighted average of the mean log transformed annual maximum floods from n years:, $\hat{q}'_{logmean} = \frac{1}{n}\sum_{i=1}^{n} ln(\hat{q}_i$)), and the index flood estimate form 7.1.

$q_{ind} = exp\left(\frac{\hat{q}'_{logmean} \cdot 0.0762 + \ln(\hat{q}_{ind.o}) \cdot 0.0961/n}{0.0961/n + 0.0762}\right)$ (eq 8.6)

where $q_{ind,0}$ is estimated from (41). A 95% confidence interval is then given by $q_{ind} * / K_{qind}$ where

$K_{qind} = \exp\left(1.96 * sqrt\left(\frac{0.0762 \cdot 0.0961/n}{0.0961/n + 0.0762}\right)\right)$ (eq 8.7)

The uncertainty in the index flood is reduced by 50% when using three years of local data, and for ten years with local data, the regional estimate of index flood is given a weight of 1/8 and for longer time series it can be ignored.

This method will be implemented in NEVINA by letting the users manually enter local observations of annual maximum floods.

8.3.3 Flood frequency analysis at sites with > 10 years of data

Local flood frequency analysis uses streamflow observations to estimate the design floods. The standard approach is to extract the annual maximum floods and fit a statistical distribution to these data. The following distributions common to use (see e.g. Kobierska et al., 2018 for an overview): Generalized extreme value (GEV), Gumbel, Generalized logistic, and Log-Pearson Type III distribution. The distributions can be fittet to the data using several approaches. The most common are ordinary moments, L-moments, Maximum likelihood, and Bayesian. Kobierska et al. (2018) recommend the Bayesian estimation approach with a prior on the shape parameter or the L-moment method is recommended for parameter estimation.

In Engeland et al. (2020) recommendations that are tailored to Norway are provided. If we have more than 10 years of data, a full Bayesian estimation is recommended, with priors from the regional model (Eqations 7.1 – 7. 5) is recommended. Alternatively, if you have more than 20 years of data, use the following priors: $q_2 \in (91.0 l/s/km^2, 1026\ l/s/km^2)$, $q_{50}/q_2 \in (1.55, 2.40)$ og $q_{200}/q_{50} \in (1.12, 1.27)$. This Bayesian estimation is implemented in Hydra II at NVE.

8.3.4 Use of historical data

Systematic observations of water levels and streamflow started in the late 1800s in Norway. To get information on flood events before this, historical sources can be helpful. In order to use historical flood information in a flood frequency analysis, it is important to be able to extract flood levels (m) that can be used to calculate flood discharge (m^3/s). Flood marks on rocks, rocks, buildings, bridges, and descriptions of how high the water has been in the terrain are therefore very useful.

When we include historical information in flood frequency analysis, we need to know either the size or the number of floods exceeding a specified threshold within a period. Examples of use of historical data in Norway are provided in Engeland (2018a, 2018b) and Støren m.fl. (2018). It is recommended to use a Bayesian approach where thre likelihood components are combined: (i) the likelihood for the floods observed by the gauging station, (ii) the likelihood for the large floods exceeding a specified threshold during the historical period and (ii) the likelihood for the years with no large floods during the historical period. One example how this approach can be applied is provided below. At Elverum two flood stones shows flood levels back to 1675, including the large flood 'Storofsen' in 1789 (Figure 8.2). Time series of systematic and historical data is shown in Figure 8.3. The sensitivity of the flood frequency estimates to the use of historical data is shown in Figure 8.4. We included the historical data in two ways (i) we used the assessed flood sizes (m^3/s) and (ii) we reduced the importance of the 1789 flood by assuming it was the largest during the Holocene. We see that the design flood estimate as well as the uncertainty is sensitive to the use of historical data. It is therefore important to use historical information of high quality.

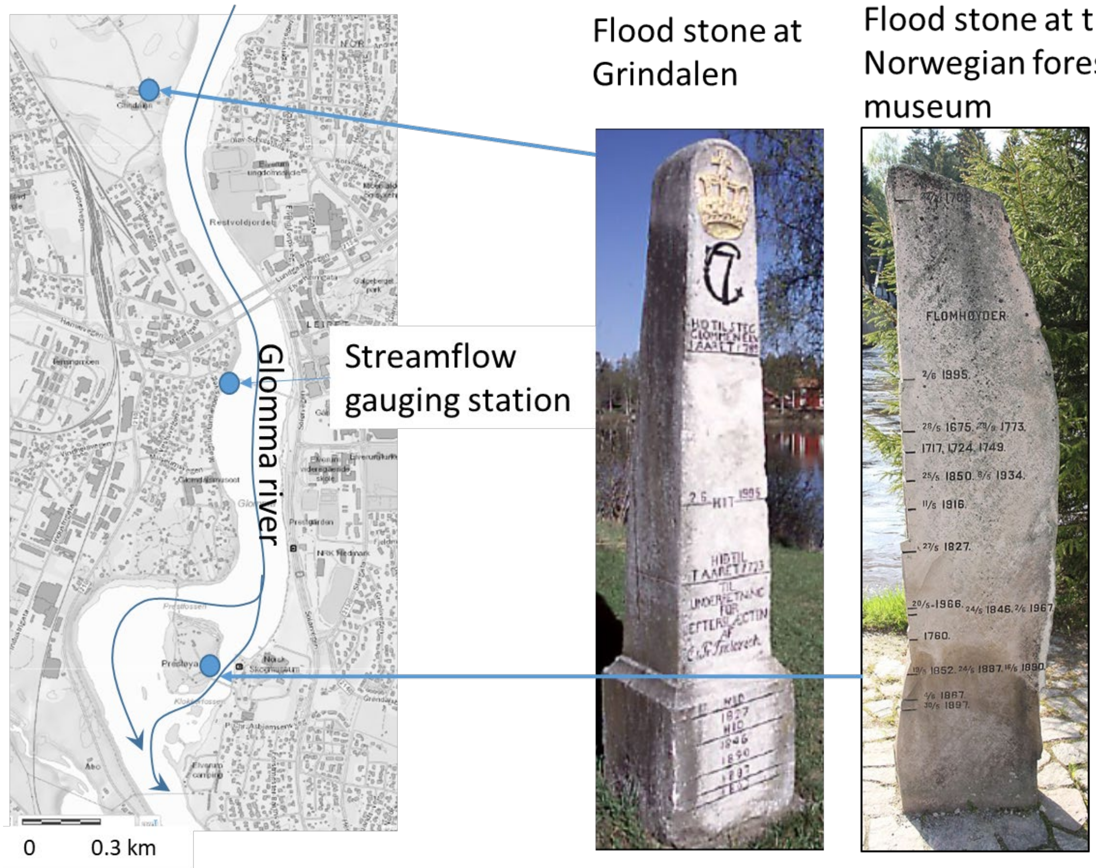


Figure 8.2: Location of the flood stones and the gauging station at Elverum (left), the flood monuments at Grindalen (middle) and the Norwegian forest museum (right).

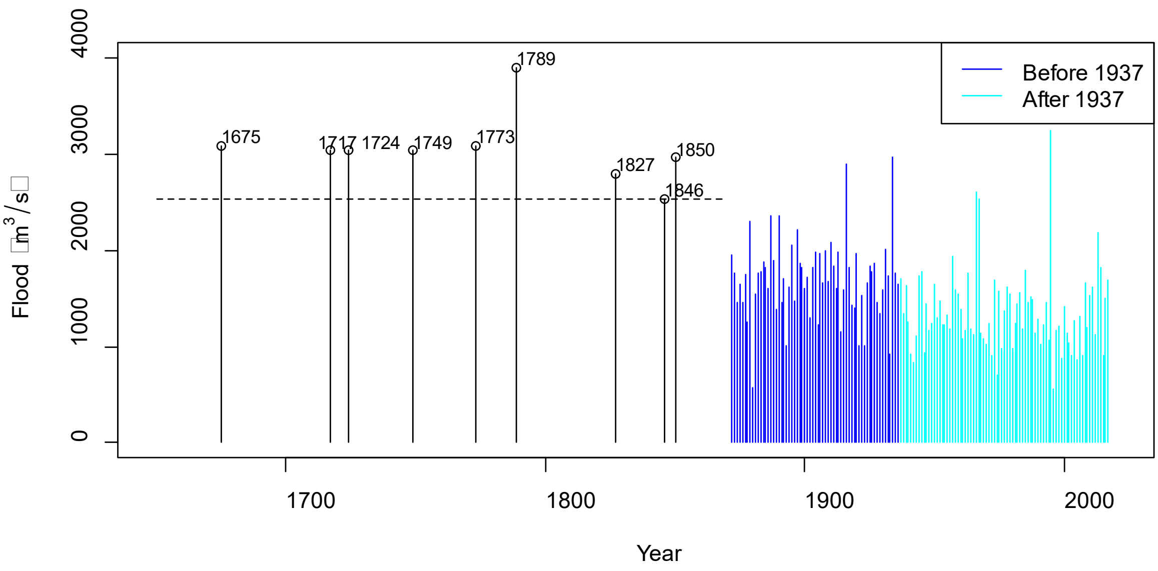


Figure 8.3: Systematic and historical flood data at Elverum.

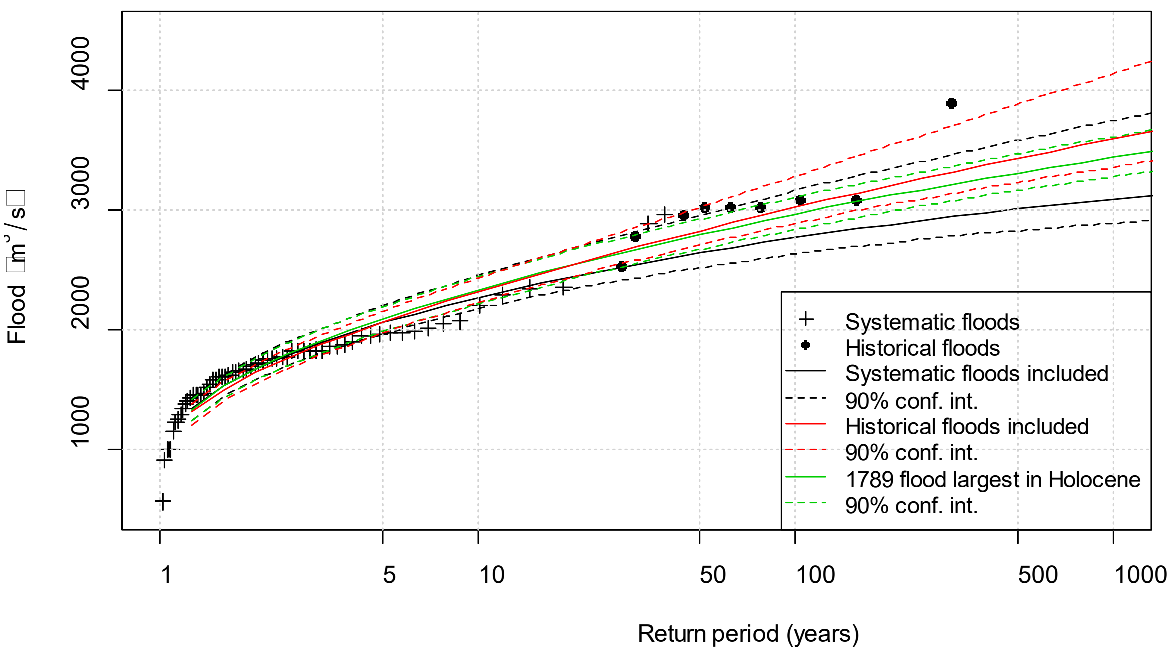


Figure 8.4: The sensitivity of flood frequency analysis to historical floods.

8.3.5 Flood frequency analysis for peak floods.

For many applications, the flood frequency for the flood peaks is required. In particular for small catchments where the difference between daily foods and peak floods is substantial. As a part of the NIFS project, a regional flood frequency analysis for peak floods was performed for small catchment sin Norway (Glad et al., 2014). The traditional approach is to perform flood frequency analysis on daily floods and then calculate a scaling factor that is used to estimate the peak floods. The scaling factor should be larger than one. This approach is followed in Engeland et al. (2020). Which approach to estimate the design flood depends on the availability of both peak flood and daily flood data and the catchment size. It is, in many cases, useful to test and evaluate several approaches in order to obtain robust estimates.

8.3.6 Flood frequency analysis at ungauged sites

For ungauged sites, the recommendation depends on catchment area. For catchments smaller than 60 km^2 the regional model provided in Glad et.al., (2014) is recommended:

$$Q_M = 18.97 Q_{NV}^{0.864} exp\left(-0.251\sqrt{A_{SE}}\right) \tag{8.8}$$

where Q_M (m^3/s) is the mean annual flood, and Q_{NV} (m^3/s) is the mean annual streamflow for the period 1961-1990 (Beldring et al, 2002),

The growth curve is given as:

$$\frac{Q_T}{Q_M} = 1 + 0.308 Q_N^{-0.137}\left[\Gamma(1+k)\Gamma(1-k) - (T-1)^{-k}\right]/k$$ (eq 8.9)

where Q_T (m^3/s) is the flood with a return period of T years, Γ is the gamma function and k is given by:

$$k = -1 + 2/[1 + exp(0.391 + 1.54 * A_{SE}/100)]$$ (eq 8.10)

For catchments larger than 60 km^2, the regional model described in chapter 7.4.1 can be used combined with an equation that estimates the ratio φ between median daily floods and peak floods:

$$\varphi = 1 + \exp\begin{pmatrix} -0.556 + 1.16 * log_{10}(Q_N) + 0.275 * log_{10}(A_{SE}) \\ +0.0329 * A_{SE} * ln(W_{Med4Max}) - 1.961 * log_{10}(A) \\ -1.62 * \sqrt{A_{SE}} \end{pmatrix}$$ (eq 8.11)

8.3.7 Flood frequency analysis at sites with < 10 years of data

The recommended approach depends on catchment size. For catchments smaller than 60 km^2, the index flood as described in 7.5.1 combined with local estimates of the index flood is recommended.

$$Q_m^* = exp\left(\frac{n * 0.135(\overline{x} + 0.132/2) + 0.132log(Q_m)}{n * 0.135 + 0.132}\right)$$ (eq 8.12)

where $\overline{x}$ is the mean annual maximum log-transformed flood and Q_m is the estimate from eq 8.8

For catchments larger than 60 km^2 , depending on the availability of daily data, one of the approaches described in 7.4 combined with the peak flood-daily flood ratio estimated from local data is recommended. If now peak flood data are available, equation 8.11 can be used get the ratio.

8.3.8 Flood frequency analysis at sites with > 10 years of data

For this case there are several alternatives depending on how long time series of daily flood are available.

- If we have less than 25 years of peak flood data and more than 50 years of daily data, the full Bayesian model for daily floods described in 8.4.3 is recommended. The scaling factor is estimated from local data.
- If we have more than 25 years of local peak flood data, it is recommended to use the local data for estimation.
- If we have between 10 and 25 years of local peak flod data, several of the approaches described in this section might be compared.

8.4 Rainfall-runoff modelling

Rainfall-runoff modelling provides an alternative to the use of flood frequency analysis for deriving flood frequency estimates. In rainfall-runoff modelling, a rainfall input is converted to a flow output using a model of catchment response.

The model PQRUT is a simplified, eventbased model, which has often been used by NVE. Figure 8.5

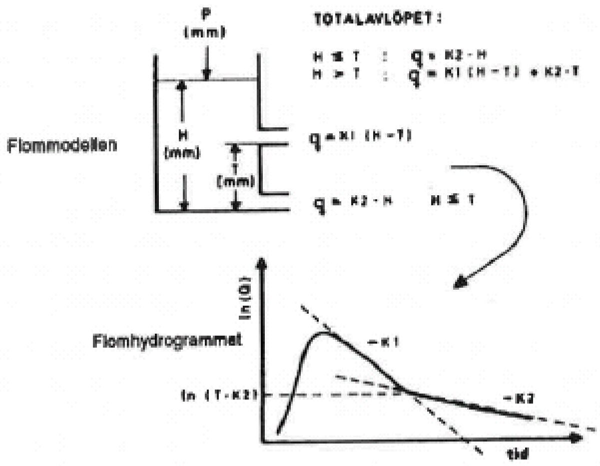
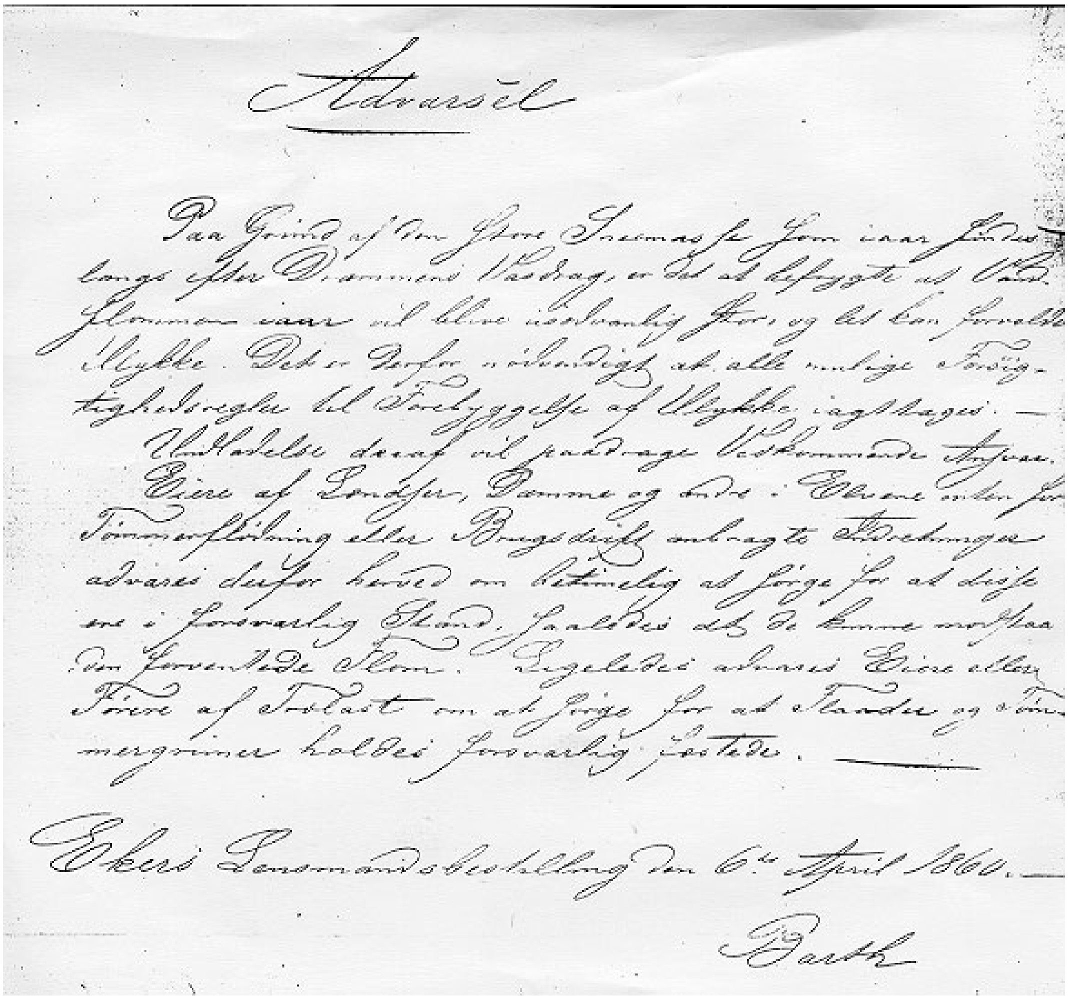


Figure 8.5 The three parameter rainfall-runoff model used in PQRUT.

8.5 Flood forecasting

The Norwegian Water Resources and Energy Directorate (NVE) operates today early warning services for multiple weather-induced hazards, including floods, risk of landslides and snow avalanches, ice conditions and several local warning systems for large rockslides. Large floods have caused severe damages in the past and some army officers and engineers has attempted to warn local people of the flood risk. A large spring flood in River Drammenselv in 1853 may have inspired the county governor in Buskerud county to order the local Police chief at Eiker to issue a flood warning. The earliest flood forecast was issued 6 April 1860 as shown in Figure 8.6, almost two months prior to the extreme flood in 1860. The snowfall was exceptional in districts from Gudbrandsdalen and westwards into Drammenselva, Numedalslågen, Skienselva and several watercourses draining to the south coast. The aim of the message was to warn the owners of properties next to River Drammenselv to secure their properties from the expected large spring flood. The warning was later re issued by the police in Oppland county.



Advarsel

Paa Grund af den store Snemasse som i aar findes langs efter Drammens Vasdrag, er det at befrygte at Vaarflommen i aar vil blive usedvanlig stor, og let kan foraarsage Ulykke. Det er derfor nødvendigt at alle mulige Forsigtighedsregler til Forebyggelse af Ulykke iagttages. — Undladelse deraf vil paadrage Vedkommende Ansvar. Eiere af Lændser, Damme og andre i Elvene under for Tømmerflødning eller Brugsdrift anbragte Indretninger advares derfor herved om betimelig at sørge for at disse ere i forsvarlig Stand, saaledes at de kunne modstaa den forventede Flom. Ligeledes advares Eiere eller Førere af Trælast om at sørge for at Stabler og Tømmergrinder holdes forsvarlig fastede. —

Ekers Lensmandsbestilling den 6te April 1860. —

Barth

Figure 8.6 The warning issued by Police Chief Barth prior to the extreme flood in June 1860.to make some attempt of flood warnings.

Experiences after the extreme floods in 1789, 1860, 1916, and 1927 may have inspired engineers to inhabitants living near Lake Mjøsa. Based on observing the rate of increase in the water level in large lakes like Lake Mjøsa attempts were made to assess the water level in Lake Mjøsa the next days during the large floods in 1927 and 1934 (Aftenposten 1927, 1934). Based on empirical relationships between the water levels observed at different stations, quantitative projections were attempted in River Gudbrandsdalslågen during the flood in August-September 1938 (Klæboe, 1938b). Hegge (1968) established regressions equations between upstream and downstream stations in River Glomma, which he used for predicting the flood level at the lower stations in 1967.

The operational national flood forecasting service was established after the severe flood 16 October 1987 causing severe damages in coastal rivers near the Oslofjord (Engen, 1988). The Norwegian Water Resources and Energy Directorate inaugurated the national flood forecasting service at a regional scale for monitoring and forecasting floods in 1989. The service was evaluated after the extreme flood *Vesleofsen* in 1995, resulting in a reorganisation and strengthening of the service. The service was re-evaluated in 2011 as NVE was given the task of preventing damages caused by slides. The service was established as Section for forecasting floods and landslides at the Hydrology department of NVE. NVE uses the concept jordskredfare to the probability of occurrence of landslides, slides caused by floods, slush avalanches and smaller displacements caused by specific weather- and hydrological conditions at a specific location.

NVE has run a national flood forecasting and warning service since 1989. The service came into operation after a severe flood in October 1987, causing considerable damages in coastal rivers near the Oslofjord (Engen, 1988). In 2009, the directorate was given the responsibility to initiate a national forecasting service for rainfall and snowmelt induced landslides, later on covering slush slides (streams of waterlogged snow) as well. This service was officially launched in October 2013, as a joint achievement across public agencies: the Norwegian Meteorological Institute (MET), the Norwegian Public Road Administration (NPRA), the Norwegian Rail Administration (Bane NOR) and NVE. At about the same time, an extensive snow avalanche warning service was being built up. The services are parts of a political effort to improve the society's awareness towards geohazards, as well as to enable individuals and communities threatened by a hazard, to prepare and act appropriately and in sufficient time to reduce losses.

The flood forecasting service disseminates stream flow forecasts and flood warnings on a regional level. The local emergency authorities consider, based on previous experiences of local damage potential, which local actions are needed to adequately respond to the disseminated awareness level. Flood zone maps and various vulnerability maps are used for local preparedness.

The forecasts and warnings are published on the web site Varsom.no, which is a common portal for geohazards, including meteorologically induced hazards, disseminated by MET. Warnings are classified according to four awareness levels, a scale in wide international use, e.g. at the European alert site meteoalarm.eu. Green awareness level indicates generally safe conditions. At yellow level, the situation requires vigilance and may cause local damages. Orange awareness level is a severe situation that occurs rarely and requires contingency preparedness. Severe damages may occur, and flood return periods of more than 5 years must be allowed for. The extreme case is red level, a situation that occurs very rarely, with flood return periods exceeding 50 years. The situation requires immediate attention and may cause huge losses.

The awareness level is assessed at least twice a day and applies for the coming three days. The public is invited to subscribe to awareness bulletins, to stay informed for selected awareness levels, types of hazards and geographical region. If there is a warning of orange or red awareness level for some kind of hazard, county emergency divisions in the affected counties are informed directly.

Hydrological catchment models constitute an essential part of the flood forecaster's decision support tool. The models are integrated units in an operational system that makes updated meteorological data from MET, i.e. observations and weather forecasts, available for visualization and as input data for the hydrological models. Data used in the warning services are presented on the web site xgeo.no. Based on the map and point in time, data from meteorological and hydrological stations and other observation sources as well as from models, are aligned with recorded events and field data. High quality observed meteorological data from the official network are interpolated to a 1 by 1 km2 continuous grid. Much effort is put into improving these grids by utilizing new and comprehensive data sources, like private on-line meteorological stations and radar data. Hydrological stream flow data from the ~500 online stations are shown point- based. Both Short-range and global scale meteorological forecasts are applied and interpolated to the xgeo.no grid. Updated hydrological forecasts are made several times a day, according to when meteorological updates are available. At present, models are operating at time steps og 3 hours av 24 hours. The system provides hydrological forecasts with lead times up to nine days, besides season scenarios, used to assess long term probabilities for floods. Meteorological ensemble forecasting systems are increasingly taken into use as input data. At present, an ensemble of 30 members from the short-range weather forecast model is applied as input data to the 3-hourly models. Season scenarios use both an historical weather ensemble, as well as a global scale extended (40 days) weather forecast ensemble as input data. A spin-off of the hydrological forecasts is estimates of energy inflow to reservoirs for hydropower production. Simulated energy inflow is, in turn, used to update the Power Market Simulator (Samkjøringsmodellen) for simulating the hydropower system.

The catchment model system is made up by three different hydrological models, namely HBV, DDD and DDM type models. The models have been developed on different platforms and have entered the flood forecaster's scene successively. The HBV model is among the classical, conceptual hydrological precipitation – runoff models. It was developed far back in the seventies (Bergstrøm, 1976) designed for a reasonable demand of computer capacities, as was available at that time. The original model has undergone numerous revisions and improvements, and today there are several implementations of HBV available. The DDD (Distance Distribution Dynamics) model (Skaugen and Onof, 2014; Skaugen et al., 2015) is a rainfall-runoff model that introduces new concepts in its description of the subsurface and of runoff dynamics. The model parameters are defined to be functions of catchment characteristics and can be determined by GIS. The model has thus proved to work well in ungauged catchments. Apart from these physically based conceptual models, a selection of statistical, data driven models are being run in parallel.

In addition to the catchment models, a distributed model operates on a 1 x 1 km^2 xgeo grid, covering Norway. Simulations and forecasts of gridded water balance components are shown at the web site xgeo.no. These water balance components are the basis for estimates of various hazard indexes, indicating increased risk of e.g. land- and slush slides. A wide range of snow characteristics are of widespread use, both for flood forecasting and in the avalanche warning service.

9 Floods and climate change.

9.1 "Noah or Joseph" - does large floods occur as single large events or in groups of a number of years?

Mandelbrot and Wallis (1968) introduced the concepts of the Noah- and Joseph effects from the biblical description of the deluge of Noah and the tribulations of Egypt during the seven dry and seven wet years predicted by Joseph. One recent example of a year with an abundance of floods, storms and slides causing extensive damages in Norway, is 2011. As described in Chapter 5, heavy rainfall causing floods is linked to a few large-scale typical weather patterns. This year most of these weather patterns have occurred, lasting in several weeks.

Avalanches and landslides closed many roads and the main railway lines between Østlandet and Trøndelag in the winter.

A major flood in East Norway caused damages of 260 million NOK in June 2011. Heavy showers in the summer caused numerous local floods at Østlandet, Vestlandet and Trøndelag. Remnants of some tropical cyclones caused local floods at Vestlandet in the early autumn.

Severe storms named *Berit*, *Cato* and *Dagmar* caused extreme damages from strong wind as well as storm surges in November and December. The total damages from natural disaster amounts to 2,3 billion NOK, which is a new record. A question has been raised, whether this is linked to the effects of climate changes.

In order to explore this is to examine if other similar years appear in the historical records. The number of flood events is low in most years, but occasionally many floods have occurred within a year. The 1930s was a warm period and is characterised by an abundance of floods in most of the years. A large spring flood occurred in smaller streams from River Trysilelv to River Drammenselv in May, a major rainfall flood in Nordland 17 October and a large flood from River Mandalselv at Sørlandet to Kvam at Hordaland in early November 1931. Two winter floods occurred at Vestlandet, Trøndelag and Nordland in January and two floods in December 1932. A major flood occurred in the central mountain district around Dovrefjell in July. The flood in River Driva was the largest on record. It was said that the flood in River Jora at Dombås was the largest since Storofsen. Rivers Orkla and Nidelva had a large flood in early June, Finnmark in middle June and in Nord-Trøndelag in late September.

A large spring flood occurred from River Numedalslågen to River Otra at Sørlandet in 1933. A tornado felled 100.000 trees at Nordmarka in Oslo. A major spring flood occurred in Rivers Glomma, Gudbrandsdalslågen, Drammenselv, Numedalslågen, Skienselv, Strynselv, Rauma, Aura, Orkla, Gaula, Nidelv, Stjørdalselv, Namsen, Åbjøra and Vefsna in May 1934. Rivers in Øst-Finnmark and rivers draining over the national boundary to Sweden did also flood. An intense rainfall flood occurred in early August in the southern part of Rivers Drammenselv, Numedalslågen, Skienselv and Nidelv. Another heavy rainfall flood struck in early September in Rivers Sjoa, Vinstra, Drammenselv, Numedalslågen and Skienselv. Another rainfall flood occurred in coastal rivers from Nord-Hordaland to Sunnfjord.

A large flood occurred in Rivers Rauma and Eira in Romsdal and Rivers Orkla and Gaula in Trøndelag at the end of June 1936. A local rainstorm in Folldal in East Norway resulted in a one-day rainfall of 125,5 mm. Sørlandet and Sørvestlandet har several floods in late December. The largest spring flood on record in River Flisa at Knappom occurred in 1937. Major jökullhlaups occurred in Rivers Jostedøla and River Sima in west Norway this year.

A large flood occurred in coastal rivers in Møre and Romsdal in early March 1938. The flood occurred together with a large storm surge *Storrånna*. A late summer flood flood occurred in the upper reaches of River Glomma, River Gaula, River Nidelv and River Stjørdalselv. Gudbrandsdalen suffered from a locally extreme rainfall flood in late August/early September, causi.2ng damages of 1 million NOK. This flood was also severe in River Drammenselv, River Numedalslågen and River Skienselv. Large jökullhlaups occurred simultaneously in Rivers Sima and Jostedøla causing extensive damages. Another flood occurred at Sørlandet and Jæren in early October. A flood occurred in coastal rivers from River Opo at Odda to Svelgen at Sunnfjord.

Several rivers on both sides of the water divide had large spring or summer floods in 1939. An extreme rainstorm flood caused severe damages in River Gaula and Orkla in

August 1940 and was large in Rivers Nidelv and Stjørdalselv. The flood extended into the upper Glomma basin, but was less severe here. A minor rainfall flood occurred from Ryfylke to Sunnfjord in early September and another flood one week later. An extreme flood occurred from River Sira to Sunnfjord in late November 1940. This flood was caused by an atmospheric river as described in Chapter 5.

The occurrence floods in the 1930s show some similarities with the most recent years, starting in 1987. A review of the long-term historical record shows many periods poor in floods.

Some of the most severe floods in the past seem to have occurred just before or just after the most severe spells of cold weather during the Little Ice Age. The period 1695-1697 is named *Svartårene* (The black years) by historians. Prior to these years, a number of severe floods occurred in Trøndelag. The extreme flood at West Norway in December 1743 occurred at the end of another severe spell 1740-1742. Another major flood occurred at Voss in 1745. *Storofsen* occurred after a cold spell starting in 1773/74 and ending in 1789. A severe flood occurred at West Norway in 1790 and a major spring flood in Skienselv and Randselv in June 1792.

9.2 What does climate projections indicate about future floods?

Regional climate projections for Norway indicate likely increases in temperature and precipitation. The mean temperature is projected to increase in all seasons between 3,4° and 6,0°C by the end of the 21th Century if greenhouse gas emissions continue to increase unchecked (RCP 8.5) and by 1.7 – 3.7°C if emissions stop increasing by the middle of the century (RCP 4.5) (Hanssen-Bauer et al., 2017). The mean annual precipitation is expected to increase by 7 to 23 percent under continued high emissions and by 3-14% under the more moderate scenario. In both cases, the projections indicate large regional differences between seasons and the different regions in Norway. The largest increases in precipitation will occur in the autumn and winter.

Changes in the temperature and precipitation will lead to changes in the frequency and magnitude of floods in Norway. More of the precipitation will fall as rain. The snow will start to accumulate later in the autumn and will melt earlier in the spring. The total volume of snow will decrease in lowland areas as result of more frequent rainfall events in the winter. The variation from one year to another will still be large, and there will still be some years with abundant snowfall, although less frequently than in the past. The volume of snow that accumulates in the mountains will also decrease, but to a lesser degree. The reason for this is that the precipitation will increase in the winter months and because of the lower temperatures in mountainous regions, some of this will fall as snow. Large snowmelt floods are, however, expected to be less common as the risk of late melting in the lowlands coinciding with snowmelting from the higher elevations in the mountains will decrease.

Lawrence (2016; 2020) has studied the effect of climate change on the mean annual flood and on floods with a return periods of 10-1000 years for 115 Norwegian catchments. The studies utilise a large ensemble of projections for daily temperatures and precipitation representing a range of climate models and methods for analysing the outcomes. Daily discharge and other hydrological variables are simulated for a reference period (1971-2000) and a future period (2071-2100), and the changes between these two periods is then estimated for each catchment.

The projected data series are based on a series of assumptions and on different parameterisations of the models, which all contribute to uncertainty in the results. The climate projections are based on assumptions regarding future social, economic and technological developments and the consequences of these for increases in greenhouse gas concentrations in the atmosphere. The global climate models operate at a coarse spatial resolution, leading to a smoothing of the contours of land as well as the topography. The topography has a strong influence on the distribution of the temperature and precipitation. It is therefore necessary to downscale the results to a higher spatial resolution, taking into account the Norwegian topography, amongst other factors. The different methods for downscaling introduce new uncertainties. The hydrological models are also not error free and can introduce new uncertainties in the projected discharges. The models were run with 25 different parameter sets for each catchment to account for some of this uncertainty. The flood magnitudes at different return periods were obtained for each data series by flood frequency analysis. The chosen distribution function and the method of estimation also introduces additional uncertainty (Lawrence, 2020) in the projections, leading to a range of estimated changes for each individual catchment.

The results show a strong regional pattern of change in the projected floods for the mean annual flood as well as the floods with higher return periods, in spite of the uncertainties in the projections. The largest percentage increases in flood magnitudes are expected to occur in Western Norway and in Nordland county. Coastal rivers are projected to have increasing floods everywhere, except in Finnmark county. The large inland catchments in Hedmark county and parts of Oppland county and in Troms and Finnmark will most likely have decreases in flood hazard. Regions with increasing floods are typical those where rainfall dominates flood generation, whereas districts with decreasing floods are those where snowmelt dominates.

The climate projections indicate that precipitation will increase in the winter, and that winter floods will, in general, be more common. Winter runoff will therefore increase over all of Norway. In inland rivers with very low winter discharges under the current climate, the percentage increase in flow levels can be very high. As the temperature increases, the portion of the precipitation that falls as rain at higher elevations will also increase. An increase in temperature of 3°C corresponds to an increase of 500 meters in the altitude of the transition zone between snowfall and rainfall. Precipitation falls as rainfall at lower elevation and as snow at higher elevation in many steep catchments in Western Norway and in Nordland. Heavy precipitation has not always caused large winter floods in these catchments in the past, but can be more severe as larger parts of the catchment contribute to high flows during winter precipitation in a future climate.

Spring floods will shift from the spring and into the winter months in lowland areas and from the early summer and into the spring in the mountains and in northernmost Norway. The total amount of rainfall is projected to decrease in the summer, but the intensities are likely to increase. The capacity of the air to contain water vapour increases strongly with the temperature according to the Clausius-Clapeyron equation. If the vertical temperature gradient is high, this can increase the vertical velocity of the air, which together with higher concentrations of water vapour will cause more intense rainfall. This can produce more intense summer rainstorms, particularly in inland regions of Norway, and this will in turn lead to an increase in flood hazard in small catchments that react quickly to intense rainfall.

Flood hazard maps are an important tool for planning developments in flood prone areas. The consequences of climate change on the estimate of the 200-year return period flood is now usually taken into account when preparing flood hazard maps in Norway by applying a climate change allowance. This allowance distinguishes between three categories: 1) areas in which no increase in flood hazard is expected (0% allowance); 2) areas in which a moderate increase is expected (20% allowance); and 3) areas in which a large increase in flood hazard is expected (40% allowance). The allowance represents a rough estimate of the magnitude of the projected changes, taking into account the large uncertainty underlying climate projections and in using those projections in areas without sufficient hydrological data. Guidance for applying a climate change allowance in different regions and for different types of catchments is given in Lawrence (2016) and is based on the regional pattern shown in Figure 9.1 below for RCP 8.5 (i.e. under high levels of greenhouse gas emissions throughout the 21st century. In addition, small catchments in all regions are expected to have an increase in flood hazard, due to increases in precipitation intensities, so an allowance of at least 20% and often up to 40% is recommended for use in small catchments and other catchments that respond rapidly to rainfall throughout Norway.

Figure 9.1 shows the projected percentage change in the flood with a 200-year return period between the current climate (1971-2000) and the future climate (2071-2100) for the case of moderate emissions (RCP 4.5) and high emissions (RCP 8.5).

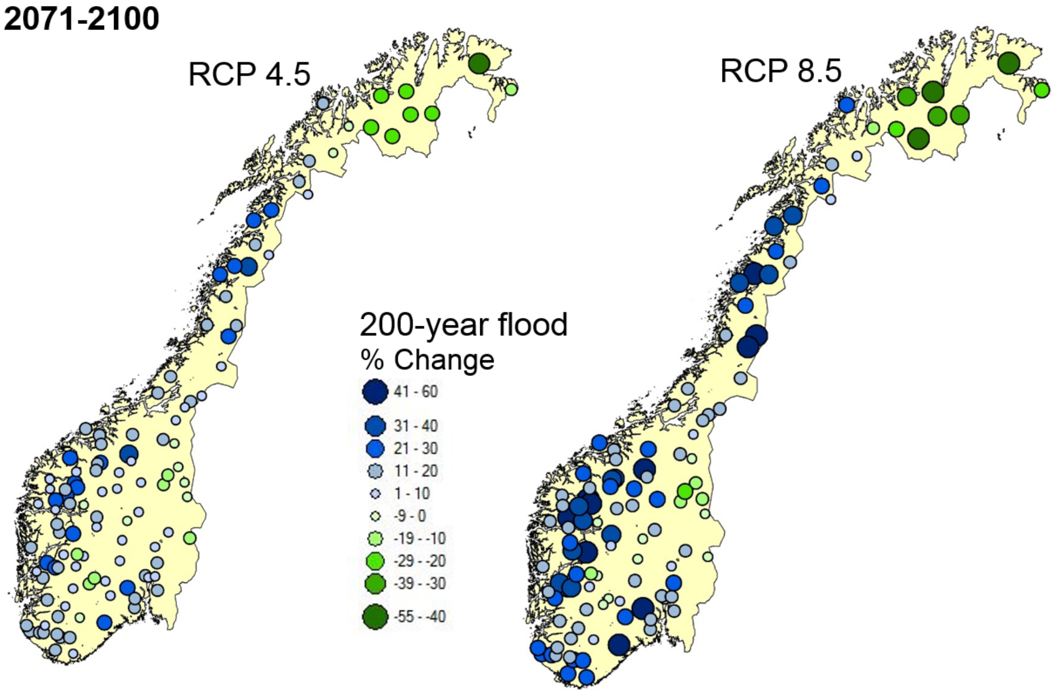


Figure 9.1. Projected percentage change in the flood with a 20-year return period based on a moderate greenhouse gas concentration pathway (RCP 4.5) and a high concentration pathway (RCP 8.5). Source: Lawrence, 2016

10.References

Acreman, M.C. 1989. Extreme Historical Floods and Maximum Flood Estimation. J.IWEM,1989

Aftenposten. Newspaper reports on the floods in 1860, 1879, 1910, 1916, 1918, 1927, 1934, 1938, 1940, 1953, 1957, 1958, 1966, 1967, 1987, 1995, 2005, 2011, 2013.

Akslen, N. (1975) Ulykka i Brekkøya 1789. I O.T. Kvaale (red): *Gamalt frå Lom, Lom Heimbygdslag*, 1975.

Amundgård, A. (1968) Ulykker i Lesja i eldre tid. *Årbok for Gudbrandsdalen 1968*, p. 180.

Andersen, B. (1981) Flomsikring på Møre. Fossekallen 1981:5, s 12-13.

Andersen, B. (1996) Flomsikring i Norge i 200 år. *Norges Vassdrags- og Energiverk*, Oslo.

Andersen, P. (1973) The distribution of monthly precipitation in southern Norway in relation to H. Johansen weather types. *Årbok for Universitetet i Bergen . Mat.Naturv. Serie 1972 No. 1. Norwegian University Press*. Bergen . Oslo.

Andresen, L., Johnsen, Ø., & Kristoffersen, D. (1987) Uværet 16. og 17. oktober DNMI KLIMA 35/87.

Anker, B. (1789) En beskrivelse av forholdene efter Storofsen. Extract from a letter.

Anon. (1928) Innstilling fra Komitteen for minskning av skadeflommen i Skiensvassdraget. *Telemark fylkesting*.

Anon. (1950) Ein "Våegard" i Bøverdalen. *Årbok for Gudbrandsdalen 1950.*

Anon. (1954) Skrida – Folkeminne frå Gausdal. *Årbok for Gudbrandsdalen 1954*, s 142.

Anon. (1987) Om veret i 1930-åra. *Gå observert frå Lesja og Lesjaskog, 1987*, s 5-19.

Asvall, R.P. (2010) Hvordan is i vassdrag dannes – og hvordan vassdragsreguleringar påvirker isen i norske vassdrag. *NVE Rapport 20/2010*, 87 s.

Austigard, B. (1976) Nytt om Tjellefonna. *Romsdalsmuseets årbok 1976*.

Barth (1860) Advarsel (Warning). Eker Lensmannsbestilling. Unpublished note.

Basberg, L., Foss, I. & Rokoengen, K. (1996): Hvor og hvordan skjedde Norges largest naturkatastrofe? Gauldalsskredet i 1345. *Institutt for geologi og bergteknikk, Norges Teknisk-Naturvitenskapelige Universitet (NTNU),Trondheim. Geonytt 1-96.*

Bauer. I. H.,Førland, E., Haddeland, I., Mayer, S., Nesje, A., Nilsen, J. E. Ø., Sandoe, S., Sandø, Sorteberg, A. & Ådlandsvik, B. (2015). Klima i Norge 2100. NCCS-report No 27s015.

Beldring, S., Førland, E.J. & Sælthun, N.R. (1989) Store flommer. En sammenlikning mellom nedbørepisoder og flommer i norske vassdrag. *DNMI-rapport 24/89 KLIMA/VH oppdragsrapport 12-89.*

Beldring, S., Sakshaug, H. & Eken, M. (2012) Flom og stor vannføring forårsaket av ekstremværet Frida august 2012. NVE Rapport 2012/31.

Berg, P. (1936) Elvebrot og isgang ved Aanstad i Skjåk 1743. *Årbok for Gudbrandsdalen 1936*, s 71.

Bergwitz, J.K. (1924) Da nybroen gikk i 1860. Kongsberg som Bergkoloni. Bergstad og Kjøpstad. *Grønahl & Søn, Kristiania 1924.*

Bergström, S. 1976. Development and application of a conceptual runoff model for Scandinavian catchments. SMHI Report RH07.

Bing, K. (1938) Dæmmevand. Turistforr. *Bergens By og Stifts Årbog* , s. 1894-95.

Borgersen, V.S. (2007) *Langs Lågen 2007*, s 22-25.

Braskerud, B. (2014) Grønne tak og styrtregn. NVE-report no 65/214.

Bruaset, O. (1992) Orkanen. *Det Norske Samlaget. Oslo 1992*. 191 s.

Bruheim, M. (1978) Då Storofsen fløtte Bismo over på hi sida. *Årbok for Gudbrandsdalen, 1978*, s 73-74.

Brustugun, T. (1967) Ymse frå dødsfall-listene for Lom frå 1736 og utover. *Årbok for Gudbrandsdalen, 1967*, s 99.

Budstikken 5. Aargang, nr. 103-4. 9 juli 1824, side 825-32. Summarisk Forklaring af 1790 over den Skade som Almuen i Hedemarken Amt har lidt ved Vandflom i Julii Maaned 1789.

Burn D.H. and Arnell, N. (1993) Syncronity in global flood responses. Journal of Hydrology, 144 (1993) 381-404.

Bøe, A. (1788-1793) Væropptegnelser fra Gausdal. *Arkivnett, Oppland.*

Bøe, P.C. (ed) Lundquist, D. & Lunde, A.E. (1996) The 1995 flood in the Glomma and Lågen river basins. Glommen and Laagens Brukseierforening. 20 s.

Børke, O. (1942) Sørum herred. *A.W. Brøggers boktrykkeri AS,* Oslo

Cappelen, P. (1789) Til Cancelliet den 5.te Sept. 89. *Copiebog for Wey Wæsenet i Aggershus Stift*, Riksarkivet, Oslo.

Christensen, E. & Furuholmen, G.R. (1938) Øvre Mjølkedalsvatn overrasker. *D.N. Turistforenings Årbok 1938*, s.228-229.

Christian IV (1644) Skattelettelser pga avlingssvikt, svikt i fiskeriene og sykdom på buskapen. *Norske Rigsregistranter VIII side 602.*

Christian IV (1649) Skattelettelser pga avlingssvikt, svikt i fiskeriene og sykdom på buskapen. *Norske Rigsregistranter IX.*

Collett; J.P. (1973) Skaflommer. *Solør-Odal*, s 58-59.

Collett, J.P. & Tanga, G. (1974) Flom og uår. *Solør-Odal*,s 132-133.

C.O.S.R. En sanfærdig og sørgelig Beretning om det store Regn, som faldet i Gudbrandsdalen og tilgrændsende Egn og den derved foraarsagede Vandflom den 22de og 23de Juli 1789, hvorved deels ved Oversvømmelser og deels ved Jordskred, tvende Kirker, en stor Deel Gaarde og Husmandspladser bleve meget beskadigede og en Deel aldeles ruinerede, saa at deres Sted ikke kan kjendes, Many Mennesker druknede og Many Kreature omkom. Sangvis forfattet under Melodi: Naar jeg betænker den Tid og Stund. Fremsagt af den som ønsker, at enhver Kristen opmærksom vilde give Agt paa Herrends Revselse. *Trykt og forlagt av H.J.Selmer, Lillehammer ca 1840.*

Dahle, H. (1883-84) Røros Kobberværk 1644-1894. *Grøndahl, Trondheim*. 543 s.

Dalen, K. & Dalen, A. (1960) Røldal bygdebok. *Røldal kommune.*

Dannevig, B. (1960) Aktieselskabet Arendals Fossekompani 1896-1911.

Dannevig, H., Groven, K. & Aall, C. (2016) Naturfareprosjektet - Oktoberflaumen på Vestlandet i 2014. *Rapport 36/2016, NVE, Oslo 54 s.*

Dehli, M. (1960) Fredrikstad Bys Historie. Fredrikstad. Bd 1-3. Bd 1: 475 s, bd 2:519 s bd 3 562 s.

Devik, O., Eswall, E. & Saxegaard, N. (1929) Vinterisganger i Østerdalen. *NVE Medd. 2*, 72 s.

Devoli, G., I.K. Engen, Hoseth, K.A. & Pettersson L.- E. (2013) Flom og skred i Troms juli 2012. NVE/Oslo Rapport 24/13. 37 s.

Drageset, M. (2003) Når vatnet kjem utan kontroll. Flaumskade i Innvik i 1919. *Årbok for Nordfjord 2003.*

Dybedahl, A. (1990) Rissa bygdebok. Bd 1 fra de eldste tider til 1814. *Rissa kommune. Steinkjer trykkeri AS.*

Dyrrdal, A.V (2012) Estimation of extreme precipitation in Norway and a summary of the state-of-the -art . Met report no 08/2012 Climate. 32 s.

Dyrvik, S. (1972). Etnesoga. *Etne bygdeboknemnd.*

Dørum, E. (1989). Storofsen, I: Bøgda vår. *Oppdal historielag,* s 5-13.

Daae, Aa. (1915) Sneskredet 6.februar 1679. *Årbok for Sunnmøre Historielag 1915*, s 77-90

Eggen, E. (1943) Vingelen. Sogeminner frå heimbygda. *Normann forlag, Oslo*, 368 s.

Eikeland, S. (1969) Årdal – frå istid til nåtid. *Bygdeboknemnd for Årdal. Ingvald Dahle AS, Sandnes.*

Eikenes, O., Njøs, A., Østdahl, T. & Taugbøl, T. (red) (2000) Flommen kommer – Sluttrapport fra HYDRA – et forskningsprogram om flom. *NVE, Oslo.*

Einbu, A. (1994) Raumabanen – Snøskreder, jord og steinras. *Årsskrift 1994. Lesja Historielag.*

Einbu, A. (1998) Storflåmen i 1938. *Årsskrift 1998, Lesja Historielag*, s 55-94.

Einung, H.H. (1926) Tinn soga. *Eigi forlag, Rjukan.*

Einung, H.H. (1927) Storflommen i Tinn. *Rjukan kommune.*

Eken, M. (2012) Ekstremværet Frida. Modum kommunes opplevelser og erfaringer. ppt-foredrag

Engel, H. (red), Krahe, P., Nicodemus, U., Heininger, P., Pelzer, J., Disse, M. & Wilke, K. (2002) Das Augusthochwasser 2002 in Elbegebiet. *Bundesanstalt für Gewässerkunde, Koblenz, Tyskland.*

Engen, I.K. (1988) Flommen på Sør- og Østlandet i October 1987. *Publikasjon nr V 15. Vassdragsdirektoratet.*

Engeset, R.V., Schuler, T.V. & Jackson, M.(2005) Analysis of the first Jøkullhlaup at Blåmannsisen in northern Norway and implications for future events. *Annals of Glaciology 42*, p 35- 41.

Evjen, S. (1953) Number and directions of cyclones passing Norway and the Norwegian Sea. *Meteorologiske annaler bd. 3, Nr 9.*

Falck-Muus, R. (1932) Kvikne Kobberverk 1631-1931. *Sv. Bergs o.Brukstidning 11*, s 65-72, 77,82, UB.

Finne-Grøn, S.H. (1921) Elverum – En bygdebeskrivelse II – Bygdens almenne historie. *Cammenmeyers boghandel, Oslo.*

Five , I. (1909) Elvevollerne i Gudbrandsdalen. Jordbunnsbeskrivelse nr 17 1919, s 10.

Fjellstad, L.M. (1970) I grendom. *Solør-Odal nr 4* 1970.

Fladeby, R. (1961) Eidsvoll bygds historie bd I 2 del. *Eidsvoll bygdebokkomite, Oslo.*

Flatin, T. (1914) Buskerud Amt. Jubilæumsskrift 1814-1914. *Drammen*, 515 s .

Folkevennen 1895, s 225-256. Ofsen i 1789.

Fonna, H. & Svarteberg, K. (1952) Aal Bygdesoge. *Fabritius & Sønner, Oslo.*

Forseth, Iver (2000) Flommar i Gudbrandsdalen. *Årbok for Gudbrandsdalen 2000*, s 159-183.

Foss, M. (1750) Justdalens kortelige Beskrivelse i Berge, J.C. (1802-3) (ed).

Fosvold, A. (1937) *Bygdebok for Storelvdal. I-II. Hamar.*

Framgang, nr 60 Lillehammer 14. juli 1889. Vandflommen i 1789.

Frey, J. (1962) Da Mjøsdammen reddet Rjukan frå undergang. *Fossekallen 1962:2*, s 12-14.

Friis, J. (1968) Rekonstruksjon av naturlig flom i Begnavassdraget våren 1967. *Rapport nr 6/68 NVE – Vassdragsdirektoratet - Hydrologisk avdeling. Oslo juni 1968*. 23 s + vedlegg.

Furseth, A. (2006) Skredulykker i Norge. *Tun Forlag.*

Førland, E., Mamen, J., Dyrrdal, A.V., Grinde, L. & Myrabø, S (2015) Dimensjonerende korttidsnedbør Naturprosjektet Dp 5 Flom og vann på avveie. *Rapport nr 134-2015. Norges vassdrags og energidirektorat.*

Gerstengarbe, F.W. & Werner, P.C. (1999) Katalog des Grosswetterlagens Europas (1881-1998) nach Paul Hess und Helmuth 71 sBrezowsky. *Potsdam, Offenbach a.M.*

Gjerdåker, J. (1988) Snøskred og ulukker 9.februar 1928. *Gamalt frå Voss, 1988*, s 7-14.

Gjone, T. (1965) Solum bygds historie bd 2. *Solum kommune.*

GLB (1947) Glommen og Laagens Brukseierforening (1918-1943)

Glückstad (1849) Letter to the amt from the local vicar, describing an extreme rainfall event causing river bank failures and causing rockfall at the farm Husby at Øksendalen at Nordmøre.

Golding, B. (ed) (2005) Boscastle and North Cornwall Post Flood Event Study - Meteorological Analysis of the Conditions Leading to Flooding on 16 August 2004. Forecasting Research Tecgnical Report No. 459. Numerical Weather Prediction, UK.

Grefstad, O. (1929) Storflaumen i 1789. *Orkdølafylket nr 1, 1929*, s. 62-66.

Grobøl, S.(1990) Storofsen 1789 – Naturkatastrofen som satte sitt preg på Østlandet. *Solør-Odal 1990*, s 3-22.

Grove J.M. & Battagel, A. (1989) The rains of December 1743 in Western Norway. *N. Geogr. Tidskr. 43*, s 215-220.

Grue, T. (1943) *Os i Østerdalene I. Røros*, 653 s.

Grønningsæter, B. (1840) Journal eller Dagbog. *Avskrift ved L. Tafjord (1944).*

Guddal, P.M. (1967) Om fonnskré, steinskré og elvebrot i Nordfjord fram til 1868. *Årbok for Nordfjord 1967.*

Gundersen, I. M. & Loktu, L., (2012) E6 Gudbrandsdalen – Innlandets Pompeii. *Kulturhistorisk museum, Universitet i Oslo. Det norske arkeologmøtet NAM 2012 i Tromsø 7.- 9. november.*

Guttormsen, O. & Killingtveit, Å. (1984) Flomforhold i Gaula. Virkninger ved en eventuell kraftutbygning. NHL Rapport 2-84032, 81 s.

Haddeland, I. (2011) Flommen Østafjells juli 2011. *NVE Dokument 9/2011*. 14 p. + vedlegg.

Hagen, A. (1995) Storflommen. Chr. Schibsteds Forlag, Oslo 1995, ISBN 82-516-1571-2, 139 s.

Hagen, O.T. (1952) Kvikne. Ei bygdebok I. Bygdesoga, *Boksentralen Oslo*, 446 s.

Hals, H. (1978) Lillestrøms historie. 1-2) Skedsmo kommune, 483 og 396 s.

Halvorsen, I. (1942) On the distribution of precipitation over Southeastern Norway when fronts pass from the west and from the southwest. *Meteorologiske annaler. Bd. 1. Nr. 11.*

Hansen, A. (1990) Storofsen i 1789 og de skader den førte til her i Ringsaker. Ringsaker, Veldre og Brøttum historielag 1990.

Hanssen, H.S. (1975) Storelvdal. *Østerdalen trykkeri, Elverum,* 285 s.

Haraldsen, T.K. (1989) «Stor-Ofsen» - et 200 års minne.

Hattestad, A. (1960) Storflaumen i 1860. *Årbok for Gudbrandsdalen 1960*, s 64-68.

Haugland, A. (2001) Ølen gard og ætt.

Haukedal, J. (1981) Bygdebok for Horg. Busetnad og folkeliv i Horg, Melhus 1981.

Hedmarks amtstidende (1860). Newspaper report of the flood in 1860.

Hegge, K. (1968) Store flommer – beregning og varsling. *Vann no 3 1968,* s 59-72.

Hegge, K. (1997) Vårflommen i Glomma 1995. Flommens utvikling fra Barkaldsfoss til Øyeren. En undersøkelse av vannbalansen i vassdraget basert på kvalitetsvurdering av målinger og observasjoner i flomperioden. *Glommens og Laagens Brukseierforening.*

Hegstad, R., Sæter, A. & Killingtveit, Å. (1975) Flomundersøkelser i Gaula. *Institutt for Vassbygging, Trondheim.*

Helland, A. & Steen, H. (1885) *Tidskrift for Naturvidsk.*, Trykket i sin helhet i *Gauldalsminne 1966*, s 339-372.

Helland, A. (1898) Søndre Trondhjems amt, Topografisk – Statistisk Beskrivelse 2 Del. . *Norges Land og Folk*

Helland, A. (1900a) Bratsberg Amt, Topografisk – Statistisk Beskrivelse. 1 Del. *Norges Land og Folk VIII.*

Helland, A. (1900b) Bratsberg Amt, Topografisk – Statistisk Beskrivelse. 2 Del. *Norges Land og Folk VIII.*

Helland, A. (1901a) Nordre Bergenshus Amt, Topografisk – Statistisk Beskrivelse *Norges Land og Folk XI*2 Del. *Norges Land og Folk*. 1 Bd, p. 108.

Helland, A. (1901b) Nordre Bergenshus Amt, Topografisk – Statistisk Beskrivelse *Norges Land og Folk XIV: 2*

Helland, A.(1902a) Hedemarkens Amt. Topografisk – Statistisk Beskrivelse. 1 Del *Norges Land og Folk*

Helland, A.(1902b) Hedemarkens Amt. Topografisk – Statistisk Beskrivelse. 2 Del *Norges Land og Folk*

Helland, A. (1903a) Lister og Mandals Amt amt, Topografisk – Statistisk Beskrivelse 1 Del. *Norges Land og Folk IX*

Helland, A. (1903b) Lister og Mandals Amt amt, Topografisk – Statistisk Beskrivelse 2 Del. *Norges Land og Folk IX*

Helland, A. (1904a) Nedenes amt, Topografisk – Statistisk Beskrivelse 1 Del. *Norges Land og Folk IX*

Helland, A. (1904b) Nedenes amt, Topografisk – Statistisk Beskrivelse 2 Del. *Norges Land og Folk IX*

Helland, A. (1905) Raset paa Ravnefjeld i Loen, *Naturen nr 9, 1905*, s.161-171.

Helland, A. (1911) Romsdals Amt, *Norges Land og Folk*, Bd 1.

Helland, A. (1913) Kristians Amt, Stenskred, jordskred og sneskred. 1 Del *Norges Land og Folk*, Bd 1, s. 224, 228 samt «Flommen i 1789 eller Ofsen» s. 279-291.

Helland, A. (1913) Kristians Amt, Topografiske – Statistiske Beskrivelse. 2 Del. *Norges Land og Folk V.*

Helland, A. (1913) Kristians Amt, Topografiske – Statistiske Beskrivelse. 3 Del. *Norges Land og Folk V.*

Helland, A. (1913) Kristians Amt, Topografiske – Statistiske Beskrivelse. 4 Del. *Norges Land og Folk V.*

Helland, A. (1914) Jarlsberg og Larvik Amt, Topografiske – Statistiske Beskrivelse. 1 Del. *Norges Land og Folk VII.*

Helland, A. (1915) Jarlsberg og Larvik Amt, Topografiske – Statistiske Beskrivelse. 2 Del. *Norges Land og Folk V.*

Henden, A. (2007) Flaumen i 1941 også kalla *Fløda*. *Årbok for Nordfjord 2007.*

Hestnes, E. (1995) Flommen i 1698. *I bøgda vår*, s. 86-87.

Hiorthøy (1775)

Hjort, P. & Krag (1846) Efterretninger om Røraas Kobberverk og Præstegield. Malling, Christiania., 338 s.

Hoff, H. (1945) Orkangerboka. *Orkanger kommune*.1945

Holmqvist, E. & Pettersson, L.-E. (2008) Flommen på Sør- og Østlandet januar 2008. NVE Dokument

Holmqvist, E. (2009) Flommen på Sør- og Østlandet våren 2008. NVE Dokument 2009/7.

Holmqvist, E. (2010) Flaumane i Midt-Noreg i mai og juni 2010. *NVE Dokument 2010/12*. 19 s. + vedlegg.

Holmsen, G. (1934) Lerfall i årene 1930-1932. *NGU 40*, 36 s.

Horgen, J.E. (1985-1993) Bygdehistorie for Fet. Bd 2-5. *Fet kommune*, 710s, 769 s, 684 s 727 s.

Hosking,,J.R.M (1986a) The Use of Historical and Palaeological Flood Data. Review of statistical flood frequency report. *Open file report 5. Institute of Hydrology, UK.*

Hosking,,J.R.M (1986b) Regional Homogeneity. Review of statistical flood frequency report. *Open file report 6. Institute of Hydrology, UK.*

Hovdhaugen, E. (1952) Ofsesumaren 1789 In: Venabygd. *Årbok for Gudbrandsdalen 1952*, s 15-18.

Hovdhaugen, E. (1973) Gardar og slekter i Fron. Bd 1-2.

Hovdhaugen, E. (1976) Storofsen 1789. In: *Bygda vår. Ringebu historielag.*

Hovdhaugen, E. (1979) Ofsen i Ringebu. Redselssommaren 1789. *Hemgrenda. Ringebu historielag,* s 7-22.

Hovstad, B. (1971) "Storofsin" på prestegarden på Ringebu. *Årbok for Gudbrandsdalen 1971*, p.138-140.

Hyldbakk, H. (1957) Bygdesoge for Surnadal. *Surnadal kommune.*

Høgåsen, M. (1947) Flaumen og jordskade i Kvam. *Årbok for Gudbrandsdalen 1947*, s 145-151.

Høgåsen, O.M. (1953) Vågå Herad. I: *Norske Gardsbruk*, Oppland fylke III, Gudbrandsdalen, bind XI: s 1006-1008.

Haave, A. (1990) Storofsen i 1789 og de skader den førte til her i Ringsaker. Ringsaker, *Veldre og Brøttum historielag.*

IKSOV (1999) Das Hochwasser 1997. *Internationale Kommission zum Schutz der Oder gegen Verunreingung, Wroclaw 1999, ISBN 83-916202-7-1.*

Ile, T. (1980) Då hunger herja og farang for. In: *Bygdebok for Øyer, bd 4. Natur og kultur – Innsyn og utsyn*, s 125-132.

Jahrmann (1789) Fra storflommen på Vågå 25 juli fra Ulsberg. VG 220 30/juli 1903

Johannesen, W.M. (1955-63) Fra gamle dager på Nordmøre. *Årsskrift Nordmøre.*

Johansen, E., Opstad, L. & Dehli, M. (1976) Sarpsborg før 1839, *Sarpsborg kommune*, 440 s.

Johansen, H. (1963) Litt om hyppighetsfordeling av sirkulasjonstyper i Vest- Norge. *Dansk Met. Inst. Charlottenlund. Medd. 1964:17, s 37-41.*

Johnson, G. B. (1861) Mine Betraktninger og Anskuelser over Communicationerne i Norge. *Cammenmeyer*, Kristiania, 173s.

Jonson, N. (1914) Eker – Træk av en storbygds saga. Kristiania.

Juveli, B. (1995) Om flommen i Rollag 1927. *Langs Lågen 3 - 95*

Jørstad, F.A. (1964) Nedbør, skred og skader i Nord-Norge ved regnværet i oktober 1959. NGI rapport F 334, 14s

Kanalvæsenets Historie (1881a). 2. Glommens Vasdrag. *Kanalkontoret, Kristiania*, 279 s.

Kanalvæsenets Historie (1881b). 3. Vormen og Laugen. *Kanalkontoret, Kristiania*, 396 s.

Kanalvæsenets Historie (1881c). 5. Drammens Vasdrag. *Kanalkontoret, Kristiania*, 388 s.

Kanalvæsenets Historie (1882a). 4. Laugens Vasdrag. *Kanalkontoret, Kristiania*, 84s.

Kanalvæsenets Historie (1882b). 5. Mindre Vasdrag med afløb til Kristianiafjorden og Sverige. *Kanalkontoret, Kristiania*, 131 s.

Kanalvæsenets Historie (1883a). 7. Skiens Vasdrag. *Kanalkontoret, Kristiania*, 350 s.

Kanalvæsenets Historie (1883b). 8. Vasdrag vestenfor Skienselv til og med Sireaaen. *Kanalkontoret, Kristiania*, 531 s.

Kanalvæsenets Historie (1888). 9. Det Vesten- og Nordenfjeldske Norge. *Kanalkontoret, Kristiania*, 279 s.

Kanestrøm, I. & Mamen, J. (1988) Distribution of heavy precipitation in Northern Norway and the effect of Orography. *Institute Report Series no 70. Institutt for Geofysikk, Universitetet i Oslo.*

Kanestrøm, I. & Smits, J. (1988) Regional precipitation distribution in Trøndelag. *Institute Report Series no 71. Institutt for Geofysikk, Universitetet i Oslo.*

Kindem, L. (1933) Vossaboki. *Voss bygdeboknemnd, Voss.*

Kington, J.A. (1979) A synoptic climatological study of the Glomma river flood disaster of July 1789.

Report to Norsk Vandbygningskontor A.S. *Climatic Research Unit, University of East Anglia, Norwich, UK*, 41 s.

Kington, J.A. (1988) The Weather of the 1780s over Europe. *Cambridge University Press, Cambridge, United Kingdom*,166 s.

Kirkeby, B. (1966) Odalsboka inntil 1819. *Sør- og Nord- Odal kommuner.*

Kjær, A.N. (1885) Smålenenes Amt. Topografisk – Statistisk – beskrivelse. *Norges Land og Folk I.*

Kleivane, I. (2011) Flaumen i Sør-Noreg, juni 2011. *NVE- Dokument 11/2011*, 60 s + vedlegg.

Kleiven, I. (1908a) Ofsin 1789. I Gamle Daagaa. Forteljingo og Bygde-Minne fraa Vaagaa. Vågå kommune. *H.Aschehoug & Co, Kristiania.*

Kleiven, I. (1908b) Storflaumen. In: *I Heimegrendi. Vågå komm. H. Aschehoug & Co, Kristiania.*

Kleiven, I. (1915) Gamal bondekultur i Gudbrandsdalen. Lom og Skjåk*, H. Aschehoug & Co, Kristiania.*

Kleiven, I. (1923) Lesja og Dovre. *H. Aschehoug & Co, Kristiania.* 374 s.

Kleiven, I. (1926) Østre og Vestre Gausdal. *H. Aschehoug & Co, Kristiania.* 320 s.

Kleiven, I. (1928) Ringbu. *H. Aschehoug & Co, Kristiania.*

Kleiven I. (1930) Fronsbygdin. *H. Ascheoug & Co, Oslo*, 447 s.

Kleiven, I. (1949) Storflaumen. In: *I Heimegrendi. Vågå komm. H. Aschehoug & Co, Oslo.*

Klæboe, H.(1938a) Flommene i Mjølkedalen. *Norsk Geografisk Tidsskrift. Bd VII Hefte 3 1938.* s 113-125.

Klæboe, H. (1938b) Storflommen aug.-sept. 1938. *Norsk Geografisk Tidsskrift. Bd VII Hefte 5-8 1938.* Hydrografisk oversikt, s 211-225.

Klæboe, H. (1949) Grunntrekk av Norges Hydrologi. *Norsk Geografisk Tidsskrift Bd.*

Knyge, M. (1999) Hallingdalselven – noen historiske trekk. (River Hallingdalselv – some historical events). *Dølaminne. Årbok for Hallingdal. Hallingdal Historielag.*

Kolden, J. (1989) Ofsen 1789. *Lite gåmålt frå Lom, Heim og bygd 1989*, s 42-49.

Kolltveit, O. (1963) Odda, Ullensvang, Kinsarvik. *Kinsarvik Bygdeboknemnd.*

Kolltveit, O. (1977) Granvin, Ulvik og Eidfjord i gamal tid og ny tid. *Granvin, Ulvik og Odda bygdeboknemnd.*

Kolstad, G. (1989) Storofsen i 1789. *Nes og Helgøya 1988/89.*

Kraft, J. (1820) Topographisk- Statistisk Beskrivelse over Kongeriget Norge. *Grøndahl, Christiania. 689 s.*

Krag, G.B. (1988) Storflommen i Vågå 1938 – Et femtiårsminne. *Notat i NVE's bibliotek.*

Kristensen, Ingvar (1911) Beskrivelse av Numedalslågen. *Vasdragsdirektoratet*, Kristiania.

Kvammen, A. (1968). Storflaumen i 1789 og noko om skaden i Kvikne. *Årbok Gudbrandsdalen 36.*

Kvernmoen, T. & Kvernmoen, G. (1921) Flomoptegnelser (1740-1839) . Oppbevares på Glomdalsmuseet. Publisert i Finne-Grønn: Elverum. En bygdebeskrivelse, s 241-246.

Laberg, J. (1938) Lærdal og Borgund. *John Grieg. Bergen,* 928 s.

Lamb, H. (1972) Britisk Isles Weather Types and a Register of the Daily Sequence of Circulation Patterns 1861-1971. *Geophysical Memoirs No. 16.* (Second Number, Volume XVI), Meteorological Office.

Lamb, H. (1982) History, Climate and the Modern World. *Methuen, London and New York.*

Landesverein Sächsischer Heimatschuts (Hrsg.) *Mitteilungen Band XVI. Heft 9-12. Themenheft zur Hochwasserkatastrophe in Osterzgebirge.* Dresden 1927). (http://www.ruwenzoricow.de/hochwasser1927.html)

Langsholt, E., Holmqvist, E. & Kejo, D.W. (2014) Flom og jordskred i Nordland og Trøndelag desember 2013. Rapport 19/2014. NVE Oslo. 35 s.

Langsholt, E. Roald, L.A., Holmqvist E. & Fleig, A. (2015) Flommen på Vestlandet oktober 2014, Rapport 11/2015. NVE Oslo. 69 s.

Laudal, T. (1951) Biri-Snertingdal bygdebok. Gjøvik.

Lauvrak, S. (1989) Den store flaumen. Skrift for Froland og Mykland Historielag nr 5 1989.

Lawrence, D. & Hisdal, H. (2011) Hydrological projections for floods in Norway under a future climate. *NVE Report no 5 2011*, 47 s

Leirfall, J. (1970) Liv og lagnad i Stjørdalsbygdene. Stjørdalsboka bind 1. *Stjørdal og Meråker kommuner, Steinkjer trykkeri, Steinkjer.*

Liestøl,O. (1956). Glacier dammed lakes in Norway. *N.Geogr.Tidsskr.15*, s 121-149

Lillebrænd, P.(red) (1972). Valdres bygdebok III fyrste delen. *Valdres bygdeboklag*, Leira, Valdres, s.306-307.

Lillebø, P.A. (1941/1999) Sunnylven bd I og II, *Stranda.*

Lillejord, S. & Steinsland, E. (1976) Bygdebok for Moland. Gard og Ættesoge.

Lillehammer, A. (1991) Soga om Sauda. *Sauda kommune.*

Lillehammer Tilskuer (1860). Newspaper report of the flood in 1860.

Lillevold, E. (1949) Hamars historie. *Hamar*. 646 s.

Lillevold, E. (1961) Bygdenes historie Aurskog og Blaker Bd 3, *Bygdeboknemda for Aurskog og Blaker*.

Lillevold, E. (1963) Trysilboka. 4 Alminnelige del. 1. Elverum, 445 s.

Lillevold, E. (1972) Vinger bygdebok. Elverum, 580 s.

Lillevold, E. (1973a) Vekst gjennom nød. I: Åmot bygdebok. *Elverum trykk*.

Lillevold, E. (1973b) Trysilboka. Garder og slekter. I. Elverum, 759 s.

Lillevold, E. (1973b) Trysilboka. Garder og slekter. II. Elverum, 804 s.

Lillevold, E. (1975) Trysilboka. Garder og slekter. III. Elverum, 448 s.

Liseth, E. (1938) Flomkatastrofen ved Demmevasshytta. *D.N.Turistforrenings Årbok 1938*, s225-227.

Lunde, Aa. (1973) Sandsværs historie. Bd 1. Bygdehistorien fram til 1964. Kongsberg.

Mamen,J.& Iden, K,A. (2010) Analyse av korttidsnedbør i Norge (1967-2009) met.no report np 11/2010 Climate 46 s.

Mandelbrot, B. & Wallis, J.R. (1968) Noah, Joseph and Operational Hydrology. *Water Resources Research 4(5):* s 909-918.

Mandt, C. (1953) Elver og sjøer, Flombrott og øyer. Brandvalboka, p.22-41.

Marsh, T. & Hannaford, J. (2007) The summer 2007 floods in England and Wales – a hydrological appraisal. *Centre for Ecology and Hydrology*, Wallingford, UK. 32 pp. ISBN: 978-0-9557672-4-1.

Mathismoen, A. (1999) Ved flaumstor elv. *Dølaminne. Årbok for Hallingdal. Hallingdal Historielag.*

Meli, J.J. (1985) Den store regnflommen i augustdagene 1940-The flood. *Hembygda 1985. Os kulturstyre. (Os/Dalsbygda i Østerdalen)*, s. 31- 32.

Mork, J. & Hoel, O. (2002) Storflaumen i Driva i 1932. *I bøgda vår 2002*, s. 43-48.

Morthoff, J.B. (1949) Løtenboka. Garder og slekter.

Mølmen, J. (1934) Gamle vannstandsmerker i Gudbrandsdalen. *Den norske turistforenings årbok 1934*, p 136-138.

Mørch, A. (1978) Krødsherad bd 1. *Krødsherad kommune.*

Nilsen, Y. (1880) Reisebreve 1880, kapittel 5.

Nitter, M. (1998) Variability in the atmospheric circulation of the North Atlantic region in the period 1881-1893. *PhD-Thesis University of Bergen 1988.*

Noer, G. & Bøyum, G. (2012) Storflommen i Sør- og Midt-Troms 14-15 juli 2012. *Met.no info No 14 ISSN 1503-8017. MetKlim/VNN*. 6 s.

Nordli, P.Ø. (2001) Spring and summer temperatures in south eastern Norway 1749-2000. *NORPAST Rapport Klima 1, 2001.*

Nordli, P.Ø., Lie, Ø., Nesje, A. & Dahl, S.O. (2002) Spring/Summer Temperature Reconstruction, Western Norway 1734-2002. *Rapport Klima 26, 2002.*

Nordli, P.Ø. (2004) Spring and summer temperatures in Trøndelag 1701-2003. *met.no report 5, 2004 – climate.*

Norges Offentlige Utredninger (1996): Tiltak mot flom. *NOU 1996:19.*

Nordstoga, O. (1983) Isgang i Trysilelva. Årbok for Trysil 1983.

Norske Intelligens-Sedler No. 31. Onsdagen den 5. August 1789.

Norske Intelligens-Sedler No. 32. Onsdagen den 12. August 1789.

Nygård, B. (1944) Sarpsfossen i dikt og virkelighet, *Tell Forlag, Oslo.*

Nygård, J.H. (1949a) Haltdalen og haltdalingen. I. Trondheim, 420 s.

Nygård, J.H. (1949b) Haltdalen og haltdalingen. II. Trondheim, 420 s.

Olafsen, O. (1907) Ullensvang. Bergen

Olafsen, O. (1917) Den store Vandflom i Hardanger. *Hardanger tidsskrift 1917*, p.12-20.

Ohnstad, A. (1962) Aurland bygdebok.

Otnes, J. (1982a) Gamle flommerker langs Glåma. *Årbok for Glåmdalen 41. Årgang*, s 6-26.

Otnes, J. (1982b) Store flommer i Begna. (Large floods in River Begna). *Langs Begna (The Association for Regulation of the Begna Catchment 75 years. Harald Lyche Co, Drammen, Norway.*

Pedersen, J.V.L. (2007) Drama i dalen. *Dølaringen Boklag.*

Pettersson, L.-E. (2001) Glommas bifurkasjon ved Kongsvinger. *NVE Rapport 1/2001*.

Pettersson, L.-E. (2010) Flommen i Nord-Norge mai 2010. *NVE Dokument 8/2010*.

Pettersson, L.-E. (2010) Flommen i Sør-Norge oktober 2010. *NVE Dokument 10/2010*.

Pettersson, L.-E. (2011) Flommen i Nord-Norge juni 2011. *NVE Dokument 8/2011*.

Pettersson, L.-E. (2011) Flommen i Trøndelag august 2011. *NVE Dokument 12/2011*. 29 pp.

Pettersson, L.-E. (2012) Flommen i Troms i juli 2012. *NVE Rapport 12/2012*. 19 pp.

Pfister, C. (2011) The monster swallows you. Disaster memory and risk culture in Western Europe. *Rachel Carson Center for Environment and Society.* 23 pp.

Pontoppidan, E. (1752) Det første Forsøg paa Norges Naturlige Historie. København 1752.

Pitt, M. (2007) The Pitt Review. *Cabinet Office, 22 Whitehall London SW1A 2WH, UK.*

Ramberg, K. (1974) Gudbrandsdalen. *Bygd og by i Norge, Gyldendal*.

Raubakken, O. (1968) Verste vær i manns minne. *Naturen nr. 1/68.*

Raubakken, O. (1989) Ofsen i 1789 – Eit 200- års minne. *Årbok for Gudbrandsdalen 1989.*

Reinton, L. & Reinton, S. (1943) *Folk og Fortid i Hol, Oslo.*

Riksarkivet:

a) Inkomne saker til Rentekammerets 1. kontor 1789-93:
Journalene M, N, og O med kopibøker 1789-93.

b) Norske Forestillinger 23 VIII 1791 og 20 XI 1792

c) Kongelige Resolusjoner nr. 27, 31 VIII 1791 og nr 31, 28 XI 1792

d) Matrikkelvesenet. Affældingsforretninger i Gudbrandsdalen 1792.

e) Matrikkel for Gudbrandsdalens fogderi 1795, Rentekammerets skatteregnskap. Formuesskatten 1789. "Mandtals- og Skatte- Protocol for Søndre Gulbrandsdalens Fogderi; Christian Amt, Froen etc. Sogn, indretet og ført efter Forordning af 11. Marts 1789. (Her er skattene ført opp og i oversiktsregnskapene er nevnt fradrag pga The flood i 1789 for Lom, Lesja og Vågå Prestegjeld, ikke for Fron).

f) Fogderegnskapet for Gudbrandsdalen 1788-1815:

i) 1791, bilag 106 og 108. Beregning over den Skatte Frihed som efterskrevne Gaarder i Fron Sogn, der ved Jordskreeder og Vandflom haver taget Skade, i Følge Kgl. Allernaadigste Resolution af 28. Novemb. 1792 ere tilstaaet.
ii) 1792, bilag 104. Beregning over den Skatte Frihed som efterskrevne Gaarder i Fron Sogn, der ved Jordskreeder og Vandflom haver taget Skade, i Følge Kgl. Allernaadigste Resolution af 28. Novemb. 1792 ere tilstaaet.

g) Sagmanntallet 1788-1815.

h) Kværnmantallet 1789-91.

i) Forordning 1.X. 1802. "Jord afgift, Gudbrandsdalens Fogderi. A. Deliberationsprotokoll No. 38.

j) Underrettsprotokoll for Søre Gudbrandsdalen, Tingbok 1789-90.

Riksen, S. (1969) Privatarkiv nr 273. Kronologisk fortegnelse om skader forvoldt ved fjellskred, stenskred, flom, sneskred og jordfall. Første del: Kronologisk fortegnelse over all resolusjoner vedrørende skyldavtak. Annen del: Utdrag av avtaksforretninger for 1063 gårder eller bruk: 110 som fikk skade under The flood i December 1743 og 953 som fikk skade under Stor-Ofsen 22 July 1789 på Nordmøre, i Sør-Trøndelag, Gudbrandsdalen, Østerdalen, Øvre Romerike, Land og Numedal. *Riksarkivet*, Oslo

Roald, L.A. (2002) The large flood of 1860 in Norway. Proc. of the International Conference: Extreme of Extremes, Reykjavik, Island. *IAHS Publication no. 271*, p 173-178.

Roald, L.A. (2003) Two large 18th Century flood disasters in Norway. In: Thorndycraft, V.R., Benito, G., Barriendos, G. & Llasat M.C. (ed). *Proc. of the International Workshop PHEFRA (Palaeofloods, Historical Data & Climatic Variability: Applications in Flood Risk Assessment)* held at Barcelona, Spain, October 2002. ISBN-84-921958-2-7.

Roald, L.A. (2008) Rainfall, Floods and Weather Patterns. *NVE Oppdragsrapport A No 14/2008*. 43 pp.

Roald, L.A. (2010) The link between atmospheric circulation and rainfall floods in Norway. *The XXVI Nordic Hydrologic Conference: Hydrology: From Research to Water Management. 9-12 August 2010.*

Roald, L.A. (2012a) Large floods in Norway. In: Kundzevics, Z. (ed). IAHS

Roald, L.A. (2012b) Historical Floods in Norway - Causes and Consequences. *XV International Conference of Historical Geographers. 6-10/8- 2012 Praha. Czechia.*

Roald, L.A. (2013) Det regne så det søyde og tora slo - Flom i Norge. *Forlaget Tom &Tom. NVE-rapport nr 56-2013.* 184 p. ISBN 978-82-92916-15-5.

Roald, L.A. (2015) Flommen på Østlandet i mai 2013. *NVE-rapport nr 21/2015*. 65 pp.

Rolsboka 1784-1825/1905 (1945) *Nord-Trøndelag Historiske årbok 1945*, p 71-90.

Rolsdorph & Kierschow (1775)

Rogstad, St.H. (1930). Litt om Lerfallet ved Kvasshyllan i Gauldal 1345. Gauldalsminne 1930, p 282-286..

Rokoengen, K. (1999) Hvor lå Hagevatnet – Ingeniørgeologiske undersøkelser i Langedalen 1 km nord for Støren i Gauldalen i Sør-Trøndelag. Gauldalsminne. Snøfugl, Meldal.

Rokoengen, K., Nørman Jespersen, M., Kleiv, R.A. & Sæterbø, E. (2001): The 1345 slide and flood disaster in the Gauldalen valley, Mid-Norway: a new interpretation. *Norsk Geogr. Tidsskr. Vol. 55 57-70.* Oslo, ISSN 0029-1951.

Ropeid, A. (1965) Hønefoss historie. *Ringerike kommune.*

Rudie, G. (1966) Bygdebok for Eidsberg, Bygdehistorien.Bd 1., 559 s.

Rugsveen, M. (1989) "Det regne så det søyde". Storofsen i Elverum i 1789 – 200 år since. *Alfarheim: Årbok for Elverum nr 4. 1989. Elverum Historielag*, s 8-22.

Rybakken, O.T. (1989) Om Stor-Ofsen og skadene i Øyer. *I Gamle Fotefar*. *Øyer og Tretten Historielag*, s 12-25.

Ryningen, A. (1985) Valle kommune. Gard- og ættesoge. *Valle kommune*, Hyllestad.

Rød, A. (1967) *Glåmdalen 148/67*

Rønåsen, I. (2001) Fra 1550-åra til 1723 – Uår i gamle dager og 1723 til utpå 1800-tallet. Grueboka – Voll/Vollermoen.

Saga, T. (1997) Storflommen i Lågen i 1927. *Langs Lågen*. Nr 4 – 1997.

Saloranta, T. (2014) New version (v.1.1.1) of the seNorge snow model and snowmaps for Norway. Rapport 6/2014. NVE30 s.
Sande, J. (1981) Sunndalsboka bd V - Tid som var. Bygdehistoria fram til 1840. *Sunndal kommune.*

Schive, G. (1828) Glommens Farbargjørelse. *Magasin for Naturvidenskaberne*, bind 10 1828.

Schneider, J.A. (1914) Fra det gamle Skien. Kap. XII Storflom 1792. *Erik St. Nilssens Bokhandel*, Skien.

Schøning, G. (1761) Kort beretning om endeel Uaar og Misvæxt. *Det Trondhjemske Selskabs Skrifter Første Deel: 129-62, København*. (Liste over kalde år 1294- 1340 og år med avlingssvikt fra 1315).

Skinnerud, A. (1980) Storflommen 1789. Ved Hallvar Haug. *Landingen. Årbok 1980. Lands museum, Opplandstrykk*, Gjøvik.

Skirbekk, H. (1983) Elverum bygdebok I. Bjølset og Hagen. Elverum,311 s.

Skirbekk, H. (1984) Elverum bygdebok. II Elverum, 328 s.

Skrede. M. (1953) Åsnesboka bd I. *Elverum*. 584 s.

Skrede. M. (1956) Åsnesboka bd I. *Elverum*. 568 s.

Skullerud, K. (1995) Flommen. *Exlex Forlag as,* Oslo 1995, ISBN-82-7776-013-2, 205 s.

Skorgen, B. (1996) Gards- & Ættebok for Nesset, bd VIII. *Nesset kommune*.

Solemsdal, A. (1999) Bygdebok for Holms sokn. *EKH trykk*, Molde 1999.

Solhjell, K.O. (1992) Bygdehistorie for Nore og Uvdal, bd 1 og 2, *Nore og Uvdal kommune.*

Sommerfeldt, C. (1791) og Jordskiælv i Christians Amt i Aggershus Stift den 22. og 23. Juli 1789. *Minerva*, København, Sept 1791, s 424-426.

Sommerfeldt, C. (1793) Efterretninger angaaet Christians amt. *Topografisk Journal* Hefte 14. Bd 4, p.12.

Sommerfelt, W. (1943) Ofsen i 1789 og dens virkninger i Kvam. Hovedfagsoppgave i Geografi, Universitetet i Oslo, *Fron Historielag,* 1972.

Soularanta, T. (2014) New version (v.1.1.1) of the seNorge snow model and snow maps for Norway. Rapport 6/2014 NVE 30 s.

Stang, C. (1996) Stor-Ofsen. Lillehammer og Fåbergs historie. Bind 1, del 2 1600-1800-tallet. *Thorsrud lokalhistoriske forlag, Lillehammer.*

Steimoeggen, E. (1952) Alvdal: ei bygdebok. Garden og ætta *Alvdal bygdeboknemnd*, 662 s.

Steimoeggen, E. (1966) Storflommen i 1789. Alvdal: ei bygdebok. Bygda gjennom tidene. *Alvdal bygdeboknemnd*, 402 s.

Strand. O. (1935) Ad flommen i mai 1934. *NVE-unpublished report,* 20 s.

Strand, O. (1941) Rapport – ad flommen i Gaula 24-8-1940, 111 s med vedlegg.

Stranden, H.B. & Sund, M. (2013) Flom og skred i Nord-Norge mai 2013. *NVE Rapport 54/2013.*53 s.

Stranna, O. (1925) Lundesoga. Skien, 767 s.

Streitlien, I.A. (1974) Bygdebok for Folldal. Gard og ætt. I. Elverum, 413 s.

Streitlien, I.A. (1977a) Storofsen i 1789. Tynset bygdebok – Topografi – geologi – historie, *Rosenborg offsettrykk, Trondheim*, p.175-176.

Streitlien, I.A. (1977b) Storflaumen 1867. Tynset bygdebok – Topografi – geologi – historie, *Rosenborg offsettrykk, Trondheim*, s 214-215.

Streitlien, I.A. (1977c) Storflaumen 1934. Tynset bygdebok – Topografi – geologi – historie, *Rosenborg offsettrykk, Trondheim*, s 232-234.

Strøm, B. (1888) Stavanger Amt. Topografisk – Statistisk beskrivelse. *Norges Land og Folk XI.*

Strøm, H. (1762-1769) Beskrivelse over Søndmør. København.

Strøm, R. (1978) Many Noringer drept av skriur som løsnet etter langvarig regn. *Langs Lågen 1978.*

Stuland, A. (1924) Kvinnherad sokn, *Skauns trykkeri*, Norheimsund.

Støen, P.B. (1968) Ætt og minne. *Trondheim.* 132 s

Sveie, H.O. (1987) Flommen i Gaula (1940) og skadene på Rørosbanen. *Gauldalsminne.*

Svelle, H. (1961) Boka om Gol. *Grøndahl & Søns boktrykkeri*, Oslo.

Svendsen G. & K. Werswick (1961). Fjellene dreper. Utsnitt av norsk katastrofehistorie gjennom 300 år. Tiden, Oslo, 199 s.

Sydtveit (1984)

Sælthun, N.R. (1999) Flommer og flomberegninger. Kurset Gf-GG 141. Institutt for geofysikk, Universitetet i Oslo.

Sætren, G. (1903) Om Skiensvasdragets regulering. *Fremskrids bogtrykkeri, Skien*, 1903, 21pp.

Sætren, G. (1904) Beskrivelse av Glommen. *Kristiania.*

Sætren, G. (1907) Beskrivelse av Skiens Vasdrag. Mallingske Boktr., Kristiania, 265 s.

Søgnen, R. (1942) Beregning av sjøers naturlige reguleringsevne og flommer i norske vassdrag. *Joh Nordahls Trykkeri, Oslo* 1942. 56 s.

Tanga, G. (1971) Skaflommer. *Solør-Odal*, s 44-48, 110.

Teigen, T. (2000) Redselsnatten i Kvam. Gåmålt frå Qvam nr 1-2000. Medlemsblad for Kvam Historiske Foreining Årgang 4.

Timberlid, J.A. (1982) Bygdebok for Gaular.

Thyness, V. og Evensen, P. (2012) Ekstremværrapport. Hendelse Frida, 06.08.2012. *met.no info No. 15. Oslo 17/8 2012*. 16 s.

Tokheim, L.S. (1992) Skreer og flaumar på Eitrheim, i nyare tid. *Hardanger 1992*, s 90-92

Torstensen, B. (1998) Storflommen i Lågen i 1927 –Suppleringer fra Larvikdistriktet. *Langs Lågen. Nr.2 – 98*, s 96.

Tronshaug, O.M. og Tronshaug, A.J. (1977): Innset bygdebok bd 1 – Kultur. Innset.

Tråen, E., Bjørkvik, T., Sjulstad, S. & Grønseth, J. (2001) Livet langs Numedalslågen. Villmarksfoto/Bokprosjekt Lågen 2001, s 296- 297.

Tveito, O.E. and Roald, L.A. (2005). Relations between long-term variations in seasonal runoff and large-scale atmospheric circulation patterns. Met.no report no 7/2005 Climate.

Ullestad, E. (1998) Flaum. Gamalt frå Voss, 1988, s 142-143.

Urtegaard, G. (1991) Balestand Gards og ættesoge bd 2. *Balestrand kommune 1991.*

Ve, S. (1971) Bygdebok for Årdal. *Årdal sogelag. Boktrykk LL, Bergen.*

Vedin, H. & Eriksson, B. (1988) Extrem arealnederbørd i Sverige, 1981-1988. SMHI *Meteorologi nr. 76*, 1988.

Væringstad, T. & Devoli, G. (2012) Flom og jordskred i Trøndelag mars 2012. Rapport 79/2012, NVE Oslo. 75 s

Veslestøl, H. (1924) Skriudn i Ål. *Dølaminne*, s 25-29.

Vevstad, A. (1987) Arendalsvassdraget – et vassdrag. Arendals Vassdrags brugseierforening 1907-1912 . . . . 1987, Arendal 1987.

Vibe, J. (1895) Buskeruds Amt. Topografisk – Statistisk Beskrivelse. *Norges Land og Folk VI*

Vigeland, N.P. (1942) Økonomisk administrativ historie. Norske bygder, Glåmdalen, Griegs forlag, Bergen, s 51-81.

Vigeland, N.P. (1961) Sør-Odal II. Ulleren og Oppstad, Gard og Ætt. Kongsvinger, 334 s.

van Bebber, J. (1882) Typische Witterungs-Erscheinungen. Aus Arch dt Seew, Hamburg, 5, No. 3, 1882, pp.1-45.

Wang, Storm. Scener fra Vandflommen. *Skillingmagasinet.* 5 s.

Werenskiold, W. (1936) Natur- og levevilkår I Øst-Norges fjellbygder. *Universitetetes radioforedrag 1936, s 17.*

Wessel-Berg, F.A. (1843) Rescripter,, Resolutioner og Collegiebrev for Norge 3. Bind, 1843. 12 mars & 14 mai 1790, 28 jan 85 25 mars 1791, fra Støren9 april 1790 og fra Vågå 28 jan 1791.

Wettergren, P.B. (1923) Avskrift av kaldsboken for Moe. Historielaget for Telemark og Grenland. Skien 1923, s 67-69.

Wigenstad, T. (1987) Veret i 1930-åra. *Frå gåmålt frå Lesja og Lesjaskog.*

Wilson, D., Fleig, A.K., Lawrence, D., Hisdal, H., Pettersson, L.-E., Holmquist, E. (2015) A review of NVE's flood frequency estimation procedures.

Wiltshire, S. and Beran, M. (1986) Multivariate Techninues for the Identification of Homogenous Flood Frequency Regions, Baton Rouge Symposium May 1986.

Wiltshire, S. and Beran, M. (1987) A Significance Test for Homogeneity og Flood Frequency Regions. In: V.P.Singh (ed). Regional Flood Frequency Analysis, 147-158. D.Reidel Publishing Company.

Øisang, O. (1942) Rørosboka II. Røros Kobberverks Historie, Trondheim, 476 s,

Østhagen, S. (1961) Elverum elektrisitetsverk gjennom 50 år. *Elverum*, 176 s.

Østlund, J.H. (1999) Ringerike i gamle dager. *Kolltorp forlag 1999.*

Østmo, A. (1985) Storofsen. Oversiktsregisteret. *Infotrykk, Ski.*

Østro, T. (1985) Gard og slektshistorie for Flå i Hallingdal.

Østvedt E. (1963) Fløtningen i Telemark gjennom 300 år. *Skien*, 538 s.

Øverland, O.A. (1903) Fra storflommen 1789. *Verdens Gang nr 220.* 30. juli 1903.

Øverland, O.A. (1913) De norske bygdemagaziner 1913 s 429 & 440.

Øyen, L.E. (1994) Gard og Ættesoge for Luster kommune. Band V Jostedals sokn. Luster kommune.

Øygarden, L., Eggestad, H., Standring, W.J.F., Goffeng, G. & Vagstad, N. (1996) Flommen i 1995 – Skader på jordbruksarealene langs Glomma og Gudbrandsdalslågen. Jordforsk rapport nr 29/96, Ås.

Øyjorde, O. (1965) Da “Storofsin” herja i Bøverdalen. Årbok for Gudbrandsdalen 1965, s 60-62.

Øyjorde, O. (1967) Den gamle Bøverdalskirka. *Årbok for Gudbrandsdalen 1967*, s 85-87.

Aamlid, P. (1986) Om broene og flommen 4 oktober 1892. Øyestad Historielags Årsskrift 1986.

Åsen, K. (1986) Nissedal bygdesoge bd III.

Aasmundstad, K.P. (1935) Frå Kvikne og Skåbu. Frå Jordlaupssåmåra. *Dølaringen 1935*, s 47-49.

Aasmundstad, P. (1889) «100 Aar siden». *Framgang nr 71, Lillehammer 31.Aug 1889.*

Aasmundstad, P. (1899) Ei øltrøys. *Syn og Segn 1899, s 226-228.*

Aasmundstad, P. (1901) Flaumen i 1789. *Syn og Segn 1901, s 87-92.*

Appendix A. Overwiew of Norwegian regional, county and district names.

Regional names

Sør-Norge	**South Norway**		
		Østlandet	**East Norway**
		Sørlandet`/Southcoast	
		Vestlandet	**West Norway**
		Midt-Norge	**Mid Norway**
Nord-Norge	**North Norway**		

Counties		*Region*	*Subregion(s)*
Østfold	**Østlandet**		
Vestfold	**Østlandet**		
Akershus	**Østlandet**		
Oslo	**Østlandet**		
Hedmark	**Østlandet**		
Oppland	**Østlandet**		
Buskerud	**Østlandet**		
Telemark	**Østlandet**		
Aust-Agder	**Sørlandet**		
Vest-Agder	**Sørlandet**		
Rogaland	**Vestlandet**	**Jæren**	
		Ryfylke	
Hordaland	**Vestlandet**	**Sunnhordaland**	
		Hardanger	
		Nordhordaland	
Sogn og Fjordane	**Vestlandet**	**Sogn**	
		Sunnfjord	
		Nordfjord	
Møre og Romsdal	**Midt-Norge**	**Sunnmøre**	
		Romsdal	
		Nordmøre	
Sør-Trøndelag	**Midt-Norge**		
Nord-Trøndelag	**Midt-Norge**		
Nordland	**Nord-Norge**	**Helgeland**	
		Salten	
		Lofoten og Vesterålen	
Troms	**Nord-Norge**		
Finnmark	**Nord-Norge**		

Some of the counties has been joined into larger units in 2020, while other counties remain. The new County Viken comprises now former counties Østfold, Akershus and Buskerud new County Inland Hedmark and Oppland, The Nn County comprise and named Vestfold and Telemark, The newCounty Agder of Aust- and Vest-Agder, County Vestland of Hordaland and Sogn og Fjordane, County Trøndelag of Sør and Nord-

Trøndelag and Troms and Finmark as a joined county. The other counties still remain as separate units.

Lars Andreas Roald

Floods in Norway

Appendix B

East and South Norway

Table of contents

1. Introduction to Appendix B

Appendix B documents historical floods in East and South Norway. The area covered by Appendix includes most of the large catchments in Norway. The structure of the Appendix B is based on the largest watercourses. The area covered in the Appendix has been divided into 8 areas each representing a major catchment in the south-east part of Norway.

Part 1 – Overview by water courses: Østlandet and Sørlandet

This Appendix describes large floods in East and South Norway (Østlandet og Sørlandet). The Appendix comprises three parts. The first part gives an overview of the number of stations within each unit, information about annual floods known from historical sources and later observed floods at gauging stations in the rivers from Rogaland to Sogn og Fjordane counties in Norway. The rivers are ordered from River Haldenselv to River Sira next to Jæren. The region described in the report includes most of the larger watercourses in East Norway where data or information about historical floods prior to the observations are available.

The second part includes the catchment characteristics for each station and gives in tabular form the date and rank of the ten largest floods observed at each station. Most of the long-term series have been affected by hydropower regulations. The effect of regulations is that the flood magnitudes is reduced from the start of the operation of the hydropower scheme. The rank given in the tables refer to the observed data. The flood magnitudes have not been corrected to naturalized discharges from the start of the regulation. This is the reason why fewer large floods occur in recent years in many flood series. The flood series are also shown as graphs for many long-term series. Actual discharges are not listed in the tables, but the discharge is given for the largest flood in each series in the unit m^3/sec, l/sec km^2 and mm/day. These values may change when the rating curve is updated.

The second part comprise also tables of past historical floods at the current station where such information has been found.

The third part describes many historical floods. Most large floods extend over more than one river and can also extend across the boundary between the regions described in each Appendix.

Some old floods prior to the start of observations are given, based on other historical sources. Most of the descriptions cover floods based on observations. The description of each flood includes graphs of observed specific discharge and daily rainfall and snowdepths and groundwater and soil moisture contents where this information is available. The causes of the floods are given with a description of the initial conditions and the weather type causing the flood. Some information of flood damages is also given where this information is available.

Part 1.1 – Overview of the underlying data

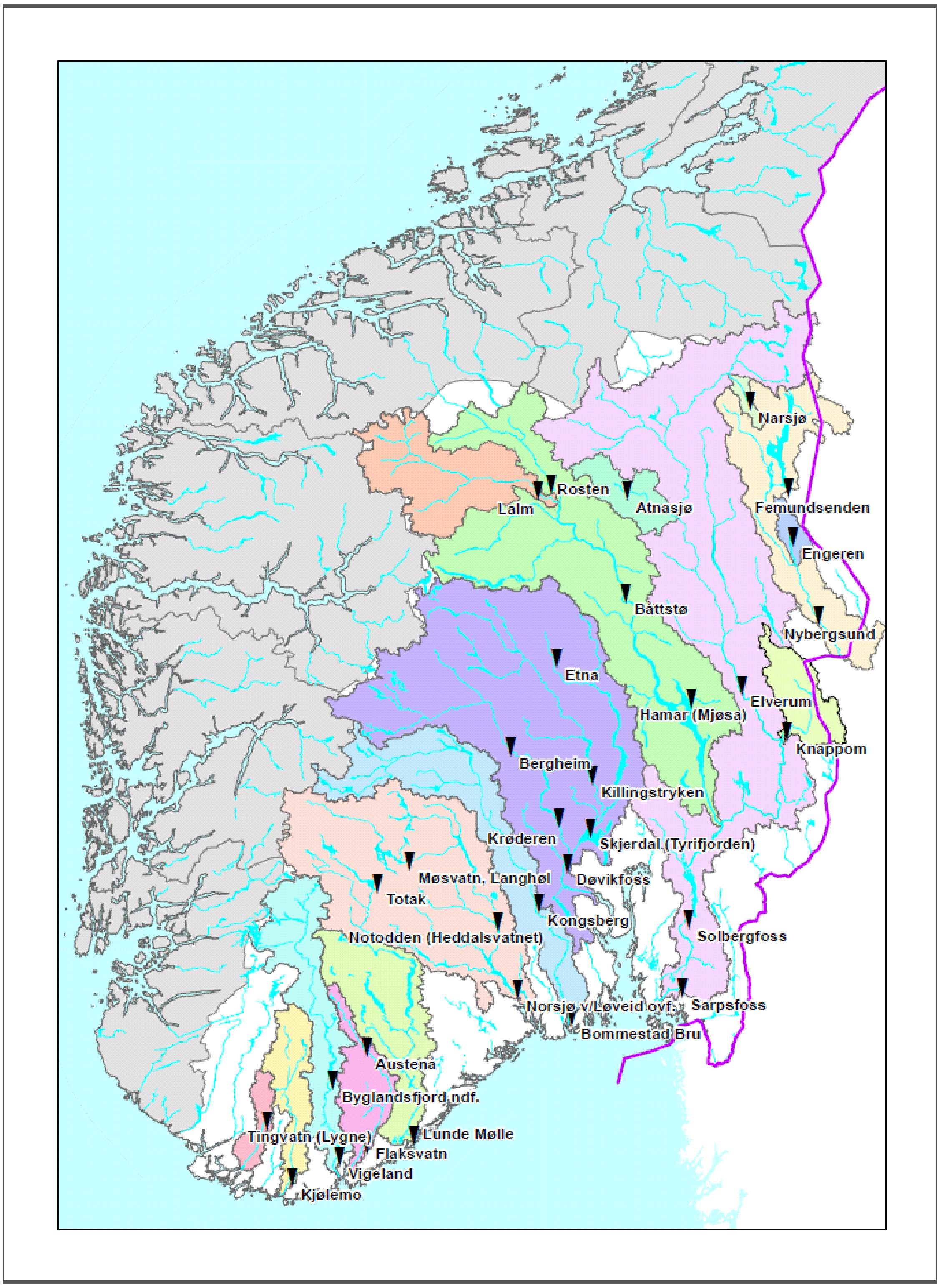


Figure 1. Overview of the catchments with long-term flood series in East Norway (Østlandet) and South Norway (Sørlandet)Used in the book: Det regne så det søyde og tora slo – Flom i Norge. Map produced by Søren Kristensen.

The current study is based on 138 stations in addition to the 34 stations used in the previous book in Norwegian. The Region Østlandet comprise mostly large watercourses with several stations in each river. Some data from the 19th Century prior to the data available on the NVE databases have also been used.

The flood data included also many stations with shorter series in the upper part of the larger catchments, especially at Østlandet.The number of stations used at Østlandet in the study is 104 stations and at Sørlandet 30 stations. This appendix describes large floods at Østlandet and Sørlandet. This appendix comprises three parts. The first part gives an overview of the number of stations utilized in the study for each major water cource in the region. The location of long-term stations is shown in Figure 1. The study utilized also additional shorter series. For selected rivers are historical floods listed where past floods are known prior to direct observations of the water levels. lists the largest annual floods known from historical sources and later observed floods at shorter gauging stations in the rivers of southeastern Norway. The rivers are ordered from the border to Sweden to River Sira, the watercourse near the border to the southern part of Vestlandet. The region described in the report includes most the largest watercourses in Norway. The descriptions of Glomma, Drammenselv and Skienselv comprise a number of large subcatchments. The report is structured according to the hierarchy of these rivers, following the various subcatchments to the top of each river. The number of stations in each major water course are shown in Table 1.

Table 1 Overview of the number of gauging stations used in the water courses in South East Norway.

Catchment	Number of stations	Number shown in Figure 1	Additional shorter series
Trysilelv	3	3	
Haldenselv	3	0	3
Mosselv	3		
Glomma	46	7	14
Eastern branch	21		
Western branch	25	4	21
Drammenselv	28		
Tyrifjord to sea	8	2	6
Hallingdal/Hemsedal	6	2	4
Ådalselv/Begna	11	1	10
Randselv/Etna/Dokka	3	1	2
Numedalslågen	9	2	7
Skienselv	15	4	11
Sørlandet	30		
Nidelv	6	1	5

Tovdalselv	3	2	1
Otra	4	2	2
Sira	6		6
Other stations at Sørlandet	11	3	8

Part 2 Floods at each gauging station

2.1 Østlandet

2.1.1 RIVER TRYSILELV (KLARA)

River Trysilelva or Klara is the upper part of the largest watercourse in Sweden, River Götaälv. The catchment area on the Norwegian side of the border is 5.306 square kilometers. Lake Femunden is located at the catchment. The lake is the third largest lake in Norway, covering an area of 203 square kilometers. There is a minor diversion of water from Femunden towards Feragen, Håelva and Glomma. This diversion has an insignificant effect on the large floods further downstream. Three long-term data series are available in the Norwegian side of the national border. The discharge has been observed at the gauging station 311.4 Femundsenden since 1896 at the outlet of Lake Femunden. Further downstreams the station 311.6 Nybergsund has been operating since 1909. The gauging station 311.460 Engeren is located at the tributary Engeråa and has been operating since 1912. Some sub-catchments of Engeråa cross into Norway from Sweden near water divide in east. Catchment characteristics of the three gauging stations in River Trysilelv are given in Table 2.1.1.1.

Table 2.1.1.1 Catchment characteristics for the three long-term gauging stations in River Trysilelv.

Station	311.4 Femundsenden	311.6 Nybergsund	311.460 Engeren
	Basin characteristics		
Catchment area (km^2)	1791	4420	395
Station altitude (m.a.s.l.)	652	353	472
Mean altitude (m.a.s.l)	782	781	837
Top altitude (m.a.s.l.)	1455	1748	1207
Lake (%)	18,44	8,36	4,07
Bog (%)	7,89	10,7	16,62
Forest (%)	31,99	41,33	47,44
Mountain (%)	27,24	24,2	28,24
Glacier (%)	0	0	0

Observed floods in River Trysilelv

The largest historical flood in Trysilelva was Storofsen in July 1789. The dates and ranks of the ten largest annual floods (daily values) in River Trysilelv are given in Table 2.1.1.2. Table 2.1.1.3 gives the date and discharge (daily values) of the largest observed flood at the three gauging stations in River Trysilelv.

Figure 2.1.1.1-2.1.1.3 show the annual floods observed at 311.4 Femundsenden, 311.6 Nybergsund and 311.460 Engeren. Figure 2.1.4 show the flood stone at Nybergsund in Trysil.

Table 2.1.1.2 The ranks of the largest observed annual floods (daily values) in River 1Trysilelva.

311.4 Femundsenden			311.6 Nybergsund			311.460 Engeren		
1896-2014			1909-2014			1912-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1916	5/6	6	1916	11/5	7	1916	12/5	8
1924	1-3/6	7	1920	20/5	8	1920	21/5	6
1927	28/6	4	1931	19/5	5	1931	19/5	7
1934	13/5	7	1934	6/5	6	1934	7/5	2
1944	17/6	3	1966	20/5	4	1966	20/5	5
1945	19-20/5	7	1967	2/6	2	1967	27/5	4
1966	25/5	7	1985	29/5	9	1978	25/5	10
1967	3/6	2	1986	12/5	10	1985	28/5	9
1987	18/6	5	1995	1/6	1	1995	1/6	1
1995	8/6	1	2014	26/5	3	2014	26/5	4

Table 2.1.1.3 The largest observed discharges at the three long-1term gauging stations in River Trysilelv.

Station	311.4 Femundsenden	311.6 Nybergsund	311.460 Engeren
Year	1995	1995	1995
Date	8/6	1/6	1/6
q (m^3/sec)	134,87	741,52	135,87
qsp (l/sec km^2)	75,3	170	344
qsp (mm/day)	6,5	14,7	30

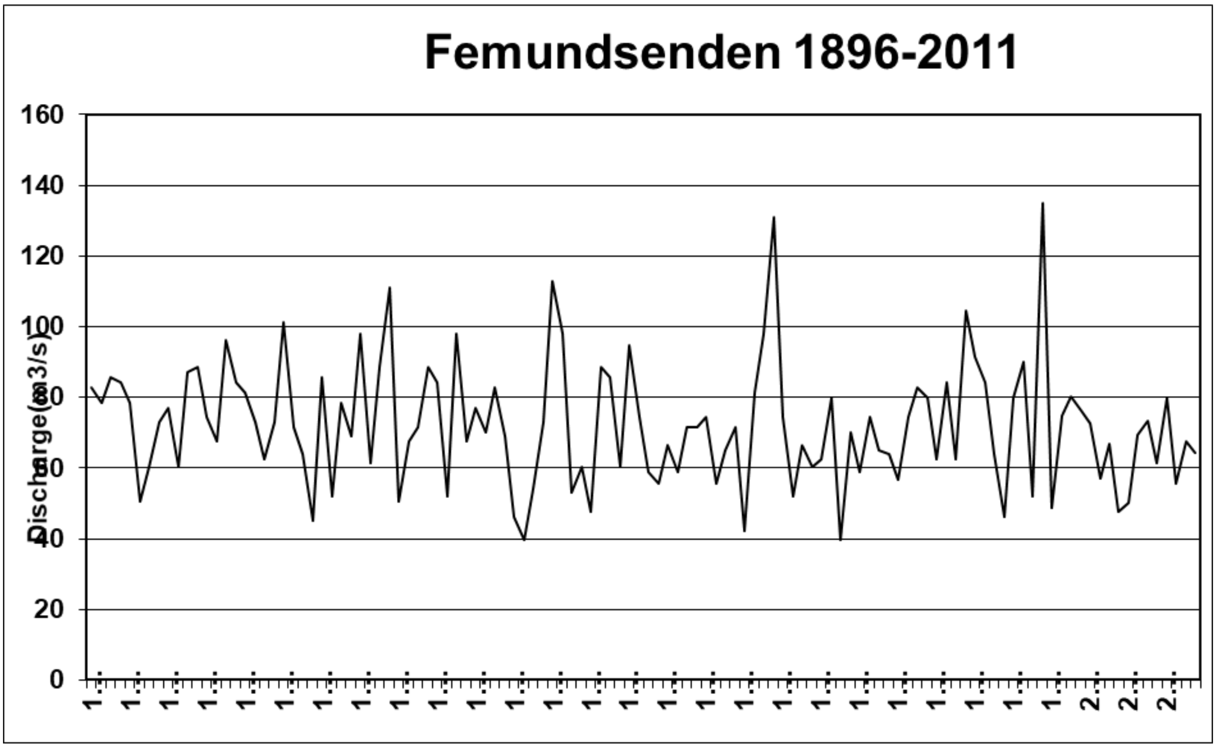


Figure 2.1.1.1 The annual flood (daily values) in River Trysilelv at Femundsenden 1896-2014.

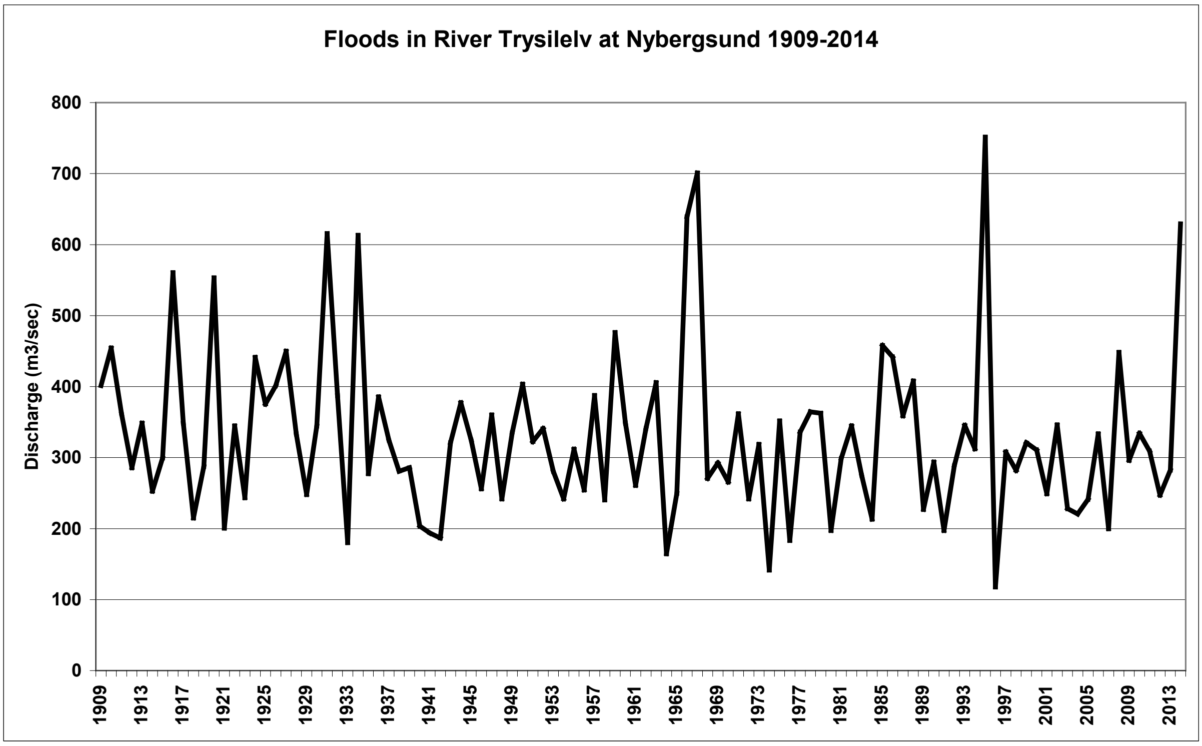


Figure 2.1.1.2 The annual flood (daily values) observed at Nybergsund 1909-2014.

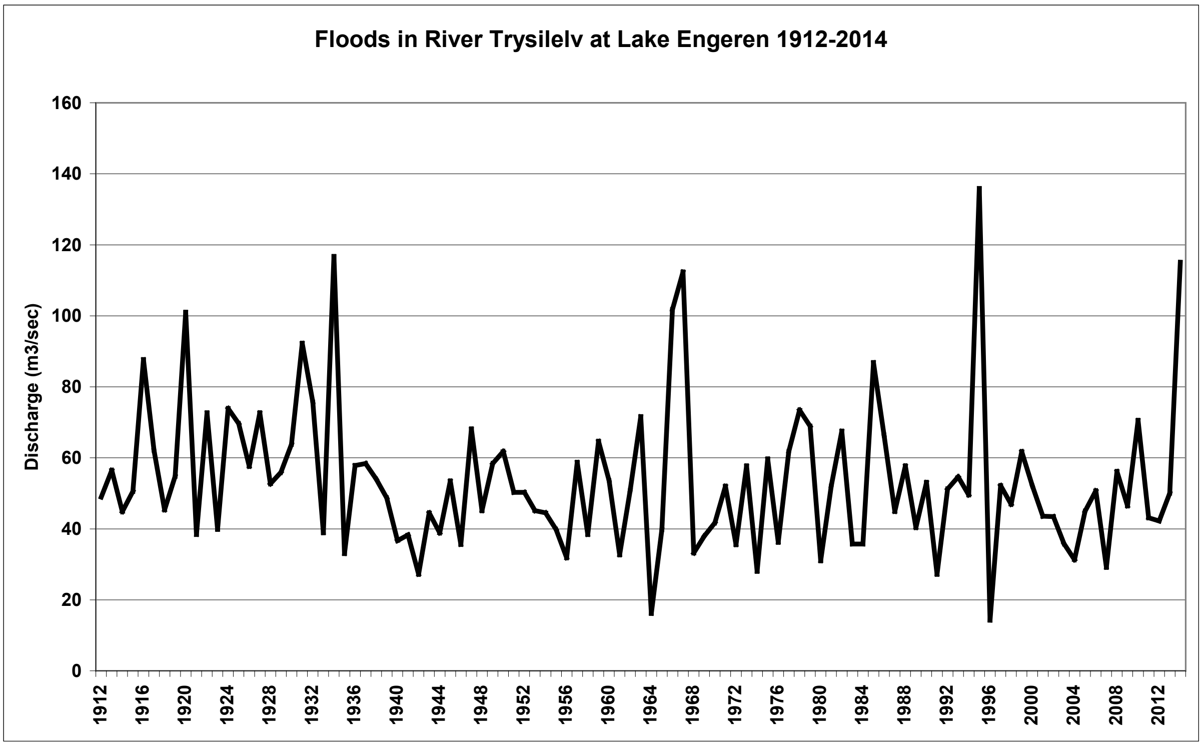


Figure 2.1.1.3 The annual flood (daily values) observed at Lake Engeren 1912-2014.

Trysil was among the municipalities which was worst affected by the flood (Bakken, 1996). The center of Trysil municipality, Innbygda, was inundated, preventing all normal activities in the center. The large Company Trysil Skog suffered severe damages.

2.1.2 RIVER VRANGSELV

River Vrangselv flows eastwards from Kongsvinger and across the border towards Sweden where it is a tributary to Lake Vänern. The water divides between River Vrangselv and River Glomma is lowlying. During large floods in River Glomma, some flood water may flow into River Vrangselv and into Sweden (Petterson, 2002). The discharge in River Vrangselv is observed at the gauging station 313.10 Magnor. The location of the station has moved slightly a few times, but a data series covering the period 1912-2014 is available at the station. The catchment characteristics and the date and ranks of the ten largest annual floods are given in Table 2.1.2.1.

Table 2.1.2.1 Catchment characteristics and dates and ranks of the ten largest annual floods at Magnor.

Station		The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	359,95	1916	13/5	1
Station altitude (m.a.s.l.)	127	1934	11/5	2
Mean altitude (m.a.s.l)	240	1937	18-18/4	9
Top altitude (m.a.s.l.)	458	1951	5/5	5
Lake (%)	4,03	1952	7/5	8
Bog (%)	5,25	1966	3/5	4

Forest (%)	81,42	1987	17/10	10
Mountain (%)	0	1988	4/9	3
Glacier (%)	0	1995	4/6	7
		2000	22/11	6

The largest one-day flood occurred in River Vrangselv at Magnor 13 May 1916 with a discharge of 116,11 m^3/sec corresponding to 323 l/sec km^2 or to a runoff of 27,9 mm/day. The annual floods (daily values) are shown in Figure 2.1.2.1.

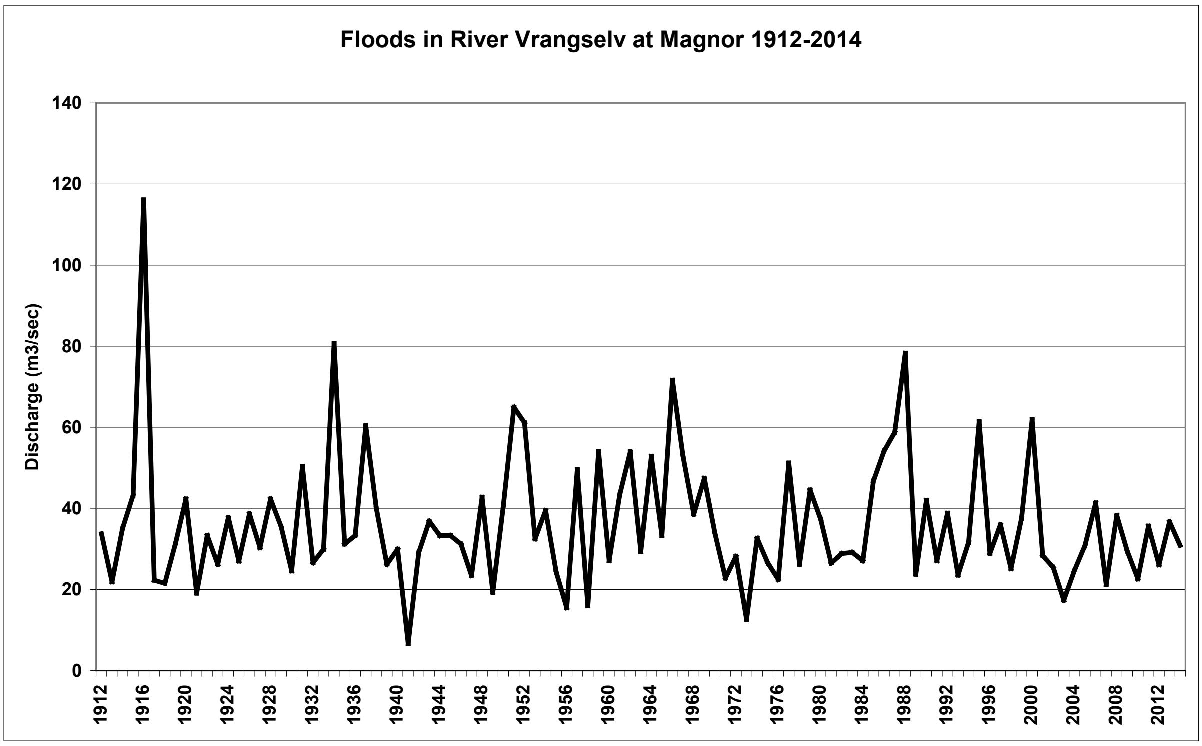


Figure 2.1.2.1 Annual floods (daily values) in River Vrangselv at Magnor 1912-2014.

2.1.3 RIVER HALDENSELV

River Haldenselv is located west of the border to Sweden in Akershus and Østfold counties flowing southwards to Iddefjord. The Halden Canal is a system of locks and weirs connecting several lakes and is used for tourist traffic in river boats. The river has been used extensively for timber floating to the industry at the town Halden at the outlet of the river. The flood in 1860 caused severe damages at the lock and weir at Brekke.

There are no long-term discharge series available from the watercourse. The discharge was observed at 1.37 Kirkevatn 1913-1928. This series includes the severe floods in 1927, with two peaks of 76,79 m3/sec (1 July) and 77,68 m3/sec (4 October) and seems to be unaffected by the regulations.

More recent data are available at three stations 1.48 Ørje 1963-2012, 1.49 Brekke 1963-2011 and 1.50 Tistedalsfoss 1963-2011. The discharge at these three stations is modified by the operation of the Canal. Table 2.1.3.1 give the dates and ranks of the ten largest floods at these stations. The floods occur generally in the late autumn or early winter. The large spring flood in May 1966 is an example of a large regional spring flood, which also occurred in River Haldenselv. The large flood in November 2000 is the largest observed in most of the lakes included in the Canal.

Table 2.1.3.1 Catchment characteristics of three stations in River Haldenselv.

Station	1.48 Ørje	1.49 Brekke	1.50 Tistedalsfoss
	Basin characteristics		
Catchment area (km2)	1010	1393	1582
Station altitude (m.a.s.l.)			79
Mean altitude (m.a.s.l)			182
Top altitude (m.a.s.l.)			406
Lake (%)			9,01
Bog (%)			3,93
Forest (%)			74,8
Mountain (%)	0	0	0
Glacier (%)	0	0	0

The Halden catchment has suffered fron large historical floods in 1860 and 1927.

Table 2.1.3.2 Date and ranks of the ten largest annual floods observed at three stations in River Haldenselv.

1.48 Ørje			1.49 Brekke			1.50 Tistedalsfoss		
1963-2012			1963-2011			1963-2011		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1964	17/10	8	1964	15/10	9	1964	17/10	9
1965	13/9	2	1965	14/9	5	1965	21/9	4
1966	7/5	1	1966	13/5	2	1966	15/5	5
1967	6/11	7	1967	30/10	10	1982	30/11	7
1977	5/5	6	1970	28/11	8	1990	12/2	3
1987	11/10	5	1974	21/11	7	1999	23/1	8
1990	5/2	4	1990	10/12	3	2000	27/11	1
1992	6/12	9	1999	26/4	6	2006	12/12	2
2000	23-26/11	3	2000	23/11	1	2008	17/1	10
2008	20/1	10	2006	9/12	4	2011	21/9	6

2.1.4 RIVER MOSSEELV OR RIVER HOBØLELV

River Mosselv flows from Lake Vansjø to the Oslofjord at Moss. The catchment area of the water course is 695 square kilometers. The catchment comprises a large lake, Lake Vansjø, which is utilised for hydropower production and for industrial production in Moss. Floods in Lake Vansjø have caused problems for farms located around the lake, because of inundation of the farmland. The upper part of the watercourse is River Hobølelv flowing from Lake Mjær at Enebakk to Lake Vansjø.

There have been several gauging stations within the catchment. The gauging station 3.7 Sæbyvatn vas active 1924-1931, the station 3.11 Sagstubekken and the station 3.22 Høgfoss 1976-2014. Catchment characteristics are given in Table 2.1.4.1, the year, dates and ranks of the ten largest floods (daily values) in Table 2.1.4.2 and the discharge of the largest floods at the three stations in Table 2.1.4.3.

The catchment includes the town Moss where the research program PRA 4.2 operated from 1975 studying urban runoff ().

Table 2.1.4.1 Catchment characteristics of Sæbyvatn, Sagstubekken and Høgfoss in River Mosseelv.

Station	3.7 Sæbyvatn	3.11 Sagstubekken	3.22 Høgfoss
	Basin characteristics		
Catchment area (km^2)	94,48	3,39	299,29
Station altitude (m.a.s.l.)	47	154	47
Mean altitude (m.a.s.l)	115	199	153
Top altitude (m.a.s.l.)	227	239	347
Lake (%)	2,32	0,6	2,39
Bog (%)	2,23	2,69	1,19
Forest (%)	80,75	96,71	71,73
Mountain (%)	0	0	0
Glacier (%)	0	0	0

Table 2.1.4.2 Dates and ranks of the ten largest floods at three stations in River Mosseelv.

3.7 Sæbyvatn			3.11 Sagstubekken			3.22 Høgfoss		
1924-1931			1951-1974			1976-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1924	31/12	8	1951	26/12	9	1976	23/10	9
1925	3/1	4	1954	29/11	3	1987	16/10	1
1926	10/11	3	1957	14/9	5	1988	3/9	8
1927	29/6	2	1958	8/5	9	1999	25/12	6
1928	24/11	6	1959	21/12	2	2000	23/11	7
1929	12/11	1	1961	2910	4	2006	8/12	3
1930	16/1	7	1963	22/5	5	2008	16/1	2
1931	27/4	5	1964	14/10	8	2011	7/9	4
			1965	4/9	7	2013	25/12	10
			1967	29/10	1	2014	16/2	5

Table 2.1.4.3 The discharge of the largest flood (daily values) at the three gauging stations in River Mosseelv.

Station	3.7 Sæbyvatn	3.11 Sagstubekken	3.22 Høgfoss
Year	1929	1967	1987
Date	12/11	29/10	16/10
q (m^3/sec)	29,46	2,00	101,67
qsp (l/sec km^2)	312	591	340
qsp (mm/day)	26,9	51,6	23,4

2.1.5 RIVER GLOMMA

River Glomma has the largest catchment in Norway of 41.767 square kilometers. The sources of the watercourse extend from the water divide toward River Nidelv, River Gaula, River Orkla and River Driva in Sør-Trøndelag, River Rauma and River Tafjordelv in Møre og Romsdal, River Strynselv and rivers flowing toward the Lusterfjord in Sogn og Fjordane as well as the eastern part of River Drammenselv. Some small parts of the catchment are also located at Sweden.

The river splits into two main branches at Vormsund in Akershus. The eastern branch flows from Østerdalen and Glåmdalen while the western branch flows from Gudbrandsdalen towards Lake Mjøsa and River Vorma to Vormsund. Further downstream the river flows through Lake Øyeren and through Follo and Østfold to the outlet to the Oslofjord at Fredrikstad.

2.1.5.1 The reach from Fredrikstad to Vormsund

The lowermost gauging station 2.31 Sarpsfoss in River Glomma has been operating since 1851. The catchment area is 41.806 square kilometers. There is now a display near the water fall which show the discharge.

The station 2.605 Solbergfoss has been operating since 1964. The data series has been joined with the previous series at 2.126 Langnes starting in 1901 Catchment characteristics are given in Table 2.1.5.1 for Sarpsfoss, Langnes/Solbergfoss and for the station 2.125 Mørkfoss at the outlet of Lake Øyeren which monitor the water level in the lake. Figure 2.1.5.2 show the ten largest annual floods in the joined series. The date and discharge of the largest flood at Sarpsfoss 1847-1900 and at Langnes/Solbergfoss and the date and the highest water level in Lake Øyeren at Mørkfoss (1881-2014) are shown in Table 2.1.5.3.

Table 2.1.5.1 Catchment characteristics of Sarpsfoss, Langnes/Solbergfoss and Mørkfoss.

Station	2.31 Sarpsfoss	2.126 Langnes/Solbergfoss	2.125 Mørkfoss
	Basin characteristics		
Catchment area (km^2)	41806	40537	40441
Station altitude (m.a.s.l.)	24	82	90
Mean altitude (m.a.s.l)	734	752	754
Top altitude (m.a.s.l.)	2463	2463	2463
Lake (%)	4,19	4,24	4,22
Bog (%)	7,46	7,62	7,64
Forest (%)	49,42	48,97	48,96
Mountain (%)	25,48	26,28	26,34
Glacier (%)	0,81	0,83	0,83

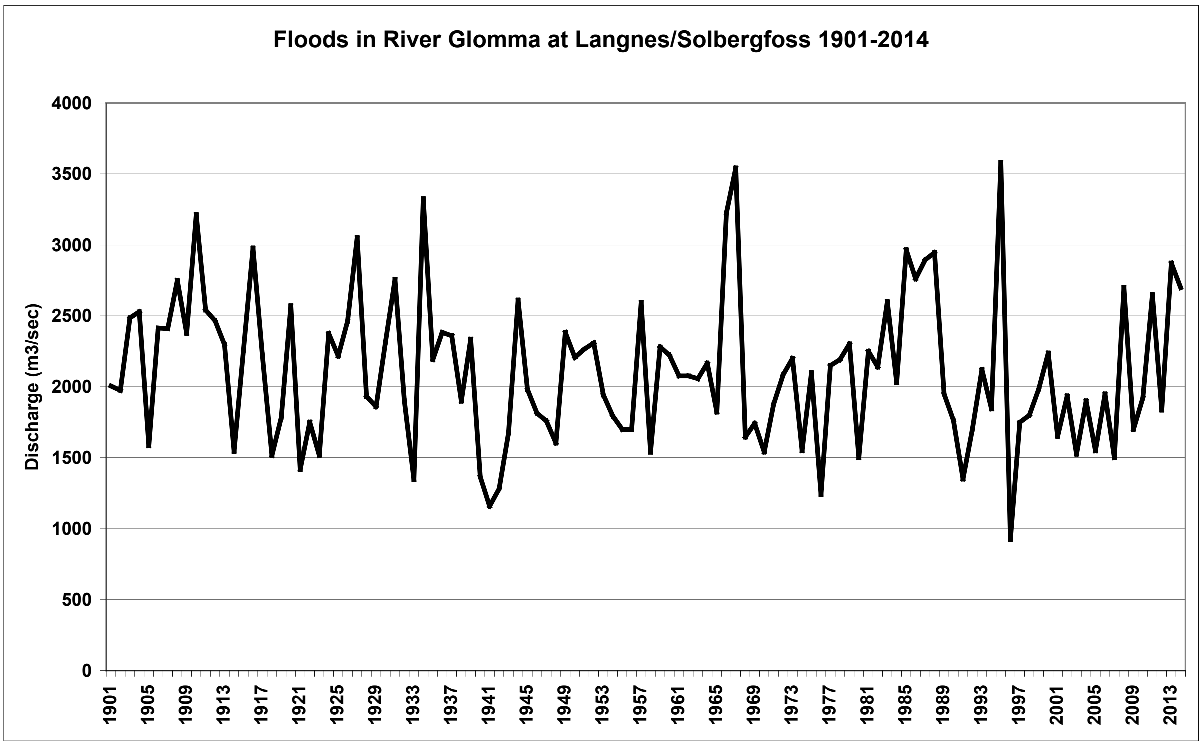


Figure 2.1.5.1 Daily discharge at 2.605 Langnes/Solbergfoss 1901-2014.

A flood mark in River Glomma located at Kulltorp, six kilometers upstreams the Sarpsfoss, show that the 1860 flood peaked 30 centimeters above the level of Storofsen.

Table 2.1.5.2 The date and ranks of the 10 largest floods observed at Sarpsfoss, at Langnes/Solbergfoss and at Mørkfoss.

2.31 Sarpsfoss			2.126 Langnes/Solbergfoss			2.125 Mørkfoss		
1847-1900			|1901-2014			1881-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1853	|8/6	10	1910	28/5	5	1890	21/5	7
1860	24-25/6	1	1916	16/5	7	1895	22-23/5	6
1863	21/6	5	1927	7/7	6	1908	6/6	9
1867	30/6-1/7	3	1934	14/5	3	1910	27-28/5	3
1868	31/5	6	1966	26/5	4	1916	16/5	5
1879	5/6	7	1967	6/6	2	1927	7/7	2
1887	29-30/5	9	1985	31/5	8	1931	24/5	8
1890	22-23/5	4	1987	18/10	10	1934	14/5	4
1895	23-25/5	2	1989	118/5	9	1966	26/5	5
1897	6/6	7	1995	10-11/6	1	1967	6/6	1

Table 2.1.5.3 The discharge of the largest flood at Sarpsfoss 1847-1900 and at Langnes/Solbergfoss and the highest waterlevel in Lake Øyeren at Mørkfoss (1881-2014).

Station	2.31 Sarpsfoss	2.126 Langnes/Solbergfoss	2.125 Mørkfoss
Year	1860	1995	1967
Date	24-25/6	10-11/6	6/6
q (m^3/sec)	3188	3580	106,61 m
qsp (l/sec km^2)	76,2	88,3	
qsp (mm/day)	6,59	7,63	

Nitelva/Leira

River Glomma flows into Lake Øyeren from the east at Leirsund. Another tributary, River Nitelva, flows into Lake Øyeren from northwest. The sources of Nitelva are in Romeriksåsene to the east and Nordmarka to the west. The river flows from Lake Harestuvatn and through Hakadal and Nittedal. There have been some gauging stations operating in River Nitelva. During the large floods in 1789 and 1860 the flood level extended Lake Øyeren to Rotnes in Nittedal. The large flood in 1910 in Øyeren was partly caused by the melting of the snow in the forested hills on both sides of Nittedal. Other rainfall floods have also caused Lake Harestuvatn to flood the main road and the railway line. One example of these rainfall events occurred 12 November 1961.

A tributary to Nitelva, River Leira, flows in from east near Lillestrøm. There are three gauging stations in Leira. The station 2.279 Kråkfoss is located near the Gardemoen airport. The station 2.280 Kringlerdal is located upstreams in River Leira and the station 2.284 Rotua in a tributary Rotua draining part of the hills to the west. Catchment characteristics of these three stations are given in Table 2.1.5.4. Water was extracted in River Rotua causing data from this river to be unreliable from the 1980´s. Discharge was also observed at the gauging station 2.329 Hellen bru 1971-2001 in the tributary Gjermåa.

Table 2.1.5.4 Catchment characteristics of three gauging stations at Romerike.

Station	2.279 Kråkfoss	2.280 Kringlerdal	2.287 Rotua
	Basin characteristics		
Catchment area (km^2)	418	265,44	55,88
Station altitude (m.a.s.l.)	105	175	199
Mean altitude (m.a.s.l)	445	519	470
Top altitude (m.a.s.l.)	803	807	649
Lake (%)	4,05	5,55	4,73
Bog (%)	4,89	6,48	4,6
Forest (%)	75,75	83,85	90,15
Mountain (%)	0,04	0,06	0
Glacier (%)	0	0	0

The observations at these stations started in 1966. The year, the date and the rank of the ten largest floods are shown in Table 2.1.5.5 and the date and discharge of the largest flood (daily values) in Table 2.1.5.6.

The station Kråkfoss is located on old marine clays at Romerike, and the catchment is susceptible to quick clay slides. The late summer and autumn 1883 were wet, causing three small slides near River Leira in the Ullensaker municipality. A major clay slide occurred 26 November, releasing 1.3 mill. m3 clay into the river, killing 6 people. The slide cased a 12,5 m tall dam to form near Kråkfoss. The wet autumn was caused by remnants of four tropical hurricanes from the Atlantic. The cause of this extreme weather is discussed on page 103 in Appendix D. The slide occurred at the village Ask in Gjerdrum muncipality, which suffered from the disastrous slide occurring 30. December 2020.

Table 2.1.5.5 The date and ranks of the ten largest floods observed at three gauging stations at Romerike.

2.279 Kråkfoss			2.280 Kringlerdal			2.287 Rotua		
1966-2014			1966-2014			1967-2001		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1966	23/5	8	1966	23/5	4	1967	14/5	1
1983	17/10	5	1967	17/5	7	1968	16/5	8
1987	16/10	1	1975	11/5	10	1969	9-10/5	3
1988	3/9	3	1977	7/5	9	1970	9/5	6
1998	27/4	6	1983	17/10	7	1971	6/5	10
2000	11/10	2	1987	16/10	1	1972	3/5	4
2002	2/5	9	1988	3/9	6	1983	17/10	9
2005	4/11	4	1998	27/4	5	1987	16/10	2
2008	2/5	7	2000	10/10	2	1988	25/11	7
2011	7/9	10	2008	2/5	8	2000	26/5	5

Table 2.1.5.6 The dates and discharge of the largest annual flood (daily values) observed at three stations at Romerike.

Station	2.279 Kråkfoss	2.280 Kringlerdal	2.287 Rotua
Year	1987	1987	1967
Date	16/10	16/10	14/5
q (m^3/sec)	171,55	93,79	20,39
qsp (l/sec km^2)	397	353	365
qsp (mm/day)	34,3	30,5	31,5

The station Kråkfoss is located on old marine clays, and the catchment is succeptible to quick clay slides. A large clay slide occurred in November 1883, killing six people living on the Holum farm. A dam was formed, raising the upstream level of the river 12,5 meter near Kråkfoss. A 6 km long lake was formed upstream the dam. When the dam failed, a floodwave destroyed all bridges down to Lake Øyeren.

River Glomma from Leirsund toVormsund

The large floods in River Glomma have caused widespred inundations in the lowlying districts around Lake Øyeren. The water level was observed at several locations at the lake as well as in the upstream river from 1846. Figure 2.1.5.2 show the levels of the annual flood in Lake Øyeren 1881-2014.

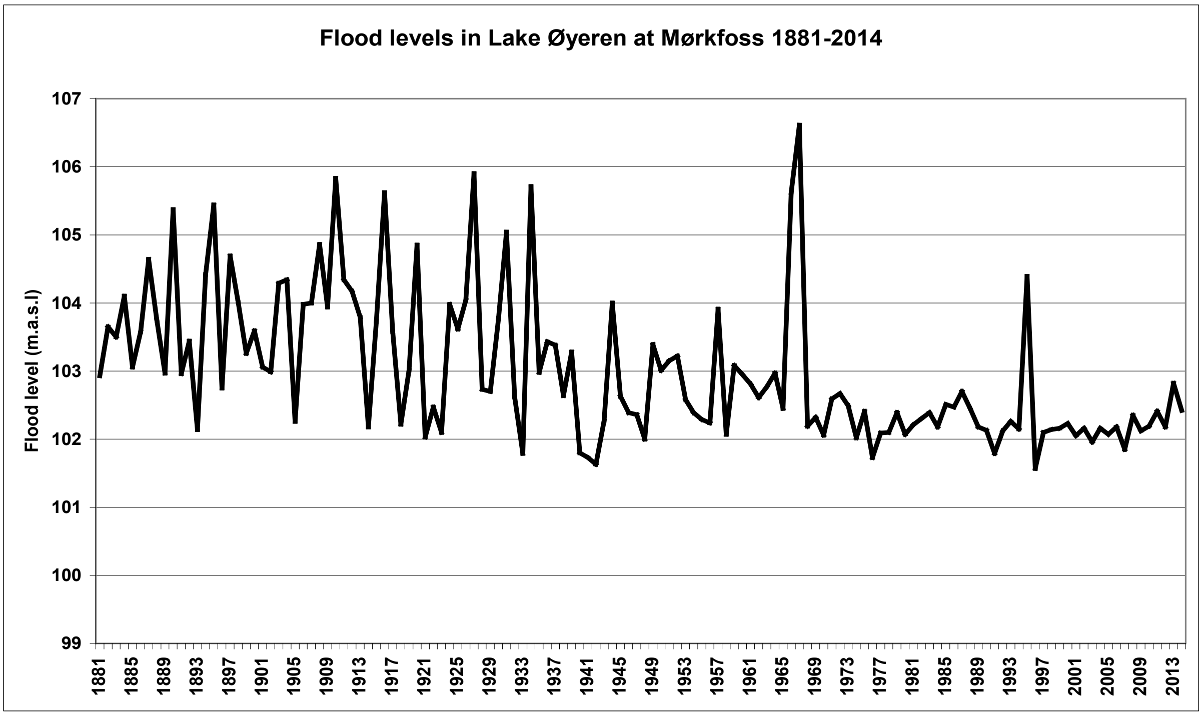


Figure 2.1.5.2 Flood levels in Lake Øyeren 1881-2014.

River Glomma flows into Lake Øyeren at the inland delta at Fetsund. Further upstreams the discharge has been observed at 2.17/124 Blaker (1869-1908, 1923-1946), 2.429 Rånåsfoss from 1996, 2.123 Årnes (1869-1933, 1975-1991) and 2.87/122 Skarnes (1864-1874). River Vorma flows into Glomma at Vormsund from the north, just upstream Årnes and River Oppstadåa from Lake Storsjøen at Skarnes. The inflow from Vorma has been estimated by the "two-scale" method at 2.197 Ertesekken.

Figure 2.1.5.3 show the flood stone at Fløtningsmuseet at Fetsund. The top of the stone marks the level of “Storofsen” in 1789. Most of Lillestrøm was also inundated in 1860 as seen from a woodcut in a newspaper that year, see Figure 3.1.14.7 on page 129. Note that the level of “Vesleofsen” in 1995 only reached the basis of the flood stone. Although the regulation of the Glomma water course is moderate, the operation of the reservoirs was sufficient to reduce the flood level of Lake Øyeren significantly. Large floods has nevertheless caused severe damages in the Lillestrøm district many times, as summarised in descriptions in Aftenposten and in several local papers in 1910, 1916, 1927, 1934, 1966, 1967 and 1995. These floods caused also a lot of public interest, and therefore attracted many visitors.

Figure 2.1.5.3 The flood stone at Lensemuseet at Fetsund (left) and the flood levels of the largest floods (right).

River Rotua is a tributary joining River Glomma from the north near Sørumsand. The river drains farmland situated on marine clays. A major clay slide occurred in the catchment "Løren-fallet" 18 June – 20 July 1794. The river was dammed by a wall of 19 meter, causing a 9 kilometers long lake to form upstream. The dam was opened manually by road workers and military personell. This required 139 days of digging.

2.1.5.2 Glåmdalen and Solør Odal

The district from Vormsund in the south to Elverum to the north have suffered repeatedly damages from the large floods in Glomma. The river channel has shiftet many times in the past, inundating and eroding farmland and causing severe damages. When large floods occur, the outflow from River Vorma can cause backwater effects in River Glomma. During large floods further upstreams in River Glomma water can flow through Opstadåa into Lake Storsjøen at Solør. The lake serves as a detention storage, releasing the water into the main river as the water level in Glomma drops. At Kongsvinger water can flow over a threshold and into River Vrangselv, which drains to Sweden (Petterson 2001). During large floods flood water has flowed into Lake Nuguren from the main river at Nor.

Upstream Kongsvinger a succession of long-term observations exists at the gauging station 2.2 Nor 1951-1866 and from 1936, 2.120 Nors bru 1851-1935 and 2.393 Norsfoss 1965-2014. The catchment characteristics are given in Table 2.1.5.7 for the three stations. Figure 2.1.5.5 show the annual floods in the joined series.

Table 2.1.5.7 Catchment characteristics of three gauging stations in Solør and Glomdalen.

Station	2.2/120/393 Nor	2.142 Knappom	2.616 Kuggerudåa
	Basin characteristics		
Catchment area (km^2)	18932	1646	43,38
Station altitude (m.a.s.l.)	147	170	171
Mean altitude (m.a.s.l)	749	411	376
Top altitude (m.a.s.l.)	2170	807	510
Lake (%)	2,72	1,84	3,1
Bog (%)	10,59	15,93	11,31
Forest (%)	54,43	72,75	85,14
Mountain (%)	22,31	0	0
Glacier (%)	0	0	0

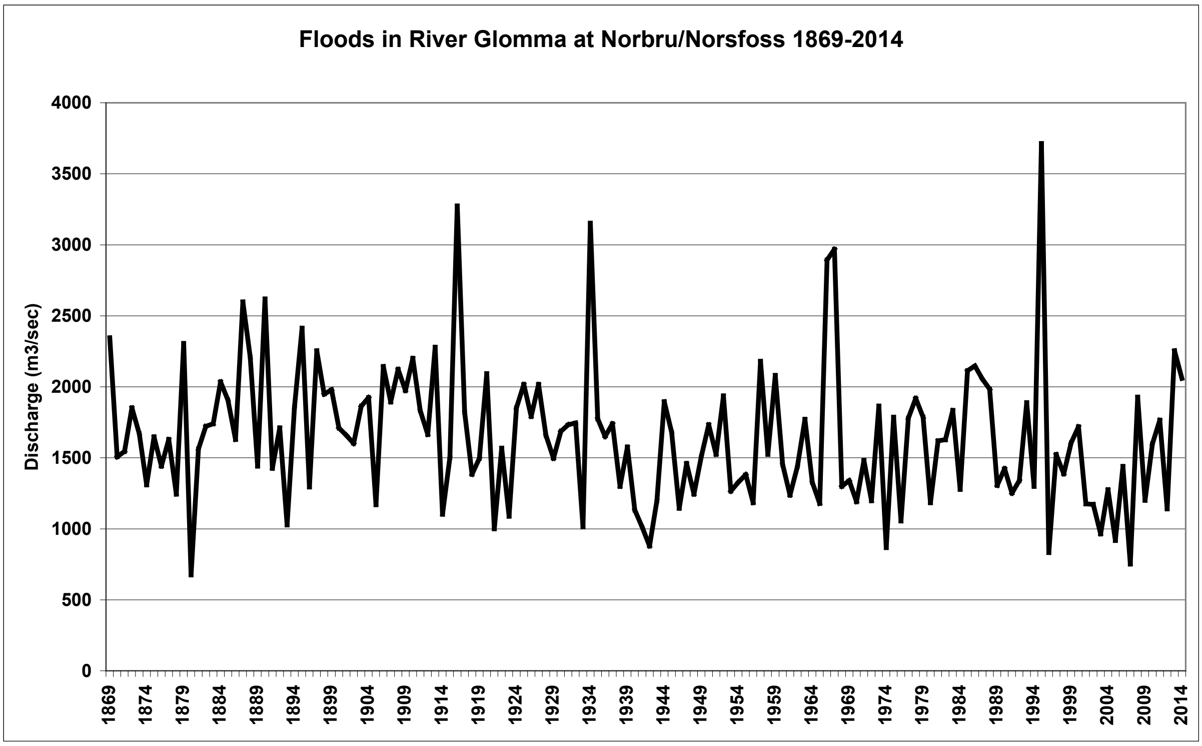


Figure 2.1.5.4 The annual floods in River Glomma at Norsbru/Norsfoss in River Glomma at Grue.

River Flisa is a tributary to River Glomma from the east. The gauging station 2.142 Knappom is located at this river. The catchment is not affected by hydropower developments. Some small reservoirs releasing water for timber floating caused several smaller floods in the spring in the past. The data series started in 1916. The large floods in River Flisa differ often from the large floods in River Glomma, because the catchment is lowlying and with more forests compared to the upstreams catchments in River Glomma. Ice run floods occurs often in the spring in the river. The date and ranks of the ten largest floods in Glomma at Nor, at Kuggeruåa i Odal and and at Knappom at Flisa is given in Table 2.1.5.8, and the date and discharge of the largest daily value in Table 2.1.5.9.

Tab 2.1.5.8 The ten largest annual floods (daily values) at the three stations in Glåmdalen.

2.2/120/393 Nor			2.142 Knappom			2.616 Kuggerudåa		
1869-2014			1916-2014			1968-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1869	19/6	8	1924	3/6	4	1969	9/5	8
1879	30/5	9	1931	19/5	4	1977	6/5	3
1890	18/5	6	1937	23/4	1	1979	26/4	9
1895	4/5	7	1959	1/5	8	1986	5/5	4
1913	6/5	10	1966	17/5	9	1988	5/5	1
1916	12/5	2	1977	8/5	6	1994	26/4	10
1934	10/5	3	1981	13/5	10	1997	8/5	5
1966	21/5	5	1986	6/5	3	1999	10-11/4	6
1967	3/6	4	1997	8/5	2	2000	21/11	7
1995	3/6	1	1998	30/4	7	2006	2/5	2

Table 2.1.5.9 The date and discharge (daily values) of the largest floods at the stations in Glåmdalen

Station	2.2/120/393 Nor	2.142 Knappom	2.616 Kuggerudåa
Year	1995	1937	1988
Date	3/6	23/4	5/5
q (m^3/sec)	3176,06	396,66	12,34
qsp (l/sec km^2)	168	241	255
qsp (mm/day)	14,5	20,8	22,0

Remarks: The floods in River Flisa differ in timing as well as severity with many large floods in the main river. The rank of the annual flood in Flisa is given in Table 2.1.4.10 in some of the large flood years in River Glomma.

Table 2.1.5.10 The rank of floods in River Flisa during large floods in River Glomma in Glåmdalen.

	2.142 Knappom						
Year	1927	1934	1967	1995	2011	2013	2014
Date	29/5	3/5	15/5	7/5	13/4	20/4	25/10
Rank	19	20	46	30	59	56	43

2.1.5.3 Østerdalen

The Glomma from Elverum to the water divide

The eastern branch of River Glomma flows through Glåmdalen and Østerdalen with some tributaries from the east: Rena, Nøra and Håelva. From the west tributaries flow from the water divide towards Gudbrandsdalen: Åsta, Imsa, Trya, Atna and Folla, Tunna and Vangrøfta. Atna and Folla drain the north and east facing parts of the Rondane massif reaching up to 2178 m.a.s.l. The rest of the catchment comprises lower mountains.

The observations started at 2.119/604 Elverum in 1871 at Elverum. The flood levels are known from several earlier large floods, which have been marked on the old floodstone, Grindalsstøtta. Further upstream 2.117/112 Stai has been operating since 1917 at Storelvdal. The gauging station 2.227 Barkaldfoss has been operating further upstream since 1935. The catchment characteristics of Elverum, Stai and Barkaldsfoss are given in Table 2.1.5.11.

Upstreams the junction with River Folla the gauging station 2.116 Auma was operating 1916-1977. The station 2.269 Hummelvoll has been operating further upstream since 1962. The gauging station 2.603 Glåmos bru is located at Røros. The station has been operating since 1902. Further upstream another long-term data series exists at 2.114 Aursunden ndf. This series is almost identical with the series from Glåmos bru. The catchment characteristics of Auma, Hummelvoll and Glåmos bru are given in Table 2

Table 2.1.5.11 Catchment characteristics of gauging stations in the main branch of River Glomma in Østerdalen below Alvdal.

Station	2.119/604 Elverum	2.117/112 Stai	2.227 Barkaldfoss
	Basin characteristics		
Catchment area (km^2)	15447	8932	6634
Station altitude (m.a.s.l.)	180	258	440
Mean altitude (m.a.s.l)	817	895	898
Top altitude (m.a.s.l.)	2170	2170	1851
Lake (%)	2,74	2,89	3,58
Bog (%)	10,58	11,58	8,71
Forest (%)	50	40,67	37,33
Mountain (%)	27	37	37,71
Glacier (%)	0	0	0

Table 2.1.5.12 Catchment characteristics of gauging stations in the main branch of River Glomma in Østerdalen upstreams Alvdal.

Station	2.116 Auma	2.269 Hummelvoll	2.603 Glåmos bru
	Basin characteristics		
Catchment area (km^2)	3646	2357	797,9
Station altitude (m.a.s.l.)	479	592	639
Mean altitude (m.a.s.l)	827	827	842
Top altitude (m.a.s.l.)	1619	1593	1572
Lake (%)	4,98	6,88	12,44
Bog (%)	10,57	11,07	9,73
Forest (%)	42,97	38,04	32,05
Mountain (%)	28,3	29,42	35,81
Glacier (%)	0	0	0

Figure 2.1.5.5 The flood stone at the Forestry museum (right) and the flood stone at Grindalen (left).

Observed floods in Glomma in Østerdalen:

Flood levels are known at several locations prior to the systematic monitoring at gauging stations (Kvernmoen & Kvernmoen, 1921; Otnes (1982a). Some of these levels have been marked on flood stones erected at the site where historical flood levels are known. The year and dates of large floods known at Storelvdal, Elverum and Nor are given in Table 2.1.5.13. The flood levels are also documented at flood stones at Elverum and Tynset. Figure 2.1.5.5 show the flood stones at the Forestry museum and the flood stone at Grindalen, both at Elverum. Figure 2.1.5.6 show the observed annual floods at Elverum (1871-2014). The dates and ranks of the ten largest observed floods at gauging stations on the main river from Elverum to Alvdal is given in Table 2.1.5.14 and the date and discharge of the largest daily flood in Table 2.1.5.15. The dominant flood season in Østerdalen is in the spring or early summer. The hydrographs of the ten largest observed floods at Elverum are shown in Figure 2.1.5.7.

Further upstreams in River Glomma, there is a new flood stone at Tynset upstreams Alvdal. The flood levels of the floods in 1934, 1967 and 1995 are shown on this stone. The dates and ranks of the ten largest floods observed at three gauging stations upstreams Alvdal are shown in Table 2.1.5.16. Table 2.1.5.17 shows the date and discharge of the three largest daily floods observed at the three stations.

Table 2.1.5.13 Historical floods observed at Storelvdal, Elverum and Nor.

Year	Date	Remarks
Ca 1450		Østerdalen and Glåmdalen
In 1520s		Glomdalen at Grue
1544		Extreme flood
1650	Spring	Ice run flood. Damages at Storelvdal
1675	28-29/5	Ice run flood. Damages at Storelvdal
1683	28/5	Storisgangen at Storelvdal
1704	Autumn	
1717	24/5	Damages in most of the valley.
1721	Spring	Ice run flood. Damages in Storelvdal
1724	Spring	Comparable to 1717
1727	Spring	Moderate in Glomma
1740	30/8	Rainstorm flood in Glåmdalen
1749	24/5	Comparable to 1717 and 1724
1772	Early june	
1773	24-30/5	Storefloden
1773	18-19/8	Autumn flood at Elverum
1774	Spring	Solør
1789	21-23/7	Storofsen
1846	24-26/5	
1850	26/5	
1867	21/6-1/7	Flood in the upper part of the catchment
1879	27-31/5	
1887	24-25/5	

Table 2.1.5.14 The dates and ranks of the ten largest floods observed at gauging stations in the main branch of River Glomma below Alvdal in Østerdalen.

2.119/604 Elverum			2.117/112 Stai			2.227 Barkaldfoss		
1872-2014			1917-2014			1935-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1879	27/5	8	1908	7/6	10	1935	17/6	7
1887	24/5	7	1913	4/5	8	1944	10/6	4
1890	16/5	6	1916	11/5	5	1945	15/5	9
1897	30/5	9	1934	8/5	2	1958	28/5	10
1916	11/5	3	1944	11/6	9	1966	20/5	5
1934	19/5	2	1966	20/5	3	1967	30/5	2
1966	8/5	4	1967	31/5	4	1973	2/6	6
1967	20/5	5	1973	2/6	6	1985	28/5	8
1995	2/6	1	1995	2/6	1	1995	3/6	1
2013	23/5	10	2013	23/5	7	2013	23/5	3

Table 2.1.5.15 The dates and discharge of the largest daily flood at three stations in River Glomma below Alvdal.

Station	2.119/604 Elverum	2.117/112 Stai	2.227 Barkaldfoss
Year	1995	1995	1995
Date	2/6	2/6	3/6
q (m^3/sec)	3238,97	1947,77	1469,86
qsp (l/sec km^2)	210	217	221
qsp (mm/day)	18,1	18,8	19,2

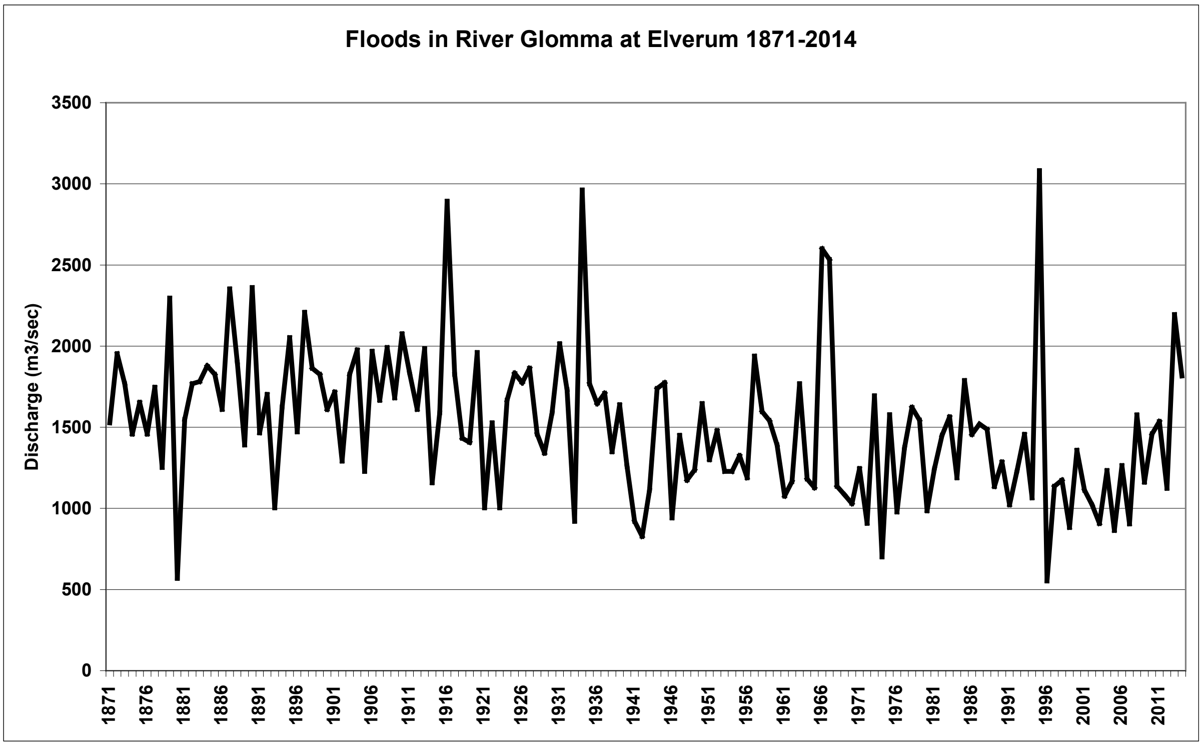


Figure 2.1.5.6 Annual floods (daily values) in River Glomma at Elverum 1871-2014.

Table 2.1.5.16 The year, dates and ranks of the ten largest floods observed at gauging stations in the main branch of River Glomma upstreams Alvdal in Østerdalen.

2.116 Auma			2.269 Hummelvoll			2.603 Glåmos bru		
1916-1977			1962-2014			1902-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1934	8/5	1	1966	19/5	2	1903	1-2/6	9
1938	15/6	8	1967	27/5	6	1906	19/5	6
1940	25/8	10	1973	1/6	8	1907	18/6	4
1944	11/6	2	1976	21/5	6	1910	25-26/5	8
1958	28/5	7	1985	29/5	3	1917	5/6	2
1966	20/5	4	1989	1/8	5	1926	7/6	1
1967	30/5	4	1992	24/5	4	1927	30/6,1/7	10
1973	2/6	3	1995	2/6	1	1938	10/6	7
1975	12/5	9	1997	9/6	10	1989	1/8	3
1976	22/5	6	2011	17/8	8	1995	6/6	5

2.1.5.17 The date and discharge of the largest daily flood observed at stations in River Glomma upstreams Alvdal.

Station	2.116 Auma	2.269 Hummelvoll	2.603 Glåmos bru
Year	1934	1995	1926
Date	8/5	2/6	7/6
q (m^3/sec)	692,51	468,18	186,72
qsp (l/sec km^2)	190	193	217
qsp (mm/day)	16,4	16,7	18,7

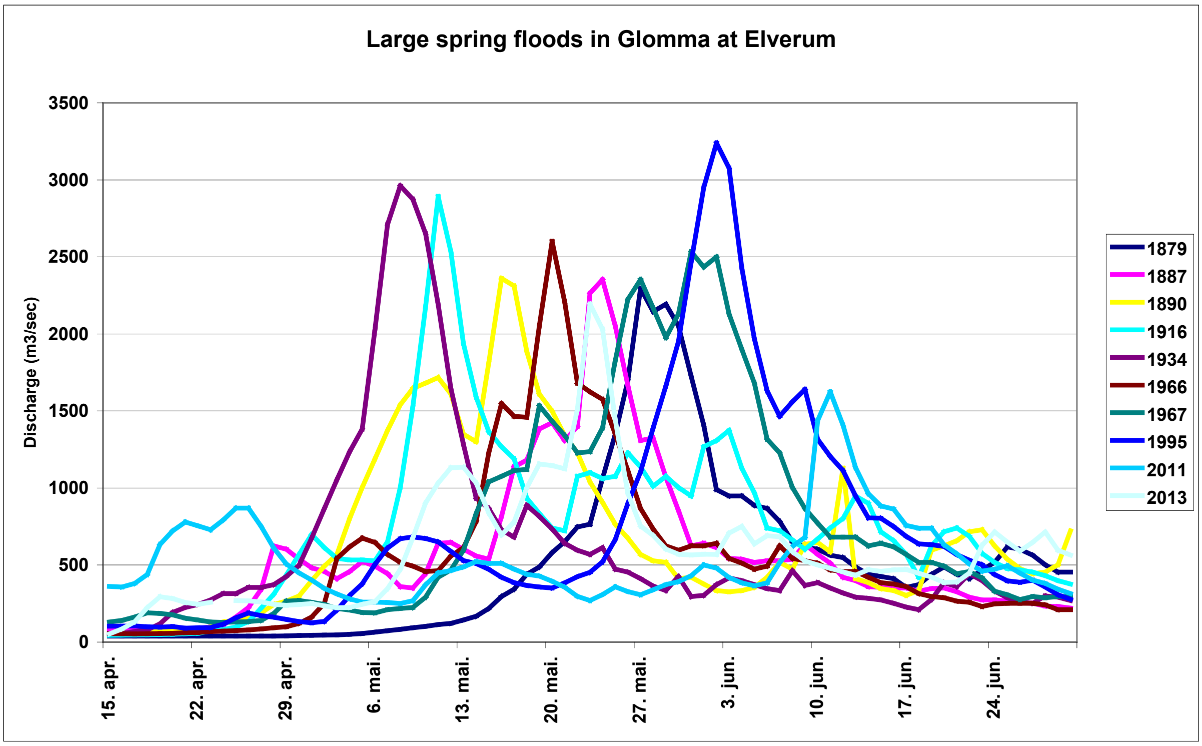


Figure 2.1.5.7 Daily discharges of the largest observed floods in River Glomma at Elverum.

Tributaries to River Glomma in Østerdalen

The junction betweeen the tributary Nøra and River Glomma is at Os in Nord-Østerdalen. A gauging station is located at the Nøra catchment at Lake Narsjø. The station 2.11 Narsjø has been operating since 1931. The annual flood is almost exclusively the spring flood, which occurs in 72 percent of all years in May and 18,5 percent in June. The annual flood has occurred in August, simultaneously with extreme floods in River Gaula, as 24 August 1940 and 16 August 2011. These floods are, however, not among the largest annual floods in River Nøra.

River Folla flows from the southeastern part of Dovrefjell eastward to the junction with River Glomma at Alvdal. There are some gauging stations in the river. The station 2.129 Dølplass has been operating since 1908. The long-term precipitation station 09100 Foldal has been operating since 1895. The station was equipped with a shield in 1907. 28 July 1935 a one-day rainfall of 125,5 mm was observed at the station. Unfortunately, there are no observations of the discharge in River Folla during this event. The gauging station 2.9 Vålåsjø in River Folla has been operating since 1922. The catchment area of Vålåsjø is 119 square kilometers.

Parts of the discharge east- and northwards from Rondane massif flow through River Atna into Lake Atnasjø. A long-term gauging station 2.32 Atnasjø has been operating since 1916. There are a long-term precipitation series observed at the met stations 0710 Sør-Nesset since 1951 and at 0720 Atnasjø since 1903.

Catchment characteristics of the three gauging stations Narsjø, Dølplass and Atnasjø are given in Table 2.1.5.18.

Table 2.1.5.18 Catchment characteristics of gauging stations in the tributaries Nøra, Folla and Atna to River Glomma.

Station	2.11 Narsjø	2.129 Dølplass	2.32 Atnasjø
	Basin characteristics		
Catchment area (km^2)	119	2013	463
Station altitude (m.a.s.l.)	737	529	701
Mean altitude (m.a.s.l)	939	1099	1205
Top altitude (m.a.s.l.)	1593	1851	2170
Lake (%)	3,12	1,45	1,8
Bog (%)	11,73	7,33	
Forest (%)	23,86	22,14	20
Mountain (%)	48,13	56,26	69
Glacier (%)	0	0,01	0

River Imsa flows from Ringebufjellet southeastwards to the junction with River Glomma at Stai. The reach between Koppang and Stai is known as Koppangsøyene. Large floods in the two tributaries have caused severe damages to the farms on the flood plain there. These floods have often occurred as a result of severe ice runs.

River Åsta is a tributary joining River Glomma at Koppang from the west. Many of the spring floods in this river are ice run floods. These floods have caused frequent damages in Østerdalen.

River Trya flows southeastwards from Storvola to the junction with River Glomma at Koppang. There is no gauging station in this tributary. The flood in June 2011 damaged the road and railwayline at Koppang.

River Rena is a major tributary joining River Glomma from the east. The catchment of River Rena is square kilometres. River Rena flows from the north in a parallel valley to Østerdalen east of Glomma. The river flows southwards from mountains west of Trysilelv through Lake Storsjøen. There is a major tributary flowing in from the east near Rena. This tributary is named Osa. River Rena and River Osa are regulated. There are several gauging stations in the Rena catchment. A long-term series is located at 2.611 Storsjøen in River Rena 1902-2012. The discharge from the regulated Osa branch of River Rena is at 2.140 Valmtjern 1908-2012. Two gauging stations are operating in tributaries to Rena at 2.267 Mistra bru 1961-2014 and 2.265 Unsetåa 1961-2014. Catchment characteristics are given in Table 2.5.19 for the gauging stations in River Rena, Osa and Mistra.The spring flood in 1916 caused dam failure with one fatality, see Chapter 3.1.20 in this Volume. The gauging station Storsjøen ndf has been operating 1902-2014.

Catchment characteristics of the three gauging stations Narsjø, Dølplass and Atnasjø are given in Table 2.1.5.19.

Table 2.1.5.19 Catchment characteristics of gauging stations in eastern tributaries to River Glomma in the Rena catchment.

Station	2.611 Storsjøen ndf Øra	2.267 Mistra bru	2.140 Valmtjern
	Basin characteristics		
Catchment area (km^2)	2337	549,9	1175
Station altitude (m.a.s.l.)	249	320	437
Mean altitude (m.a.s.l)	765	807	624
Top altitude (m.a.s.l.)	1743	1743	1201
Lake (%)	3,32	0,89	4,54
Bog (%)	9,89	17,08	17
Forest (%)	58,09	48,92	64,65
Mountain (%)	23,39	28,05	8,09
Glacier (%)	0	0	0

The longest data series from a lowlying forested catchment east of Glåmdalen is from River Flisa at 2.142 Knappom, starting in from 1916. Catchment characteristics is given in Table 2.1.5.7. The floods have been modified by release of water from dams to facilitated timber floating in the past.

Table 2.1.5.20 Date and ranks of the ten largest floods observed at gauging stations in western tributaries to River Glomma in Østerdalen.

2.11 Narsjø			2.129 Dølplass			2.32 Atnasjø		
1930-2014			1908-2014			1917-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1932	19/5	8	1913	3/5	10	1917	31/5	11
1934	6/5	1	1916	10/5	9	1926	30/5	9
1944	10/6	11	1921	28/5	8	1934	6/5	6
1947	14/5	4	1944	10/6	2	1939	20/5	5
1950	28/7	10	1945	19/5	11	1966	19/5	2
1958	27/5	2	1966	30/5	7	1967	31/5	7
1966	19/5	3	1967	30/5	5	1973	2/6	3
1967	26/5	5	1986	3/5	9	1979	2/6	9
1978	24/5	9	1995	2/6	6	1995	1/6	1
1985	28/5	7	2011	10/6	3	2003	16/8	8
1995	2/6	6	2013	23/5	1	2013	23/5	4

Table 2.1.5.21 Flood levels of historical floods observed in western tributaries to River Glomma.

Station	2.11 Narsjø	2.129 Dølplass	2.32 Atnasjø
Year	1934	2013	1995
Date	6/5	23/5	1/6
q (m^3/sec)	67,44	516,05	209,68
qsp (l/sec km^2)	566	256	342
qsp (mm/day)	49	22	30

Remarks: Data are unfortunately missing at Dølplass 1934-1936, but data from other stations in the vicinity indicates that the flood in May 1934 may have been the largest in the series in the lower River Folla. Data is also missing from 1935 when 125,5 mm rain fell at the precipitation station Foldal 28 June.

The flood 2011 – 9-11 June - *Pinseflommen 2011* - does not rank among the largest observed floods at Elverum and Atna in spite of closed roads and damages to the railway line in Østerdalen.

The flood 2013 – 21-23 May - *Pinseflommen 2013* in Østerdalen - caused some damages to roads and railway but does not rank among the largest flood in Østerdalen except at Dølplass in River Folla. Other mountain floods in tributaries in Østerdalen in: 1939, 1947, 1958 and 1973 were neither among the largest floods in the main river.

The annual floods at Atnasjø is shown in Figure 2.1.5.8, at Rena in Storsjøen in Figure 2.1.5.9 and at Knappom in Figure 2.1.5.10.

Table 2.1.5.22 The year, dates and ranks of the ten largest floods observed at gauging stations in western tributaries from River Rena to River Glomma.

2.611 Storsjøen ndf Øra			2.267 Mistra bru			2.140 Valmtjern		
1902-2012			1961-2014			1908-2012		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1910	20/5	10	1966	19/5	4	1910		9
1916	12/5	5	1967	25/5	1	1916	11-12/5	2
1920	22/5	7	1975	12/5	7	1920	21/5	5
1931	20/5	8	1978	23-24/5	6	1931	19/5	5
1934	9/5	3	1979	18/5	7	1934	7/5	3
1957	22/5	9	1986	8/5	5	1936	12/5	7
1966	21/5	4	1987	2/5	7	1938	10/10	7
1967	28/5	2	1995	2/6	2	1950	29/7	4
1995	1/6	1	2008	3/5	10	1957	15/9	1
2011	11/6	6	2014	26/5	3	1987	14/10	10

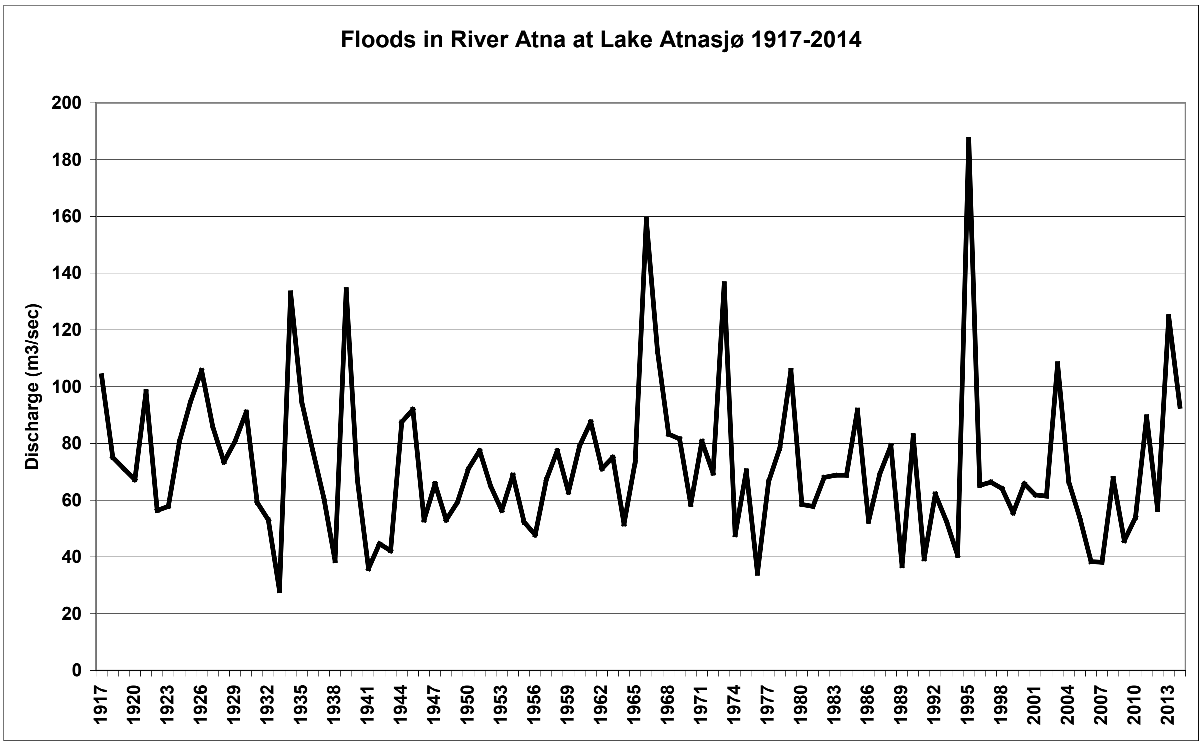


Figure 2.1.5.8 Annual floods (daily values) in River Atna at Atnasjø 1916-2013.

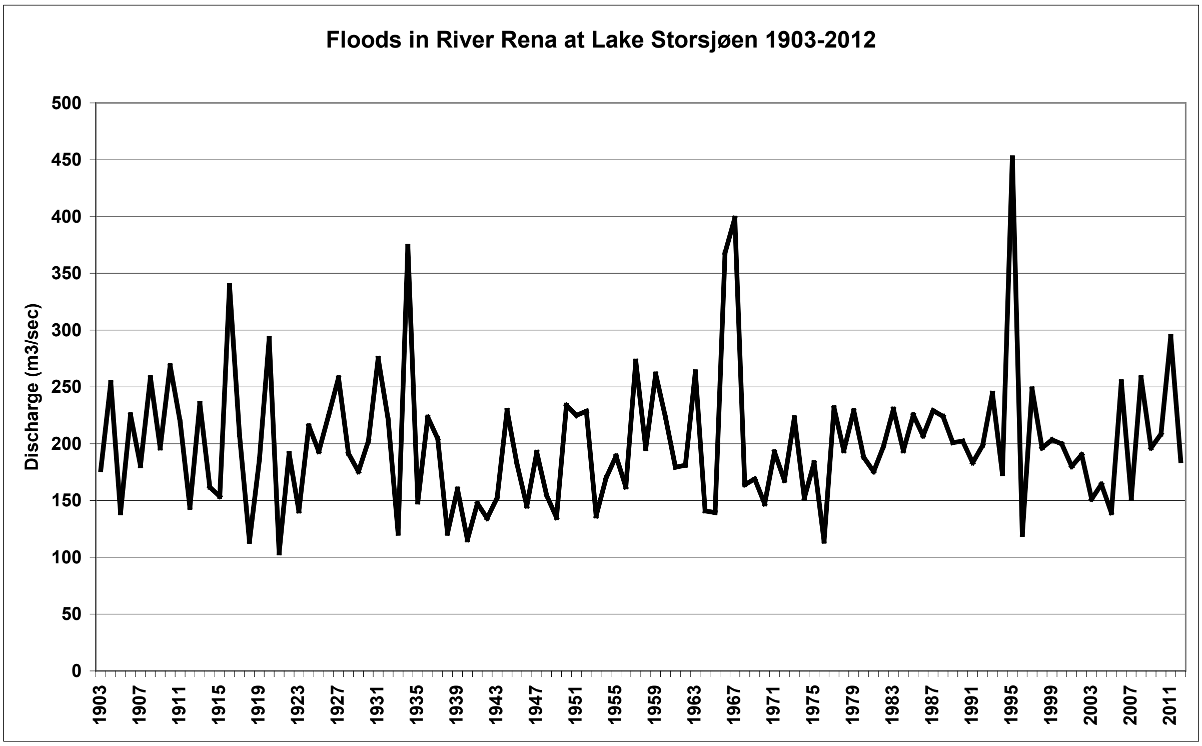


Figure 2.1.5.9 Annual floods (daily values) in River Rena at Lake Storsjøen 1917-2014.

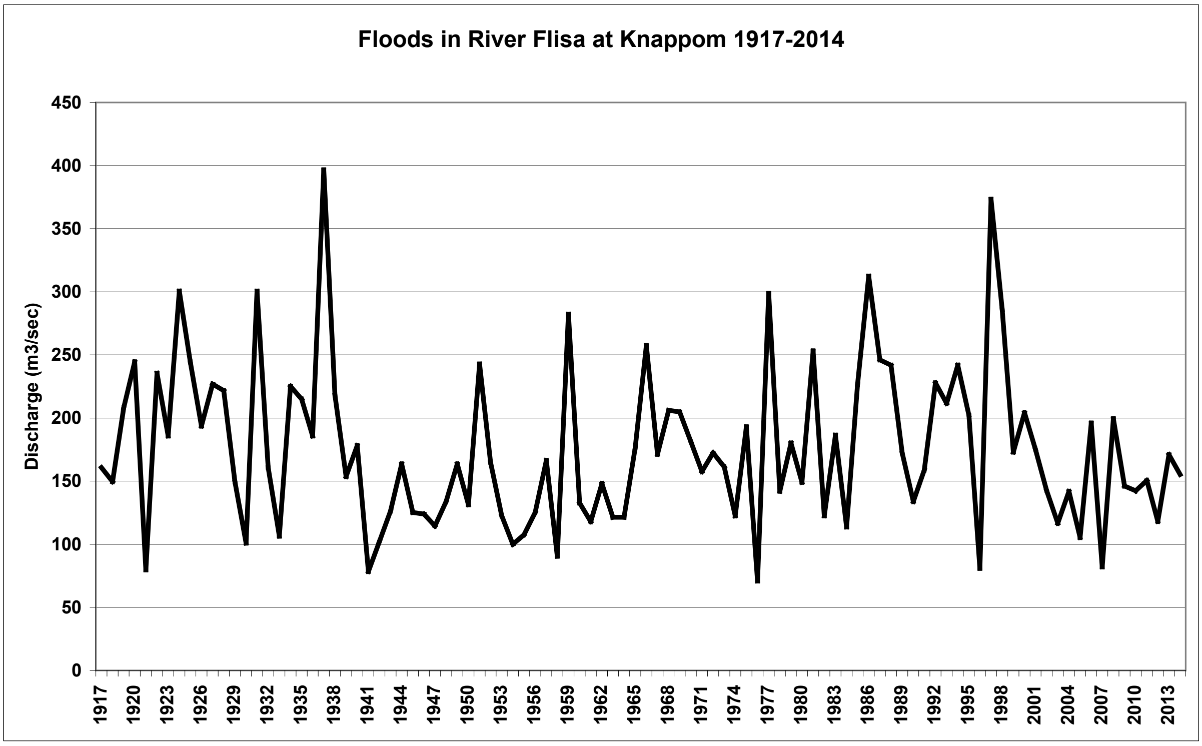


Figure 2.1.5.10 Annual floods (daily values) in River Flisa at Knappom 1917-2014.

2.1.5.4 VORMA/LÅGEN/OTTA

The western branch of Glomma comprises Vorma, Mjøsa and Gudbrandsdalslågen with tributaries: Mesna, Moksa, Frya, Ula and Jora from the east and some larger rivers Gausa, Vinstra, Sjoa and Otta from the west. Rivers Vinstra, Sjoa and Otta drain most of Jotunheimen. Steep tributaries east of Gudbrandsdalslågen can carry large masses of gravel during large floods. This has caused locally severe damages under some large floods. Among these tributaries are Rivers Moksa, Frya, Veikleåa, Ula, Ryddøla, Hjelleåa, Hindi and Jora. River Ilka flowing from west has caused severe damages at Dovre. The tributary Finna, flowing into River Otta from north at Vågåmo has caused severe damages during several large floods. Finna and the brook Nugga carries rocks and gravel which fill the riverbed, forcing water to erode new channels through the village. The tributary Tessa flowing northward to Lake Vågåvatn, River Vulu, flowing through Graffer to Garmo and River Bøvra flowing from Bøverdalen to Lom has also caused extensive damages.

RIVER VORMA

River Vorma flows from the outlet of Lake Mjøsa at Minne to the confluence with River Glomma at Vormsund. The catchment area is 17294 square kilometers. The largest tributary, River Andelva flows into Vorma from west near Eidsvoll. The river flows through a district where quick clay is present at many locations. The district has therefore suffered substantial damages from many clay slides (Løken et al., 1970; Furseth, 2006). A huge clay slide at the farm Thesen in 1795 formed a dam in Vorma, causing the river to be blocked for 111 days before the blockage could be opened. This caused a rise of the upstream river and into Lake Mjøsa of approximate eight meters.

The earliest systematic daily observations of the water level in Norway took place at Minne (1824-1827) (Schive, 1828). Campaign measurements were performed at many locations in Vorma and Glomma from 1846 and into the 1850s in connection with the construction of the railway from Kristiania to Eidsvold. Several data series exist from the second half of the 19th Century upstreams and downstreams Sundbyfoss.

Large floods in Vorma have occurred frequently and has been documented by Johnsen (1861), Sætren (1904), Helland () and several others. Flood levels are shown at a flood stone recently erected outside the bank at Eidsvoll.

LAKE MJØSA

Lake Mjøsa is the largest lake in Norway and extends from Minnesund to Lillehammer. Three towns are located on the bank of Mjøsa. The oldest town is Hamar, which is located on the east side. The lower part of Hamar has suffered from inundations at Strandgaten during the largest floods. Lillehammer is located on the east side, close to the inlet of the upstreams River Gudbrandsdalslågen. Gjøvik is located on the western side opposite to Hamar. This town was funded just before the large flood in 1860. The upper part of the town had been developed when the flood inundated the lower part, where fortunately no development had taken place yet. The water levels in Lake Mjøsa are known from 1846 onwards, but the water levels are known from three earlier floods, Storofsen i 1789 and the floods in 1808 and 1827. The level after the slide damming River Vorma at Thesen in 1795 was probably around eight meters in Lake Mjøsa, but the exact level is not known. Figure 2.1.5.11 show the water levels at Hamar brygge (1789-2013). The peak of Storofsen exceeded the peak of the 1860 by only three centimeters.

The flood levels are shown at the flood stone at Hamar brygge as shown in Figure 2.1.5.12.

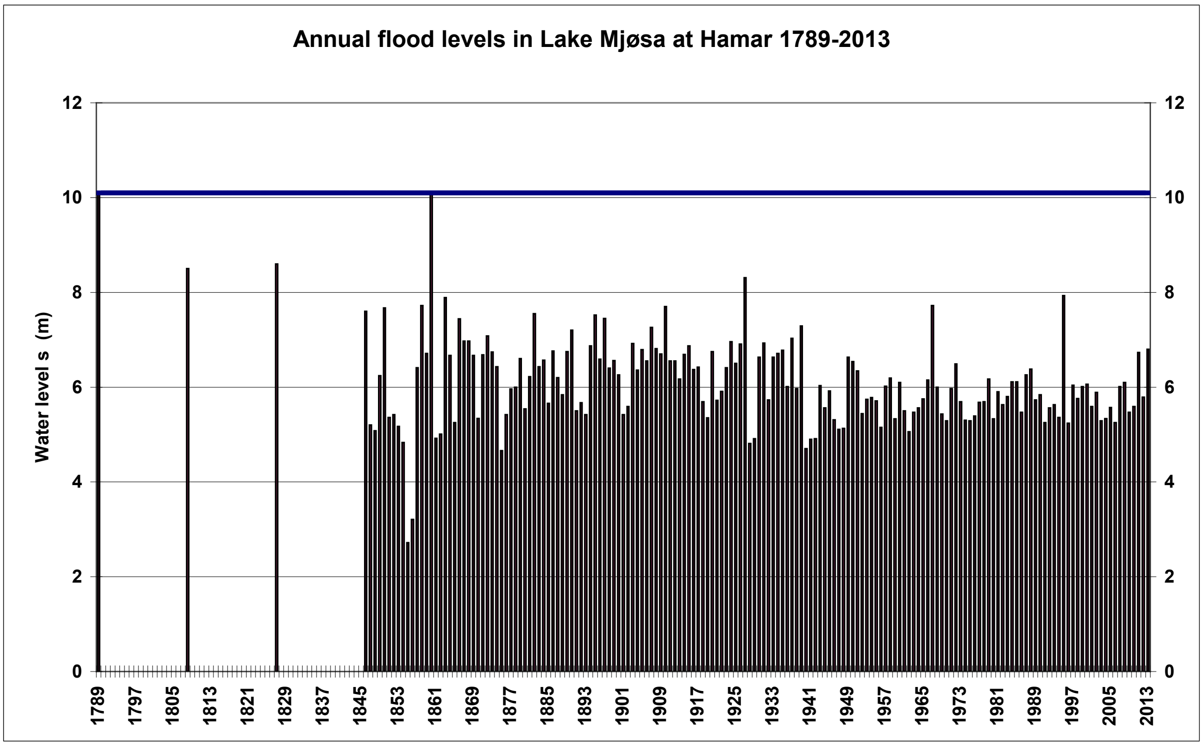


Figure 2.1.5.11 The annual flood peaks at Hamar brygge 1789-2013.

Figure 2.1.5.12 The flood stone at Hamar brygge.

Tributaries to Lake Mjøsa

Many smaller rivers, mostly in lowland catchments, flow into Lake Mjøsa. The annual flood occurs most frequently in April or May, but local rain floods have caused a occasionally local floods in these rivers such as in September 1988 from River Lena to Lillehammer and in recent years, causing local damages to buildings and delaying the construction of new roads and railway line east of Lake Mjøsa.

River Fosselva, River Svartelva, River Flakstadelva, River Brummunda and River Mesna from the East. River Fosselva flows northwestward into Mjøsa at Tangen south of Hamar, River Svartelva and River Flakstadelva into Akersvika next to Hamar, River Brummunda into the bottom of Furnesfjorden north of Hamar and River Mesna westward through the town, Lillehammer. The discharge has been observed at a few gauging stations since the 1980s in some of these rivers. Table 2.1.5.23 show catchment characters at the stations 2.464 Svartelva, 2.465 Flagstadelva and 2.323 Fura. The latter station is located at a research catchment located at a tributary to Svartelva. This station has been active since 1970. The dates and ranks of the ten largest daily floods are shown in Table 2.1.5.24 and the date and discharge of the largest flood in Table 2.1.5.25.

Table 2.1.5.23 Catchment characteristcs of three lowland catchments near Hamar east of Lake Mjøsa.

Station	2.464 Svartelva	2.465 Flagstadelva	2.323 Fura
	Basin characteristics		
Catchment area (km^2)	474,5	172,0	42,47
Station altitude (m.a.s.l.)	138	128	349
Mean altitude (m.a.s.l)	300	529	575
Top altitude (m.a.s.l.)	758	819	758
Lake (%)	1,31	0,4	0,05
Bog (%)	6,54	20,21	14,96
Forest (%)	67,97	58,62	79,99
Mountain (%)	6,54	0	0
Glacier (%)	67,97	0	0

Table 2.1.5.24 The year, dates and ranks of the ten largest floods (daily values) at stations draining towards Akersvika at Hamar.

2.464 Svartelva			2.465 Flagstadelva			2.323 Fura		
1986-2014			1986-2014			1970-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1986	5/5	1	1986	5/5	8	1988	20/8	6
1987	2/5	6	1987	16/10	6	1996	19/4	4
1988	20/8	5	1988	20/8	5	1997	7/5	8
1995	6/5	8	1992	2/5	1	1999	22/7	7
1997	3/5	7	1995	2/6	7	2008	2/5	10
2010	25/9	10	1997	8/5	10	2010	24/9	9
2011	5/9	2	2008	2/5	9	2011	5/9	2
2012	11/11	9	2011	5/9	4	2012	11/11	5
2013	22/5	3	2013	22/5	3	2013	22/5	3
2014	24/10	4	2014	24/10	2	2014	24/10	1

Figure 2.1.5.25 Date and discharge of the largest floods draining towards Akersvika near Hamar.

Station	2.464 Svartelva	2.465 Flagstadelva	2.323 Fura
Year	1986	1992	2014
Date	5/5	2/5	24/10
q (m^3/sec)	115,16	61,25	26,75
qsp (l/sec km^2)	251	354	630
qsp (mm/day)	21,7	30,6	54,4

Rivers Lena, Hunnselva, Vismunda flows into Lake Mjøsa from the west. Lake Lena drains a lowland agricultural and forested area, Toten. River Hunnselv is regulated and flows through the town, Gjøvik. River Vismunda is also a lowland catchment as River Lena.

RIVER GAUSA

River Gausa is a tributary to Lake Mjøsa flowing into the lake from northwest downstream the inlet of River Gudbrandsdalslågen between Lillehammer and Fåberg. The river has a catchment area of 932 square kilometres. West of the water divide is River Dokka, the easternmost branch of River Drammenselv. To the north River Vinstra is flowing towards Gudbrandsdalen. The waterdivide to the east faces Gudbrandsdalen.

There is one long-term gauging station in the catchment at 2.28 Aulestad which has been operating since 1930. The annual floods are shown in Figure 2.1.5.13. The catchment characteristics are given in Table 2.1.5.26 For Rivers Vismunda, Gausa and Espa, a branch of River Vinstra flowing to Gudbrandsdalen at Vinstra. There is a long-term precipitation station 13100 Vestre Gausdal, which has been active since 1895. The dates and ranks of the ten largest annual floods at Vismunda, Aulestad and Espedalsvatn are given in Table 2.1.5.26 and the date and discharge of the largest floods in Table 2.1.5.28.

Several large floods are known from historical sources in Gausdal as well as in Gudbrandsdalslågen. An important source is the weather diary of Army Captain Amund Bøe, covering some large events in the 18th Century including *Storofsen*.

A hydropower dam collapsed in the tributary Roppa 17.5 1976 producing a spectacular flood down to Lake Mjøsa, NVE has produced a film based on amateur films taken by spectators to the event.

Table 2.1.5.26 Catchment characteristics of three catchments west and northwest of Lake Mjøsa.

Station	2.463 Vismunda	2.28 Aulestad	2.415 Espedalsvatn
	Basin characteristics		
Catchment area (km^2)	190,65	290	90,8
Station altitude (m.a.s.l.)	188	193	721
Mean altitude (m.a.s.l)	689	848	1055
Top altitude (m.a.s.l.)	1066	1513	1449
Lake (%)	1,6	2,41	7,87
Bog (%)	18,49	13,68	4,63
Forest (%)	73,9	57,95	40,98
Mountain (%)	0,72	7,94	40,5
Glacier (%)	0	0	0

Table 2.1.5.27 Dates and ranks of the ten largest floods (daily values) at stations in River Vismunda, Gausa and Vinstra.

2.463 Vismunda			2.28 Aulestad			2.415 Espedalsvatn		
1986-2014			1930-2014			1976-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1987	16/10	3	1934	31/8	4	1977	28/5	8
1988	3/9	2	1952	6/5	6	1978	28/5	7
1993	3/5	7	1964	10/10	9	1983	20/5	10
1994	10/9	5	1966	19/5	3	1985	29/5	8
1995	2/6	1	1973	1/6	8	1993	4-5/5	4
2000	12/10	8	1977	25/5	10	1995	2/6	1
2002	28/5	9	1979	25/5	5	2008	12/5	6
2007	5/7	10	1988	3/9	7	2010	23/5	5
2008	2/5	6	1995	2/6	2	2013	23/5	2
2013	22/5	4	2013	23/5	1	2014	25/5	3

Table 2.1.5.28 Date and discharge of the largest floods (daily values) at stations in River Vismunda, Gausa and Vinstra.

Station	2.463 Vismunda	2.28 Aulestad	2.415 Espedalsvatn
Year	1995	2013	1995
Date	2/6	23/5	2/6
q (m^3/sec)	169,44	464,36	60,87
qsp (l/sec km^2)	889	536	639
qsp (mm/day)	76,8	46	55,2

Remarks.
The spring flood in Gausa peaked 8 May 1934 but was 50 m^3/s smaller than a subsequent rainfall flood 31 August 1934.

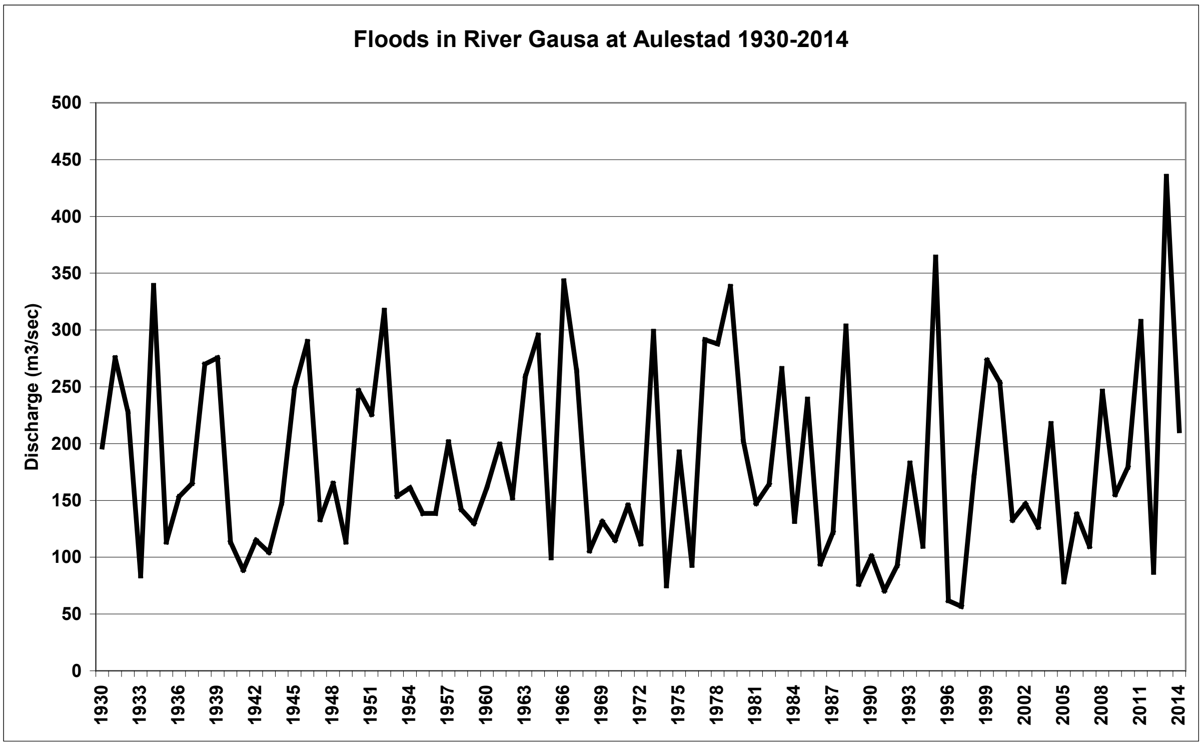


Figure 2.1.5.13 Annual floods (daily values) in River Gausa at Aulestad 1930-2014.

RIVER MESNA

River Mesna is a tributary to Lake Mjøsa flowing through Lillehammer from the east. The river is regulated. Several of the large floods from 1916 to 1995 have caused damages in Lillehammer by timber from released by the floods from the sawmills.

RIVER GUDBRANDSDALSLÅGEN

Long discharge series are available in River Gudbrandsdalslågen at 2.145 Losna and at 2.110 Skjenna in Sel upstreams the junction with River Otta succeeded by gauging stations at 2.143 Lårgård bru and 2.640 Rosten. In River Otta a long-term series starts at 2.25 Lalm in Sel/ Vågå from 1907. River Vorma with Mjøsa, Gausa, Mesna, Moksa, Vinstra and Otta are moderately influenced by hydropower regulations. The floods, downstream the dams are in most years lower than they would have been if the river was not regulated.

The data series in River Gudbrandsdalslågen at 2.145 Losna starts in 1896. Some data have been observed at the nearby station Båtstø (1884-1889). Table 2.1.5.29 gives an overview of historical floods known in Gudbrandsdalen prior to the observations

Table 2.1.5 29 The largest floods in Gudbrandsdalen according to historical sources.

Year	Date	Remarks
1342 /48	Summer?	Digerofsen - extreme flood in River Finna at Vågåmo
1655		Flood/landslide into River Bøvra at Galdesand. The Church was taken by the river.
1708	Summer?	Large flood in River Bøvra
1743	December	Ice run floods in River Otta at Skjåk and in River Bøvra
1760		Severe flood in River Gausa and in Gudbrandsdalen.
1789	21-23 July	Storofsen - extreme flood
1808	Spring	Large flood - damages at Fron and fourth highest level in Lake Mjøsa.
1827	Spring	Large flood - third highest level in Lake Mjøsa.
1846	Spring	Large flood - eight highest level in Lake Mjøsa
1850	Spring	Large flood - 10th highest level in Lake Mjøsa
1860	Mid June	Extreme flood - second highest flood in Gudbrandsdalen.
1863	Spring	Large flood - seventh highest level in Lake Mjøsa
1879	Spring	Large flood

Discharge data from Gudbrandsdalslågen at Sel was observed at 2.110 Skjenna 1878-1921, 2.143 Lårgård bru 1917-1945 and 2.614 Rosten 1945-2014. These series have been joined into a series covering the period 1878-2014. The catchment is 1.870 square kilometers at Skjenna, 1.836 square kilometer at Lårgård bru and 1.833 square kilometer at Rosten. Lårgård bru is located 300 m.a.s.l and Rosten 319 m.a.s.l. The mean altitude of the catchment is 1186 m.a.s.l, and the highest point is 2207 m.a.s.l at Dovrefjell.

Further upstreams is 2.346 Lesjaverk 1971-2014 located downstream the outlet of Lake Lesjaskogsvatn. Lake Lesjaskogsvatn has an outlet to the north to River Rauma in addition to the main outlet at Lesjaverk. Catchment characteristics of Losna, Skjenna/Rosten and Lesjaverk are given in Table 2.1.5.30. The dates and ranks of the ten largest daily floods are given in Table 2.1.5.31 and the date and discharge of the largest flood in Table 2.1.5.32.

Table 2.1.5.30 Catchment characteristics of three stations in River Gudbrandsdalslågen.

Station	2.145 Losna	2.614 Skjenna/Rosten	2.346 Lesjaverk
Basin characteristics	Basin characteristics		
Catchment area (km^2)	11212	1836/1833	89,7
Station altitude (m.a.s.l.)	179	300/319	611
Mean altitude (m.a.s.l)	1139	1186	1229
Top altitude (m.a.s.l.)	2463	2207	1741
Lake (%)	3,89	1,44	3,4
Bog (%)	3,41	2,05	1,04

Forest (%)	25,28	21,57	25,31
Mountain (%)	56,34	67,6	67,18
Glacier (%)	3	0,36	0,34

Table 2.1.5.31 The dates and ranks of the ten largest annual floods observed at gauging stations in River Gudbrandsdalslågen.

2.145 Losna			2.614 Skjenna/Rosten			2.246 Lesjaverk		
1896-2014			1879-2014			1980-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1897	9/7	7	1879	29/5	9	1981	26/5	8
1910	15/6	6	1897	30/5	4	1988	30/5	8
1916	11/5	9	1909	25/6	5	1989	21/6	1
1924	24/6	8	1921	28/5	3	1990	10/6	2
1934	10/5	5	1924	23/6	8	1993	24/5	10
1938	1/9	1	1935	17/6	6	1997	3/7	3
1939	21/6	3	1938	1/9	6	2004	8/5	6
1958	2/7	10	1971	31/5	10	2005	24/6	5
1995	3/6	2	1973	1/6	2	2011	11/6	4
2011	12/6	4	1995	2/6	1	2014	25/5	7

Table 2.1.5.32 The date and discharge of the largest flood (daily values) at the three stations on River Gudbrandsdalslågen.

Station	2.145 Losna	2.614 Skjenna/Rosten	2.246 Lesjaverk
Year	1938	1995	1989
Date	1/9	2/6	21/6
q (m^3/sec)	2851,93	662,68	22,46
qsp (l/sec km^2)	254	361	250
qsp (mm/day)	22,0	31,2	21,6

Remarks: The flood Vesleofsen 2/6 1995 ranks as no 25 at Liavatn and as no 33 at Tora

The annual floods at Losna are shown in Figure 2.1.5.14. Figure 2.1.5.15 show the bottom of the floodstone south of Ringebu. The level of Storofsen seems unreasonable compared to the 1860 flood. The most likely explanation is that the river must have been blocked by one or more landslides, temporary damming the river in 1789. Figure 2.1.5.16 show the annual floods in the composite series of Rosten/Skjenna (1879-2014). Figure 2.1.5.17 show hydrographs of the 15 largest floods in the upper Gudbrandsdal at Rosten.

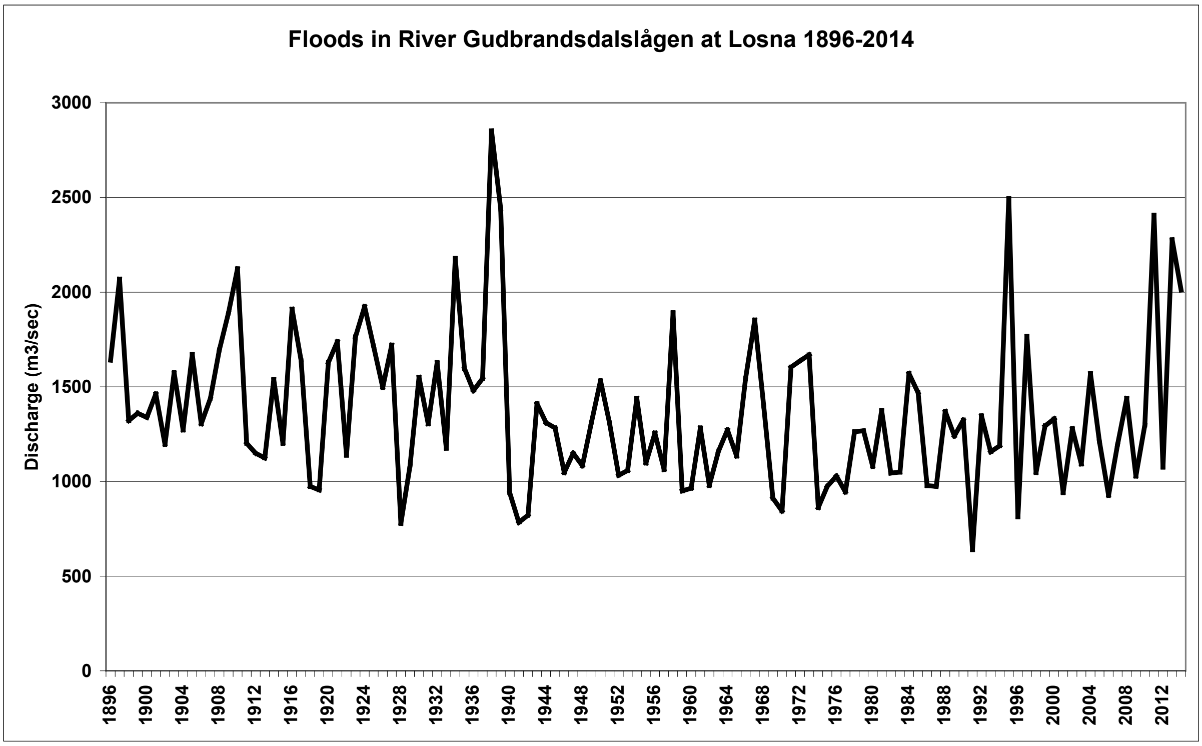


Figure 2.1.5.14 Annual floods (daily values) in River Gudbrandsdalslågen at Losna 1896 2014.

Figure 2.1.5.15 The bottom of the flood stone south of Ringebu in Gudbrandsdalen.

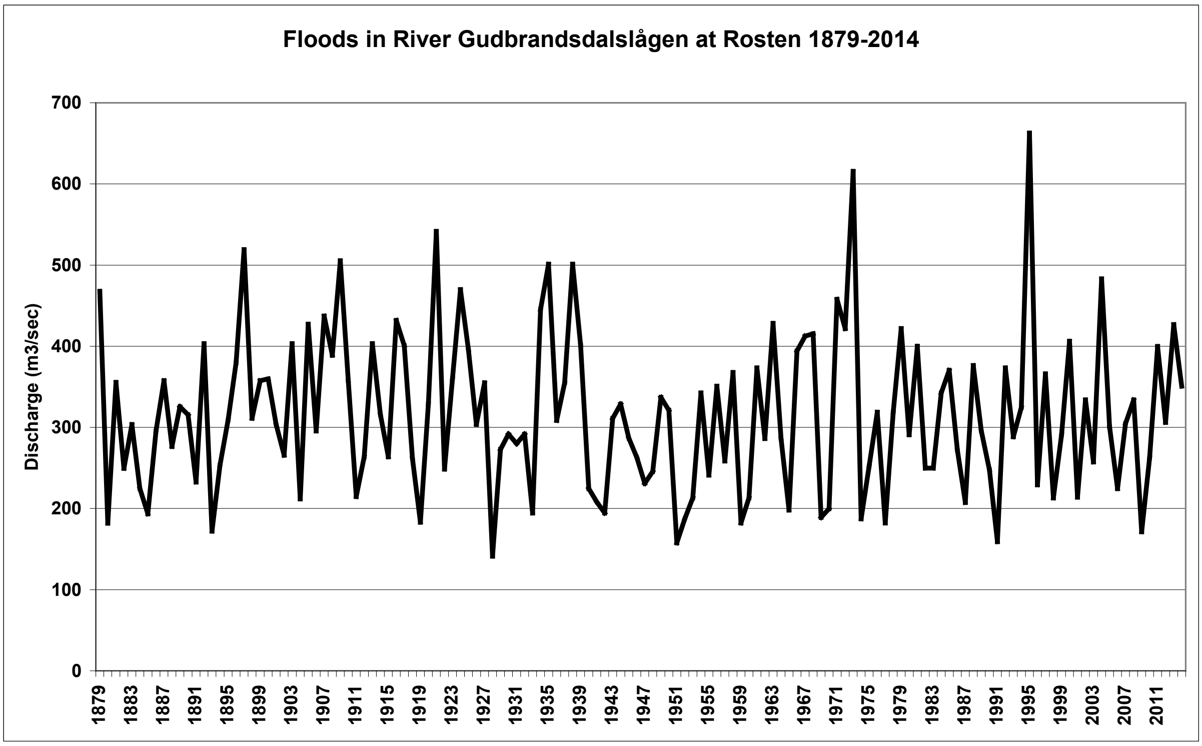


Figure 2.1.5.16 Annual floods (daily values) in River Gudbrandsdalslågen at 2.614 Rosten 1879-2014. The series comprise three series observed at slightly different locations: 2.110 Skjenna 1879-1921, 2.143 Lårgård bru 1917-1945 and 2.614 Rosten 1945-2014.

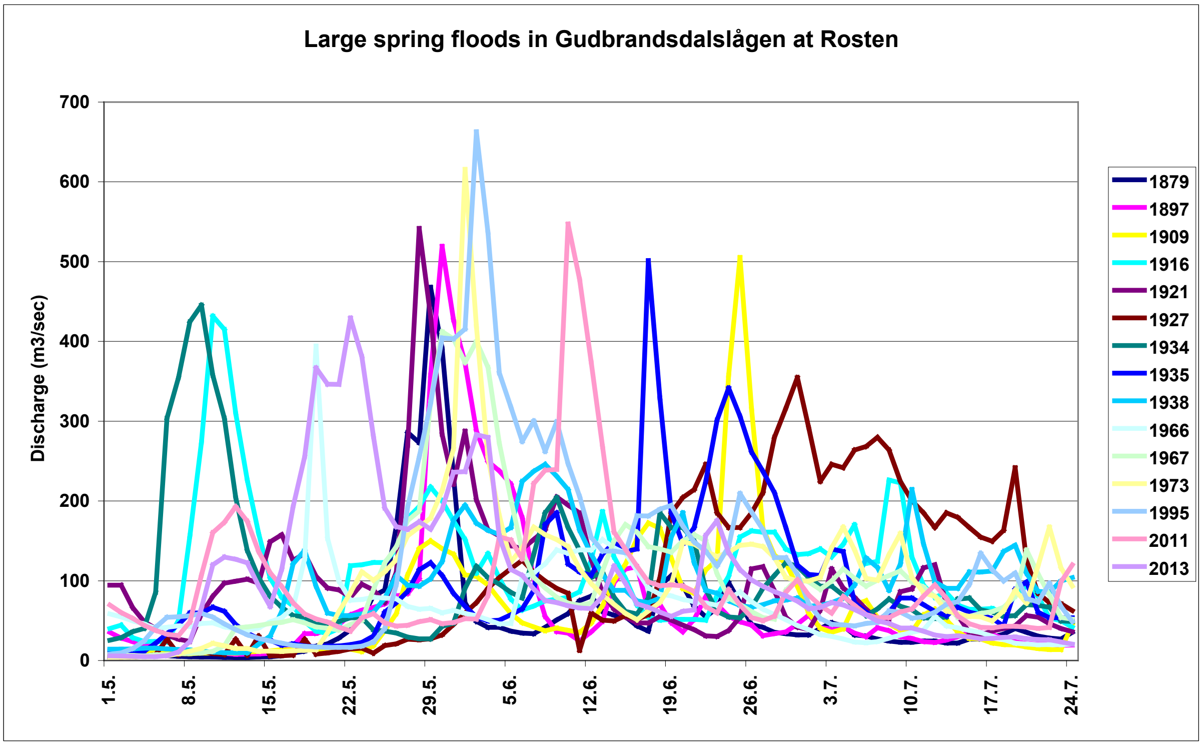


Figure 2.1.5.17 Daily discharges of the largest observed floods in River Gudbrandsdalslågen at 2.614 Rosten

The ranks of the largest floods differ between the three stations. *Storeflåmen* in 1938 was the largest observed at Losna and Otta. This flood was the seventh largest in Sel at Skjenna, because the rainfall in 1938 only fell on the western side of Gudbrandsdalen. *Vesleofsen* in

1995 was second largest observed at Losna and Skjenna but is not among the largest floods at River Otta at Lalm. The flood in May 1967 in Otta was neither among the largest floods. The snow reservoir was large in Jotunheimen in 1967 and in 1995, but the temperatures were too low to cause substantial melting until into July. The flood in Gudbrandsdalslågen was lower than in the eastern branch as most of the contribution to the flood was from snowmelt and rainfall in the lower mountains between Østerdalen and Gudbrandsdalen.

RIVER MOKSA

River Moksa is a tributary to Gudbrandsdalslågen flowing westward from the water divide towards Østerdalen to the village Tretten. The river was regulated 4 November 1944 with some reservoirs at the top of the catchment. *Vesleofsen* caused severe damages in at Tretten in 1995. The gauging station 2.243 Moksa has been operating 1945-1993.

RIVER FRYA

River Frya is a tributary to Gudbrandsdalslågen flowing southwestward from Lake Furusjøen to the village Frya just upstream Ringebu in Gudbrandsdalen. Small rivers in the Rondane massif contributes also to River Frya. The catchment area is 932 square kilometers. The lower part of River Frya flows through Venabygda, a farming district, where several farms suffered badly from *Storofsen* in 1789. River Frya carries sediments to the junction with the main river, causing a widespread delta to develop. This has pushed the main river to the western side of the valley. The gauging station 2.276 Furusjøen has been operating 1964-1988. The largest observed flood occurred 26 May 1978 with a discharge of 20,83 m^3/sec or 306 l/sec km^2 corresponding to 20,8 mm/day.

RIVER VINSTRA

River Vinstra is a major tributary to Gudbrandsdalslågen flowing eastward from the water divide towards the Årdal water course in Sogn through Lakes Bygdin and Vinstra through the junction with Gudbrandsdalslågen at Vinstra. The catchment is 1566 square kilometers. The river is regulated. Some of the sources of River Vinstra are located at Mjølkedalsbre and Uranosbre glaciers on the water divide to Utladal in Sogn. There is a glacier dammed lake in River Mjølkedøla which has caused numerous jøkullhlaup ending in Lake Bygdin. Table 2.1.5.33 summarises the known jøkulhlaups into Lake Bygdin, (Klæboe, 1938a).

Table 2.5.1.33 Jøkullhlaup in Mjølkedøla

Jøkullhlaup in River Mjølkedøla					
Year	1855	1865	1875	1879	1894
Date	11/8				
Volume					
Year	1899	1916	1921	1925	1927
Date	2/8		3/11	30/3	18/8
Volume		18	33	25	17
Year	1929	1931	1932	1936	1937
Date	13/8	14/11	15/7	4/1	30/1
Volume	12	19	3,5	26	3,5

East of the reservoirs Lake Espedalsvatn is flowing northwestwards from the water divide to river Gausa to River Vinstra at Skåbu where the river flows eastward through Kvikne to Vinstra. Districts including Gausdal, Skåbu/Kvikne/Heidal to Fron, Vågå and Lom were worst affected by *Storofsen* in 1789. Remnants of land slides can still be seen at Kvikne and Skåbu.

The River Vinstra was heavily regulated from 1922. The lakes Bygdin, Vinstervatn, Heimdalsvatn and Olstappen are reservoirs, and there is a system of diversions between different subcatchments. Farms along River Vinstra suffered badly from flood damages and landslides in 1789.

The gauging station 2.165 Bygdin ndf has a catchment area of 307,9 square kilometers. The station is located below the dam at the outlet of the reservoir at 1055 m.a.s.l. The mean altitude of the catchment is 1363 m.a.s.l, and the highest point at 2329 m.a.s.l. Bogs make up 0,93 percent, lakes 18 percent, forest 0 percent, mountains above the tree-line 78,04 percent and glaciers 2,98 percent of the catchment area. The annual floods at Bygdin is shown in Figure 2.1.5.18.

Table 2.1.5.34 Observed floods from Lake Bygdin into River Vinstra

Annual floods at 2.165 Bygdin ndf						
Year	1922	1924	1927	1929	1930	1932
Date	10/7	21/7	20/8	14/8	25-26/8	8/7
Rank	11	7	10	2	8	4
Year	1934	1938	1967	1968	1981	1988
Date	3/9	1/9	4/8	6/9	28/9	3/9
Rank	5	1	12	13	6	3
Year	1990	1992	1995	2000	2011	2013
Date	1/9	24/9	1-3/1	17/10	5/9	6-7/12
Rank	9	13	55	14	20	40

Remarks:
The floods in 1995, 2011 and 2013 does not rank among the large floods from Lake Bygdin, possible resulting from the operation of the reservoirs. The largest one-day flood occurred 1 September 1938 in River Vinstra at Lake Bygdin with a discharge of 183,58 m^3/sec corresponding to 596 l/sec km^2 or to a runoff of 51,5 mm/day.

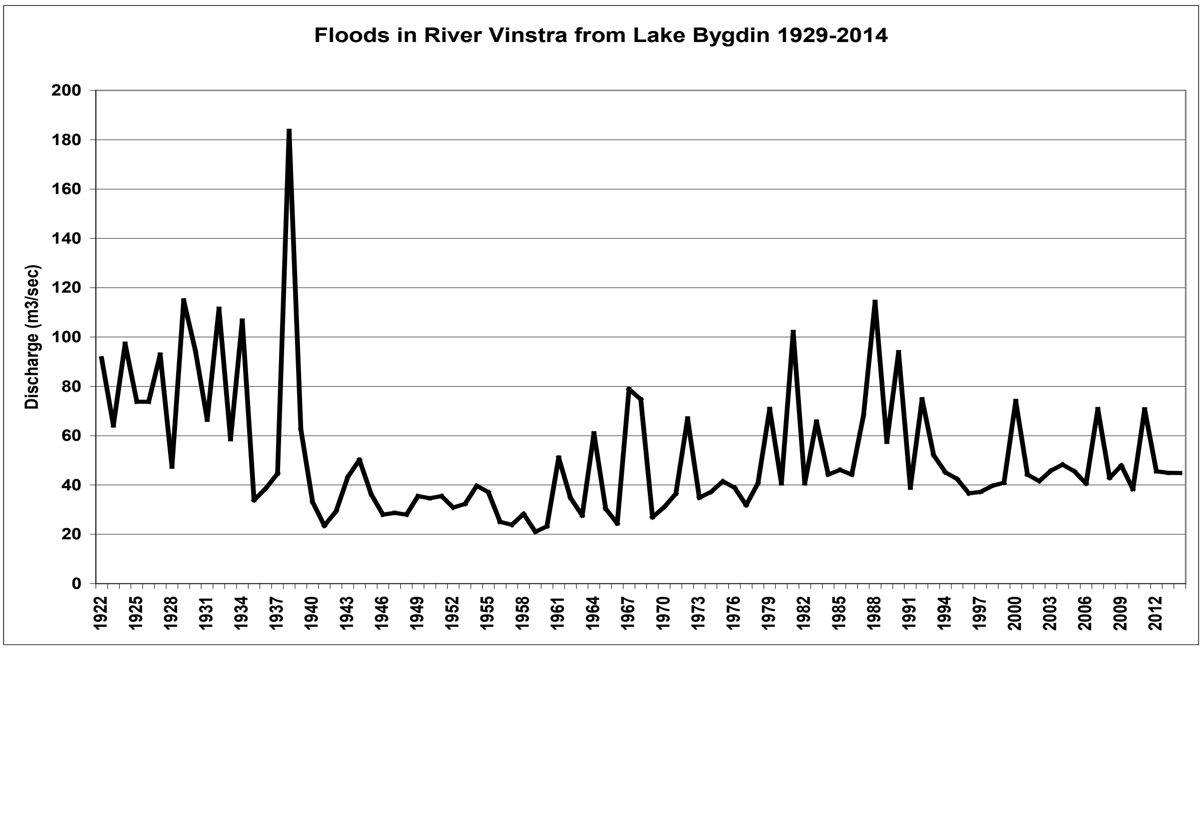


Figure 2.1.5.18 Annual floods (daily values) in River Vinstra from Lake Bygdin (daily values) 1922-2014.

RIVER SJOA

River Sjoa flows north and eastwards from Lake Gjende through Sjodal and Heidal to the confluence with River Gudbrandsdalslågen at Sjoa. The catchment area is 1518 square kilometers. The sources of the river are on both sides of Lake Gjende at 2364 m.a.s.l. to the north and at 2200 m.a.s.l. to the south. The two large Memurubre glaciers are within the catchment. The gauging station 2.161 Faukstad bru was operating 1917-1928 succeeded by the gauging station 2.595 Faukstad 1946-2014. Another nearby gauging station 2.324 Storøygardsbru was operating 1970-1996. These three stations were located at Heidal. Further upstreams the gauging station 2.13 Sjodalsvatn was operating 1930-1950 and 1965-2014. A station was also operating at the outlet of Lake Gjende 2.102 Gjende 1967-1990. The catchment characteristics of the stations at Faukstad, Sjodalsvatn and Gjende is shown in Table 2.1.5.35. The tributary Rinna flows into River Sjoa downstream Randsverk. The tributary Veo flows into River Sjoa from west below the junction with the tributary Russa. River Veo has been affected by hydropower regulations. River Russa flows eastward from Lake Russvatn, and the tributary Bessa flows eastward into Øvre Sjodalsvatn from Lake Bessvatn.

Table 2.5.1.35 Catchment chararacteristics for three stations in River Sjoa.

Station	2.161/595 Faukstad	2.13 Sjodalsvatn	2.102 Gjende
	Basin characteristics		
Catchment area (km^2)	1480,08	480	375,62
Station altitude (m.a.s.l.)	358	940	984
Mean altitude (m.a.s.l)	1263	1462	1572
Top altitude (m.a.s.l.)	2463	2362	2362
Lake (%)	4,31	9,26	8,2
Bog (%)	2,37	1,2	0,89
Forest (%)	23,24	5,25	2,29
Mountain (%)	59,75	71,48	75,42
Glacier (%)	4,87	9,04	11,59

There have been short-term measurements in River Russa just upstream the junction with River Sjoa at Russhølen and in River Memuruelv flowing southwards into Lake Gjende from Austre and Vestre Memurubre in connection with glaciological measurements in the 1970s.

Observed floods in River Sjoa

There are a several of glaciers in the upper part of the Sjoa catchment. The river carries therefore a lot of glacial sediments. There have been problems with a faulty connection between the lake and the observation well on the bank of the lake at Lake Sjodalsvatn before 2010. The data quality is therefore considered unreliable. Deposition of sediments in the controlling sections of the gauging stations has also caused changes in the relationship between the stage and discharge during large floods at other stations. The large flood in 2011 caused a major shift in the rating curve at Faukstad. The dates and ranks of the ten largest floods in the three stations in River Sjoa are shown in Table 2.1.5.36 and the date and discharge of the largest observed flood in Table 2.1.5.37.

Table 2.1.5.36 The ranks of the 10 largest floods (daily values) at stations in the Sjoa catchment.

2.161/595 Faukstad			2.13 Sjodalsvatn			2.102 Gjende		
1917-1928/1946-2014			1930-1950/1965-2014			1967-1989		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1922	9/7	10	1932	8/7	7	1967	20/7	1
1924	18/8	4	1933	22/6	10	1968	4/7	9
1951	11/8	3	1934	3/5	4	1971	1/6	6
1970	1/7	5	1938	1/9	1	1972	8/6	2
1972	8/6	8	1939	21/6	2	1973	9/6	8
1995	2/6	7	1967	21/7	8	1975	25/7	4
2007	6/7	6	1972	8/6	6	1979	25/6	5
2011	11/6	1	1997	3/7	9	1984	3/6	3
2013	23/5	2	2007	6/7	5	1985	20/7	10
2014	25/5	9	2011	12/6	3	1989	29/6	7

Table 2.1.5.37 The largest observed discharge (daily values) at the three stations in River Sjoa.

Station	2.161/595 Faukstad	2.13 Sjodalsvatn	2.102 Gjende
Year	2011	1938	1967
Date	11/6	1/9	20/7
q (m^3/sec)	791,29	330,62	192,92
qsp (l/sec km^2)	535	689	513
qsp (mm/day)	46,2	59,5	44,4

RIVER OTTA

River Otta flows eastward from the water divide to Sogn og Fjordane and Møre og Romsdal to the confluence with River Gudbrandsdalslågen at Otta in Gudbrandsdalen. The catchment area is 4063 square kilometers. River Otta has many tributaries, River Finna at Vågåmo River Aura in Skjåk and River Vulu and Tora further west from the north, River Tesse, River Vulu, River Bøvra, River Skjøli and River Tundra from the south. River Åstri flows from the west to the confluence with River Otta at Dønfoss bru.

Stations have been operating at different locations in the main river for shorter or longer periods at 2.25 Lalm, 2.148 Vågåvatn, 2.434 Ofossen, 2.223 Fredriksvatn and 2.15 Breiddalsvatn. The data series at 2.25 Lalm starts in 1907. Flood levels are known in 1789 and in 1860 based on flood marks. The series is moderately influenced by some hydropower regulations in tributaries Tesse, Aura, Framrusti and at Breiddalsvatn at the westernmost part of the main river. Table 2.1.5.38 lists catchment characteristics of Lalm, Fredriksvatrn and Breidalsvatn. The dates and ranks of the ten largest annual floods at the three stations are shown in Table 2.1.5.39 and the dates and discharges of the largest floods in Table 2.1.5.40.

Floods typical of Østlandet are dominating at the easternmost stations in River Otta. Further west floods caused by weather penetrating over the water divide are more common, most typical in Lake Breidalsvatn and River Tora. Several rivers in Jotunheimen and other alpine districts tend to have floods occurring after the lowland flood is over. Some of these mountain floods occurred in 1944, 1958, 1968, 1972 and 1973. The timing and magnitude of the floods in Otta differs often from the floods in other parts of Glomma as shown in Table 2.1.5.41. The annual floods observed at Lalm is shown in Figure 2.1.5.19. A photo of the flood stone at Lalm is shown in Figure 2.1.5.20. Figure 2.1.5.21 show the 8 largest annual floods observed at Lalm.

Table 2.1.5.38 Catchment characteristics for three long-term series in River Otta.

Station	2.25 Lalm	2.223 Fredriksvatn	2.15 Breiddalsvatn ndf
	Basin characteristics		
Catchment area (km^2)	3982	929,34	17,93
Station altitude (m.a.s.l.)	355	576	877
Mean altitude (m.a.s.l)	1326	1349	1160
Top altitude (m.a.s.l.)	2462	2006	1853
Lake (%)	3,75	6,32	11,0
Bog (%)	0,63	0,49	0,74
Forest (%)	14,37	9,05	1,92
Mountain (%)	69,76	74,93	85,27
Glacier (%)	6,23	8,01	0,88

Table 2.1.5.39 The ranks of the 10 largest observed floods (daily values) at three station with long-term data series in River Otta.

2.25 Lalm			2.223 Fredriksvatn			2.15 Breiddalsvatn		
1907-2014			1933-2005			1917-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1910	15/6	2	1935	1/6	3	1920	22/6	4
1914	7/7	5	1938	1/9	10	1923	11/7	2
1920	23/6	10	1939	21/6	4	1926	10/6	3
1923	13/7	3	1943	22/6	8	1927	9/7	6
1935	25/6	9	1944	8/7	6	1932	7/7	1
1938	1/9	1	1945	25/6	7	1935	26/8	8
1939	21/6	7	1958	1/7	1	1956	23/10	5
1958	2/7	4	1968	3/7	2	1976	29/6	7
1968	4/7	6	1985	1/10	8	1985	2/10	10
2011	11/6	8	1997	2/7	5	2005	6/7	9

Table 2.1.5.40 The largest observed discharge (daily values) at the three stations with long-term data series in River Otta.

Station	2.25 Lalm	2.223 Fredriksvatn	2.15 Breiddalsvatn
Year	1938	1958	1932
Date	1/9	1/7	7/7
q (m^3/sec)	1387,09	421,16	67,63
qsp (l/sec km^2)	348	433	530
qsp (mm/day)	30,0	39,2	45,8

Table 2.1.5.41 The ranks of the floods observed at 2.25 Lalm for years with large floods elsewhere in River Glomma.

	Flood ranks at 2.25 Lalm for other large flood years of River Glomma						
Year	1916	1927	1934	1966	1967	1995	2013
Date	11/5	8/7	9/5		21/7	3/6	25/5
Rank	53	11	22		31	36	

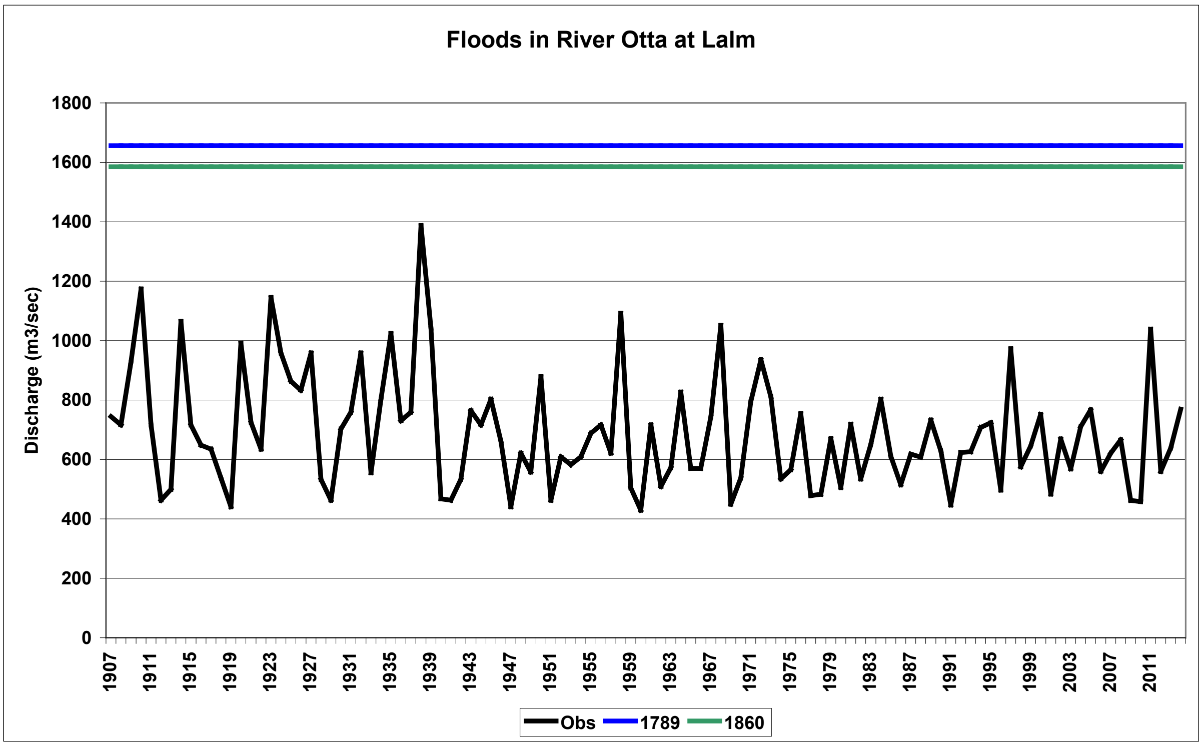


Figure 2.1.5.19 Annual floods (daily values) in River Otta at Lalm 1907-2014. Also shown: estimated peak discharges of the floods in July 1789 and in June 1860.

Figure 2.1.5.20 The flood stone at Lalm in River Otta (Photo: L. A. Roald).

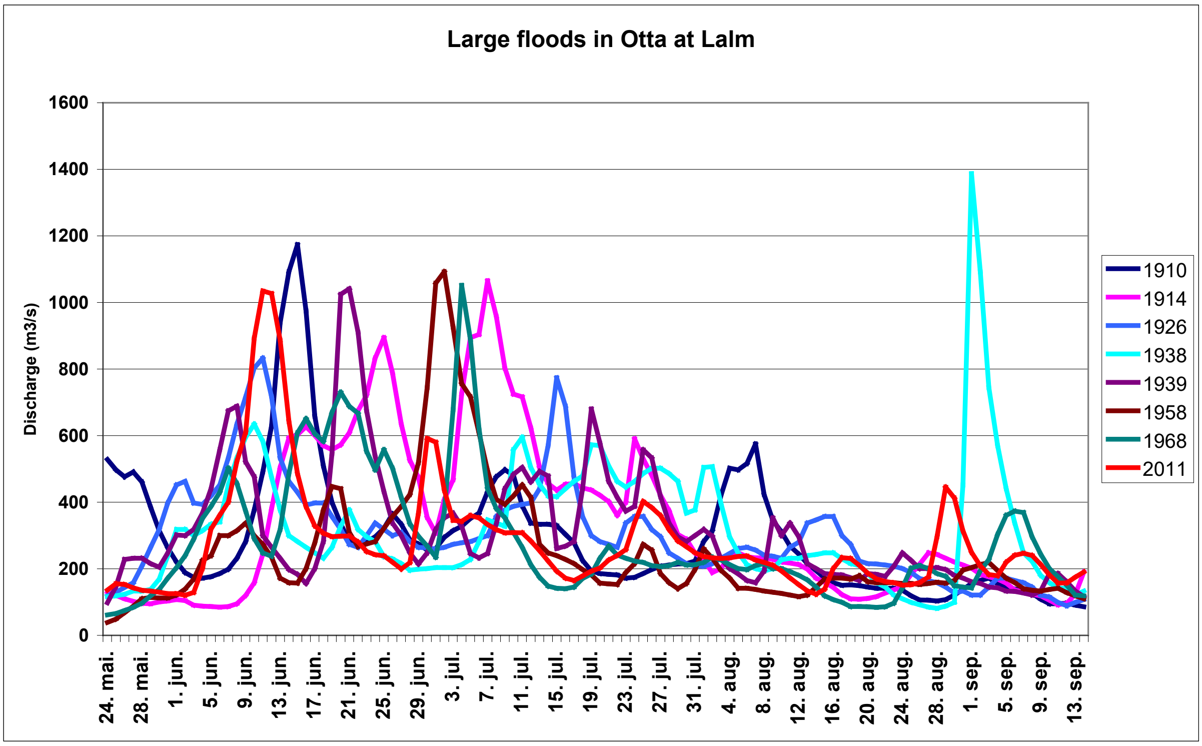


Figure 2.1.5.21 Daily discharges of the largest observed floods in River Otta at Lalm

Floods in tributaries to River Otta
Stations have also been established in the tributaries: Finna, Tesse, Bøvra, Skjøli, Tundra, Åstri, Framruste and Tora in the 1960s. Several of these stations have later been closed down. Nearly 30 year of observations are however available at several of these stations.

River Finna flows into River Otta from the north at Vågåmo. This river has had a some very severe floods prior to the start of the observations at the gauging station 2.284 Sælatunga in 1967. The river carries a lot of stones and gravel, filling up the riverbed and cutting new beds through the village. Table 2.1.5.42 list catchment characteristics and the dates and ranks of the ten largest annual floods (daily values) observed at the station.

Table 2.1.5.42 catchment characteristics and the ten largest annual floods at 2.284 Sælatunga in River Finna at Vågåmo.

Station : 2.284 Sælatunga		Floods 1969-2014		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	454,83	1972	7/6	3
Station altitude (m.a.s.l.)	423	1973	1/6	5
Mean altitude (m.a.s.l)	1370	1980	31/5	4
Top altitude (m.a.s.l.)	1	1995	2/6	2
Lake (%)	1,64	1997	2/7	6
Bog (%)	1,08	1999	29/6	5
Forest (%)	8,77	2000	1/7	8
Mountain (%)	83,68	2004	7/5	9
Glacier (%)	0,12	2011	10/6	1
		2014	19/5	7

River Bøvra flows northeastwards from the water divide at Sognefjellet to Lom. The tributaries Visa and Leira flow northwards from the highest alpine district in Norway. River Høya flow in from the west. There are some glaciers in the catchment. The gauging station 2.268 Akslen is located at the lower part of the catchments and has been operating since 1961. Another gauging station 2.94 Marstein, which was operating further downstreams 1933-1961.

The tributary Sula flows into River Bøvra at Sulheim from the north, and further upstreams flows the tributary Visa in from the south at Røysheim. The gauging station 2.299 Sulheim and the gauging stations 2.294 Visa and 2.302 Øvre Visa has been operating for some years starting in the 1970ies, but all these stations has been closed down.

The gauging station 2.290 Brustuen is located at River Bøvra upstream the junction with River Leira. The station has been operating from 1966 and is still active. Further upstreams were 2.301 Runningen located at the small tributary Runningen and the 2.300 Bøvertjern operating for a few years. River Høya is a tributary to River Bøvra flowing in from west upstream Brustuen. The gauging station 2.289 Høydalsvatn was operating 1967-1988.

The station 2.455 Elveseter has been operating in River Leira upstream the junction with River Bøvra since 1937. This station was moved a little upstreams, but a dataseries covering the years 1937 to present has been established. Catchment characteristics are given for Akselen, Brustuen and Elveseter in Table 2.1.5.43. The date and rank of the ten largest annual floods at the three stations are shown in Table 2.1.5.44 and the date and discharge of the largest flood in Table 2.1.5.45.

Table 2.1.5.43 Catchment characteristics of three gauging stations in River Bøvra.

Station	2.268 Akslen	2.290 Brustuen	2.455 Elveseter
	Catchment characteristics		
Catchment area (km^2)	796,26	253,93	133,12
Station altitude (m.a.s.l.)	475	665	708
Mean altitude (m.a.s.l)	1467	1413	1567
Top altitude (m.a.s.l.)	2462	2192	2362
Lake (%)	1,94	4,19	1,68
Bog (%)	0,4	0,35	0,27
Forest (%)	10,91	7,02	7,9
Mountain (%)	70,74	73,02	65,95
Glacier (%)	11,65	9,32	19,32

Table 2.1.5.44 The year, dates ranks of the ten largest annual floods (daily values) at three stations with long-term data series in River Bøvra.

2.268 Akslen			2.290 Brustuen			2.455 Elveseter		
1934-2014			1967-2014			1946-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1938	31/8	1	1967	20/7	4	1946	5/7	1
1939	20/6	7	1968	3/7	6	1956	22/10	9
1964	14/6	3	1972	7/6	3	1958	1/7	6
1968	3/7	8	1973	8/7	2	1962	2/10	5
1971	30/5	6	1976	27/6	10	1963	26/5	7
1972	7/6	4	1994	30/6	4	1964	15/6	7
1973	8/7	9	1997	2/7	8	1969	12/9	3
2002	11/7	5	2000	3/7	7	1972	7/6	2
2011	11/6	2	2011	12/6	1	1973	8/7	4
2014	7/7	9	2014	23/5	9	2014	7/7	10

Table 2.1.45 The largest observed discharge (daily values) at the three stations with long-term data series in River Bøvra.

Station	2.268 Akslen	2.290 Brustuen	2.455 Elveseter
Year	1938	2011	1946
Date	31/8	12/6	5/7
q (m^3/sec)	442,88	122,23	134,08
qsp (l/sec km^2)	556	481	1007
qsp (mm/day)	48,1	41,6	87,02

Remarks: The flood Vesleofsen 2/6 1995 ranks only as no 15 at Akslen, no 26 at Brustuen and no 41 at Elveseter. The flood 11/6 2011 ranks as no 21 at Elveseter, and the flood 2/6 2013 ranks as no 39 at Akslen and 22 at Brustuen.

River Skjøli flows north-eastward from Hestbrepiggene and Lomseggen towards River Otta at Bismo at Skjåk. The gauging station 2.292 Skjøli was operating 1966-1991. River Tundra flows northward from Holåbreen and Tundradalskyrkja towards River Otta at Dønfoss bru in Skjåk. The gauging station 2.295 was operating 1966-1992. River Åstri flows eastward from Sogneskarbre glacier to River Otta near Dønfoss bru in Skjåk. The gauging station 2.275 Liavatn has been operating 1964-2013. The catchment area is square 211,26 kilometers. River Framruste flows eastward from Lake Raundalsvatn to the junction with River Glomma downstream Pollfoss in Skjåk. The gauging station 2.238 Raudalsvatn ndf has been operating since 1944. The river was regulated 29/10-1942. River Tora flows southward from the water divide towards River Tafjordelv to the junction with River Otta near Billingen seter at Skjåk. The gauging station 2.291 Tora has been operating 1966-2014.

Catchment characteristics are given for Skjøli, Liavatn and Tora in Table 2.1.5.46. The date and rank of the ten largest annual floods at the three stations are shown in Table 2.1.5.47 and the date and discharge of the largest flood in Table 2.1.5.48.

Table 2.1.5.46 Catchment characteristics of three gauging stations in tributaries to River Otta upstreams Lom.

Station	2.292 Skjøli	2.275 Liavatn	2.291 Tora
	Basin characteristics		
Catchment area (km^2)	174,71	211,26	262,77
Station altitude (m.a.s.l.)	507	733	717
Mean altitude (m.a.s.l)	1607	1397	1485
Top altitude (m.a.s.l.)	2167	2080	2006
Lake (%)	1,68	5	6,23
Bog (%)	0,01	0,3	0
Forest (%)	4,38	10,64	0,07
Mountain (%)	73,7	60,33	87,42
Glacier (%)	18,72	14,24	5,4

Table 2.1.5.47 The year, dates and ranks of the ten largest observed floods (daily values) at three stations in the tributaries Skjøli, Åstri and Tora to River Otta in Skjåk.

2.292 Skjøli			2.275 Liavatn			2.291 Tora		
1967-1991			1965-2014			1967-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1967	4/8	3	1967	20/7	5	1968	3/7	1
1968	3/7	1	1968	3/7	5	1971	31/5	8
1971	7/7	6	1972	7/6	2	1972	2/7	5
1973	9/7	4	1973	8/7	4	1973	8/7	2
1974	18/6	9	1976	27/6	7	1976	27/6	7
1976	27/6	9	1979	15/8	1	1979	25/6	3
1977	15/6	5	1989	29/6	8	1984	3/6	3
1984	2/6	7	2010	22/7	3	1997	2/7	10
1985	1/10	2	2011	29/6	9	2005	6/7	9
1987	7/7	8	2014	7/7	10	2011	11/6	6

Table 2.1.5.48 The largest observed discharge (daily values) in tributaries to River Otta in Skjåk.

Station	2.292 Skjøli	2.275 Liavatn	2.291 Tora
Year	1968	1979	1968
Date	3/7	15/8	3/7
q (m^3/sec)	91,43	179,96	217,70
qsp (l/sec km^2)	523	852	830
qsp (mm/day)	45,2	73,6	71,7

Remarks: The flood in 1995 ranks only as no 25 at Liavatn and as no 33 at Tora. The flood culminated 26/6 at Liavatn and as late as 16/7 at Tora because of delayed snowmelt.

RIVER ILKA

River Ilka is a tributary to Gudbrandsdalslågen flowing eastwards from Jønndalen to the junction at the village Dovre. There are no gauging stations in this river. Several floods in River Ilka have caused damages in the past.

RIVER JORA

River Jora is a tributary to Gudbrandsdalslågen flowing southward from Dovrefjell to the junction west of Dombås. There is a bifurcation upstreams the gauging station towards River Folla. The gauging station 2.303 Dombås has been operating since 1967. A second gauging station 2.304 Jora was operating 1967-1985. The severe flood in 1938 was said to be the largest flood in River Jora since *Storofsen* in 1789. Catchment characteristics and the dates and ranks of the ten largest annual floods at 2.303 Dombås is shown in Table 2.1.5.49.

Table 2.1.5.49 Catchment characteristics and the dates and ranks of the ten largest annual floods observed at 2.303 Dombås 1968-2014.

Station : 2.303 Dombås		Floods 1967-2014		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	493,62	1977	25/5	5
Station altitude (m.a.s.l.)	575	1979	2/6	9
Mean altitude (m.a.s.l)	1321	1983	12/5	1
Top altitude (m.a.s.l.)	2207	1995	2/6	2
Lake (%)	3,24	2000	12/10	6
Bog (%)	2,03	2004	7/5	8
Forest (%)	11,15	2007	6/7	4
Mountain (%)	79,24	2008	3/5	3
Glacier (%)	0,2	2011	24/7	7
		2013	19/5	10

RIVER LORA

River Lora flows eastward from the the water divide to River Tafjordelv to River Gudbrandsdalslågen at Lesja, downstream Lesjaverk. The catchment area is 344 square kilometres. There are no gauging stations in the river.

2.1.6 RIVER DRAMMENSVASSDRAGET

River Drammenselv is the second largest watercourse in Norway. The catchment area is 17.103 square kilometers. River Drammenselv is known as River Storelva from Lake Tyrifjorden to Hønefoss, River Ådalselv to Lake Sperillen and River Begna to the water divide at Filefjell. The watercourse has several branches with tributaries from vest: River Vestfosselv at Hokksund, River Simoa at Åmot, River Snarumselv/ Hallingdalselv at Gravfoss in Geithus and River Sokna to Lake Tyrifjorden. A major tributary River Randselva with River Etna and Dokka upstreams Lake Randsfjorden flow into River Storelva from east at Hønefoss. River Urula flow into River Begna at Nes in Ådal from west. At Fagernes the rivers from Øystre and Vestre Slidre flows into Lake Strandefjord in River Begna.

The longest dataseries in the lower part of River Drammenselva is at 12.68/268 Døvikfoss. Døvikfoss is located on the main river upstream Hokksund. The observations started in 1912. As in River Glomma campaign measurements exists from the second part of the 19th Century between Hokksund and Lake Tyrifjord. These data are mostly available as series of water levels. Water levels are known at several locations both for the flood in 1853 and 1860. The discharge is heavily modified by hydropower regulation in the various branches of the watercourse. The earliest regulation occurred in 1883 in Lake Randsfjorden, and in River Begna with Lake Sperillen in 1904.

Historical floods are documented in the various branches of River Drammenselv since the 17th Century. Historical floods prior to the establishment of the gauging network are listed in Table 2.1.6.1.

Table 2.1.6.1 The largest floods known in River Drammenselv from historical sources

Year		Date	Remarks
1640			River Storelva at Hønefoss damaged bridges and buildings
1701			River Storelva at Hønefoss damaged bridges
1717			Flood in Valdres
1723			Flood in Gol
1754			River Storelva at Hønefoss damaged bridges
1774			Flood in Drammen
1775			Flood in River Hemsil
1789		21-23/6	Storofsen - extreme flood in upper part of River Begna and River Etna/Dokka, large flood in River Hallingdalselv
1792		Before 23/6	Large snowmelt flood - River Etna/Dokka
1804		Spring	Large spring flood
1808		21-22/6	Combined snowmelt and rainfall flood
1822		August	Rainstorm caused slides at Krødsherad
1837		September	Rainstorm damaged bridges. 8 fatalities in slides in Valdres.
1850		Spring	Large snowmelt flood. Riverbank failure in Hokksund.
1853		3-5/6	Severe flood upstreams Hokksund
1858		July	Severe flood and slides in River Snarumselv
1860		Mid June	Extreme flood
1879		29/5-1/6	Large snowmelt/rainfall flood
1895		20/5	Large snowmelt flood
1897		27/5	Large snowmelt flood

The water level and discharge in Lake Tyrifjorden has been observed 1887-1999 at 12.65 Skjerdal. Some tribularies join the lower part of the main river from west. River Vestfosselva from Lake Eikeren joins River Drammenselv through Vestfossen at Hokksund, River Simoa at Åmot, River Snarumselv at Geithus and River Sokna in Lake Tyrifjord. Catchment characteristics of 12.68/268 Døvikfoss, 12.65 Skjerdal and 12.114 Garhammerfoss are given in Table 2.1.6.2.

Table 2.1.6.2 Catchment characteristics of Døvikfoss and Skjerdal on the main river and Garhammerfoss in River Sokna.

Station	12.68/298 Døvikfoss	12.65 Skjerdal	12.114 Garhammarfoss
	Basin characteristics		
Catchment area (km^2)	16.020	9.905	492,53
Station altitude (m.a.s.l.)	18	60	131
Mean altitude (m.a.s.l)	818	708	446
Top altitude (m.a.s.l.)	1930	1907	1227
Lake (%)	7	7,72	3,38
Bog (%)	7,81	8,56	3,27
Forest (%)	53,57	58,29	82,42
Mountain (%)	21,42	13,61	6,67
Glacier (%)	0,25	0	0

The dates and ranks of the ten largest observed floods (daily values) in the lower River Drammenselv and River Sokna are given in Table 2.1.6.3 and the discharge of the largest flood as daily values in Table 2.1.6.4.

Table 2.1.6.3 The year, dates and ranks of the ten largest floods (daily values) in the lower River Drammenselv and in River Sokna:

12.68/298 Døvikfoss			12.65 Skjerdal			12.114 Garhammarfoss		
1912-2014			1887-1999			1936-1978,2007-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1916	12/5	3	1895	20/5	10	1950	25/8	5
1917	2/6	7	1908	6/6	4	1951	10/8	4
1926	1/6	2	1910	27/5	2	1954	23/5	8
1927	30/6	1	1916	18/5	7	1961	11/11	1
1931	20/6	4	1926	5/6	6	1964	11/10	3
1934	4/9	5	1927	2-3/7	3	1965	9/9	5
1937	21/5	8	1930	31/5	8	1977	9/5	7
1939	26/7	9	1931	30-31/5	1	2007	5/7	2
1951	29/5	10	1937	23/5	9	2008	2/5	10
1967	1/6	6	1967	7/6	5	2011	11/6	9

Table 2.1.6.4 The year, date and discharges of the largest floods in the lower River Drammenselv and in River Sokna.

Station	12.68/298 Døvikfoss	12.65 Skjerdal	12.114 Garhammarfoss
Year	1927	1931	1961
Date	30/6	30-31/5	11/11
q (m^3/sec)	2324,20	1069,27	151,98
qsp (l/sec km^2)	144	108	309
qsp (mm/day)	12,5	9,33	26,7

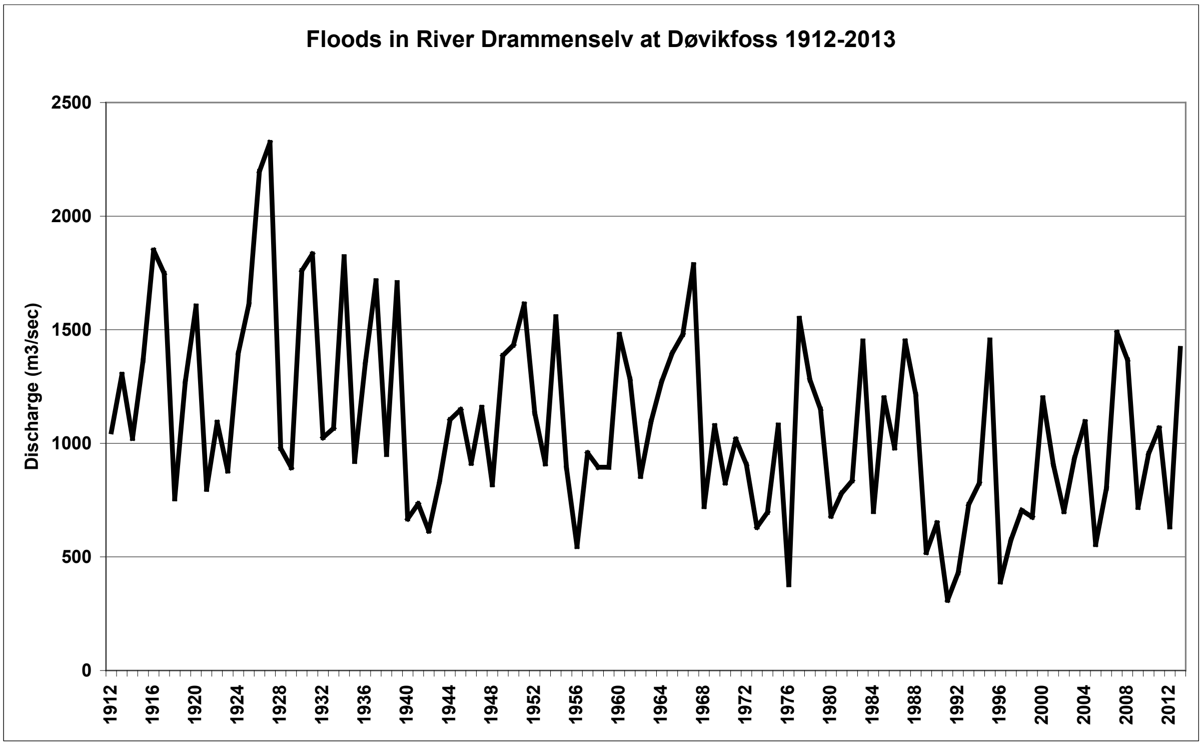


Figure 2.1.6.1 Annual floods (daily values) in River Drammenselv at Døvikfoss 1912-2014.

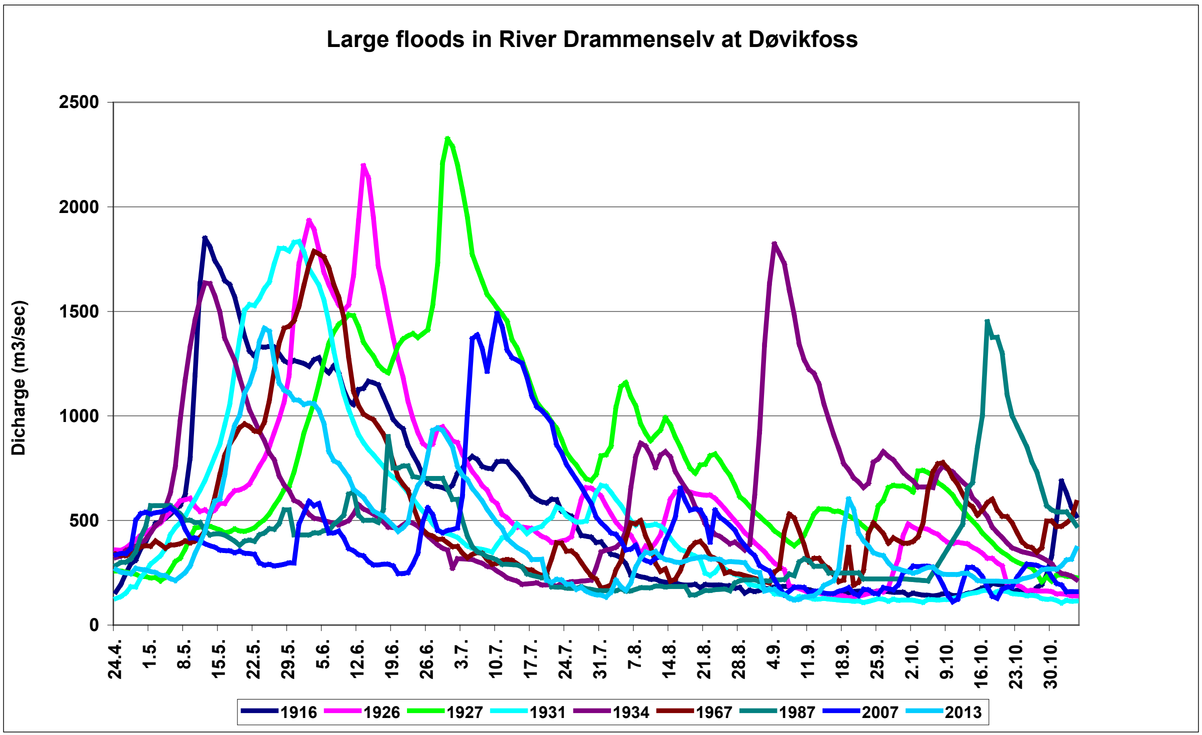


Figure 2.1.6.2 Daily discharges of the largest floods observed in River Drammenselv at Døvikfoss

2.1.6.1 RIVER VESTFOSSELVA

River Vestfosselva joins the main river at Hokksund. Upstream a large lake, Eikeren, are two gauging stations, 12.192 Sundbyfoss to the south and 12.193 Fiskum to the northwest. The latter station is located close to the water divide to River Numedalslågen, close to the town Kongsberg. The catchment characteristics of the two gauging stations are given in Table 2.1.6.5.

Table 2.1.6.5 Catchment characteristics of the two gauging stations in River Vestfosselva.

Station	12.192 Sundbyfoss	12.193 Fiskum
	Basin characteristics	
Catchment area (km^2)	74,68	51,6
Station altitude (m.a.s.l.)	54	84
Mean altitude (m.a.s.l)	195	277
Top altitude (m.a.s.l.)	625	649
Lake (%)	1,15	1,26
Bog (%)	0,63	2,98
Forest (%)	84,05	88,39
Mountain (%)	0	0
Glacier (%)	0	0

The ten largest annual floods of the two catchments Sundbyfoss and Fiskum are given in Table 2.1.6.6. The discharge of the largest floods at the two stations are given in Table 1.2.6.7.

Table 2.1.6.6 The year, dates and ranks of the ten largest annual floods of two gauging stations in River Vestfosselv.

12.192 Sundbyfoss			12.193 Fiskum		
1976-2014			1976-2014		
Year	Date	Rank	Year	Date	Rank
1976	23/10	1	1977	6/5	10
1977	6/5	3	1978	4/7	8
1987	16/10	5	1985	7/9	7
1990	1/2	9	1987	16/10	5
1994	10/9	6	1994	10/9	6
2000	30/10	4	2000	8/11	4
2006	1/5	8	2007	4/7	1
2007	3/7	2	2011	24/7	2
2012	7/8	7	2012	7/8	3
2014	7/1	10	2013	23/5	9

Table 2.1.6.7 The largest discharges (daily values observed at the two gauging stations.

Station	12.192 Sundbyfoss	12.193 Fiskum
Year	1976	2007
Date	23/10	4/7
q (m^3/sec)	66,71	24,09
qsp (l/sec km^2)	893	467
qsp (mm/day)	77,2	40,7

The peak discharge observed at Fiskum 4/7 2007 13:30 hr was 27,37 m^3/sec or 530 l/sec km^2.

2.1.6.2 RIVER SIMOA

River Simoa is a tributary from west to the lower reaches of Drammeselva at Åmot upstreams Døvikfoss. The catchment area of the tributary is 887 square kilometers. The catchment comprises a valley with farmland and forests with mountains near the water divide extending up to 1466 m.a.s.l at Norefjell. There are data series observed at Strandhengslet 1887-1902, at the outlet of Lake Kråkefjord 1930-2014 and at Eggedal 1971-2014. Four water levels from older flood was recorded as flood marks at Solumsmoen, see Figure 1. Water levels in the main river was observed at Åmot 1852-1871. There are three long term precipitation stations within or near the catchment: 24600 Grimeli from 1895, 26240 Hiåsen from 1900 and 26400 Eggedal from 1895. The catchment characteristics of Strandhengselet, Kråkefjord ndf and Eggedal are given in Table 2.1.6.8.

Table 2.1.6.8 The catchment characteristics of three gauging stations in River Simoa.

Station	12.49 Strandhengslet	12.113 Kråkefjord ndf	12.178 Eggedal
	Basin characteristics		
Catchment area (km^2)	887,41	702,16	309,77
Station altitude (m.a.s.l.)	33	103	170
Mean altitude (m.a.s.l)	483	597	846
Top altitude (m.a.s.l.)	1463	1463	1463
Lake (%)	3,57	4,39	3,14
Bog (%)	6,77	8,17	7,74
Forest (%)	71,72	69,37	59,54
Mountain (%)	8,47	10,71	21,57
Glacier (%)	0	0	0

Several large historical floods are known from Simoa. These floods are listed in Table 2.1.6.9.

Table 2.1.6.9 Large floods in River Simoa known from historical sources (Roald,2011).

Year	Date	Remarks
1653	August- September	Long-term rainstorm.
1752	August	Level marked on rockface at Solumsmoen. Severe thunderstorms after prolonged heatwave
1789	21-23/7	Storofsen, no information from Simoa, but severe damages in Numedalslågen to the west and at Sørbygda to Krøderen.
1822	23-27/8	Rainstorm. Båsen bridge and a mill at Albakts waterfall were taken.
1853	3-5/6	Large flood also in the main river.
1854	16/8	Rainstorm
1858	17-18/7	Rainstorm
1860	14-17/6	Snowmelt and rainstorm
1879	29/5-1/6	Snowmelt and rainstorm
1887	16/9	Rainstorm, roads inundated, Kopseng bridge taken.
1892	8/10	Autumn rainstorm
1895	13/8	Summer rainstorm
1927	29-30/6	Rainstorm at the end of the snowmelt.

The dates and ranks of the ten largest observed floods (daily values) in the lower River Drammenselv and River Sokna are given in Table 2.1.6.10 and the discharge of the largest flood as daily values in Table 2.1.6.11.

Table 2.1.6.10 The rank of the 10 largest observed floods (daily values) in River Simoa.

12.49 Strandhengslet			12.113 Kråkefjord ndf			12.178 Eggedal		
1887-1902			1931-2014			1972-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1887	16/9	2	1934	3/9	1	1978	24/5	9
1889	13/10	5	1939	19/7	10	1983	11/5	5
1891	15/10	7	1950	26/8	5	1987	16/10	4
1892	8/10	3	1951	10/8	7	1995	2/6	10
1894	29/4	6	1960	19/8	3	2000	13/10	3
1895	13/8	1	1961	12/10	2	2004	6/5	6
1897	30/5	4	1964	11/10	4	2007	4/7	1
1898	26/5	9	1965	10/9	9	2008	2/5	7
1899	22/5	10	1966	20/5	8	2010	17/5	8
1901	25/10	8	2007	5/7	6	2013	18/9	2

Table 2.1.6.11 The largest observed discharges (daily values) at the gauging stations in River Simoa.

Station	12.49 Strandhengslet	12.113 Kråkefjord ndf	12.178 Eggedal
Year	1895	1934	2007
Date	13/8	3/9	4/7
q (m^3/sec)	283,28	293,49	185,83
qsp (l/sec km^2)	319	418	600
qsp (mm/day)	27,6	36,1	51,8

The peak discharge observed at Eggedal 4/7 2007 05:30 hr was 196,88 m^3/sec or 636 l/sec km^2.

The extreme rainstorm *Frida* caused severe damages in Eiker in 2012. The rainfall and flood were less severe in Modum. Furter upstreams in River Simoa the flood was even less. Intense summer rainfall floods have, however, occurred many times in the inland district west of Oslo causing severe local floods. Flood marks caused by these events have been marked on stones next to roads at several locations. There is a stone close to the boundary betveen next t0 River Simoa at the boundary between at Modum and Sigdal municipality. A photo of the flood stone in Figure 2.1.6.3 show some flood marks at Solumsmoen from 1752, 1798 and 1822. These events are also known at other locations such as Tinn in upper Telemark.

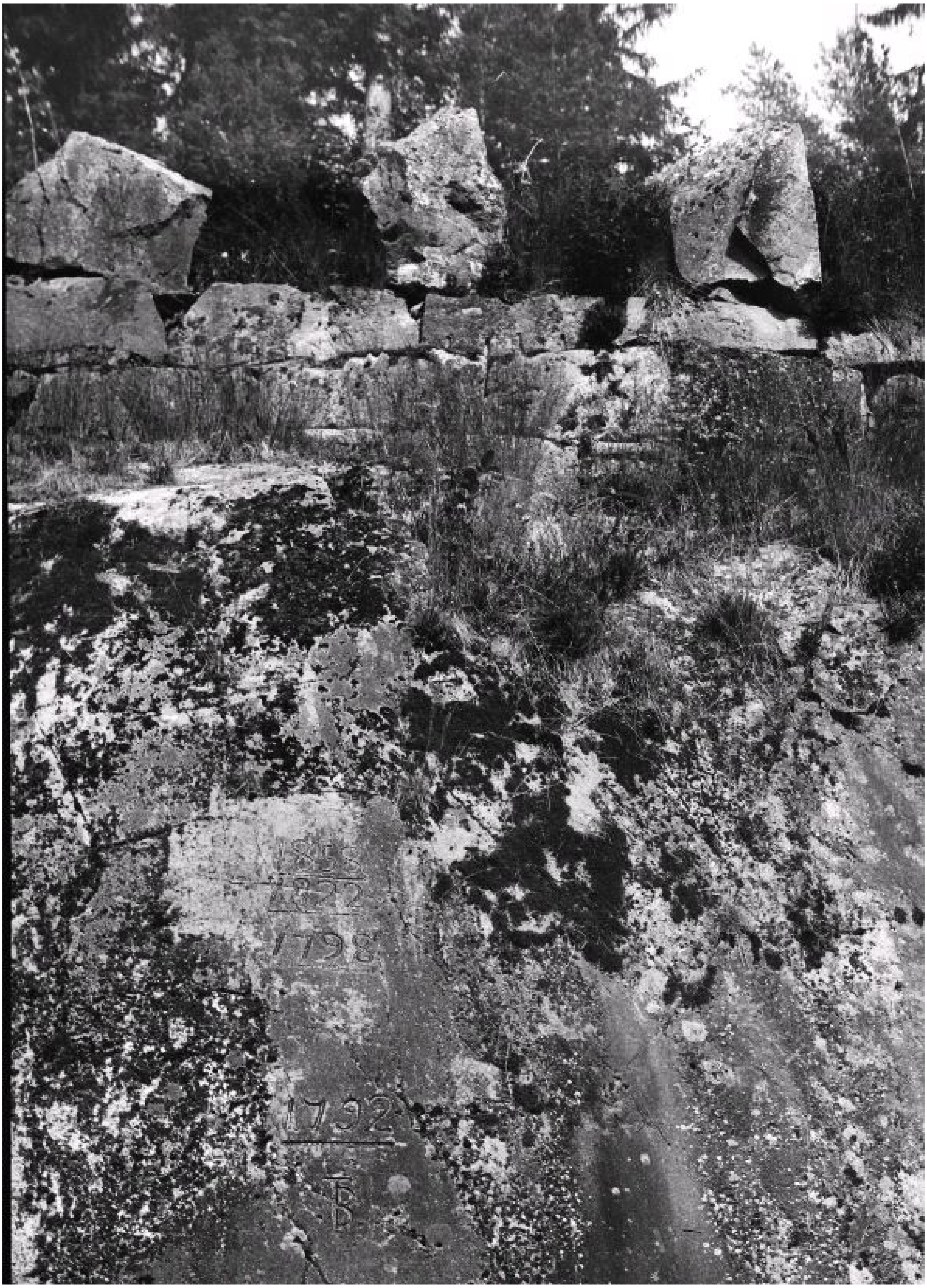


Figure 2.1.6.3 Flood marks at Solumsmoen (Photo: Olaf Strand, NVE).

2.1.6.3 RIVER SNARUMSELV AT LAKE KRØDEREN AND RIVER HALLINGDALSELV.

River Snarumselva is the name of the reach between the junction between River Drammenselv and the river from Hallingdal and Lake Krøderen at Geithus. The catchment at Gravfoss is 5.239 square kilometers. River Hallingdalselv flows into Lake Krøderen from northwest. The upper part of the river is strongly regulated both in the main branch west of Gol and in the branch from Hemsedal to the north. The dominant flood season is in the spring, in May (51 percent) and June (32 percent) of the years.

The discharge from Lake Krøderen has been observed at gauging station 12.98 Krøderen since 1889. The longest continous dataseries in the upstream River Hallingdalselv is at 12.97 Bergheim upstreams Lake Krøderen. The river was regulated in 1940. The gauging station 12.95 Ustadalsvatn was located at River Usta at the top of Hallingdal.

Table 2.1.6.12 Catchment characteristics of the three gauging stations at River Snarumselv/ Hallingdalselv.

Station	12.98 Krøderen	12.97 Bergheim	12.95 Ustadalsvatn
	Basin characteristics		
Catchment area (km^2)	5110	4237	570
Station altitude (m.a.s.l.)	132	152	766
Mean altitude (m.a.s.l)	1018	1071	1246
Top altitude (m.a.s.l.)	1930	1930	1930
Lake (%)	6,4	6,39	10,18
Bog (%)	6,81	7,06	2,39
Forest (%)	40,09	34,63	4,88
Mountain (%)	39,71	44,73	74,91
Glacier (%)	0,78	0,94	4,46

Table 2.1.6.13 The date and rank of the ten largest annual floods (daily values) observed at three gauging stations on the main branch of Rivers Snarumselv - Hallingdalselv.

12.98 Krøderen			12.97 Bergheim			12.95 Ustadalsvatn		
1889-2014			1921-2014			1909-1966		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1897	30/5-1/6	6	1924	23/6	8	1910	15/6	9
1916	12/5	1	1925	30/5	4	1914	8/7	3
1917	31/5	3	1926	30/5	6	1924	24/6	10
1925	31/5	7	1927	29/6	1	1925	12/6	8
1926	13/6	5	1934	3/9	2	1926	11-12/6	6
1927	29/6	2	1936	16/7	9	1927	30/6	4
1930	28/5	10	1937	23/6	9	1933	21/6	5
1934	6/5,4/9	4	1938	1/9	3	1939	21/6	6
1939	22/5	9	1939	20/6	7	1950	9/6	1
1954	25/5	8	2004	9/5	5	1958	3/6	2

Table 2.1.6.14 The largest observed discharges (daily values) at the gauging stations in River Hallingdalselv.

Station	12.98 Krøderen	12.97 Bergheim	12.95 Ustadalsvatn
Year	1916	1927	1950
Date	12/5	29/6	9/6
q (m3/sec)	1101,25	1045,77	235,99
qsp (l/sec km2)	215	246	414
qsp (mm/day)	18,6	21,3	35,8

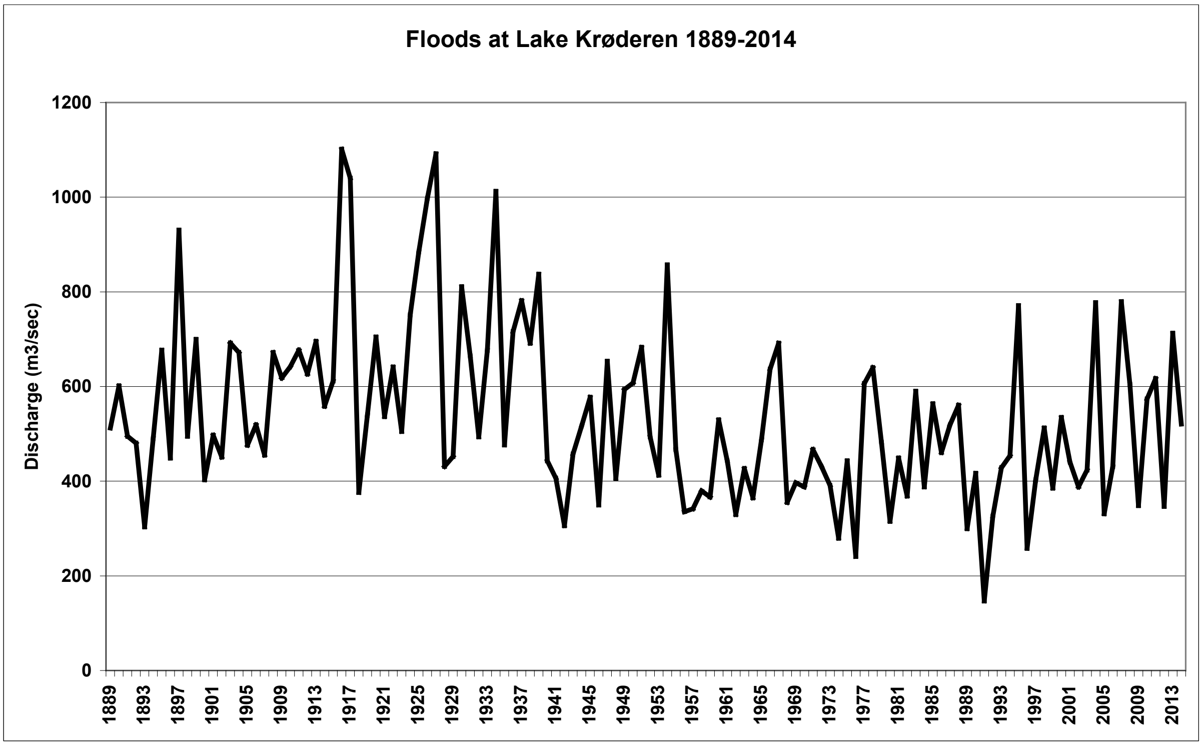


Figure 2.1.6.4 Annual floods (daily values) in River Snarumselv at Lake Krøderen 1889-2014.

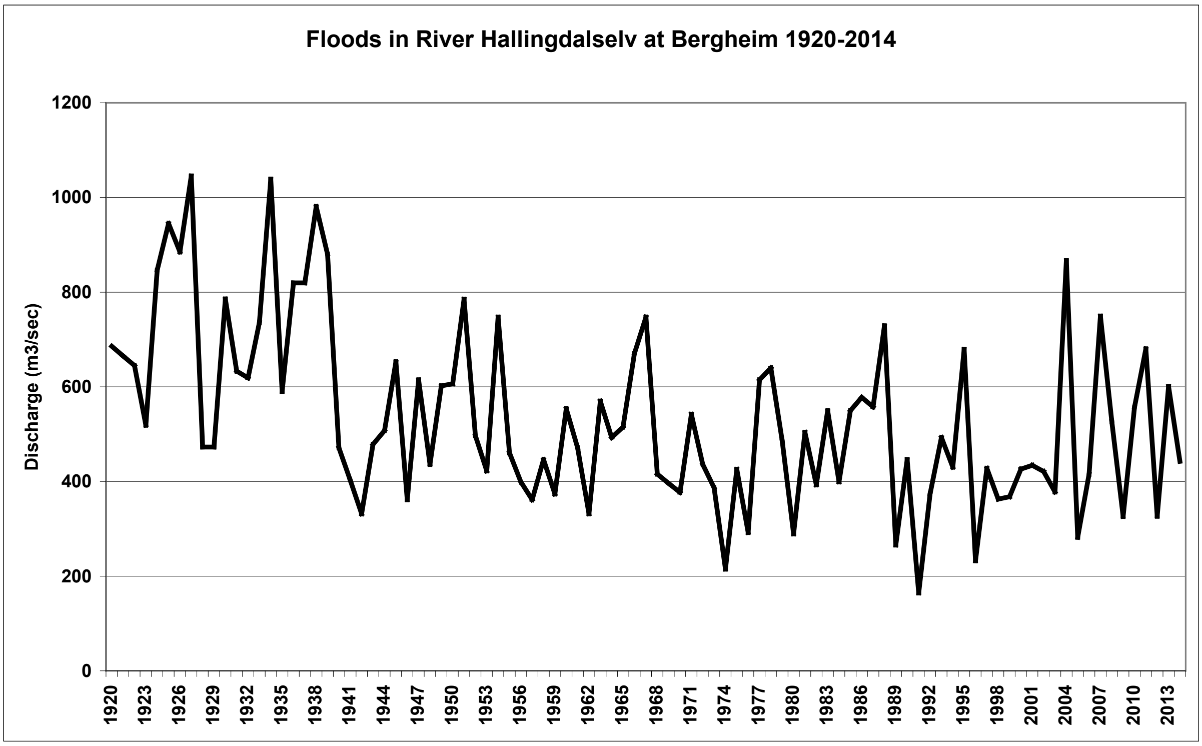


Figure 2.1.6.5 Annual floods (daily values) in River Hallingdalselv at Bergheim 1921-2014.

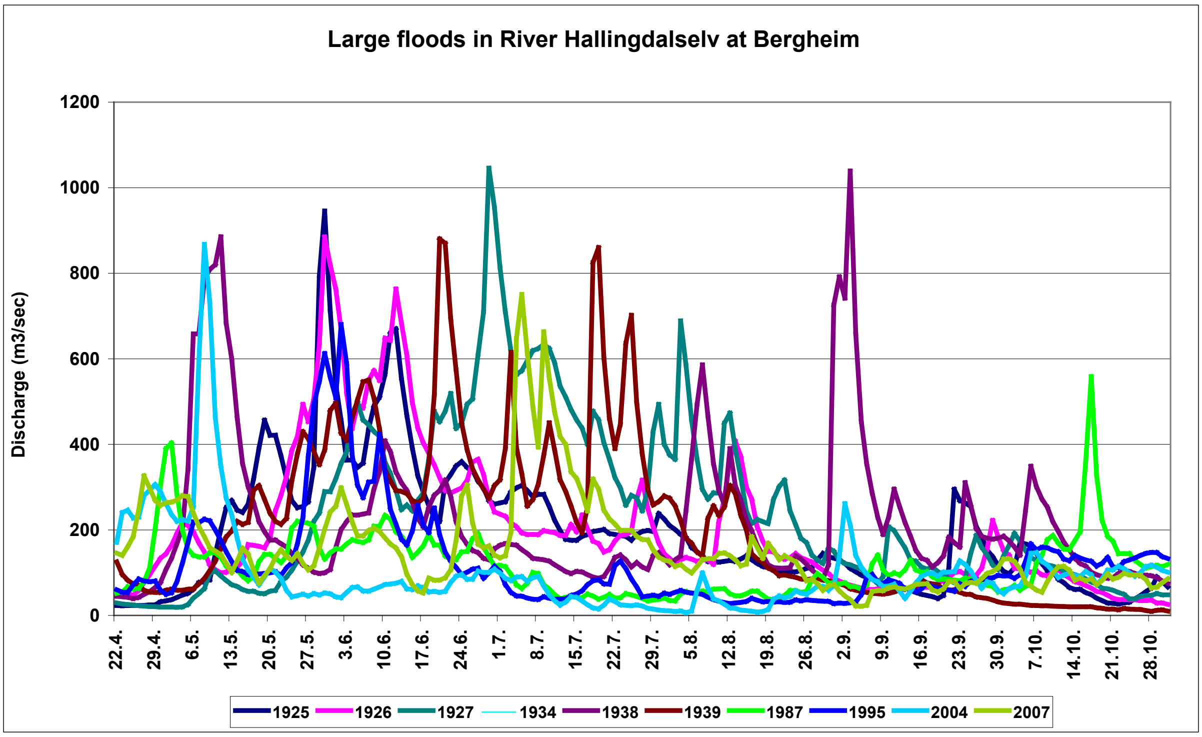


Figure 2.1.6.6 Daily discharges of the ten largest floods in River Hallingdalselv.

Tributaries to River Hallingdalselv

River Rukkedøla joins River Hallingdalselv at Nesbyen from west. The water divide is close to Lake Tunhovdfjord and Lake Pålsbufjord in River Numedalslågen. The gauging station 12.150 Buvatn is close to Tunhovd. Catchment characteristics are given in Table 2.1.6.15. The station has been operating since 1962. There have been some problems with the data quality at the station. Daily precipitation data has been observed at the meteorological station Tunhovd since 1895.

River Hemsil joins River Hallingdalselv at Gol, flowing through Hemsedal from northwest. The river was regulated in 1957. There are two gauging stations in the river at 12.137 Gjerdeslåtta and 12.215 Storeskar. The two stations has been operating since 1953 and 1987. Daily precipitation data has been observed at the meteorological station Hemsedal since 1895. Catchment characteristics of 12.137 Gjerdeslåtta and 12.215 Storeskar are given in Table 2.1.6.15. The dates and ranks of the ten largest annual floods at Buvatn, Gjerdeslåtta and Storeskar are given in Table 2.1.6.16 and the date and discharge of the largest flood in Table 2.1.6.17. River Hensil was badly affected by large springfloods in June 1775 and in June 1860.

River Votna joins River Hallingdalselv from the north at Ål. The catchment is extensively affected by regulations from 1948. The gauging station 12.118 Votna was operating 1941-1967. A severe summer rainstorm flood occurred in this river in 1876 causing severe damages in the village Ål.

River Hol joins River Hallingdalselv from west-northwest. The river flows eastward from the water divide toward River Aurlandselv. The gauging station 12.143 Ruud has been operating since 1953.

Table 2.1.6.15 Catchment characteristics of three gauging stations in tributaries to River Hallingdalselv.

Station	12.150 Buvatn	12.137 Gjerdeslåtta	12.215 Storeskar
	Basin characteristics		
Catchment area (km^2)	24,79	774,58	119,49
Station altitude (m.a.s.l.)	840	567	895
Mean altitude (m.a.s.l)	933	1261	1346
Top altitude (m.a.s.l.)	1085	1828	1814
Lake (%)	12,34	5,02	3,54
Bog (%)	14,56	4,12	4,04
Forest (%)	72,21	16,24	5,94
Mountain (%)	0,04	69,53	80,81
Glacier (%)	0	0	0

Table 2.1.6.16 The dates and ranks of the ten largest annual floods in Rivers Rukkedalselv and Hemsil - tributaries to River Hallingdalselv.

12.150 Buvatn			12.137 Gjerdeslåtta			12.215 Storeskar		
1962-2014			1953-2014			1987-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1966	19/5	1	1954	24/5	1	1988	30/5	7
1967	28-29/5	7	1962	3/10	7	1995	2/6	2
1977	25/5	7	1963	9/8	9	1997	1/7	4
1978	25/5	9	1971	30/5	3	1999	29/5	5
1983	19/5	6	1972	7/6	8	2003	5/6	10
1988	16-17/5	9	1973	1/6	10	2004	7/5	1
1995	2/6	5	1995	2/6	4	2007	4/7	2
2001	14-15/5	3	2004	7/5	2	2010	6/10	7
2004	7/5	11	2007	4/7	5	2011	11/6	3
2008	11/5	4	2011	11/6	6	2014	24/5	9
2013	17/5	2						

Table 2.1.6.17 The dates and maximum discharge (daily values) of the largest floods observed in Rivers Rukkedalselv and Hemsil - tributaries to River Hallingdalselv.

Station	12.150 Buvatn	12.137 Gjerdeslåtta	12.215 Storeskar
Year	1966	1954	2004
Date	19/5	24/5	7/5
q (m^3/sec)	6,08	394,71	68,32
qsp (l/sec km^2)	245	451	572
qsp (mm/day)	21,2	39,0	49,4

Remarks: The peak discharge observed at Storeskar 7/5 2004 was 74,74 m^3/sec or 626 l/sec km^2. The peak from 2004 was however exceeded 11 June 2011 with 79,35 m^3/sec or 664 l/sec km^2.

2.1.6.4 RIVER SOKNA

River Sokna is a tributary flowing into Lake Tyrifjord from northwest. The catchment area is 634 square kilometers. The river flows southward from the water divide towards Hedal in Vassfaret. A gauging station was established at 12.114 Garhammerfoss in 1936. The observations were discontinued 1979-2006 but have now been resumed. The river above Sandsbråten is not regulated for hydropower, but there were some small dams which were used for releasing water to facilitate floating of timber. Catchment characteristics are listed in Table 2.1.6.2, the dates and ranks of the ten largest floods in Table 2.1.6.3 and the largest observed discharge is found in Table 2.1.6.4.

2.1.6.5 RIVER ÅDALSELV/BEGNA

River Ådalselv flows between Lake Sperillen and the junction with River Randselv from east at Hønefoss. Upstreams Lake Sperillen, the name is River Begna. River Begna drains the Valdres district and flows from the water divide towards River Vinstra and River Sjoa in the Glomma/Gudbrandsdalslågen basin to the north and towards River Lærdøla to the west.

The flood regime is dominated by snowmelt floods. Most of the floods co-incide with the large snowmelt floods in the Glomma basin. Several historical floods are known in this river as shown in Table 2.1.6.19. The flood level of some of these floods have been marked on the two flood stones near the river. One of these stones is located at Lake Strandefjorden at Fagernes (Figure 2.1.6.7).

Table 2.1.6.19 Historical floods in River Ådalselv/Begna

Year	Date	Remarks
1717		Flood created River Ala from Lake Syndin
1789	21-23 July	Storofsen – Severe damages upstreams Sørum
1792	Before 24 June	Large snowmelt flood
1860	Mid June	Severe flood, possible worse than *Storofsen*
1879	29-31 May	Spring flood - rain storm at the end
1895	18 May	Spring flood
1897	29 May – 2 June	Spring flood

Figure 2.1.6.7 The flood stone at Fagernes. Photo: Lars A. Roald

Several gauging stations are located in River Ådalselv/Begna. The gauging station 12.15 Strømstøa is located downstream Lake Sperillen. Another station 12.290 is located at Bagn near the upper end of the valley Begndalen. The station Slidrefjord is located west of Fagernes below Lake Vangsmjøsi. Catchment characteristics are given for Strømstøa, Bagn and Slidrefjord in Table 2.1.6.20. The date and rank of the ten largest annual floods at the three stations are shown in Table 2.1.6.21, and the date and discharge of the largest flood in Table 2.1.6.22. The water level in Sperilllen is known back to the flood in 1860.

Table 2.1.6.20 The catchment characteristics of three long-term gauging stations in River Ådalselv/Begna

Station	12.15 Strømstøa	12.290 Bagn	12.77 Slidrefjprd
	Basin characteristics		
Catchment area (km^2)	4631	1976,54	782,07
Station altitude (m.a.s.l.)	150	220	366
Mean altitude (m.a.s.l)	875	949	1055
Top altitude (m.a.s.l.)	1907	1907	1779
Lake (%)	6,94	7,72	9,57
Bog (%)	8,57	8,81	2,31
Forest (%)	50,77	38,43	30,95
Mountain (%)	22,74	30,26	48,0
Glacier (%)	0,01	0,01	0

Strømstøa regulated: 1/1-1904
Bagn regulated: 1/10-1967
Slidrefjord regulated: 1/1-1956

Table 2.1.6.21 The ranks of the 10 largest floods observed in River Ådalselv at Strømstøa and in River Begna at Bagn and Slidrefjord.

12.15 Strømstøa			12.290 Bagn			12.77 Slidrefjord		
1908-2014			1949-2014			1908-1954		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1908	2/6	3	1951	12/8	1	1909	25/6	8
1910	25/6	3	1960	20/7	10	1924	25/6	5
1916	13-14/6	2	1963	22/8	5	1925	2/6	7
1917	1/6	1	1964	14/10	6	1926	12/6	9
1926	2/6	5	1965	9-10/9	7	1927	1/6	3
1927	1-2/7	8	1967	4/6	4	1930	27/5	10
1930	29/5	7	1987	19/10	9	1934	3/9	2
1931	27/5	6	2007	7/7	3	1936	16/6	6
1934	4-5/9	9	2011	21/7	8	1938	2/9	4
1967	4/6	10	2013	23/5	2	1939	21/6	1

Table 2.1.6.22 The dates and discharge of the largest floods (daily values) observed in River Ådalselv at Strømstøa and in River Begna at Bagn and Slidrefjord.

Station	12.15 Strømstøa	2.290 Bagn	12.77 Slidrefjord
Year	1917	1951	1939
Date	1/6	12/8	21/6
q (m^3/sec)	829,16	449,63	275,52
qsp (l/sec km^2)	179	151	352
qsp (mm/day)	15,5	13,05	30,4

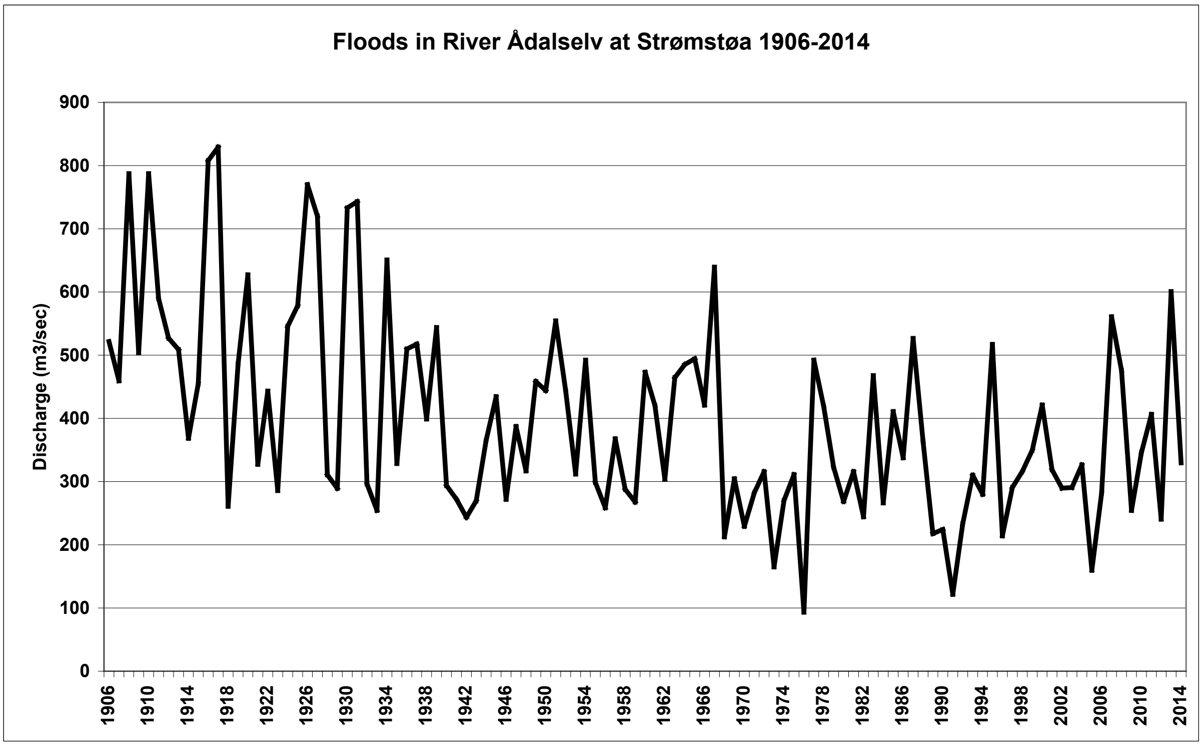


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Figure 2.1.6.8 Annual floods (daily values) in River Ådalselv at Strømstøa 1906-2014.

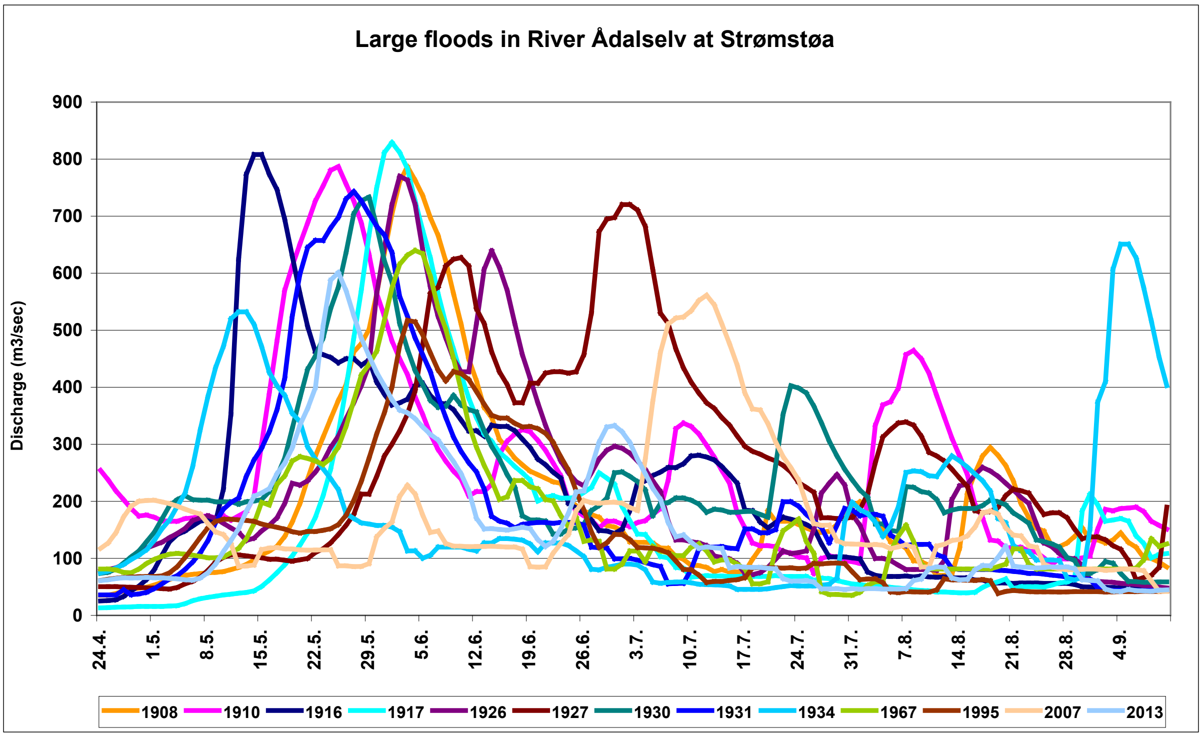


Figure 2.1.6.9 The daily discharge of 13 large floods observed in River Ådalselv at Strømstøa.

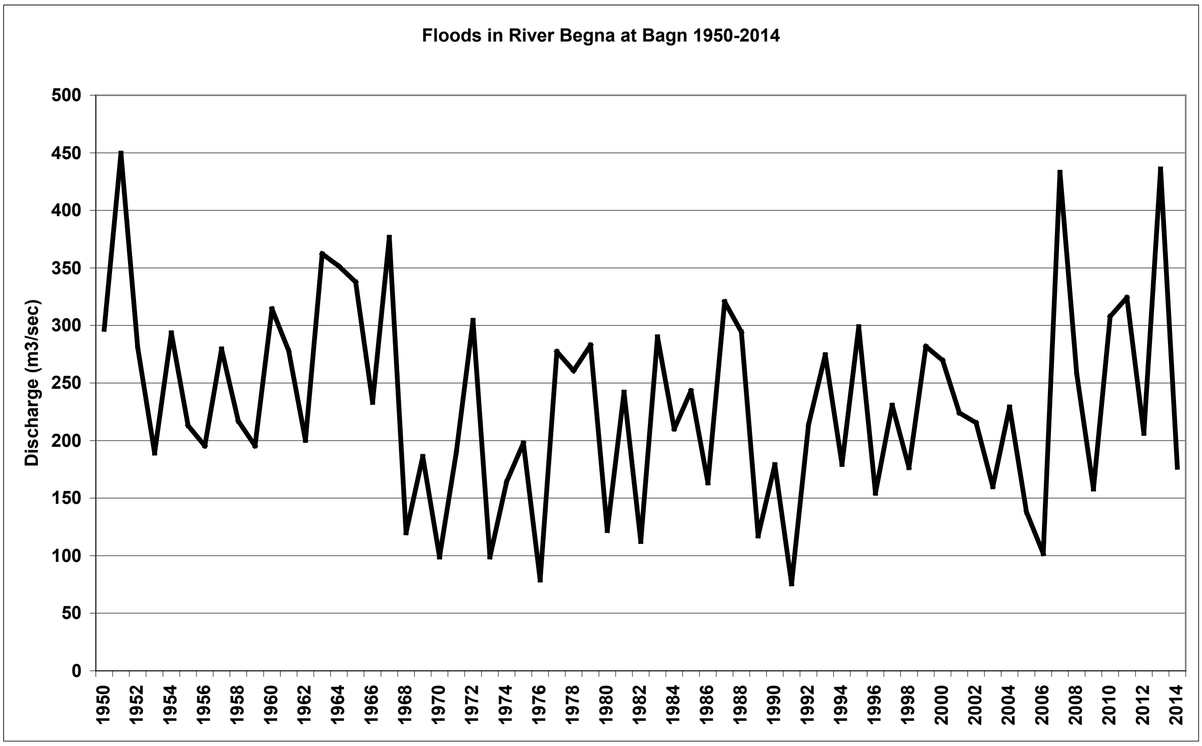


Figure 2.1.6.10 Annual floods (daily values) in River Begna at Bang 1950-2014.

River Begna flows into Lake Strandefjord at Fagernes from west. Strandefjord was regulatrd in 1921. The sources of River Begna is located at Filefjell. The river flows through Lake Slidrefjord. Discharge data are available 1907-1954 from the gauging station 12.77 Slidrefjord. Further upstreams Begna flows through Lake Vangsmjøsi. There are two tributaries, River Rysna from the north and River Ala from the south, which join the main river downstream Lake Vangsmjøsi. Lake Vangsmjøsi has been regulated since 1946. The discharge series 12.52 Vangsmjøsi covers a period with natural discharge 1921-1935. A series with regulated discharge is available from 12.182 Hugali 1964-1999. This catchment includes the catchments of the tributaries Ala and Rysna in addition to the main river from Vangsmjøsi. Additional regulation resulted in reduced floods from 2003. Catchment characteristics are given for Rysna, Vangsmjøsi and Hugali in Table 2.1.6.23 the date and rank of the ten largest annual floods at the three stations are shown in Table 2.1.6.24 and the date and discharge of the largest flood in Table 2.1.6.25.

Table 2.1.6.23 The catchment characteristics of Rysna, Vangsmjøsi and Hugali.

Station	12.13 Rysna	12.52 Vangsmjøsa	12.182 Hugali
	Basin characteristics		
Catchment area (km^2)	50,76	484,50	591,62
Station altitude (m.a.s.l.)	614	466	460
Mean altitude (m.a.s.l)	1372	1218	1211
Top altitude (m.a.s.l.)	1772	1774	1774
Lake (%)	3,94	10,49	10,37
Bog (%)	0	1,5	2,12
Forest (%)	5,91	19,79	19,26
Mountain (%)	76,83	64,46	61,63
Glacier (%)	0	0	0

Table 2.1.6.24 The dates and ranks of the ten largest floods (daily values) observed at Rysna, Vangsmjøsi and Hugali.

12.13 Rysna			12.52 Vangsmjøsa			12.182 Hugali		
1974-2014			1921-1935			1964-1999		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1990	4/5	3	1921	1/6	8	1964	11/10	3
1993	13/7	9	1923	13/7	6	1965	2/8	7
1994	20/8	5	1924	21/7	4	1967	4-5/6	7
1995	2/6	6	1925	30/5	5	1969	1-2/6	10
2001	21/6	6	1926	11/6	3	1971	1/6	4
2002	30/5	1	1927	30/6	2	1972	9/6	2
2004	6/5	10	1930	29/5	7	1993	16/7	5
2007	4/7	8	1931	31/5	10	1995	10/6	5
2011	11/6	4	1934	3/9	1	1999	14/6	7
2014	24/5	2	1935	18/6	8	2007	6/7	1

Table 2.1.6.25 The dates and discharge of the largest floods (daily values) observed at Rysna, Vangsmjøsi and Hugali.

Station	12.13 Rysna	12.52 Vangsmjøsa	12.182 Hugali
Year	2002	1934	2007
Date	30/5	3/9	6/7
q (m^3/sec)	30,88	165,21	119,71
qsp (l/sec km^2)	608	341	247
qsp (mm/day)	52,6	29,5	21,3

River Begna was badly affected by “Storofsen” in 1789 and “Storflaumen” in 1860. During “Storofsen” several landslides occurred on the northern side of Lake Vangsmjøsi. The tax was reduced at several farms after the 1860-flood. River Ala was the result of attempted digging of a canal across the water divide to the north of Lake Syndin. A severe flood in 1717 caused a permanent river to form. The rainfall floods in 1927 and 1934 rank among the largest floods in Vestre Slidre and demonstrate that the district is vulnerable to heavy rainfall in the summer.

Tributaries to River Begna

River Neselvi flows into Lake Strandefjord from Øystre Slidre to the northwest. The upstream catchment is regulated. There are long-term series in some of the lakes in this branch of the water course. Storofsen caused damages at many farms in the catchment. The flood in 1927 is the most severe observed flood at several locations. The spring floods in 1895 and 1897 are also among the largest floods in the series as well as some of the more recent snowmelt floods at Østlandet.

Table 2.1.6.26 The catchment characteristics of three gauging stations in Øystre Slidre.

Station	12.91 Rudi bru	12.88 Øvre Øyangshølen	12.92 Vindevatn
Basin characteristics	Basin characteristics		
Catchment area (km^2)	675,51	245,96	253,59
Station altitude (m.a.s.l.)	434	668	720
Mean altitude (m.a.s.l)	977	1143	582
Top altitude (m.a.s.l.)	1739	1739	1676
Lake (%)	7,8	10,1	7,5
Bog (%)	8,68	5,26	14,98
Forest (%)	34,8	14,76	30,09
Mountain (%)	33,75	63,38	25,55
Glacier (%)	0	0	0

Observed floods in Øystre Slidre:

Table 2.1.6.27 The dates and ranks of the ten largest floods (daily values) observed in River Neselvi in Øystre Slidre.

12.91 Rudi bru			12.88 Øvre Øyangshølen			12.92 Vindevatn		
1919-2014			1919-2014			1920-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1921	29/5	8	1920	7/8	1	1925	29-30/5	6
1922	25/8	5	1922	10/7	5	1926	30-31/5	5
1926	30/5	6	1924	21/8	6	1930	25/5	8
1934	3/9	6	1925	31/5	7	1934	8/5	9
1938	2/9	1	1927	30/6	2	1938	1/9	4
1951	11/8	2	1936	16/6	10	1966	20/5	6
1964	12/5	3	1938	1/9	3	1967	31/5	3
1967	31/5	4	1939	21/6	4	1995	2/6	1
1978	26/5	10	1951	16/8	9	2013	23/5	2
1995	2/6	9	1964	11/10	8	2014	25/5	10

Table 2.1.6.28 The dates and discharge of the largest floods (daily values) observed at Gauging stations in Øystre Slidre.

Station	12.91 Rudi bru	12.88 Øvre Øyangshølen	12.92 Vindevatn
Year	1938	1920	1995
Date	2/9	7/8	2/6
q (m^3/sec)	228,40	149,39	110,67
qsp (l/sec km^2)	338	607	420
qsp (mm/day)	29,2	52,5	26,3

Several farms in Øystre Slidre obtained deductions in the tax as a result of flood damages after "Storofsen".

River Åbjøra joins River Begna in Lake Aurdalsfjorden at Leira from west. This river has been regulated since 1950.

River Hølera joins River Begna in Begndalen between Bagn and Nes in Ådal from west. The gauging station 12.171 Hølervatn with data from 1968 is located at the catchment.

Table 2.1.6.29 Catchment characteristics, the date and rank of the ten largest annual floods and the date and discharge of the largest flood observed at 12.171 Hølervatn.

Station : 12.171 Hølervatn		Floods 1969-2014		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	79,75	1977	25/5	5
Station altitude (m.a.s.l.)	780	1979	2/6	9
Mean altitude (m.a.s.l)	902	1983	12/5	1
Top altitude (m.a.s.l.)	1203	1995	2/6	2
Lake (%)	6,56	2000	12/10	6
Bog (%)	17,96	2004	7/5	8
Forest (%)	57,12	2007	6/7	4
Mountain (%)	9,32	2008	3/5	3
Glacier (%)	0	2011	24/7	7
		2013	19/5	10

Table 2.1.6.30 The discharge of the largest flood (daily and peak) at Hølervatn.

Station	12.171 Hølervatn	12.171 Hølervatn
	Daily value	Peak value
Year	1983	1983
Date	12/5	12/5-19:08
q (m^3/sec)	27,39	27,87
qsp (l/sec km^2)	29,7	
qsp (mm/day)	343	349

River Urula joins River Begna at Nes in Ådal from west just upstreams Lake Sperillen. The river drains Vassfaret, a mostly forested catchment with some mountains. The river was badly affected by Storofsen in 1789, when landslides caused six fatalities at Hedal. There is a long-term precipitation station within the catchment at Hedal starting in 1895.

2.1.6.7 RANDSELVA/ ETNA

River Randselv joins River Ådalselv at Hønefoss forming River Storelva, which flows into Lake Tyrifjorden. The catchment area of the Randselv is 3765 square kilometers. The gauging station 12.228 Kistefoss is located downstreams the outlet of Lake Randsfjord. The river was regulated in 1883. The annual floods at Kistefoss is shown in Figure 2.1.6.11.

Two rivers flow into the upper end of Lake Randsfjord, River Etna and River Dokka. River Etna flows into Lake Randsfjord from north-northwest. The gauging station 12.70 Etna has been active since 1919. The catchment is not regulated except for few small reservoirs used to release water for timber floating. This release of water has modified the smaller floods. The annual floods at Etna is shown in Figure 2.1.6.12. The dominant flood season is in May (78 percent of all years). Figure 2.1.6.13 show the flood hydrographs of the nine largest floods observed at Etna.

River Dokka joins River Etna upstreams Lake Randsfjord. The gauging station 123.8 Grønvold bru has been active 1960-1989. River Dokka was regulated in 1989 and 2008.

Catchment characteristics of the three gauging stations are listed in Table 2.1.6.31, the date and ranks of the ten largest floods (daily values) in Table 2.1.6.32 and the date and the discharge of the largest observed flood (daily values) in Table 2.1.6.33.

Table 2.1.6.31 The catchment characteristics of three gauging stations in River Randselv, Etna and Dokka.

Station	2.228 Kistefoss	12.70 Etna	12.8 Grønvold bru
	Basin characteristics		
Catchment area (km^2)	3704	557	933,46
Station altitude (m.a.s.l.)	120	399	343
Mean altitude (m.a.s.l)	631	936	925
Top altitude (m.a.s.l.)	1681	1681	1521
Lake (%)	7,21	4,43	4,16
Bog (%)	10,89	17,75	17,99
Forest (%)	61,91	46,7	47,89
Mountain (%)	6,99	12,56	19,32
Glacier (%)	0	0	0

<u>The largest historical floods were according to historical sources:</u>

1789 – 21-23 July *Storofsen*
1792 – before 24 June a large spring flood at the same time as in Skienselva.
1860 – The flood hydrograph is known in Randsfjorden 1860.
1910 – The largest observed flood in Randselva.

Table 2.1.6.32 The dates and ranks of the ten largest floods (daily values) observed in River Randselv, Etna and Dokka.

12.228 Kistefoss			12.70 Etna			12.8 Grønvold bru		
1916-2014			1919-2014			1960-1989		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1920	29/5	5	1920	20/5	7	1996	19/5	2
1927	29/6	6	1927	27/6	8	1967	1/6	1
1931	28/5	1	1930	26/5	6	1978	27/5	4
1951	30/8	3	1934	8/5	10	1979	25/5	3
1966	25-26/5	4	1938	1/9	5	1980	31/5	6
1967	5-6/6	2	1966	19/5	3	1983	19/5	9
1977	30/5	10	1967	1/6	4	1984	3/6	7
1987	21/6	8	1995	2/6	1	1985	27/5	8
1993	13/8	9	2010	21/5	9	1987	16/10	5
1995	3-4/6	7	2013	23/5	2	1988	3/9	10

Table 2.1.6.33 The dates and discharge of the largest floods (daily values) observed at gauging stations in Randselv, Etna and Dokka.

Station	12.228 Kistefoss	12.70 Etna	12.8 Grønvold bru
Year	1931	1995	1967
Date	28/5	2/6	1/6
q (m^3/sec)	386,26	206,46	398,43
qsp (l/sec km^2)	104	362	427
qsp (mm/day)	9,01	31,0	36,9

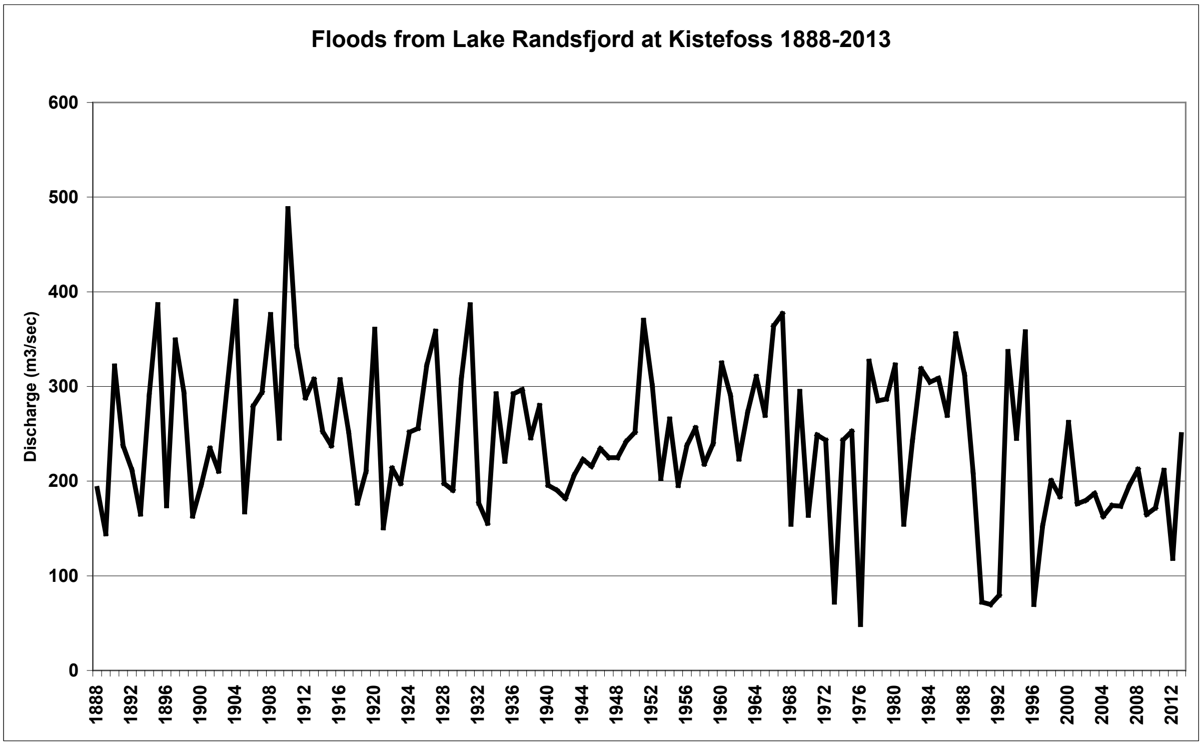


Figure 2.1.6.11 Annual floods (daily values) from Lake Randsfjord at Kistefoss 1888-2013.

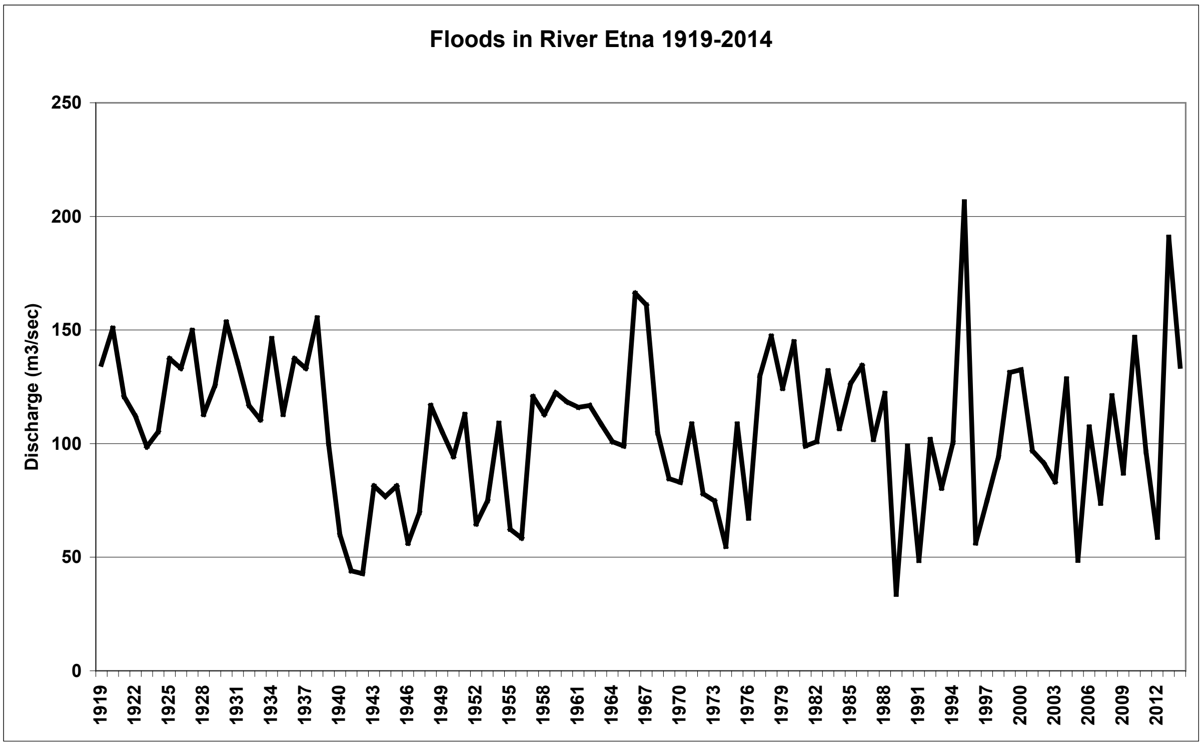


Figure 2.1.6.12 Annual floods (daily values) in River Etna 1913-2014.

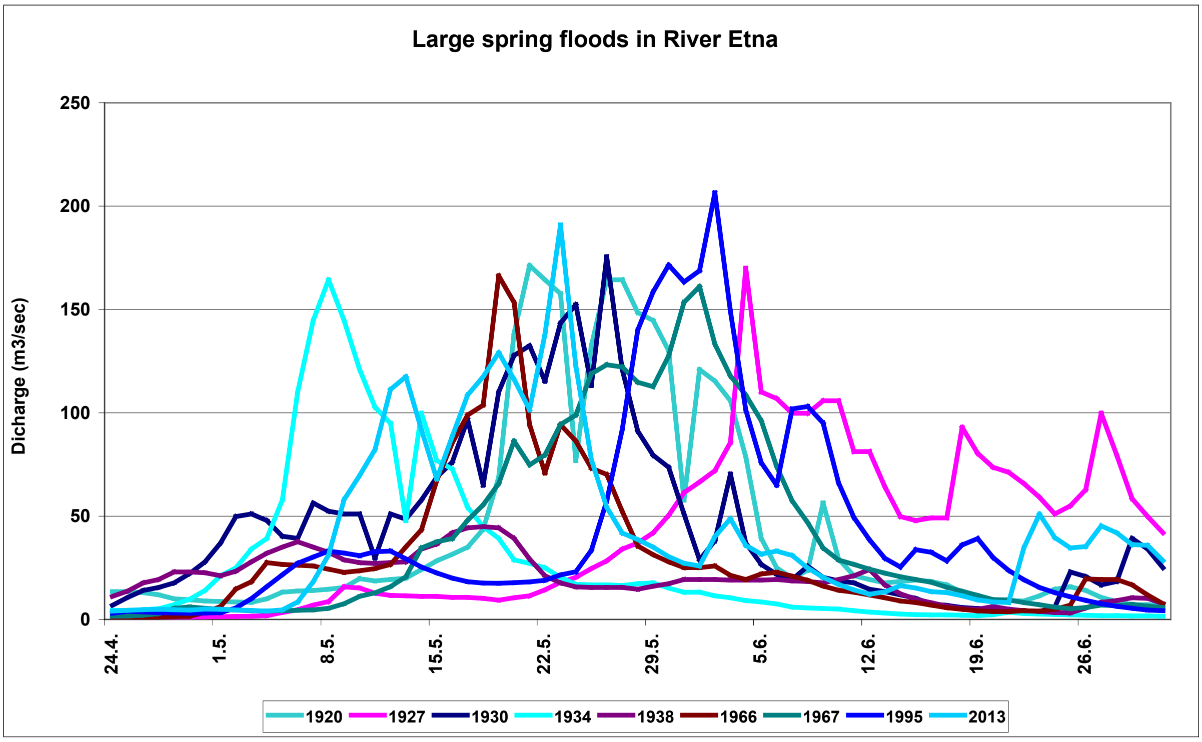


Figure 2.1.6.13The daily discharge of nine large floods observed in River Etna.

2.1.7 RIVER NUMEDALSLÅGEN

River Numedalslågen has a catchment area of 5.577 square kilometers. The upper part of the catchment drains the eastern part of the Hardangervidda plateau. The river is regulated with large reservoirs in Lake Tunnhovdfjord and Lake Pålsbufjord and in Uvdal west of Rødberg where Nore I power station is located. The lower part of the catchment is narrow with mountain ridges at both sides to Kongsberg and hills at both sides of the flood plain further south. Large floods along Numedalslågen has been documented in Tråen et al. (1977) and (Borgersen, 2007).

Table 2.1.7.1 Historical floods in Numedalslågen

Year	Date	Remarks
1532		Flood damage at Åbyfoss
1653	3/9	Flood caused by long-term rainfall
1677		Flood and landslides in Nore and Uvdal
1743	May-June	
1747		
1754	12/3	Large flood
1764	27/8	Deduction at 4 farms I, Numedal and Sandsvær
1782	19/6	
1789	20-23/7	Storofsen – damages at 50 farms in Numedal
1804	Spring	Spring flood
1808	21-22/6	Spring flood
1822	27 August	Rainfall flood
1827	Spring	Spring flood
1837	September	Flood caused by torrential rainfall
1839		Bommestad bru damaged
1841	Spring	Spring flood
1860	15-22/6	Extreme flood – snowmelt and heavy rainfall. Landslides
		in Numedal.
1879	29/5-4/6	Large flood – heavy rainfall at the end of the snowmelt
1885	11/9	Rainfall flood in Numedal
1892	8-9/10	Large rainfall flood
1897	29/5-2/6	Spring flood
1916	13-16/5	Large spring flood – locally heavy rainfall in Uvdal
1926	11-17/6	Two floods
1927	27/6-2/7	Large rainfall flood
1934	May	Large snowmelt flood
1934	4-7/8	Rainfall flood

The lowermost gauging station in River Numedalslågen was 15.18 Bommestad bru, which was active 1879-1926. The gauging station 15.1 Labru has data covering the period 1773-1907.

The gauging station 15.61 comprises the gauging station Fosserød, which was active 1927-1929. The observations were resumed 1970-2014, and the station was renamed to 15.61 Holmfoss. Upstreams Holmfoss the station 15.31 Kjerringhølen was active 1936-1953. This station was equipped with a chart recorder, and some of the charts are stored at NVE.

The gauging station 15.15 Kongsberg was active from 1912. The observations were then continued at 15.66 Gleda because of the building of Brofoss power station. Data from Gleda was used until 31/12-1982 when Pikerfoss power station was built. Recent data are observed at 15.100 Skollenborg power station. The catchment characteristics of three gauging stations on the lower Numedalslågen is given in Table 2.1.7.2, the dates and ranks of the ten largest daily floods in Table 2.1.7.3 and the date and discharge of the largest flood in Table 2.1.7.4.

Table 2.1.7.2 The catchment characteristics of three gauging stations in the lower reaches of River Numedalslågen.

Station	15.18 Bommestad bru	15.61 Holmfoss	15.15 Kongsberg
	Basin characteristics		
Catchment area (km^2)	5535,5	5201,8	4259,2
Station altitude (m.a.s.l.)	7	12	146
Mean altitude (m.a.s.l)	871	918	1039
Top altitude (m.a.s.l.)	1537	1537	1537
Lake (%)	6,64	6,92	7,85
Bog (%)	4,99	5,27	5,88
Forest (%)	49,66	47,91	40,38
Mountain (%)	31,86	33,9	41,0
Glacier (%)	0	0	0

Table 2.7.7.3 The date and ranks of the ten largest floods observed at 15.18 Bommestad, 16.61 Holmfoss and 15.15 Kongsberg on the lower reaches of River Numedalslågen.

15.18 Bommestad bru			15.61 Holmfoss			15.15 Kongsberg		
1879-1926			1970-2014			1912-2009		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1879	1/6	1	1978	5/7	10	1913	5/5	8
1882	9/7	9	1983	14/5	5	1916	11/5	2
1885	11/9	6	1987	17/10	2	1917	31/5	5
1892	9/10	3	1994	11/9	7	1925	30/5	7
1895	14/8	7	2000	13/10	3	1926	13/6	3
1897	1/6	5	2004	8/5	6	1924	30/6	1
1908	4/6	10	2007	6/7	1	1934	3/9	4
1916	12/5	2	2010	7/10	9	1937	24/6	9
1924	21/8	4	2011	25/7	4	1954	23/5	10
1925	31/5	8	2013	18/5	8	2007	4/7	6

Table 2.1.7.4 The dates and discharge of the largest floods (daily values) observed at Gauging stations on the lower reaches of River Numedalslågen.

Station	15.18 Bommestad bru	15.61 Holmfoss	15.15 Kongsberg
Year	1879	2007	1927
Date	1/6	6/7	1
q (m^3/sec)	1402,44	1020,24	1197,64
qsp (l/sec km^2)	254,93	196	281
qsp (mm/day)	21,9	16,9	24,3

There have been several gauging stations on the upper reaches of River Numedalslågen. The gauging station 15.14 Kvila was active 1919-1930. Futher upstreams the station 15.22 Båtstøhagen was active 1926-1933 and 15.25 Bruhaug 1926-1964. 15.33 Øyhølen was located near Norefjord and was active 1913-1964. The nearby gauging station 15.13 Skaget was active 1927-1963. Catchment characteristics of this station are given in Table 2.1.7.5, the dates and ranks of the ten largest floods in Table 2.1.7.6 and the date and discharge of the largest flood in Table 2.1.7.7. All these stations were affected by the upstream regulations at Nore power stations and of the later regulation of Uvdalselv.

The regulation of Lake Tunhovdfjord and Lake Pålsbufjord in 1919 and 1924, caused a large reduction in the annual floods downstreams in the main river. The station 15.13 Brofoss monitored the discharge below Tunnhovdfjord 1916-1967. Catchment characteristics of Brofoss and the upstream station 15.79 Orsjoren which is located near Dagali upstream Pålsbufjorden. The flow regime of the main river is modified by reservoirs such as Lake Halnefjord and changing diversion of Lake Tindhølen between Numedalslågen and Sima.

Table 2.1.7.5 The catchment characteristics of three gauging stations in the upper reaches of River Numedalslågen.

Station	15.13 Skaget	15.3/10 Brofoss	15.79 Orsjoren
	Basin characteristics		
Catchment area (km^2)	3108,09	1859,83	117,29
Station altitude (m.a.s.l.)	262	686	951
Mean altitude (m.a.s.l)	1152	1215	1229
Top altitude (m.a.s.l.)	1537	1537	1537
Lake (%)	9,59	12,44	12,9
Bog (%)	5,6	5,64	4,61
Forest (%)	26,9	20,47	1,56
Mountain (%)	53,8	58,59	79,67
Glacier (%)	0	0	0

River Numedalslågen had extreme floods in the upper Numedal in 1789 and 1860. The floods caused landslides, and several people perished. The catchments had probably large rainfall floods in 1752 and 1858, as in River Simoa to the east and at Tinn to the west. The largest observed floods were the spring flood in 1916 and the summer flood in 1927. The flood in 1879 was the third largest. Kristensen (1911) gives the level of the 1860-the flood at Labro. A rating curve was established there in 1873. Using this ratingcurve the peak discharge is estimated to 285 m^3/s or 302 l/s square kilometer in 1860. This indicates that the 1860-flood exceeds both the 1916- and the 1927- flood in River Numedalslågen. A large flood occurred in River Numedalslågen in July 2007. The flood was third largest in the tributary Jondalselv. This flood was not among the larger floods in the main river because of the many large reservoirs reducing the flood.

Table 2.1.7.6 The date and ranks of the ten largest floods observed at 15.13 Skaget, 15.3/10 Brofoss and 15.79 Orsjoren on the upper reaches of River Numedalslågen.

15.13 Skaget			15.3/10 Brofoss			15.79 Orsjoren		
1927-1963			1916-1967			1956-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1927	29/6	1	1916	31/5-1/6	1	1967	5/6	6
1930	26/5	6	1917	8/6	2	1971	31/5	10
1933	21/6	2	1920	24-25/6	8	1972	8/6	4
1934	3/9	3	1924	25/6	5	1983	10-11/6	8
1937	28/5	4	1925	14/6	4	1984	2/6	1
1939	20/6	5	1926	12/6	7	1985	29/5	5
1945	27/6	8	1927	2/7	3	1989	22-23/6	3
1950	23/6	9	1933	22-23/9	9	1997	15/6	9
1954	23/5	7	1937	29/6	6	2004	9/5	2
1961	24/10	10	1945	29/6	10	2007	8/6	7

Table 2.1.7.7 The dates and discharge of the largest floods (daily values) observed at gauging stations on the upper part of River Numedalslågen.

Station	15.13 Skaget	15.3/10 Brofoss	15.79 Orsjoren
Year	1927	1916	1984
Date	29/6	31/5-1/6	2/6
q (m^3/sec)	1053,07	428,83	340,05
qsp (l/sec km^2)	338,92	*	289
qsp (mm/day)	29,3	*	25,0

- Natural catchment area is not defined.

Floods in tributaries to River Numedalslågen.

River Jondalselv is a tributary to River Numedalslågen draining a subcatchment west of the main river upstreams Kongsberg. The catchment includes the southern part of Blefjell to the north and the mountains including the silver mines at Kongsberg to the south. The water divide to the west is the Tinne catchment of River Skienselv. The gauging station 15.20/21 Jondalselv has been active 1919-2014.

River Uvdalselv joins the main river at Rødberg from the west. Uvdalselv was regulated in 1965. The gauging station 15.7 Dokkeberg was active 1914-1934, and the station 12.19 Fønnebufjord 1914-2014 was located 1 km further downstream. Lake Fønnebufjord in River Uvdalselv was regulated in 1919.

River Borgåi flows into River Numedalslågen at Skjønne upstream Lake Norefjord from east. The catchment extends westward from the water divide to River Simoa. The gauging station 15.53 Borgåi has been active 1966-2014.

Lake Halledalsvatn is located at River Halledalselv north of Lake Pålsbufjord. The station has been active 1962-2014. Catchment characteristics of the gauging stations Jondalselv, Fønnebergfjord/Dokkeberg and Halledalsvatn are given in Table 2.1.8.8.

East of Tunnhov where Lake Pålsbufjord and Tunnhovdfjord are connected by a short river, there is a precipitation station 29600 Tunhovd which has been active since 1895. The water divides to the tributary Rukkedøla in River Drammenselv and the station 12.150 Buvatn is located close to Tunnhovd.

Table 2.1.7.8 Catchment characteristics of three gauging stations in tributaries to River Numedalslågen.

Station	15.20/21 Jondalselv 1919-2014	15.19/7 Fønnebufjord/Dokkeberg	15.49 Halledalsvatn 1962-2014
	Basin characteristics		
Catchment area (km^2)	125,90	690,75	59,13
Station altitude (m.a.s.l.)	229	460	846
Mean altitude (m.a.s.l)	574	1162	1028
Top altitude (m.a.s.l.)	920	1484	1185
Lake (%)	3,37	6,39	5,38
Bog (%)	5,01	4,39	5,33
Forest (%)	77,12	21,25	61,35
Mountain (%)	9,45	62,48	19,62
Glacier (%)	0	0	0

The ten largest annual floods (daily values) in the three tributaries are given in Table 2.1.7.9. The date and discharge of the largest flood is given in Table 2.1.7.10. Figure 2.1.7.1 show the annual floods in River Jondalselv 1919-2014.

Table 2.1.7.9 Date and ranks of the ten largest annual floods in tributaries to River Numedalslågen.

15.21 Jondalselv			15.19/7 15.19/7 Fønnebufjord/Dokkeberg			15.49 Halledalsvatn		
1919-2014			1915-1966			1962-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1922	23/8	7	1916	10/5	1	1966	20/5	4
1925	15/4	4	1917	30/5	10	1977	24/5	8
1927	29/6	1	1919	17/5	7	1978	17/5	5
1934	6/8	6	1927	29/6	2	1981	17/5	8
1950	25/8	1	1933	21/6	6	1983	19/5	2
1979	30/7	8	1934	31/8	4	1985	21-22/5	8
1988	20/7	8	1938	31/8	3	1995	30/5	3
2000	7/10	5	1945	31/5	8	2004	7/5	1
2007	4/7	3	1954	23/5	5	2008	12/5	7
2008	2/5	10	1961	2/6	9	2011	6/7	6

Table 2.1.7.10 The dates and discharge of the largest floods (daily values) observed at gauging stations in tributaries to River Numedalslågen.

Station	15.21 Jondalselv	15.19/7 Fønnebufjord/Dokkeberg	15.49 Halledalsvatn
Year	1927,1950	1916	2004
Date	29/6,25/8	10/5	7/5
Q (m^3/sec)	68,81	414,33	18,13
qsp (l/sec km^2)	546	600	307
qsp (mm/day)	47,2	51,8	26,5

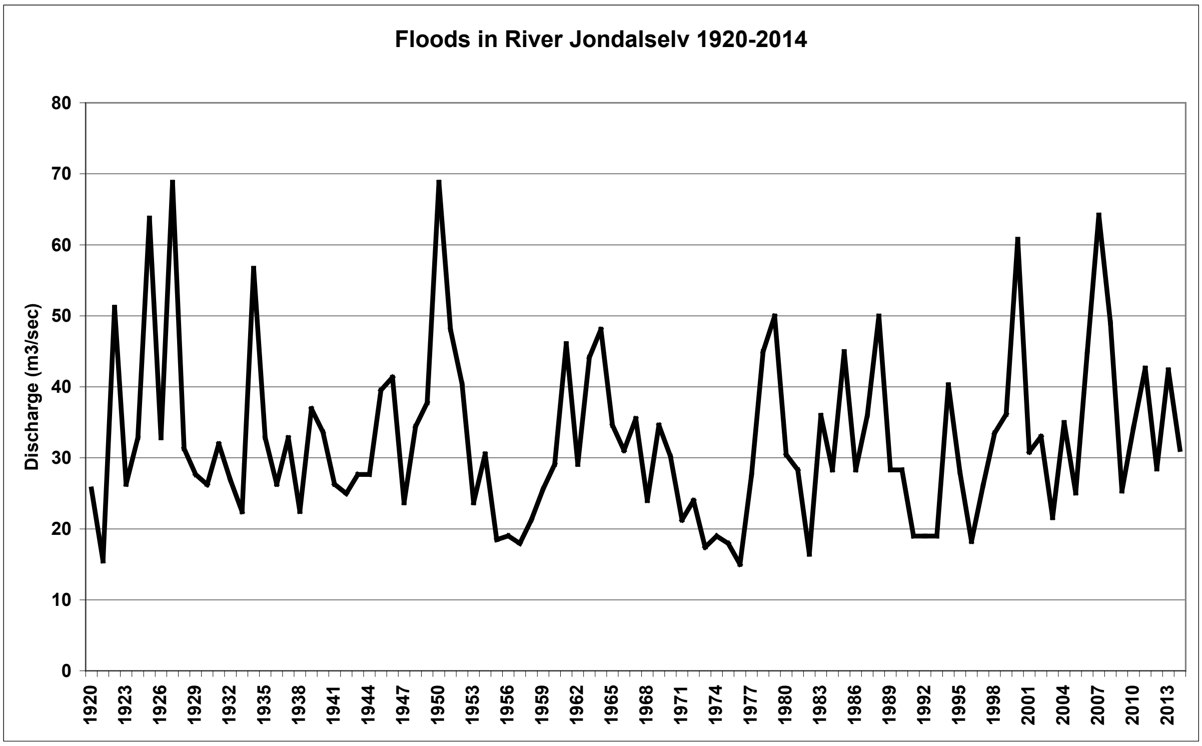


Figure 2.1.7.1 Annual floods (daily values) in River Jondalselv 1920-2014.

2.1.8 RIVER SKIENSVASSDRAGET

River Skienelv has a catchment area of 10.772 square kilometers. The gauging station Løveid is located at Lake Norsjø upstreams the first locks of the Skien Canal. The catchment area is 10.388 square kilometer at the station, which is located at 14 m.a.s.l. The mean altitude of the catchment is 919 m.a.s.l, and the highest point is at 1870 m.a.s.l, near the summit of Gausta. Bogs makes up 3,52 percent, lakes 9,16 percent, forests 45,75 percent, mountains above the tree-line 36,28 percent and glaciers only 0,05 percent og the catchment. There are two long-term data series, starting in 1852 at Løveid and 1851 at Hjellevatn further downstream in the Skien Canal. The annual flood levels are shown in Figure 2.1.8.1.

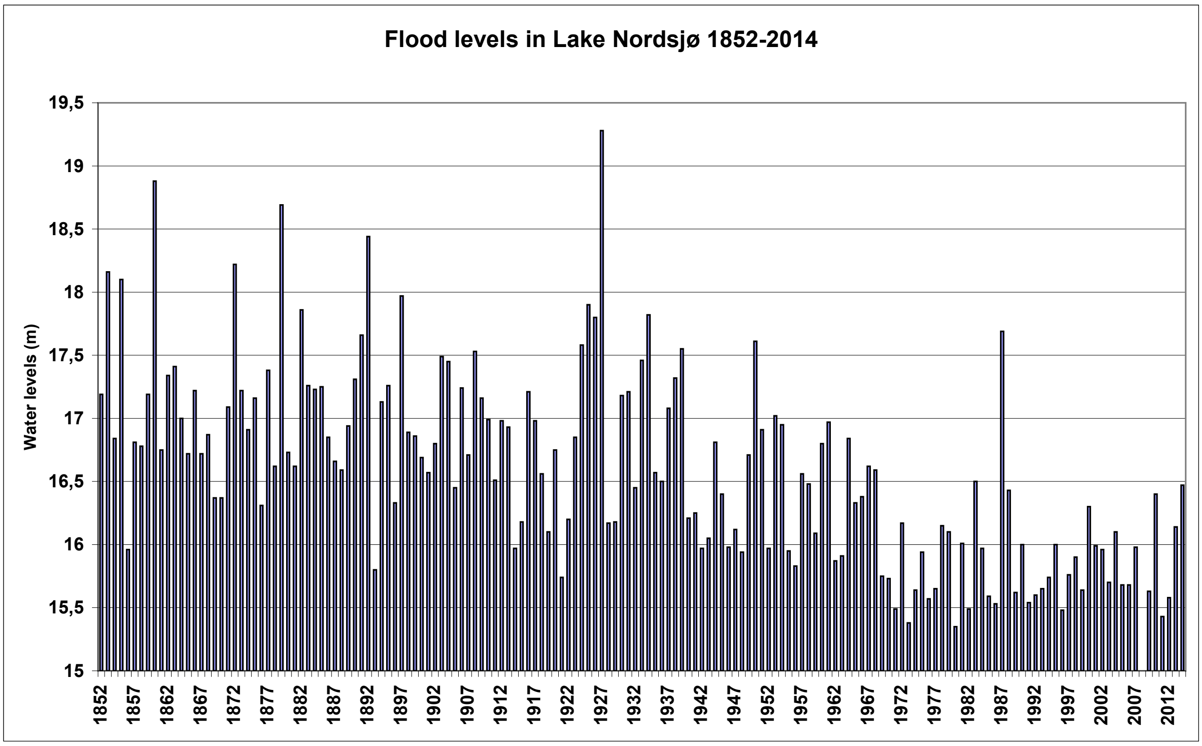


Figure 2.1.8.1 Flood levels in Lake Nordsjø.

The river was regulated from 1855. The development includes several large reservoirs, which have resulted in strongly reduced floods in the lower river. The 10 largest annual floods observed in Lake Nordsjø at Løveid are listed in Table 2.1.8.1. The lowflows have however increased as a result of the operation of the hydropower plants.

The largest floods in the water course have been documented in some historical sources from the 17th to the 19th Century as listed in Table 2.1.8.2.

The upper part of the catchment comprises two main branches, one branch in north and east which branches into the tributaries Bøelv, Heddøla and Tinne, and a second branch running westward through Lake Flåvatn, Kviteseidvatn and to Bandak and through River Tokke to Lake Totak. The lower part of the western branch comprises of a series of lakes connected with a canal with a system oflocks allowing traffic by passenger boats from Skien to Dalen.

Both branches flow from the eastern and southern part of the Hardangervidda plateau. The seasonality and magnitude of the floods in both branches have changed because of large hydropower developments.

The northeastern branch comprises Lake Heddalsvatn, with River Bøelv and Heddøla flowing into the lake from the west and River Tinne flowing into the lake from the north at Notodden. The eastern branch has large reservoirs in Lake Tinnsjø (regulated 1881/1905/09), Lake Møsvatn (regulated 1909), Lake Kalhovd/Gøyst (regulated 1917/47) and Lake Mårvatn (regulated 1914/17). River Tinne flows from Lake Tinnsjø through the power station at Kirkevoll bru. Discharge data at Kirkevoll bru is available from 1905. Lake Tinnsjø is the third deepest lake in Norway (460 m deep). Small tributaries flow into the lake from the north. The main tributary is River Måna flowing from the west through Vestfjorddalen and the town Rjukan. The valley is narrow, and avalanches and landslides occur frequently in the district. River Måna flows from Lake Møsvatn, a huge reservoir, and the discharge is strongly modified. The discharge series is available from 1909. There is a series from a small natural mountain catchment starting in 1949 near Lake Møsvatn. Water has been diverted from one of the smaller tributaries flowing into Lake Tinnsjø from the north, River Mår. The water is now released into River Måna close to Lake Tinnsjø.

The catchment of the western branch extends to the water divide to the large rivers draining to the south coast such as River Toke, River Nidelv, River Otra, and River Sira and to rivers draining westward such as River Suldalslågen. The water-divide to the north drains towards River Måna. The western branch has large reservoirs included in the Tokke power stations. The dominant flood season in the larger rivers are in the spring, but large floods in the late summer- and early autumn caused by heavy rainfall are also common. Disse floods have caused many land slides in steep terrain, most frequently at Tinn.

Historical floods in Skienselv:

Table 2.1.8.1 Date and ranks of the largest floods observed in Lake Nordsjø at Løveid.

Year	Date	Rank	Remarks
1860	21-22/6	2	
1872	14/6	5	
1879	1/6	3	
1882	10/4	8	
1892	9/10	4	
1897	6/6	6	
1926	13/6	10	
1927	30/6	1	
1934	4/9	9	

Table 2.1.8.2 Historical floods in River Skienselv known from historical sources.

Year	Date	Remarks
1645	Spring	Sawmills and dams destroyed at Skien
1653	3/9	Autumn flood. Loss of timber at Skien
1688		Large flood in River Skienselv
1721		Flood in River Skienselv destroyed 4 sawmills and damaged 5
1736	Spring	Large spring flood in River Tinne and Måna.
1752	23/8	Rainfall flood in River Tinne and Måna after drought. 34 farms in Upper Telemark suffered damages
1775	June	Large flood in Tinn. Damages at 7 farms.
1789	21-23/7	Storofsen. Damages in the lower reaches of Skienselv
1792	Before 24 June	Large snowmelt flood exceeding Storofsen in Skien
1804	Spring	Large spring flood in Skienselv
1808	21-22/6	Large flood (less than 1827). Snowmelt and thunder stor. The ironwork at Hørte was damaged
1822	August	Thunderstorm caused high water level at Skien, only exceeded in 1860.
1827	May	Large spring flood
1837	September	Widespread flood resulting from thunderstorms
1841		Flood
1858	July	Large flood in River Tinne and Måna
1860	15-22/6	Extreme flood. Snowmelt and rainfall
1879	29/5-4/6	Severe flood, snowmelt and rainfall
1892	8-9/10	Rainfall flood
1897	29/5-2/6	Spring flood

THE WESTERN BRANCH

River Tokke was regulated in 1958, and in the subsequent years some additional reservoirs and power station was added to the scheme. Data is available from the gauging station 13.34 Totak (1880-1958). The annual flood is the spring flood, which occurs in May 34,9 percent, June 61,9 percent and July 3,2 percent of all years. Snowmelt floods dominates completely; large rainfall floods occurring in the eastern parts of the catchment, are always less than the spring flood, except in smaller lowland catchments where the summer- or autumn floods often are the largest in some of the year. The water levels have been observed at several stations in River Tokke below Lake Bandaksvatn. The water level series observed at 16.40 Strengen started in 1879. This series is shown in Figure 2.1.8.2. Discharge data has been estimated at the nearby staion 16. Strengen- Hogga 1910-2012 and further downstreams at 16.43 Vrangfoss.

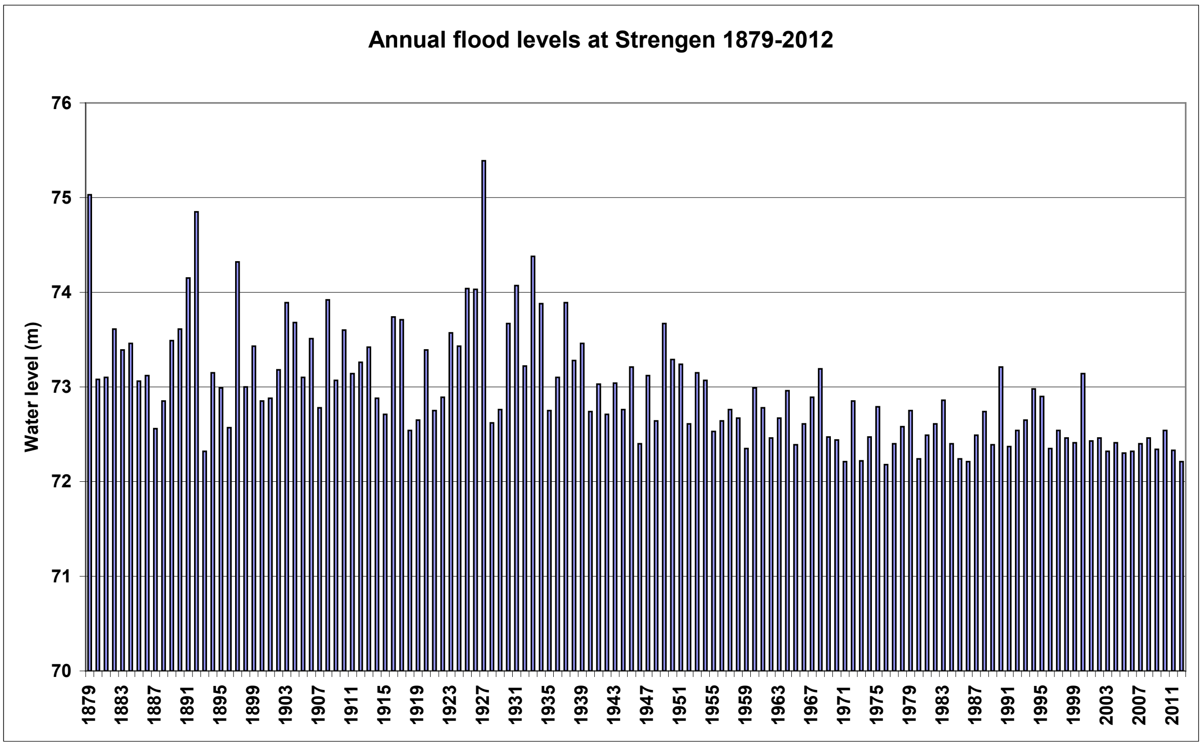


Figure 2.1.8.2 Observed flood levels at Strengen 1879-1912.

River Bøelv flows from Lake Seljordvatn to Lake Nordsjø north of River Tokke/ Vestvassdraget. The river was regulated 20/9 1944. A joint long-term series are available at 16.33 Seljordvatn and 16.51 Hagadrag since 1880. Catchment characteristics of 16.51 Hagadrag, 16.34 Totak and 16.10 Omnesfoss are listed in Table 2.1.8.3.

The long-term series have been affected by hydropower regulations. The floods have been reduced after the regulations. There are stations in many smaller catchments where the magnitude of more recent floods can be found in tributaries to the main river. 16.104 Kilen is located at River Kilåi, 16.112 Byrteåi in River Byrteå in River Rukkeåi and 16.75 Tannsvatn is located at River Tanså. These rivers are tributaries to River Tokke/ Vestvassdraget. 16.193 Hørte in River Hørteelv and 16.122 Grovå are both located at River Bøelv. 16.132 Gjuvå is a tributary to River Heddøla. Catchment characteristics of Kilen, Hørte and Byrteåi are listed in Table 2.1.8.4 and 16.75 Tannsvatn is located at River Tanså, 16.132 Gjuvå and 16.122 Grovå in River Grovå. Catchment characteristics are listed in Table 2.1.8.5.

Table 2.1.8.3 Catchment characteristics of three stations west of Lake Norsjø and Lake Heddalsvatn.

Station	16.51 Hagadrag	16.34 Totak	16.10 Omnesfoss
	Basin characteristics		
Catchment area (km^2)	726,98	855,47	807,71
Station altitude (m.a.s.l.)	115	687	61
Mean altitude (m.a.s.l)	820	1130	852
Top altitude (m.a.s.l.)	1536	1628	1870
Lake (%)	5,95	12,71	6,06
Bog (%)	3,85	5,34	4,9
Forest (%)	60,65	20,01	60,19
Mountain (%)	21,24	59,54	18,79
Glacier (%)	0	0	0

Table 2.1.8.4 Catchment characteristics of the smaller catchments Kilen, Hørte and Byrteåi in western Telemark.

Station	16.104 Kilen	16.193 Hørte	16.112 Byrteåi
	Basin characteristics		
Catchment area (km^2)	120,70	156,56	37,32
Station altitude (m.a.s.l.)	96	96	699
Mean altitude (m.a.s.l)	488	502	1270
Top altitude (m.a.s.l.)	1070	1204	1534
Lake (%)	4,8	3,14	4,3
Bog (%)	1,41	2,81	0,21
Forest (%)	61,84	73,05	12,36
Mountain (%)	9,12	18,38	80,11
Glacier (%)	0	0	0

Table 2.1.8.5 Catchment characteristics of the smaller catchments at Tannsvatn, Gjuvå and Grovå in western Telemark.

Station	16.75 Tannsvatn	16.132 Gjuvå	16.122 Grovå
	Basin characteristics		
Catchment area (km^2)	118,28	33,10	42,69
Station altitude (m.a.s.l.)	697	459	717
Mean altitude (m.a.s.l)	905	1084	914
Top altitude (m.a.s.l.)	1287	1619	1199
Lake (%)	6,69	7,16	3,1
Bog (%)	19,48	6,65	11,64
Forest (%)	53,16	27,57	59,79
Mountain (%)	16,4	55,02	21,85
Glacier (%)	0	0	0

Observed floods in the western part of the Skienselv catchment:

The dates and ranks of the ten largest annual floods at Hagadrag, Totak and Omnesfoss are listed in Table 2.1.8.6 and the date and discharge of the largest flood in Table 2.1.8.7.

The dates and ranks of the ten largest annual floods at Kilen, Hørte and Byrteåi are listed in Table 2.1.8.8 and the date and discharge of the largest flood in Table 2.1.8.9

The dates and ranks of the ten largest annual floods at Tannsvatn, Gjuvå and Grovå are listed in Table 2.1.8.10 and the date and discharge of the largest flood in Table 2.1.8.11.

Table 2.1.8.6 The date and ranks of the ten largest floods (daily values) observed at the gauging stations in River Bøelv Tokke and Heddøla.

16.51 Hagadrag			16.34 Totak			16.10 Omnesfoss		
1885-2014			1885-1957			1920-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1892	8/10	8	1889	27/5	4	1923	22/9	9
1897	30/5	4	1897	2/6	2	1925	29/5	6
1916	11/5	3	1903	11/6	3	1927	29/6	1
1925	29/5	8	1910	15/6	8	1934	6/8	2
1927	29/6	1	1925	31/5	4	1938	1/9	5
1934	7/8	5	1926	1/6	6	1939	18/7	4
1938	1/9	6	1927	30/6	1	1950	25/8	10
1966	19/5	9	1930	28/5	10	1951	9/8	7
1967	27/5	10	1937	28/5	9	1964	13/10	8
1987	17/10	2	1949	22/5	7	1987	16/10	3

Table 2.1.8.7 The dates and discharge of the largest floods (daily values) observed at Gauging stations in River Bøelv, Tokke and Heddøla.

Station	16.51 Hagadrag	16.34 Totak	16.10 Omnesfoss
Year	1927	1927	1927
Date	29/6	1/6	29/6
Q (m^3/sec)	395,50	391,67	*
qsp (l/sec km^2)	544	458	*
qsp (mm/day)	47,0	39,6	*

- The peak is missing at 16.10 Omnesfoss because of station failure.

Table 2.1.8.8 The date and ranks of the ten largest floods (daily values) observed at the gauging stations at Kilen, Hørte and Byrteåi.

16.104 Kilen			16.193 Hørte			16.112 Byrteåi		
1962-2014			1961-2014			1967-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1964	14/10	3	1961	28/10	9	1968	4/9	7
1965	12/5	2	1962	24/8	7	1969	2/6	2
1966	10/6	10	1963	9/8	2	1973	1/6	3
1967	5/6	1	1964	8/5	1	1981	27/9	9
1968	20/5	6	1967	4/10	4	1987	16/10	4
1969	9/6	5	1978	4/7	10	1998	28/6	5
1970	3/6	4	1985	5/8	5	2004	6/5	1
1981	20/9	8	1987	16/10	3	2009	30/7	8
1990	30/10	6	2007	4/7	8	2013	18/5	10
2006	1/5	9	2010	6/10	6	2014	7/7	6

Table 2.1.8.9 The dates and discharge of the largest floods (daily values) observed at The gauging stations in River Kjelå, Hørte and Byrteåi, tributaries to River Skienselv.

Station	16.104 Kilen	16.193 Hørte	16.112 Byrteåi
Year	1967	1964	2004
Date	5/6	8/5	6/5
q (m^3/sec)	66,54	113,84	57,43
qsp (l/sec km^2)	551	727	1977
qsp (mm/day)	47,6	62,8	170,8

Table 2.1.8.10 The date and ranks of the ten largest floods (daily values) observed at the gauging stations at Tannsvatn, Gjuvå and Grovå.

16.75 Tannsvatn			16.132 Gjuvå			16.122 Grovå		
1955-2014			1981-2014			1973-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1963	12/6	4	1984	18/5	8	1975	11/5	9
1966	20/5	4	1987	16/10	8	1978	24/5	3
1967	27/5	1	1988	30/5	3	1981	12/5	5
1978	24/5	2	1995	1/6	5	1982	30/9	10
1983	17-18/5	10	2000	11/10	7	1984	18/5	6
1987	17/10	8	2001	9/10	6	1987	16/10	2
1995	30/5	7	2010	16/5	4	2000	1/5	7
2004	7/5	6	2011	24/7	10	2004	6/5	1
2010	7/10	9	2013	18/5	2	2010	4/10	8
2013	19/5	3	2014	24/5	1	2013	18/5	4

Table 2.1.8.11 The dates and discharge of the largest floods (daily values) observed at gauging stations in River Tannselv, Gjuvå and Grovå, tributaries to River Skienselv.

Station	16.75 Tannsvatn	16.132 Gjuvå	16.122 Grovå
Year	1967	2014	2004
Date	27/5	24/5	6/5
q (m^3/sec)	39,67	14,07	27,83
qsp (l/sec km^2)	335	425	652
qsp (mm/day)	29,0	36,7	56,3

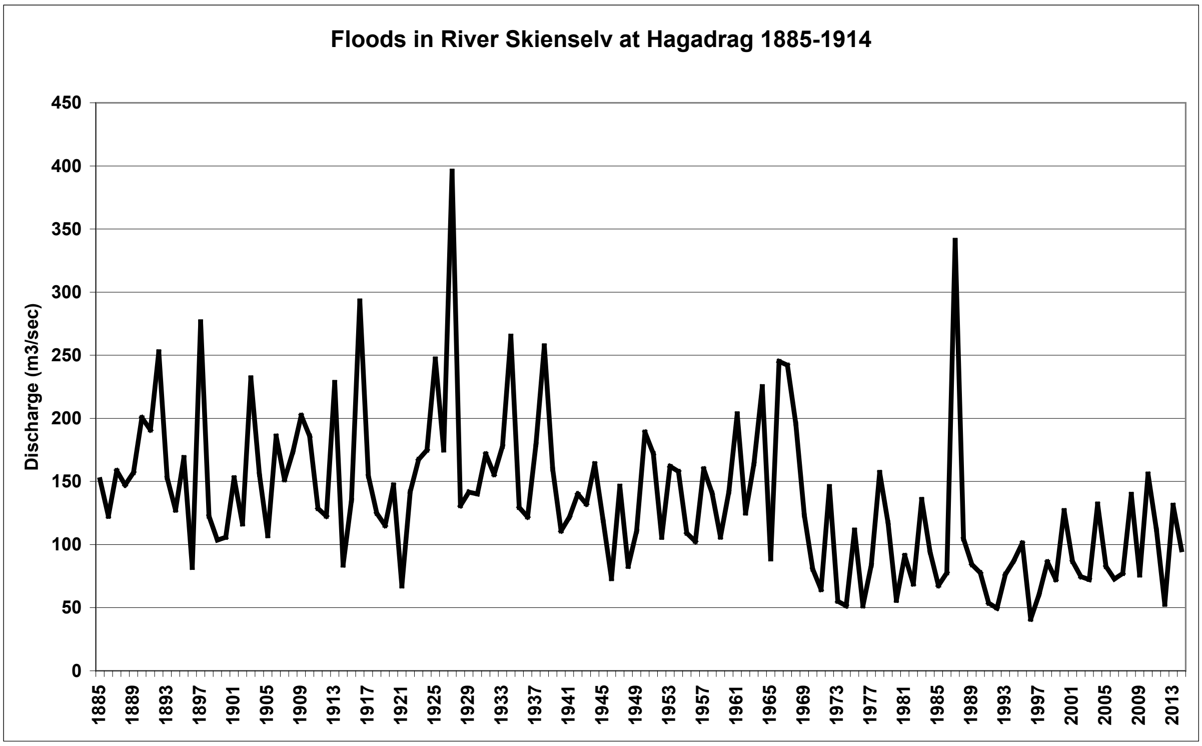


Figure 2.1.8.3 Annual floods (daily values) at Bøelv at Hagadrag 1885-2014.

THE EASTERN BRANCH

Two rivers flow into Lake Heddalsvatn at Notodden, Lake Heddøla from the west and River Tinne from the north. Spring floods are common in these rivers. Large rainfall floods in August and September are however more common in these rivers than further west. These floods have often caused severe damages.

RIVER HEDDØLA

The catchment includes the northern flank of Lifjell and Mæjefjell to the south and the mountains in Hjartdal including the southern flank of Gausta to the north and northwest. There is a long-term precipitation station in the catchment, 31900 Tuddal, starting in 1895, and a station 32200 Lifjell just outside the catchment to the south. The catchment includes the long-term gauging station 16.10 Omnesfoss. Catchment characteristics are given in Table 2.1.8.3, the date and ranks of the ten largest floods in Table 2.1.8.6 and the discharge of the largest flood in Table 2.1.8.7. The river was regulated in 1958.

RIVER TINNE

River Tinne flows from Lake Tinnsjø to Lake Heddalsvatn at Notodden. The main gauging station in the Tinne catchment is 16.23 Kirkevoll bru, which have been operating since 1908. Lake Tinnsjø has a major tributary from the west, River Måna, flowing from Hardangervidda through Lake Mjøsvatn and Vestfjorddalen through the industrial town Rjukan. Lake Møsvatn is a large reservoir for the Frøystul power station.

The station 16.23 Kirkevoll bru is located at River Tinne downstream Lake Tinnsjøen. There are two gauging stations in Tiver Måna 16.19 Møsvatn Langhøl and 16.20 Møsvatn ndf below the reservoir Lake Møsvatn. The data series at 16.19 starts in 1906. The data series is strongly modified by the regulations as shown in Figure 4.1 on page 20 in Volume 1. The largest flood was nevertheless the disastrous flood in 1927. The precipitation has been observed at the precipitation station 31410 Rjukan. The highest one-day rainfall of 134 mm was observed at the station 29 June 1927.

River Gøyst flows into Lake Tinnsjø from the north. Further east, River Mår flows into Lake Tinnsjø from Lake Kalhovdfjord and from Lake Mårvatn. River Mår and Gøyst are strongly regulated. Lake Kalhovdfjord and Lake Gøyst form a joint reservoir to Mår power station in Vestfjorddalen downstream Rjukan. Lake Mårvatn is also regulated. This river has caused severe damages to the priest farm and the road close to Lake Tinnsjøen, especially in 1822, July 1858 and May-June 1879. During the flood in 1858 20 landslides occurred in the upper part of the catchment.

Another river Austbygdåi flows into Lake Tinnsjø further east. There are two gauging stations in this river, 16.128 Austbygdåi and 16.127 Viertjern both with shorter data series. The catchment characteristics are given for 16.23 Kirkevoll bru, 16. 66 Groset 16.128 Austbygdåi in Table 2.1.8.12, the ranks and the dates of the ten largest annual floods in Table 2.1.8.13 and the date and discharge in Table 2.1.8.14.

The Tinne catchment includes the mountain Gausta 1880 m.a.s.l on the southern side of Vestfjorddalen. The mountain slopes are steep, and landslides occur frequently during severe rainstorms.

River Grosetbekken is a tributary from north to River Måna east of the large Møsvatn reservoir. The gauging station 16.66 Grosetbekken has been active from 1949 to 2014. The catchment has been used for research, and several other variables has been observed at the station. Upstream Lake Møsvatn is another gauging station 16.140 Kvenna located. This station has been operating 1987-2014, but with many gaps in the observed series.

Table 2.1.8.12 Catchment characteristics of stations in River Tinne, Grosetbekken and Austbygdåi.

Station	16.23 Kirkevoll bru	16.66 Groset	16.128 Austbygdåi
	Basin characteristics		
Catchment area (km^2)	3845,4	6,60	343,6
Station altitude (m.a.s.l.)	180	939	201
Mean altitude (m.a.s.l)	1166	1005	1137
Top altitude (m.a.s.l.)	1866	1058	1484
Lake (%)	10,68	7,1	3,94
Bog (%)	4,3	20,22	3,81
Forest (%)	23,6	66,82	32,65
Mountain (%)	58,36	2,47	55,77
Glacier (%)	0,01	0	0

Table 2.1.8.13 The largest floods in River Tinne known from historical sources

Year	Date	Remarks
1736	Spring	
1752	23/8	Thunderstorms after prolonged heatwave
1775		
1789	21-23/7	Heavy rainfall (Vb-type) Less intensive than further east.
1858	7/7	Summer rainfall combined with snow melt
1860	15-17/6	Heavy rainfall combined with snow melt
1879	29/5	Thunderstorm at the end of the peak of the snow melt

Table 2.1.8.14 The dates and ranks of the ten largest annual floods (daily values) in River Tinne, Grosetbekken and Austbygdåi.

16.23 Kirkevoll bru			16.66 Groset			16.128 Austbygdåi		
1905-2014			1950-2014			1977-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1908	4/6	8	1950	19/8	10	1978	24/5	10
1924	20/8	6	1954	22/5	7	1984	2/6	9
1926	13/6	8	1966	19/5	2	1987	16/10	4
1927	30/6	1	1967	31/5	3	1988	28/5	5
1930	6/8	10	1970	16/5	4	1995	2/6	7
1934	3/9	3	1971	12/5	7	2002	12/5	8
1938	6/10	7	1981	12/5	6	2004	6/5	1
1939	19/7	4	1987	16/10	9	2007	4/7	6
1950	20/8	2	2004	6/5	1	2013	16/5	2
1987	18/10	5	2013	18/5	5	2014	24/5	3

Table 2.1.8.15 The dates and discharge of the largest floods (daily values) observed at Gauging stations in River Tinne, Grosetbekken and Austbygdåi.

Station	16.23 Kirkevoll bru	16.66 Groset	16.128 Austbygdåi
Year	1927	2004	2004
Date	30/6	6/5	6/5
q (m^3/sec)	985,52	3,48	124,87
qsp (l/sec km^2)	256	528	363
qsp (mm/day)	22,1	45,6	31,4

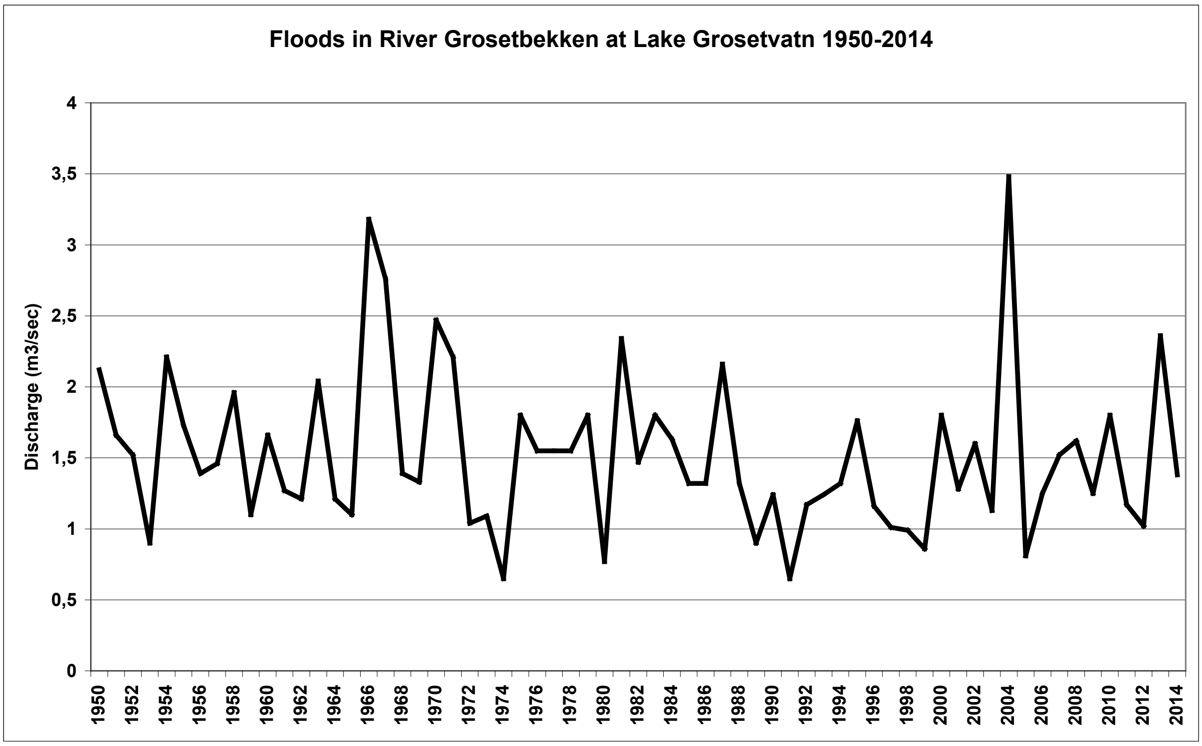


Figure 2.1.8.4 Annual floods (daily values) in River Grosetbekken 1950-2014.

2.2 Sørlandet

2.2.1 KRAGERØVASSDRAGET-VEGÅRDSELV-GJERSTADELV

Some small coastal rivers in Vest-Telemark and Aust-Agder have experienced large floods caused by intense rainfall. The only long-term series is from Dalsfoss in River Toke starting in 1908. This series is strongly affected by regulations. A few short series exist in these rivers. A few intense rainfall floods are known in these rivers. The specific runoff is very high in some of these events (Kanalvæsnets historie vol, 1883b).

The gauging station 18.08 Ubergelv had a catchment area of 289,89 square kilometres. Data has been observed from 1924 to 1971. The gauging station 18.10 Gjerstad in River Gjerstadelv has a catchment area of 236,23 square kilometres. Data has been observed from 1981 to 2014. Catchment characteristics of 17.10 Dalsfoss, 18.8 Ubergelv and 18.10 Gjerstad are listed in Table 2.2.1.1. The dates and the ranks of the ten largest annual floods are listed in Table 2.2.1.2 and the date and discharge of the largest flood in Table 2.2.1.3.

Table 2.2.1.1 Catchment characteristics of the three gauging stations in River Toke, Ubergelv and Gjerstadelv

Station	17.10 Dalsfoss ndf	18.8 Ubergelv	18.10 Gjerstad
	Basin characteristics		
Catchment area (km^2)	1158	289,81	236,23
Station altitude (m.a.s.l.)	38	75	50
Mean altitude (m.a.s.l)	287	236	313
Top altitude (m.a.s.l.)	908	506	657
Lake (%)	6,7	10,25	3,45
Bog (%)	2,61	5,31	4,87
Forest (%)	82,48	82,25	81,76
Mountain (%)	3,68	0	2,9
Glacier (%)	0	0	0

Table 2.2.1.2 The date and ranks of the ten largest annual floods in River Toke, Ubergelv and Gjerstadelv.

17.10 Dalsfoss ndf			18.8 Ubergelv			18.10 Gjerstad		
1909-2014			1924-1971			1980-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1916	1/11	8	1930	20/9	8	1981	20/9	1
1934	3/9	7	1934	16/12	6	1984	23/11	9
1937	23/4	6	1937	21/4	3	1986	29/8	4
1949	24/11	2	1949	24/11	2	1987	17/10	3
1950	26/8	5	1950	25/8	4	1990	6/7	2
1953	4/11	1	1953	3/11	9	1992	3/12	6
1954	7/5	8	1954	5/5	7	1999	16/8	7
1959	16/11	6	1958	3/11	10	2000	8/11	5
1961	12/11	3	1959	15-16/11	1	2008	16/1	10
1987	17/10	4	1970	19/11	5	2009	4/11	8

Table 2.2.1.3 The dates and discharge of the largest floods (daily values) observed at gauging stations in River Toke, Ubergelv and Gjerstadelv.

Station	17.10 Dalsfoss ndf	18.8 Ubergelv	18.10 Gjerstad
Year	1953	1959	1981
Date	4/11	15-16/11	20/9
q (m3/sec)	555,75	125,34	147,80
Qsp (l/sec km2)	480	432	626
Qsp (mm/day)	41,4	37,4	54,1

2.2.2 RIVER NIDELV

River Nidelv flows from the east side of the water divide towards River Otra and Tovdalselv towards Arendal and the North Sea. To the East, the catchment extends to River Vegardselv and to the north to the water divide of River Skienselv. River Nidelv has two main branches, the eastern Nisserelven and the western Fyriselv. These branches have both a large regulated lake, Nisservatn and Fyrisvatn. A third branch, River Gjøv, joins River Fyriselv from the west downstream Lake Fyrisvatn. The two main branches join at Åmot forming River Nidelv. The catchment area of Nisserelv is 1352 and River Fyriselv 1028 square kilometers.

The river has been extensively used for floating timber from the 18-Century. Failing sale of the timber, caused the river to be full of rotting logs which had to be cleared away. The river is now regulated for hydropower production.

The longest dataseries is at 19.40 Lunde mølle where observations startes in 1874. The river was regulated in 1899. Catchment characteristics are given i Table 2.2.2.2. Another series was established at 19.127 Rygene representing the same catchment in 1900. The annual flood occurs most frequently in the late summer or autumn; in August 11 percent, September 15 percent, October 24 percent and November 19 percent of all years. The annual flood occurs in May in 19 percent of all years. Higher up in the catchment the annual flood occurs in May from 35 til 59 percent of the years. The gauging station 19.55 Jørundland is located at 19.55 River Gjøv. The observation started 2 July 1934. The river was regulated in 1963.

Historical floods are listed in Table 2.2.2.1.

Table 2.2.2.1 Floods known from historical sources:

Year	Date	Remarks
1727		Flood at Asdal lense caused loss of timber
1749	13-14/5	Messel bro taken by the river.
1789	21-23/7	Storofsen. Asdal timber boom failed
1799	14/10	Large flood in River Hiså
1817	17/7	Flood in Nisserelv and Fyrisdal
1837	20/9	Large flood from Vegårdselv to Otra. Rainstorm after snowfall
1839		Flood broke Asdal timber boom. Loss of timber.
1850		Flood at Gjevenes
1855		Flood in Fyrisdal
1858	7/7	Flood in River Sitjeå in Fyrisdal
1858	17-18/7	Flood in Nisserelv
1860	June	Large flood, Asdal timber boom failed
1875	Autumn	Flood in Nidelva, timber stuck at Blakstad bro.
1879	31/5	Severe flood in Nidelva
1892	8/10	Rainfall flood at Lunde mølle in Nidelva. Asdal boom broken

Table 2.2.2.2 Catchment charcteristics of three gauging stations in River Nidelv.

Station	19.40 Lunde mølle	19.127 Rygene total	19.55 Jørundland
	Basin characteristics		
Catchment area (km^2)	3947,36	3947,36	342,68
Station altitude (m.a.s.l.)	18	31	227
Mean altitude (m.a.s.l)	547	547	698
Top altitude (m.a.s.l.)	1520	1520	1003
Lake (%)	11,08	11,08	13,36
Bog (%)	4,28	4,28	5,65
Forest (%)	68,26	68,22	58,16
Mountain (%)	11,35	11,35	17,96
Glacier (%)	0	0	0

Table 2.2.2.3 Catchment characteristics of three small not regulated stations in River Nidelv.

Station	19.80 Stigvassåi	19.79 Gravå	19.76 Tovsliøytjønn
	Basin characteristics		
Catchment area (km^2)	14,49	6,31	116,05
Station altitude (m.a.s.l.)	148	312	536
Mean altitude (m.a.s.l)	263	659	739
Top altitude (m.a.s.l.)	429	1063	1003
Lake (%)	1,79	0,32	13,37
Bog (%)	4,37	4,6	6,14
Forest (%)	91,4	69,41	60,46
Mountain (%)	0	17,27	18,8
Glacier (%)	0	0	0

Table 2.2.2.4 Date and rank of the ten largest floods (daily values) at the three gauging stations in River Nidelv.

19.40 Lunde mølle			19.127 Rygene total			19.55 Jørundland		
1874-2014			1900-2014			1934-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1874	9/10	7	1933	22/6	9	1935	15/11	2
1875	14/10	3	1937	23/4	5	1937	18/5	9
1877	15/11	9	1949	24/11	3	1938	4/10	8
1879	31/5	3	1950	28/8	7	1950	24/8	6
1892	8/10	1	1951	23/11	9	1957	6/11	10
1937	23/4	10	1953	4/11	2	1959	15/8	1
1949	17/11	6	1959	17/11	4	1967	26/5	5
1953	4/11	5	1961	29/10	6	1987	17/10	3
1959	17/11	8	1967	5-6/11	8	1990	6/7	4
1987	18/10	2	1987	18/10	1	2000	31/10	7

Table 2.2.2.5 Date and discharge of the largest flood (daily values)

Station	19.40 Lunde mølle	19.127 Rygene total	19.36 Jørundland
Year	1892	1987	1959
Date	8/10	18/10	15/8
q (m^3/sec)	1467	1215	173,13
Qsp (l/sec km^2)	372	308	506
Qsp (mm/day)	32,2	26,6	43,7

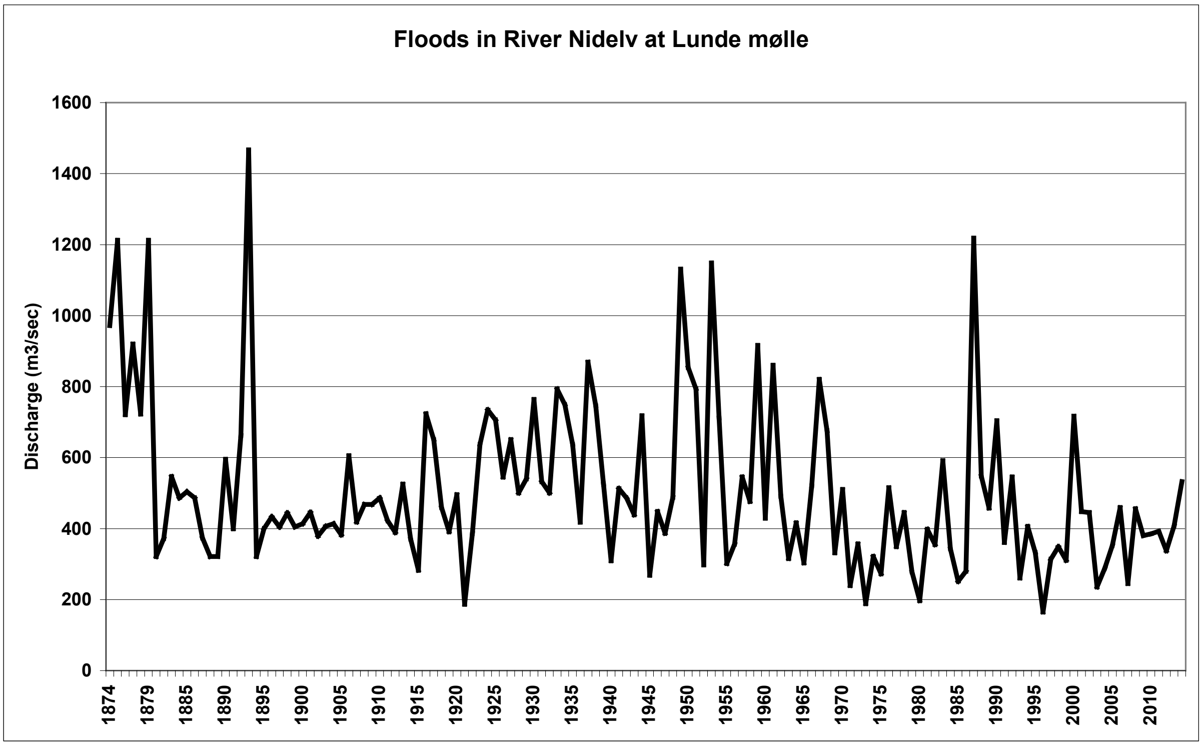


Figure 2.2.2.1 Annual floods (daily values) in River Nidelv at Lunde mølle 1874-2013.

Table 2.2.2.6 Date and rank of the ten largest floods (daily values) at three not regulated catchments in River Nidelv.

19.80 Stigvassåi			19.79 Gravå			19.76 Tovsliøytjønn		
1972-2014			1970-2014			1969-2002		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1974	20/10	9	1977	6/5	6	1970	12/5	6
1981	20/9	8	1979	14/8	6	1975	11/5	3
1987	16/10	2	1982	30/9	5	1978	24/5	2
1990	16/7	1	1983	16/10	3	1979	16/5	9
1992	11/12	6	1987	16/10	1	1983	11/5	4
1994	1/4	7	1993	3/8	10	1987	17/10	1
2000	13/11	5	2000	24/4	9	1990	6/7	5
2001	9/10	10	2004	6/5	8	1994	1/5	7
2006	28/8	3	2008	29/4	4	2000	1/5	8
2008	16/1	4	2010	16/5	2	2001	9/10	10

Table 2.2.2.7 Date and discharge of the largest flood (daily values) at three not regulated catchments in River Nidelv.

Station	19.80 Stigvassåi	19.79 Gravå	19.76 Tovsliøytjønn
Year	1990	1987	1987
Date	16/7	16/10	17/10
q (m^3/sec)	16,10	2,63	77,61
qsp (l/sec km^2)	1111	416	669
qsp (mm/day)	96,0	36,0	57,8

2.2.3 RIVER TOVDALSELV.

River Tovdalselv is the water course between River Nidelva and River Otra at Sørlandet. The catchment area is 1.802 square kilometers. The lower part of the catchment is somewhat affected by regulations, but the upper part with the gauging station Austenå is not regulated. The longest dataseries is 20.3 Lake Flaksvatn where observations started in 1899. The annual flood occurs most frequently in October (18 percent) and November (23 percent) at Flaksvatn which is in the lower part of the catchment. Heavy rainfall is the most common cause of these floods. The annual flood occurs in the spring in April and May in 12,5 percent each of all years. The catchment at Flaksvatn was regulated in 1960. Table 2.2.3.1 list floods in River Tovdalselv known from historical sources.

Table 2.2.3.1 The largest floods in River Tovdalselv known from historical sources.

Year	Date	Remarks
1837	12-15/9	
1864	17-18/9	
1875	14/10	
1892	3-9/10	

The gauging station 20.2 Austenå has catchment area of 276 square kilometers. The annual flood at Austenå is most frequently the spring flood occurring in May (35 percent) but can also occur in the autumn, preferably in October (18 percent) or November (15 percent).

Lake Oggevatn is located at a tributary to River Tovdalselv joining the main river from northwest at Flaksvatn. The gauging station 20.6 Ogge has been operating since 1950.

The gauging station 20.11 Tveitdalen is a small forested research basin. The catchment area is 0,44 square kilometers. Long-term precipitation stations have been active since the 1890s at 38450 Herefoss, 38600 Mykland and 38800 Tovdal.

Catchment characteristics of the gauging stations at Austenå, Flaksvatn and Ogge is given in Table 2.2.3.2. Table 2.2.3.3 lists the dates and ranks of the ten largest floods (daily values) and Table 2.2.3.4 the date and discharge of the largest flood at the three stations.

Table 2.2.3.2 Catchment characterisics of three gauging stations in River Tovdalselv.

Station	20.3 Flaksvatn	20.2 Austenå	20.6 Ogge
	Basin characteristics		
Catchment area (km^2)	1780,66	276,42	244,19
Station altitude (m.a.s.l.)	19	228	190
Mean altitude (m.a.s.l)	354	763	298
Top altitude (m.a.s.l.)	1146	1146	565
Lake (%)	7,64	11,9	6,48
Bog (%)	7,85	5,59	10,57
Forest (%)	74,44	61,87	80,43
Mountain (%)	5,92	20,28	0,09
Glacier (%)	0	0	0

Table 2.2.3.3 Date and rank of the ten largest floods (daily values) at three stations in River Tovdalselv.

20.3 Flaksvatn			20.2 Austenå			20.6 Ogge		
1899-2014			1924-2014			1950-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1916	1/11	7	1927	4/6	2	1951	22/11	9
1930	22/9	5	1928	3/5	9	1954	5/5	3
1931	4/11	9	1938	4/10	4	1957	7/11	10
1937	22/4	4	1957	6/11	6	1959	16/11	1
1949	24/11	3	1959	15/8	8	1970	20/11	7
1954	6/5	8	1968	28/9	10	1976	13/10	4
1959	15/8	1	1978	24/5	7	1977	10/11	8
1987	17/10	2	1987	16/10	1	1987	17/10	5
1992	3/12	6	2008	1/5	3	1990	2/2	6
2001	10/10	9	2014	31/8	5	1992	4/12	2

Table 2.2.3.4 Date and discharge of the largest flood (daily values) at three stations in River Tovdalselv.

Year	1959	1987	1959
Date	15/8	16/10	16/11
q (m^3/sec)	934,26	132,91	142,3
qsp (l/sec km^2)	525	481	582
qsp (mm/day)	45,3	41,5	50,2

The annual floods at Flaksvatn are shown in Figure 2.2.3.1 and at Austenå in Figure 2.2.3.2.

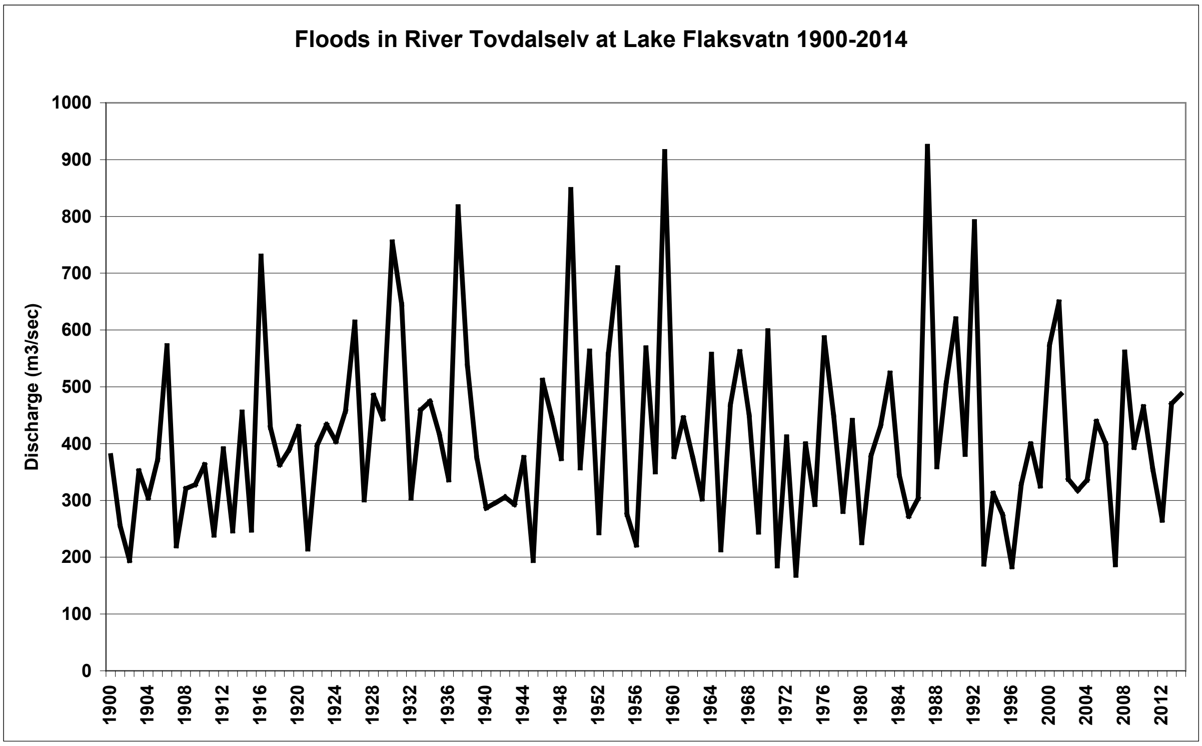


Figure 2.2.3.1 Annual floods (daily values) in River Tovdalselv at Lake Flaksvatn 1900-2014.

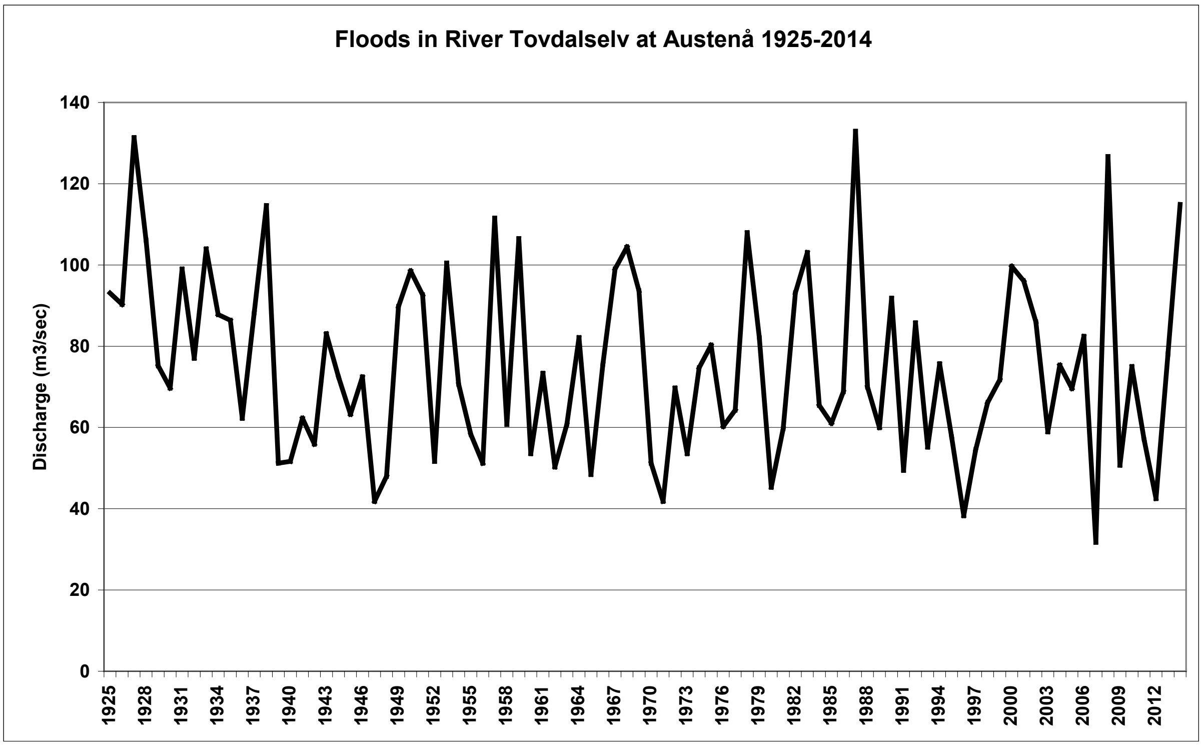


Figure 2.2.3.2 Annual floods (daily values) in River Tovdalselv at Austenå 1900-2014.

2.2.4 RIVER OTRA

River Otra is the second largest water course at Sørlandet with a catchment area of 3.610 square kilometers. The river flows from Setesdalsheiene through Setesdalen towards Kristiansand. The catchment comprises two large lakes, Lake Åraksfjord ansd Lake Byglandsfjord. The river is strongly regulated by 11 power stations and two pumping plants. Long-term precipitation data are known at 39100 Oksøy, 39170 Kristiansand, 39220 Mestad, 40400 Bykle and 40900 Bjåen.

Water levels are known from a few large floods at Vallabø. The oldest gauging station started monitoring the water levels at Storstrømmen in 1883, and local information exists about some earlier floods. The discharge downstreams Lake Byglandsfjord has been observed since 1912. The total discharge is observed at Vigeland and later at Heisel gauging stations. The joint data series starts in 1930. The annual flood in Setesdalen is usually the spring flood in May or June, at Byglandsfjord 19 percent and at Hoslemo further upstream in 32 percent in both months.

Table 2.2.4.1 Large floods in River Otra from historical sources

Year	Date	Remarks
1672/73		
1721		Level 0,3 m below floor of church at Vallabø
1773	5/8	
1776		Level 0,3 m above floor of church at Vallabø
1789		Strai timber boom failed
1837	20/9	Level 7,5 m above ref. at Vallabø, Strai timber boom failed
1860		Level 6,9 m above ref. at Vallabø
1862		Level 6,6 m above ref. at Vallabø

Table 2.2.4.2 Catchment characteristics of three gauging stations in River Otra.

Station	21.11 Heisel	21.24 Byglandsfjord ndf	21.21 Hoslemo
	Basin characteristics		
Catchment area (km^2)	3687,25	2805,43	827,49
Station altitude (m.a.s.l.)	18	201	681
Mean altitude (m.a.s.l)	784	908	1105
Top altitude (m.a.s.l.)	1530	1530	1530
Lake (%)	9,25	10,48	12,66
Bog (%)	4,66	3,64	3,98
Forest (%)	48,27	39,42	18
Mountain (%)	33,72	43,2	63,69
Glacier (%)	0	0	0

Table 2.2.4.3 Date and rank of the ten largest floods (daily values) at three stations in River Otra.

21.11 Heisel			21.24 Byglandsfjord ndf			21.21 Hoslemo		
1930-2014			1913-2014			1919-1981		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1933	20/6	1	1913	5/5	8	1920	22/6	5
1934	6/10	9	1920	11/7	9	1927	29/6	2
1938	15/10	2	1927	1/7	6	1924		4
1951	22/11	10	1929	26/10	7	1933	18/6	1
1953	3/11	8	1933	20-21/6	1	1938	13/11	9
1957	6/11	3	1938	5/10	10	1939	20/6	5
1959	16/11	7	1983	17/10	3	1940	27/11	8
1967	5/10	6	1987	16/10	5	1950	8/6	9
1987	16/10	4	1990	7/7	4	1953	4/12	3
1990	6/7	5	2008	7/7	2	1967	4/10	7

Table 2.2.4.4 Date and discharge of the largest flood (daily values) at three stations in River Otra.

Station	21.11 Heisel	21.24 Byglandsfjord ndf	21.21 Hoslemo
Year	1933	1933	1933
Date	20/6	20-21/6	18/6
q (m^3/sec)	1400	1000	798,8
qsp (l/sec km^2)	379	356	965
qsp (mm/day)	32,8	30,8	83,4

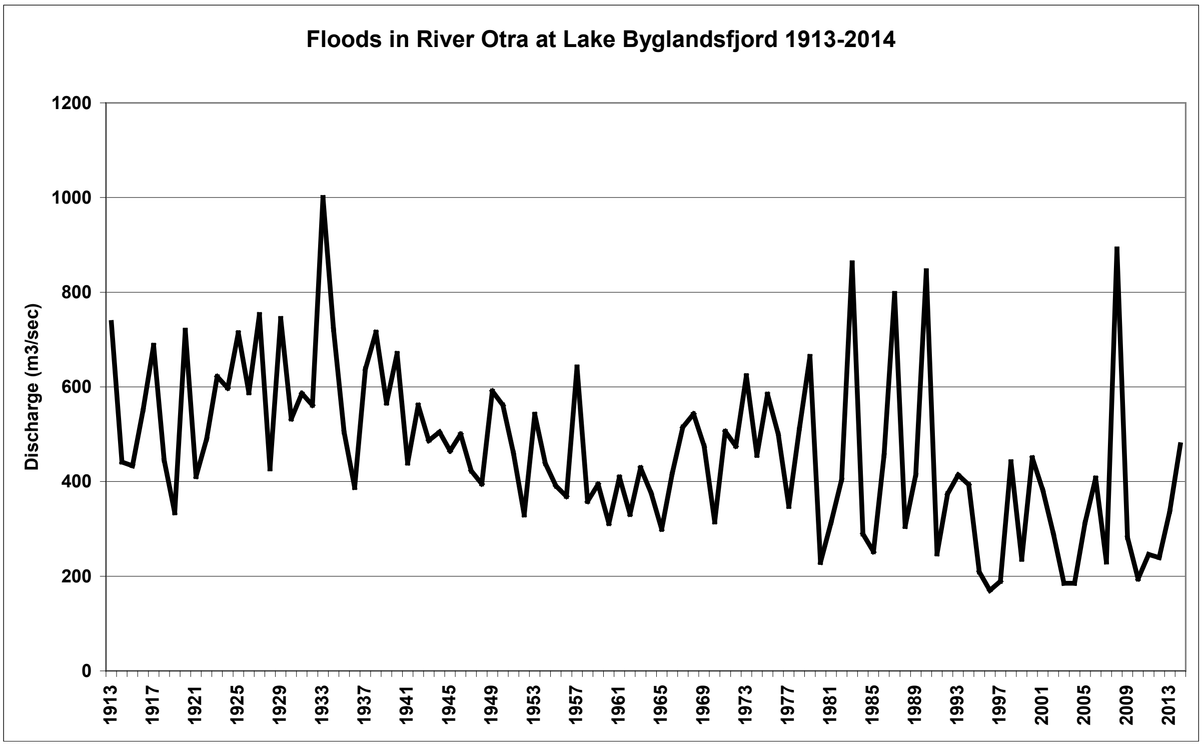


Figure 2.2.4.1 Annual floods (daily values) in River Otra at Lake Byglandsfjord 1913-2014.

2.2.5 RIVER SØGNEELV

River Søgneelv is located between River Otra and River Mandalselv. The gauging station 22.22 Søgne has been active since 1972. Catchment characteristics, the dates and ranks of the ten largest floods and the date and discharge of the largest flood is shown in Table 2.2.5.1.

Table 2.2.5.1 Catchment characteristics, the date and ranks of the ten largest annual floods and the date and discharge of the largest flood at Søgne.

Station 22.22 Søgne		The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	203,58	1974	15/11	10
Station altitude (m.a.s.l.)	6	1976	14/10	1
Mean altitude (m.a.s.l)	198	1979	2/11	9
Top altitude (m.a.s.l.)	485	1984	25/12	6
Lake (%)	3,88	1987	17/10	8
Bog (%)	5,99	1989	30/10	3
Forest (%)	81,51	1990	2/12	5
Mountain (%)	0,11	2001	5/10	4
Glacier (%)	0	2004	16/1	2
		2008	6/12	7

Data is missing for 1992. The flood 3 December this year is likely to have exceeded the flood in 1976.

2.2.6 RIVER MANDALSELV

River Mandalselv is located at Sørlandet in Aust- and Vest-Agder. The river flows from the mountains between Setesdal and Øvre Sirdal to the North Sea at Mandal. East of the catchment is River Søgneelv and River Otra further north. To the west the boundary is toward River Audna, River Lygna and River Kvina further north.

The gauging station 22.4 Kjølemo has been operating since 1896. The river was regulated in 1931. The annual floods at Kjølemo is shown in Figure 2.2.6.1. Two other long-term stations have been active at 22.2 Ørevassoset 1922-1956 and at 22.5 Austerhus 1922-1985.

The catchment characteristics of 22.4 Kjølemo are given in Table 2.2.6.1. Flood regime is characterised by mostly autumn- and winter floods from August to January. The largest annual flood occurs most frequently in October (21 percent) and November (21 percent). The annual flood occurs in some years as the spring flood in May (15 percent). The river was regulated in 1931. Other long-term series have been actiove at 22.2 Ørevassosen and 22.5 Austerhus. Currently 11 power stations are utilising the river; six of these stations are large. One large flood is known from historical sources in 1864. The dates and ranks of the ten largest annual floods (daily values) are given in Table 2.2.6.2 and the date and discharge of the largest daily flood is given in Table 2.2.6.3.

Two long-term precipitation has been active in River Mandalselv since the 1890s, 41350 Bjelland and 41480 Åseral.

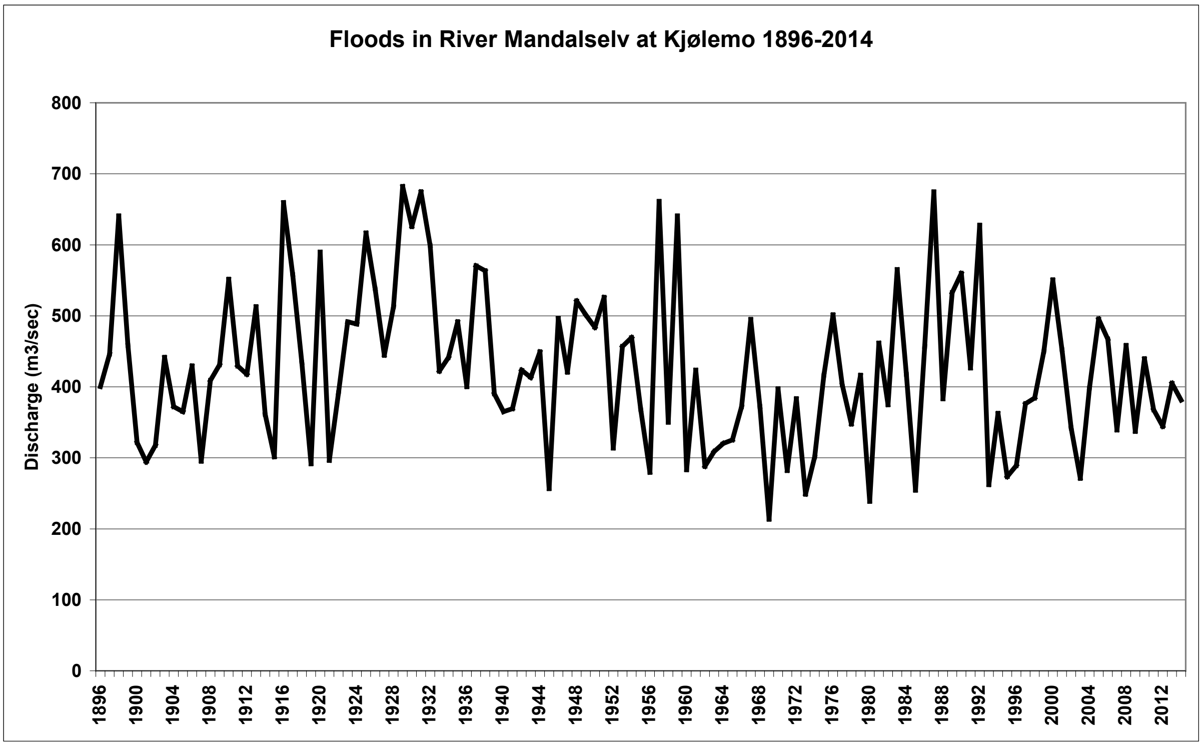


Figure 2.2.6.1 Annual floods (daily values) in River Mandalselv at Kjølemo 1896-2014.

Table 2.2.6.1 Catchment characteristics at the gauging stations at Kjølemo in Mandalselv and Tingvatn and Møska in Lygna.

Station	22.4 Kjølemo	24.1/9 Tingvatn	24.8 Møska
	Basin characteristics		
Catchment area (km^2)	1.757,7	272,16	121,41
Station altitude (m.a.s.l.)	10	185	8
Mean altitude (m.a.s.l)	560	588	32,5
Top altitude (m.a.s.l.)	1160	964	613
Lake (%)	7,88	9,51	9,04
Bog (%)	6,15	6,13	3,08
Forest (%)	47,14	37,08	76,92
Mountain (%)	33,02	36,52	8,44
Glacier (%)	0	0	0

Table 2.2.6.2 The dates and ranks of the ten largest annual floods (daily values) at Kjølemo, Tingvatn and Møska

22.4 Kjølemo			24.1/9 Tingvatn			24.8 Møska		
1896-2014			1923-2014			1978-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1898	3/11	6	1929	25/10	2	1983	17/10	7
1916	1/11	5	1931	5/11	3	1984	25/12	6
1925	29/5	10	1932	18/12	5	1990	31/1-1/2	4
1929	26/10	1	1936	8/1	8	1992	3/12	1
1930	22/9	9	1946	27/11	4	1993	20/12	9
1931	5/11	2	1987	17/10	8	1994	1/4	9
1957	6/11	4	1990	30/10	5	2004	5/10	5
1959	16/11	6	1992	3/12	1	2005	8/1	8
1987	17/10	2	2005	8/1	7	2008	16/1	3
1992	3/12	8	2008	1/5	10	2011	14/9	2

Table 2.2.6.3 The dates and discharge of the largest annual flood (daily values) at Kjølemo, Tingvatn and Møska

Station	22.4 Kjølemo	24.1/9 Tingvatn	24.8 Møska
Year	1929	1992	1992
Date	26/10	3/12	3/12
q (m^3/sec)	682,27	195,75	97,93
qsp (l/sec km^2)	388	719	807
qsp (mm/day)	33,5	62,1	69,7

2.2.7 RIVER AUDNA

River Audna flows from Grindheimsvatn through Audnedal in Vest-Agder to the sea at Sniksfjorden. The catchment of River Audna is 55,81 km^2. The tributary Trylandselv was regulated in 1922. There is one gauging station in the water course 23.4 Brådlandsvatn, which have been operating since 1976. Catchment characteristics and the dates and ranks of the ten largest floods are given in Table 2.2.7.1. The largest flood was observed at Gaupefossen 3 December 1992 of 183 m3/s. The discharge is least in the summer and largest in the autumn or winter. Autumn rainfall and some snowmelt are usually the cause of floods in the river as well as in other lowland rivers at Sørlandet.

Table 2.2.7.1 Catchment characteristics and the dates and ranks of the ten largest floods in Lake Brådlandsvatn.

Station 23.4 Brådlandsvatn		The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	58,94	1984	25/12	5
Station altitude (m.a.s.l.)	177	1987	16/10	3
Mean altitude (m.a.s.l)	360	1990	31/1	4
Top altitude (m.a.s.l.)	549	1992	3/12	1
Lake (%)	12,3	1997	2/3	10
Bog (%)	7,44	2000	13/11	8
Forest (%)	74,07	2005	8/1	6
Mountain (%)	2,56	2008	16/1	2
Glacier (%)	0	2011	15/12	9
		2014	3/1	7

The discharge observed 3/12 1992 was 62,57 m^3/sec (daily value) corresponding to 1062 l/sec km^2 or 91,7 mm/day. The peak value was 77,23 m^3/sec corresponding to 1310 l/sec km^2 observed 3/12 03:23. This peak was exceeded 6/12 2015 by 74,79 m^3/sec (daily) value corresponding to 1269 l/sec km^2 or 109,6 mm/day. The peak value was 85,20 m^3/sec or 1445 l/sec km^2 observed 6/12 10:00.

2.2.8 RIVER LYGNA

River Lygna flows from Oddevassheia in Fjotland to Lyngdal in Vest-Agder. West of Lygna flows River Kvina and to the east River Audna. The catchment of Lygna is 661 square kilometers. The gauging station 24.2 Tingvatn is located downstreams Lake Lygne and has been operating since 1922. The gauging station 24.8 Møska is located at a tributary northwest of Lyngdal in Lake Skolandsvatn. The station has been active since 1978. Catchment characteristcs are given in Table 2.2.6.1 at page 105.

The annual flood in River Lygna occurs most frequently in the autumn or winter, usually from August to January. The annual flom occurs in October 21 percent and in November 21 percent of the years. The spring flood in May occurs in 15 percent of all years. The catchment has been regulated since 1931.

The dates and ranks of the ten largest daily floods and the date and discharge of the largest floods at Tingvatn and Møska is shown in Table 2.2.6.3 and Table 2.2.6.4 at page 106. The annual floods at Tingvatn is are shown in Figure 2.2.8.1.

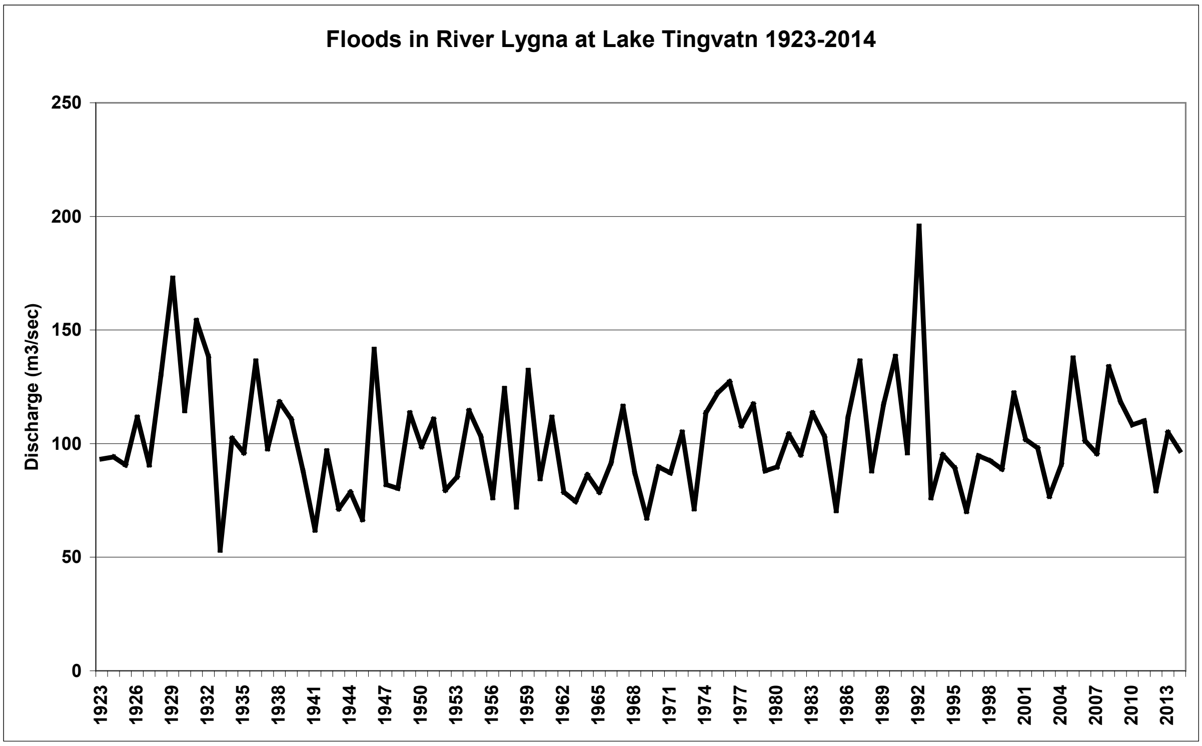


Figure 2.2.8.1 Annual floods (daily values) in River Lygna at Lake Tingvatn 1923-2014.

2.2.9 RIVER KVINA

River Kvina flows from the mountains east of Øvre Sirdal to Kvinesdal at Fedafjord. The water course is located between River Lygna to the east and River Sira to the west. The catchment area is 1413 square kilometers. The river has two main branches, Kvina to the west and Litleåna to the east. The precipitation station 42580 Risnes I Fjotlans has been active since 1895.

The gauging station 25.1 Rafoss has been active since 1912. The gauging station 25.2 Mygland has been active since 1931. Catchment characteristics of the two stations are given in Table 2.2.9.1.

Table 2.2.9.1 Catchment characteristics of two stations in River Kvina and one in River Fedaelv

Station	28.1 Rafoss	25.2 Mygland	25.7 Refsti
	Basin characteristics		
Catchment area (km^2)	1147,6	46,93	202,68
Station altitude (m.a.s.l.)	123	329	27
Mean altitude (m.a.s.l)	847	555	290
Top altitude (m.a.s.l.)	1431	876	596
Lake (%)	1,91	5,11	9,8
Bog (%)	13,3	8,82	4,34
Forest (%)	15,3	15,98	76,16
Mountain (%)	65,16	30,11	4,97
Glacier (%)	0	0	0

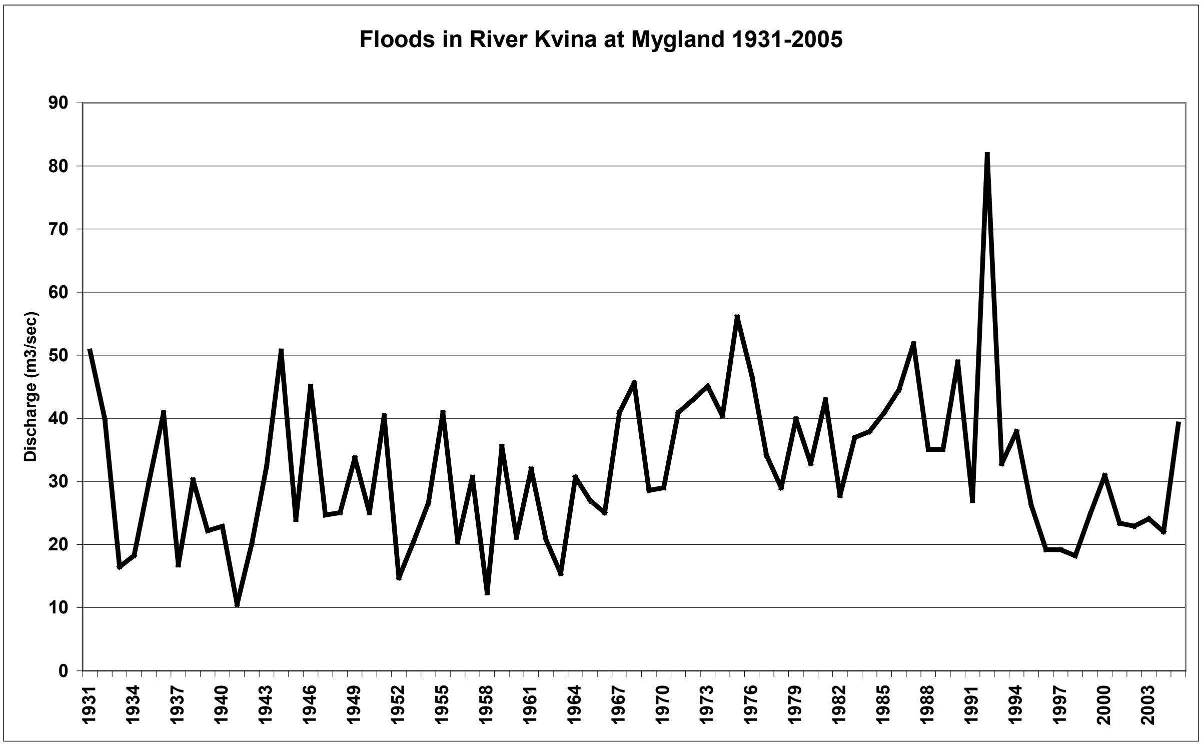


Figure 2.2.9.1 Annual floods (daily values) in River Kvina at Mygland 1931-2005.

The date and ranks of the ten largest annual floods (daily values) at the two stations in River Kvina are given in Table 2.2.9.2, and the date and discharge of the largest flood (daily values) in Table 2.2.9.3.

Table 2.2.9.2 The dates and ranks of the ten largest annual floods (daily values) at Rafoss, Mygland and Refsti.

25.1 Rafoss			25.8 Mygland			25.7 Refsti		
1912-2014			1931-2005			1898-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1913	10/6	10	1931	4/11	4	1898	3/11	3
1916	5/6	8	1944	2/12	4	1909	11/12	10
1920	19/5	9	1946	25/11	9	1924	28/12	8
1925	29/5	4	1968	29/10	8	1929	25/10	2
1936	21/12	6	1973	23/11	9	1931	5/11	7
1949	19/5	2	1975	26/9	2	1936	15/12	6
1951	25/12	7	1976	13/10	7	1943	7/10	4
1957	21/12	3	1987	17/10	3	1975	26/9	5
1967	4/10	1	1990	29/10	6	1992	3/12	1
1975	26/9	5	1992	1/12	1	2009	26/10	9

Table 2.2.9.3 The dates and ranks of the ten largest annual floods (daily values) at Rafoss Mygland and Refsti.

Station	25.1 Rafoss	25.8 Mygland	25.7 Refsti
Year	1967	1992	1992
Date	4/10	1/12	3/12
q (m^3/sec)	579,12	81,81	132,15
Qsp (l/sec km^2)	449	1743	652
Qsp (mm/day)	43,2	150,6	56,3

2.2.10 RIVER FEDAELV

River Fedaelv is a small river flowing southwards to the Fedafjord west of River Kvina. There is one long-term series in the water course from the gauging station 25.7 Refsti. The station has been operating 1898-2014 with a break 1976-1990. The river was regulated before the start of observations in 1898.

The annual floods (daily values) at Refsti are shown in Figure 2.2.10.1.

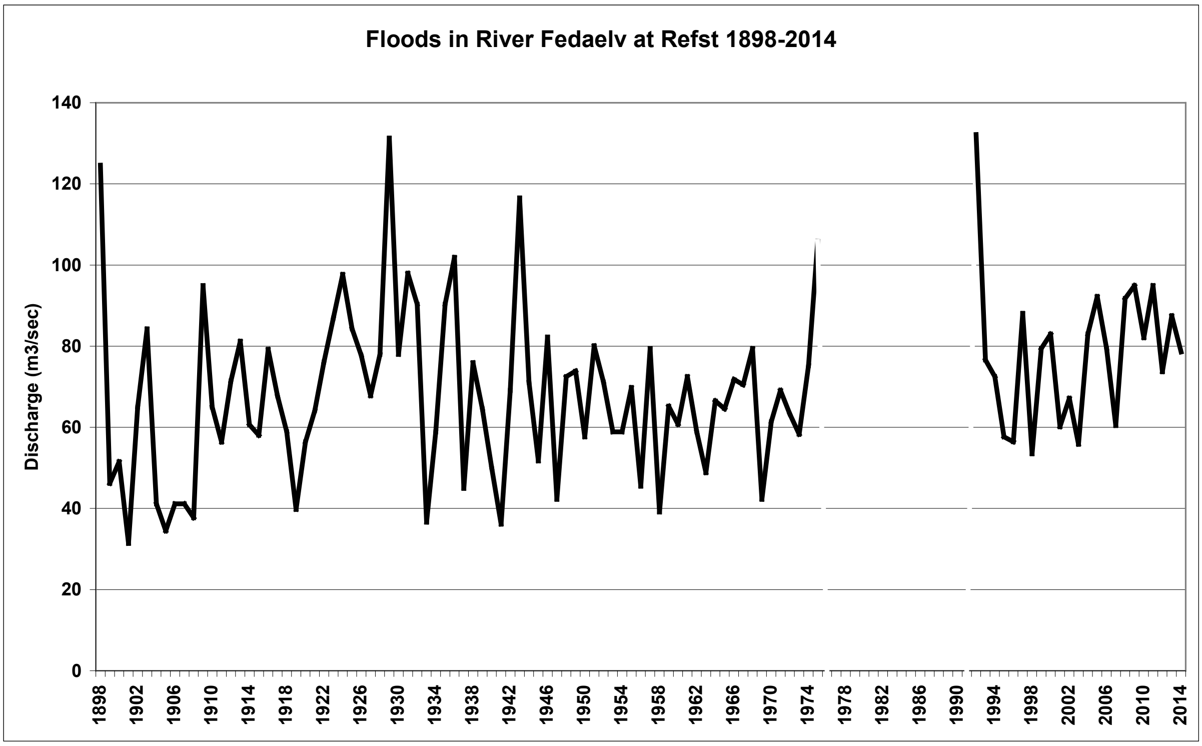


Figure 2.2.10.1 Annual floods (daily values) in River Fedaelv at Refsti 1898-2014.

Catchment characteristics are given in Table 2.2.9.1. The date and ranks of the ten largest annual floods (daily values) at Refsti is given in Table 2.2.9.2, and the date and discharge of the largest flood (daily values) in Table 2.2.9.3.

2.2.10 RIVER SIRA

River Sira flows from Storevatn east of Valleheiene to the North Sea at Flekkefjord between River Kvina to the east and River Bjerkreimselv to the west. The catchment area is 1923,4 square kilometers. Some smaller subcatchments were regulated in 1934-35, but the main river was regulated from 1965 in connection with the large Sira-Kvina hydropower development.

The catchment comprises two large lakes, Lundevatn and Lake Sirdalsvatn ansd a large reservoir, Svartavatn.

River Sira is located on the boundary between Vest-Agder and Rogaland and the flood regime includes floods both of those occurring at Sørlandet and in the southern part of Vestlandet. There are some long-term series from 1896 to the start of the regulations in 1965/67 at 26.7 Lake Sirdalsvatn and 26.8 Lake Lundevatn. Further upstream there is a long-term series from 26.4 Lake Fidjelandsvatn. Catchment characteristics of the three long term series are given in Table 2.2.10.1, the dates and ranks of the ten largest daily floods in Table 2.2.11.2 and the date and discharge of the largest flood in Table 2.2.11.3.

Table 2.2.11.1 Catchment characteristics of three log-term gauging station in River Sira.

Station	26.8 Lundevatn	26.7 Sirdalsvatn	26.4 Fidjelandsvatn
	Basin characteristics		
Catchment area (km^2)	1899,67	1528,11	506,07
Station altitude (m.a.s.l.)	49	50	566
Mean altitude (m.a.s.l)	693	774	938
Top altitude (m.a.s.l.)	1420	1421	1420
Lake (%)	12,26	11,7	13,53
Bog (%)	1,52	1,5	0,62
Forest (%)	22,88	17,87	6,53
Mountain (%)	56,06	63,44	76,81
Glacier (%)	0	0	0

Table 2.2.11.2 The dates and ranks of the ten largest annual floods (daily values) at the tree long-term stations in River Sira.

26.8 Lundevatn			26.7 Sirdalsvatn			26.4 Fidjelandsvatn		
1896-1967			1894-1967			1920-1972		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1898	5/11	1	1898	3/11	1	1925	29/5	9
1910	18/5	5	1910	16/5	2	1929	25/10	3
1913	5/5	3	1913	3-4/5	5	1931	5/11	6
1916	16/10	2	1916	15/10	4	1934	6/5	5
1929	27/10	4	1920	19/5	10	1938	8/11	6
1931	6/11	10	1925	29/5	8	1940	27/11	1
1936	23-24/12	6	1926	15/11	7	1949	18/5	10
1943	8/10	8	1927	3/10	9	1954	17/9	8
1957	7/11	7	1929	25/10	3	1967	30/5	2
1967	2/6	8	1967	31/5	5	1971	22/10	4

Table 2.2.11.3 The dates and ranks of the ten largest annual floods (daily values) of the three large catchments in River Sira.

Station	26.8 Lundevatn	26.7 Sirdalsvatn	26.4 Fidjelandsvatn
Year	1898	1898	1940
Date	5/11	3/11	27/11
q (m^3/sec)	825,10	810,86	478,76
qsp (l/sec km^2)	434	531	744
qsp (mm/day)	37,5	45,8	64,3

The annual floods at Lake Lundevatn are shown in Figure 2.2.11.1 and at Lake Fidjelandsvatn in Figure 2.2.11.2.

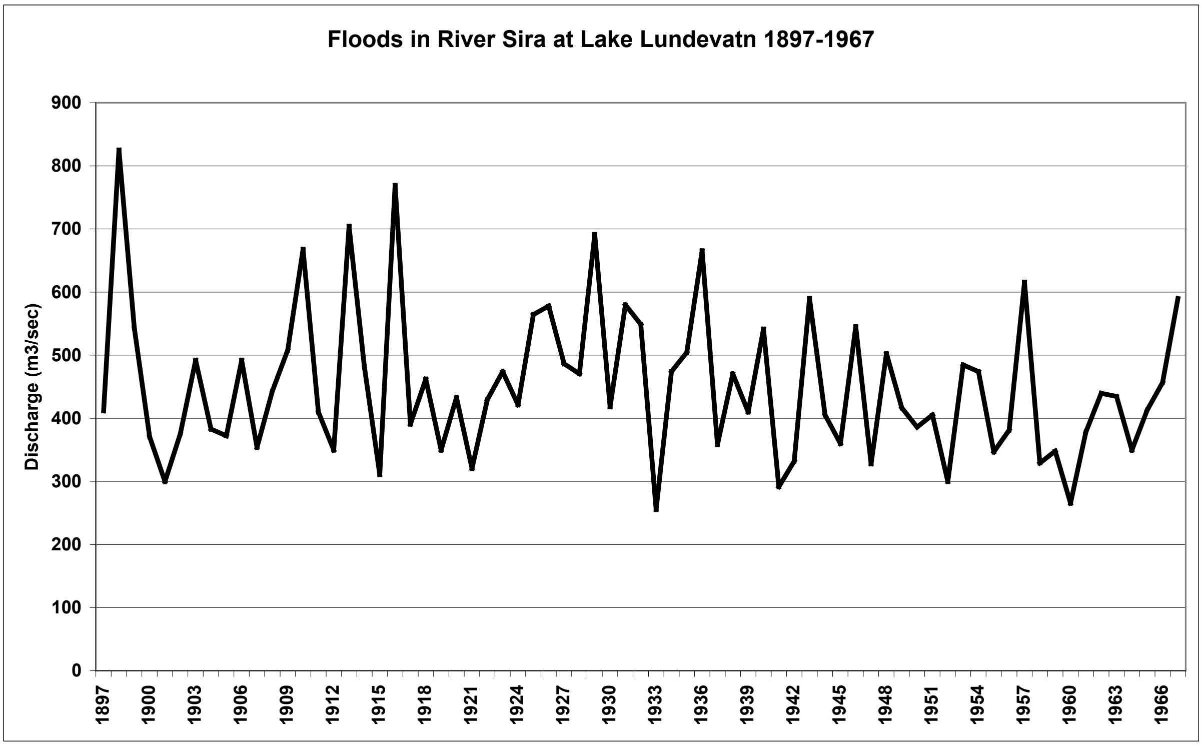


Figure 2.2.11.1 Annual floods (daily values) in River Sira at Lake Lundevatn 1897-1967.

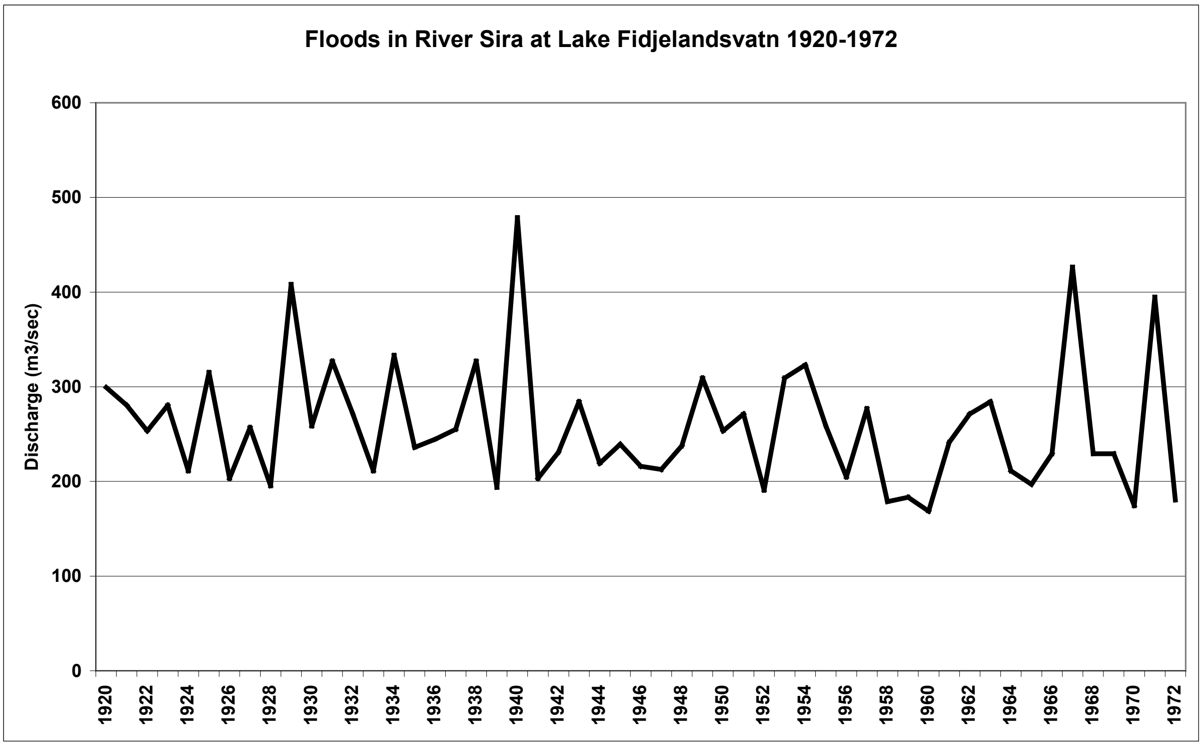


Figure 2.2.11.2 Annual floods (daily values) in River Sira at Lake Fidjelandsvatn 1920-1972.

Most of the long-term series lack flood information of floods after the regulation. There are some stations in smaller basins with data series starting in the early 1970s. These series are located at small tributaries not affected by the regulation of the main river. The station 26.21

Sandvatn and 26.26 Jogla is located east and the station 26.20 Årdal is located on the western side of the main river. Catchment characteristics of the three stations are given in Table 2.2.11.4. The dates and ranks of the ten largest daily floods are given in Table 2.2.11.5 and the data and discharge of the largest daily flood in Table 2.2.11.6.

Table 2.2.11.4 Catchment characteristics of the three stations in smaller catchments of River Sira.

Station	26.21 Sandvatn	26.26 Jogla	26.20 Årdal
	Basin characteristics		
Catchment area (km^2)	27,5	31,12	77,25
Station altitude (m.a.s.l.)	306	612	113
Mean altitude (m.a.s.l)	470	1002	478
Top altitude (m.a.s.l.)	647	1194	748
Lake (%)	10,04	2,86	8,98
Bog (%)	8,8	0,58	2,24
Forest (%)	44,51	2,92	38,08
Mountain (%)	34,87	92,2	24,64
Glacier (%)	0	0	0

Table 2.2.11.5 The dates and ranks of the ten largest annual floods (daily values) at the tree smaller catchments in River Sira.

26.21 Sandvatn			26.26 Jogla			26.20 Årdal		
1971-2014			1973-2014			1970-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1975	26/9	8	1973	31/5	8	1976	13/10	8
1984	25/12	8	1975	26/9	1	1984	1/1	10
1990	5/2	3	1981	12/5	4	1990	16/3	8
1992	3/12	1	1987	16/10	10	1992	2/1 *	2
1997	2/3	4	1999	26/4	7	1997	2/3	3
2000	31/10	7	2004	7/5	6	2000	31/10	5
2005	7/1	5	2009	20/11	2	2005	7/1	4
2009	20/11	6	2010	6/10	2	2006	11/12	7
2010	7/10	2	2011	27/11	9	2009	20/11 **	1
2011	14/9	9	2013	18/5	5	2011	27/11	6

Table 2.2.11.6 The dates and discharge of the largest annual flood (daily values) of the three smaller catchments in River Sira.

Station	26.21 Sandvatn	26.26 Jogla	26.20 Årdal
Year	1992	1975	2009
Date	3/12	26/9	20/11
q (m^3/sec)	24,61	33,14	88,85
qsp (l/sec km^2)	895	1065	1150
qsp (mm/day)	77,3	92,0	99,4

* Two large floods at 26.20 Årdal in 1992 (2/1 88.22 m3/sec and 2/12 76,6 m3/sec)

** Two large floods at 26.20 Årdal in 2009 (12/1 81,28 m3/sec and 20/11 88,85 m3/sec)

Long-term precipitation stations have been active since 1895 at 42720 Bakke, 42800 Tonstad, 4289 Skreådalen and 42950 Øvre Sirdal.

3 Part 3 – Description of large floods at Østlandet and Sørlandet

3.1 Large floods at Østlandet

3.1.1 Ice run flood at Østerdalen in 1650.

An ice run flood caused severe damages at the Stai farm at Storelvdal. The value of the farm was reduced from a "fullgard" to a "halvgard" (Fosvold, 1937). The Bakken farms were moved from Koppangsøya to the Mainland (Hanssen, 1975). A smaller river at Lier at Aurskog shifted from its previous bed, causing a mill to close (Lillevold, 1961).

3.1.2 The large rainfall flood in Buskerud and Telemark in 1653.

Long term rainfall ravaged Buskerud and Telemark from late August to early September 1653 (Sætren, 1907; Hansen, 1963).

Flood damages

Numedalslågen

Most of the sawmills were destroyed (Tråen et al, 2001).

Farrisvatn

The dam at the outlet of Lake Farrisvatn failed 2-3 September as a result of a slide (Jørstad, 1968; Nyhus, 2003). The flood destroyed sawmills and other industry below the dam. The manor farm Fritsøe hovedgård was located below the dam at a spit of land which was eroded by the flood. The buildings were taken by the flood as well as the priest farm and half of the cemetrary (Helland, 1914, 1915; Bjerke, 1996).

Skienselv

The level of Lake Hjellevatn at Skien rose high above its banks. The flood water was pouring into Lake Bryggevatn and into the buildings at Eidet. The customs office and some neighbour buildings were taken. The large dam *Klosterdammen* at Damfossen failed and 50.000 planks was washed out into the fjord. Further upstreams the flood caused damages at Lunde (Stranna, 1925) and at Ulefoss and further upstreams in upper Telemark at sawmills and grain mills (Dalland, 2000).

3.1.3 When River Bøvra took the church at Galdesand in 1655.

An old stave churge served the local village at Galdesand at Lom until a flood removed the church (Rolsdorph & Kierschow, 1775; Øyjorde, 1967). The flood may have undermined the riverbank, or has caused a slide which carried the church to the river. The church floated downstream until it hit a rock at a bend of the river. The church was smashed, but the church bell is said to be hanging on the roch, which later was known as "*Klukkberget*" according to a local legend.

3.1.4 *Storfloden* in River Glomma in 1675 - the earliest known flood level in Norway.

After a cold winter with much ice in the upper part of Rivers Glomma and Gaula, the spring flood started with large ice runs in late May. The tributary Folla caused severe damages at the Baugen farms at Alvdal (Steinmoeggen, 1952). River Glomma and the smaller tributaries damaged Westgård, Stai, Nystu Møkleby, Sætre, Hovde, Stenvig, Strand, Ophus, Kroken, Furuset, Evenstad and Messelt farms at Storelvdal (Hanssen, 1975). The damages were partly caused by the extensive removal of forests at the flood plain for the mining industry.

Storelvdal were ravaged by new floods 28 May 1683 (*Storisgangen*) and in 1691 at Stai. Glomma washed away the soil and the seeds from the fields, and deposited enormous amount of sand elsewhere (Fosvold, 1937). Damages at Atnosen is described in Sæter (1908)

The damages at Ygle farm at Åmot were assessed (Lillevold, 1971). The farm Bånerud suffered damages at Elverum (Stener, 1985). The flood at Elverum is described in Finne-Grønn (1921).

The church and churchyard at Vinger were damaged by the flood, causing the church to be moved in 1697 (Vigeland, 1942). Disen, Seim, Lineset, Gjersøyen, Dysterud and Stubbmoen farms at Sør-Odal was damaged, while the sawmill at Gjerstad at Fet was destroyed (Vigeland, 1961). Timber owned by citizens of Christiania was taken by the flood and drifted downstreams, causing severe financial difficulties for the owners (Morthoff, 1949; Rudie, 1966). The flood in Øyeren is described in Dørumsgaard (1955).

There was also a flood simultaneously in River Gaula in Sør-Trøndelag.

3.1.5 The spring flood in 1717 in River Glomma

A major spring flood occurred in River Glomma in May 1717, especially in Østerdalen. The flood caused severe damages at the Baugen farms in Alvdal (Steinmoeggen, 1952). The flood culminated 24 May in Storelvdal where it was the largest since the flood in 1675 (Hanssen, 1975). It is mentioned at Atnosen about a deduction assessment in 1721 which is said to have taken place in the entire valley. The flood caused severe damages at Storelvdal and at Heradsbygd at Elverum further downstream (Finne-Grønn, 1921; Fosvold, 1937; Otnes, 1982). Erosion caused riverbank failures at Ljømo and Skjefstad. The flood level at the flood stone of Forestry Museum at Elverum is the same as in the floods in 1724 and 1749. Further downstream the damages were assessed at 39 farms in Hof, 61 farms in Grue and 11 farms in Vinger. The large farms Seim, Oppstad, Vestre Os, Gjersøyen and Store Ulleren suffered damages and obtained deduction in Sør-Odal (Kirkeby, 1975, 1990). The flood caused damages around Lake Øyeren. At Sarpsfossen the flood culminated 1 foot below the top of the hill and a new dam. The flood caused losses of timber at Sarpsborg (Johansen et al, 1976). Several sawmills were taken at Fredrikstad, and timber came drifting into the fjord (Dehli, 1960).

River Begna flooded simultaneously in Valdres in 1717. There is a tributary flowing northward from Lake Syndin at Vang, named River Ala. This river was created by the flood, because a local farmer had dug a small channel from the lake to provide his farm with water across the water divide in 1689.

3.1.6 Ice run flood in River Glomma in 1721

Ice runs caused a major flood, damaging Atnaoset, Trønnes, Westgård, Negård, Stai, Messelt, Møkleby, Furuset, Kroken, Ophus and Strand farms at Storelvdal. The flood was especially large in the tributaries Trya and Nesta where 36 farmers suffered damages. . Most of the farms moved the houses to safer ground away from the river (Devik, 1919; Fosvold, 1937; Hanssen, 1975).

New floods occurred at Storelvdal in 1724 and 1726 resulting in relocation of the farms at Koppangøya except the Bakken farms between 1736 and 1757. The farms at Westgårdjordet were relocated after 1721, and the Messelt farms in the 19th Century.

Another flood occurred 24 May 1749 in Østerdalen after another snow winter. The level was said to be as large as the floods in 1717 and 1724, but less than the flood in 1675 (Kvernmoen, 1921).

3.1.7 The large flood at Gudbrandsdalen and in Trøndelag in May 1760.

Intense snow-melting caused a major flood at Gudbrandsdalen and Gausdal during the night of 29 May. The priest Andreas Pihl wrote that the level of River Lågen rose 7-8 alen (more than 4 meter). Fields and grassland were inundated, and many houses were destroyed or damaged. The flooded farmland was covered by sand, gravel and stones. River Gausa destroyed all bridges except for Bøbrua. Many mills were lost, and several smallholdings were damaged (Hiorthøy, 1785; Five, 1919). Eleven farms obtained tax deductions for two to six years. The damages were also severe at Fåberg. The snowmelt caused a severe flood in River Bøvra at Lom (Grove, 1988). The farm Vekkje at Skjåk was damaged by a slide, and received tax deduction for 6 years (Kleiven, 1915).

Money was collected at the churches in Gudbrandsdalen to support the flood victims. The collection resulted in a sum of 313 riksdaler. The victims in Gausdal obtained 60, Fåberg 80, Øyer 47, Ringebu 36, Fron 47, Vågå 20 and Lom 23 riksdaler. The damages were less severe in Lesja, which obtained nothing.

The flood caused also damages in Østerdalen, worst at Røros. A previous flood occurred there in 1755, and several houses built after this flood suffered damages (Dahle, 1894). The flood was said to peak 3/4 alen lower that in 1749 at Elverum (Kvernmoen, 1921).

The flood was also large in Trøndelag. River Orkla caused severe damage at the farm Grut. The farmland at the farm Negard Hovin was covered with sand and gravel by the flood in River Gaula, causing a tax deduction of 50 %. The flood caused also damages at Stjørdal, Verdal and on the Fosen peninsula.

3.1.8 The severe flood in Glomma in 1773 (*Storefloden*)

The floods in River Glomma started to increase after a period of smaller floods at Østlandet. Large floods occurred both in 1771 and 1772, but these floods were by far exceeded by the severe flood, which peaked 29-30 May 1773. The flood co-incided both in the eastern branch in Østerdalen and Glomdalen and in Gudbrandsdalslågen and in Vorma.

The winter was cold and heralds the start of a cold period lasting until 1788/1789. The flood level is marked at several flood stones. The earliest flood stone was set ut at Grindal at Elverum after instructions by crown prince Frederik (later king Frederik V), who visited Elverum 23 July 1778. The flood ranks as the second highest at the flood stone at Grindal only exceededed by Storofsen by 0,93 meter, and the third highest at the flood stone at Forestbruksmuseet when the level of Vesleofsen is included. The water level at Stai in Storelvdal was 1,4 meters below the level in 1789.

An autumn flood caused by rainfall occurred in River Glomma in 18-19 August 1773 (Kvernmoen, 1921). Another flood occurred in the lower part of Glomma, as well as in River Numedalslågen and River Otra in 1774. This flood destroyed the Silli sawmill near Sarpsborg.

Flood damages

Flood damage occurred at Kvikna in Østerdalen (Falck-Muus, 1932).

The damages were assessed at Strand, Opphus, Messelt, Kroken, Vestgard, Møkleby and Furuset at Storelvdal and deduction was granted 30 June 1774. The farms Åset, Sorknes, Ygle, Alme and Nygården at Åmot had also the damages assesses after the 1773 flood (Lillevold, 1967, 1971; Hanssen, 1975). The farm Økset at Elverum had most of its fields inundated, and the tax was reduced by 75 % as the result of the assessment. The farms Odden and Bosevjen suffered also severe damages. Odden was relocated afterwards away from the river (Finne-Grønn, 1921). Much of the damages to the fields were deposision of sand on the inundated fields.

The flood damage was also severe in Grue and Solør. The fields at Ulleren and along Oppstadåa were all inundated at Whitsunday. It was neccessary to travel with boats between the farm buildings at Disen. The fences were drifting away and were no obstacle to the boat traffic. The field at Gjersøyen were inundated for almost three weeks. Most of the fields had been sown and fertilized. All seed was destroyed by the flood, causing the spring work to start anew. The grassland was covered by sand and gravel. There was a shortage of grain in the autumn, and the grass crops failed both in 1773 and 1774 (Vigeland, 1942, 1961; Kirkeby, 1990). It was therefore neccessary to buy fodder for the farm animals, or to reduce the stock o at farms as Disen, Dysterud, Ullern, Sandnes, Hornes and on the other farms along Oppstadåa.

3.1.9 Storofsen - The worst flood disaster on record 21-23 July 1789

Storofsen was primarily a rainfall flood occurring after a long sequence of cold years. Large amount of snow accumulated through a sequence of cold years. Snowmelt contributed also to the flood because of exceptionally high temperatures.

The precursor of the disaster

A major spring flood occurred at Østlandet in 1773, starting a cold period, which lasted until the spring of 1789. Another spring flood occurred in 1774 in Glåmdalen, but the subsequent years were characterised by small spring floods. The worst natural disaster since the colonisation occurred at Iceland in 1783. A volcanic fissure, Laki, started to erupt southwest of Vatnajökull. More than 130 volcanic pipes started to emit an enormous amount of magma. The atmosphere was polluted by fluoride and sulphurous gasses, causing the grassland to be poisoned. About 50 % of the farm animals and between 20 and 25 % of the population at Iceland died because of fluorosis. The gas reached the stratosphere and was transported towards Europe. When the cloud came over Bergen, some people believed that they smelt a major fire somewhere. The gas blocked for incoming solar radiation, causing a very cold winter on both sides of the Atlantic. The gas caused a kind of dry mist over the northern part of Great Britain, which caused excessive mortality among the farm workers as the gas caused severe lung problems.

The eruption lasted into 1784. The winter 1783/84 was extremely cold in Europe, causing many European rivers to freeze. The cold weather is descibed by Benjamin Franklin, who realised that there was a link between volcanic eruptions and cold weather. The weather changed dramatically in Germany in February 1784 from freezing cold to un-seasonally heat, and torrential rainfall causing large floods partly linked to ice jamming with subsequent failure of ice dams. A gauging station at Cochem is shown in Figure 1, where the water level of historical floods in the Moselle can be seen as flood marks. The uppermost mark, above the two windows, shows the level of the 1784 flood, which must have been close to 10 meters.

The years following the Laki eruption were cold in Europe causing widespread starvation in many European countries. It is assumed that this was a contributing cause of the French revolution in 1789. Several avalanches caused fatalities in Nordfjord and Sunndal at Nordvestlandet in Norway. The autumn was cold in Trøndelag, and the year was called *Storfroståret* at Stadsbygd. A flood caused severe damages at two farms at Årdal in Sogn.

The subsequent years were without large flood. Prolonged spells of cold and dry weather in the winter must have caused deep layers of frozen ground in the inland valleys.

The winter and spring 1788/1789

The early winter was cold and dry. The county governor Chr. Sommerfeldt (1791, 1793) reported that the year started with a severe drought, as a result of the long and dry frost period of the previous autumn. A quantity of snow fell at Østlandet 1-3 and 21-28 February. March and the first two weeks of April were cold and dry. The second half of April had a mixture of snow, sleet and rain at Gausdal, and the snow melted in the fields.

The nights of 3-4 May were very cold (Bøe, 1789). The temperatures started to rise after a snowfall on the 5 May. An ice run flood destroyed a bridge in Gausdal 9 May when the temperatures climbed to above 10° C. Several landslides occurred simultaneously. Another cold spell occurred 12-14 May. The rest of the May was wet and mild. June was warm and humid. Thunder was frequent in the second part of the month. The crops were developing very well, and the farmers expected the crown year of the Century.

Mild winds from southeast in combination with heavy rainfall 18-19 May caused the snow to melt in the lowlands. The farm Tveithaug at Romerike suffered damages from the spring flood. The damage was assesses resulting in a proposal of a tax deduction.

John Kington at the Climate Research Unit at the University of East Anglia has reconstructed weather maps of the 1780's (Kington, 1973). He reconstructed later daily weather maps for the period 20-24 July 1789 (Kington, 1979): Based on this weather maps, Arne Østmoe has described the weather causing Storofsen (Østmoe, 1985).

Figure 3.1.9.1 The gauging station at Cochem near Moselle in Germany. The level of the 1784-flood can be seen over the two windows. (Photo: Lars A. Roald)

The weather type causing *Storofsen* in Norway is well known in Germany. As described in Vol I, Van Bebber (1891) identified five typical circulation patterns occurring in Europe. *Storofsen* was caused by the Vb-Tief, characterised by blocking anticyclones in the Atlantic

Ocean, and another located over Finland or near the Kola Penninsula. Bertween these two anticycolones, a low with cooler air extends into the North Sea from the Norwegian Sea. Warm and humid air is streaming northwestward from the Mediteranian. Quasi-stationary rainstorms are mowing northwestward in the boundary zone beteen the warm air to the east and the cooler air further west.

July 1789 - *Storofsen*

The weather prior and during to Storofsen was documented by captain Amund Bøe in Gausdal. The hot weather continued through July. Thunder and rain occurred almost every day. The temperature rose, and the sultry weather made it highly uncomfortable for out-door activities. The soil became saturated above the layer of frozen ground. The heavy rainfall started 20 July in the evening. The intensity of the thunderstorms increased on the 21 July as the quasi-stationary front came in over Østlandet with cool maritime air masses in the west and varm air of Mediterranean. Landslides started to run in the steep hillsides of Østerdalen, Gudbrandsdalen, Valdres and Numedal. The rainfall was even worse on Wednesday 22 July. Brooks turning into torrential streams appeared in the steep hills, causing slides, and tearing away farmhouses as well as fields. The flood plain next to the main rivers was inundated, and the rivers could shift into new beds because of erosion or deposition.

The flood occurred in River Glomma, Drammenselv, Numedalslågen, Skienselv, Nidelva, Otra, Driva, Surna, Orkla and Gaula as shown in the map in Figure 3.1.9.2. The most severe flood occurred in Glomma where both the eastern and the western branch flooded simultaneously. There is no information about flood damages downstream the county boundary between Buskerud and Oppland in River Begna.

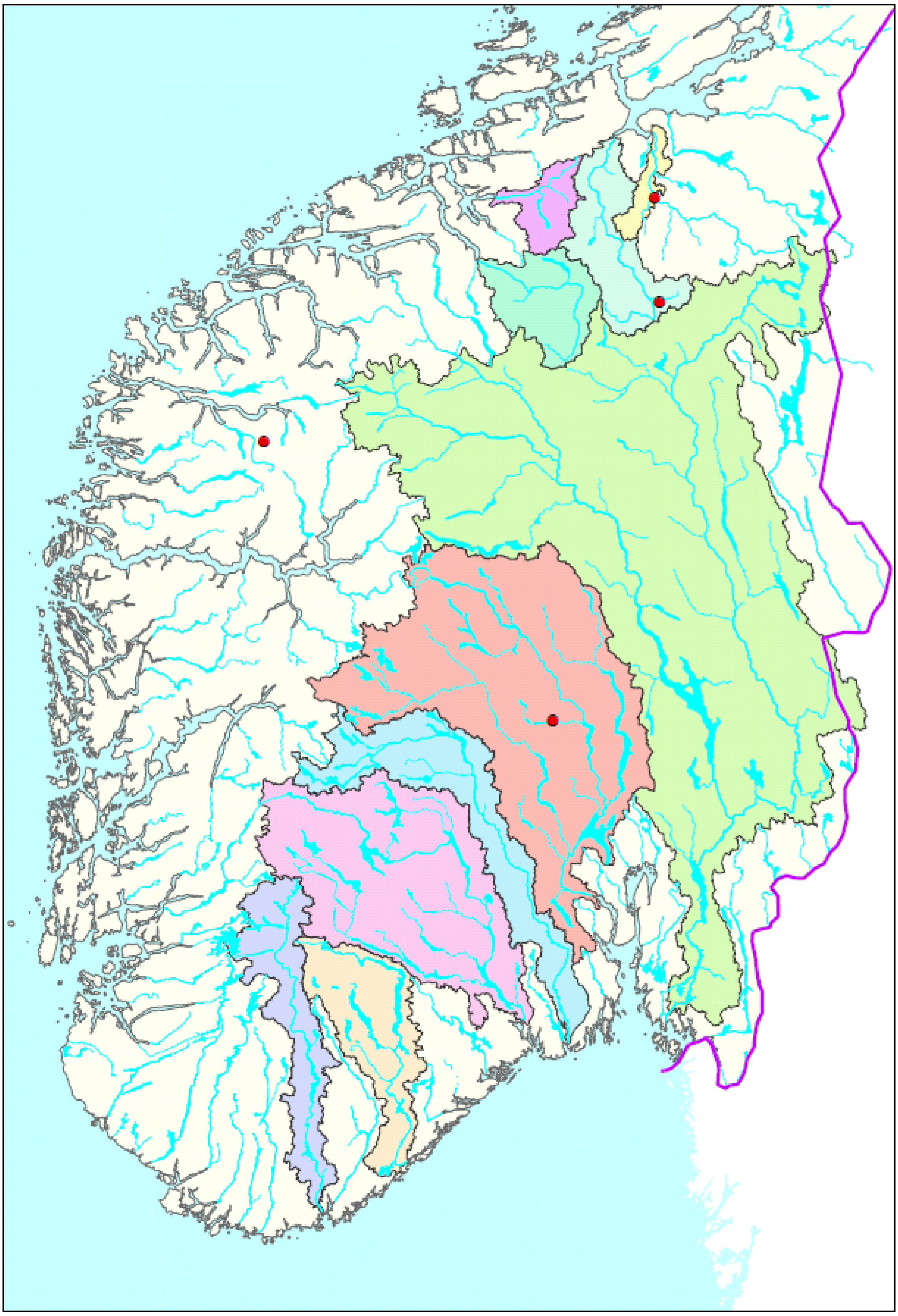


Figure 3.1.9.2 The water courses affected by Storofsen.

Figure 3.1.9.3 An artists impression of Storofsen in River Glomma at Sarpsfossen.

Flood magnitudes

The peak discharge at Stai in Østerdalen was estimated to 2500 m3/sec (NVE, 1922).
The peak discharge at Elverum was estimated to 3900 m3/sec (GLB, 1947).
The huge inflow into Lake Øyeren caused the lake to increase in length from 34 to 52 kilometers. The peak discharge out of Lake Øyeren was estimated to 4700 m3/sec (GLB, 1947).

Flood damages

Trysil

Storofsen caused damages in Elvdalen and Ljørdalen in Trysil (Lillevold, 1963). The damages at 39 farms were assessed to 1353 rdlr. River Klara on the Swedish side of the border had not, however, a major flood (Østmoe, 1985).

Glomma

River Glomma comprises an eastern and a western branch. The eastern branch comprises Østerdalen and Glåmdalen while the western branch comprises Vorma, Mjøsa and Gudbrandsdalen. The damages differ between the two branches partly because of differences in the local topography. The extreme weather did cause more disastrous damages in the western than in the eastern branch. The damages in the eastern branch were mostly caused by inundation of farms and farmland on the flood plain. Fields and grassland suffered badly from erosion and loss of soil as well of deposition of sand. The damages to the farmland were quite similar to the damages caused by Vesleofsen in 1995 where the flood protection works were opened to prevent them for breaking down completely. The farm animals seem to have still been on the farms during the flood, causing severe losses because of drowning. It is described from Odal that cowsheds came drifting in the river with dead cattle hanging in their chains inside.

Østerdalen

A local assembly (ting) took place at Nysted at Tynset 21-23 July. The thunder storms interrupted the discussions and the local judge "sorenskriveren" who chaired the assembly closed the "ting" with a remark which can be translated to "The rain is pouring down, and rhe thunder was rolling so the windows were shaking." He then made some comments about the acts of God before he dismissed the participants of the "ting". River Glomma was rising quickly and the farmers from the downstream village Alvdal discovered that the flood had taken their boats which they used to reach the site of the "ting". The farmers had to walk in the mountain sides of the valley to get home (Streitlien, 1977). Growing brooks caused several landslides at Tynset. A slide dammed a brook, Storbekken, for 24 hours before the dam failed. The resulting flood washed away buildings on two farms and deposited silt and gravel over the fields of these farms.

Many farms were located on the flood plain at Alvdal. Several tributaries join River Glomma at Alvdal, and the farms were quickly inundated by the flood from Rivers Sivilla, Auma, Sølna, Egminda and Folla as well as from the main river Glomma (Steinmoeggen, 1966; Rugsveen 1989). River Folla eroded large sandbanks, and the sand was deposited on the farmland. Many peoples were in danger of perishing, but fortunately all were rescued. Many landslides occurred in the steep mountain slopes. Many grain mills were destroyed. The buildings at 12 farms had to be rebuildt at locations less vulnerable to other floods.

The tributary Imsa released a large amount of gravel and sand into River Glomma at Storelvdal causing a dam to form. The dam caused backwater to Koppangsøyene (Andersen, 1996). The damages were assessed at 16 farms.

The bottom of the valley turned into a lake further downstream at Åmot. Buildings and trees came drifting. Dead farm animals were found at many places when the flood finally receeded. The damages were most severe on farms on the west side of the valley, but some farms on the east side suffered also damages (Lillevold, (1973). The damages at Åmot were described in Norske Intelligenssedler in 1790.

Tributaries such as Otta, Hårrenna and Åkeråa caused damages to farms in upper Rendal. The damages affected mostly grainmills, sawmills and stampehus next to the rivers.

The crown prince had ordered that a flood stone should be erected at the farm Grindalen at Elverum during his visit to the district. This stone was erected before Storofsen in 1788, but the level of Storofsen was later marked on the stone at Grindalen.

Figure 3.1.9.4 The flood stone at Grindalen at Elverum.

Many farms at Elverum suffered damages from Storofsen, partly from erosion and partly from deposition of a huge amount of sand and gravel on the fields. The damages were assessed from the autumn of 1789 to the late summer 1790. The losses in Østerdalen are summarised in Table 3.1.9.1.

Table 3.1.9. Summary statistics of the damages in Østerdalen in 1789.

District	Number of			Number of fatalities		
	farms	Small-holdings	Validation (rdlr)	Horses	Cattle	Sheeps and goats
Elverum	23	2	7790	14	128	
Åmot	30	5	14081	19	160	240
Stor-Elvdal	16		47580	56	435	691
Rendalen	21		2948	57	315	545
Tynset	47		18819	71	405	961
Kvikne	36		4013	27	194	359
Trysil	39		1353	0	0	0
Sum	212	7	96602	244	1637	2705

Glåmdalen

Glåmdalen extends from Elverum to the junction between Glomma and Vorma at Vormsund. This spring two smaller floods had already ocurred in Glåmdalen (Rød, 1967). The farm Hov at Kongsvinger had suffered from inundation of the farmland, making it necessary to sow and to fertilize the grainfields twice. All was washed away by Storofsen. River Glomma caused damages at 188 farms as the river flooded over the riverbanks. The river flooded into Lake Nugguren at Nor in Brandval. The churchyard and the farm Brandvold wrere the only part of Brandval on dry land. The last remnants of the farm Øien at Roverud, which once was the richest farm in the village, disappeared in the flood. The buildings of old and new priest farms were inundated, filling the basements and collapsing the chimney. The fields were covered by debris such as timber, fences, mud and sand (Mandt, 1789).

Brandval historielag has mapped the level of Storofsen from Nord at Brandval to Eidsfossen at Våler as a contribution to the 200 years anniversity of Storofsen based on floodmarks and other local information (Grobøl, 1991).

When the stage at Vinger surpasses a certain level, water will flow over a treshold and into River Vrangselv and into Sweden at Magnor. This river was described as a lake in 1789. The church yard at Matrand is said to have been iundated in 1789, and four coffins came floating (Fjellstad, 1970).

When the water level is high at the junction between River Glomma and River Oppstadåa in Sør-Odal, water flows into Lake Storsjøen from Glomma. Lake Storsjøen serves as a detention storage for the flood further downstream in River Glomma. This cause however damages, mostly from inundation of farmland, to farms in Sør-Odal which also suffered damages in 1789.

The deduction reports of flood damages at each farm in Glomdalen are missing in the documents collected by S. Riksen at Riksarkivet. Table 3.1.9.2 summarises the damages in each of the districts in Glåmdalen which was affected by *Storofsen*.

Table 3.1.9.2 Summary statistics of the flood damages in Glåmdalen in 1789.

District	Number of			Number of fatalities
	farms	Small-holdings	Validation (rdlr)	Farm animals
Øvre og Nedre Solør, Hof, Åsnes, Grue	41		8765	249
Brandval	81		20401	539
Vinger og Eidskog	22	5	6482	222
Odalen		9	8706	228
Sum	188	14	44264	1338

Storofsen did not cause fatalities in the eastern branch of River Glomma, but the ravages at Alvdal at the junction with the tributary Folla came very close to cause several fatalities. The huge loss of farm animals is likely to have occurred because more of the stock still was at the home farms when the flood occurred compared to the western branch.

The western branch

Table 3.1.9.3 summarises the damages in Gudbrandsdalen. The confluence of the eastern and the western branch of River Glomma is at Vormsund, where the western branch, River Vorma, joins with the main river. The western branch comprises of river Vorma from the junction with the main river at Vormsund to Lake Mjøsa. River Gudbrandsdalslågen flows into Lake Mjøsa from the north with several tributaries running westward into the alpine areas of Jotundheinen and some shorter river flowing from the mountains in the east. Kleiven (1908b) describes the flood in Gudbrandsdalen, Vågå in 1908a), Lom and Skjåk in 1915, in Lesja and Dovre in 1923, in Østre and Vestre Gausdal in 1926 and in Fronsbygdin in 1930.Rybakken (1989) describes the flood at Øyer, Kleiven (1928) and Hovdhaugen (1952, 1976, 1979) at Ringebu and Fyksen (1995) at Gausdal. The flood at Fron has been documented by Sommerfelt (1943). Most of the damages in Gudbrandsdalen was caused of landslides. The summer 1789 was therefore locally named *Skriusommaren*. The most severe damages of *Storofsen* occurred in Gausdal, Fron, Vågå, Lom and Lesja where most people perished. Landslides occurred at most of the farms in the hillsides as new brooks appeared everywhere from the intense rainfall. Slides dammed River Gudbrandsdalslågen at Rosten upstreams the village Sel and somewhere near Øyer downstreams Fåvang where the water levels shown at the floodstone indicates a level in 1789 must have resulted from a downstreams damming. Two slides met in River Sjoa at Skogsbygda in Heidal. When the resulting dam failed, the flood wave destroyed all bridges in Heidal, and caused some fatalities. A slide at the later village Bismo at Skjåk moved the bed of River Otta to the south. River Ula deposited sand and gravel from the Rondane massif to the east moving the bed of River Gudbrandsdalslågen westward at Selsverket.

Farms on the flood plains were mostly inundated. The flood in River Finna caused severe damages at Vågåmo. The bridge crossing over to the southern side of Lake Vågåvatn was taken. Floods and slides caused severe damages and fatalities at Garmo and in Bøverdalen at Lom, (Øyjorde, 1965; Kolden, 1989). The lower part of Skjåk suffered also from damages (Hosar, 1995). Most of the damages was to farms and farmland as shown in Figure 3.1.9.4.

Severe damages occurred also next to River Vinstra (Aamundstad, 1935). River Vinstra is the tributary to River Numedalslågen from Lake Bygdin, south of the Sjoa and north of the Gausa basins and of the water divide towards River Drammenselv at Valdres.

Table 3.1.9.3 Summary of the damages caused by Storofsen in Gudbrandsdalen.

District	Number of			Number of fatalities			
	Farms	Small-holdings	Validation (rdlr)	People	Horses	Cattle	Sheeps and goats
Fåberg	38		18910	0		2	6
Gausdal	70		64836	5	1	25	105
Øyer	53		2745,4	0		1	
Ringebu	47		18255	0	1		13
Fron	153		107911	20	7	34	79
Vågå	155		119659	24	6	60	360
Lom	136		69285	6	2	36	129
Lesja	23		18862	6	0	11	11
Sum			4200465	61	17	169	703

Table 3.1.9.4 Summary of damages to the farmland and losses of buildings in Gudbrandsdalen in 1789.

District	Fields (mål)		Grassland (mæling)		Buildings	
	Damaged	Ruined	damaged	Ruined	Damaged	Ruined
Fåberg	92,5	136,5	466,25	516,33	147	25
Gausdal	691	118,5	2587,5	348,5	348	23
Øyer	51,33	126,6	81,75	110,25	41	6
Ringebu	62,5	200	263	988,47	155	64
Fron	2014,3	555,83	2616,3	558	809	270
Vågå	1790,7	992,5	1989,2	228,25	1082	208
Lom	717,5	337,83	1541,3	301	335	121
Lesja	118,5	89,5	450,75	467,5	117	18
Sum	5538,3	2557,3	10006	3518,3	3034	735

Lake Mjøsa rose to a record high level, which never have been exceeded later. Farms close to the lake suffered from inundation. Large volumes of debris were deposed between Fåberg and Mjøsa and at the outlet of Lake Gausa. Some unidentied bodies were found in the depositions and buried at Lillehammer. The water in the lake was polluted and full of debris and needed some years to clear.

Farms and smallholding suffered damages in Ringsaker (Hansen, 1990) and at Nes (Kolstad, 1989) on the eastern side of Lake Mjøsa. Figure 3.1.9.3 show that the lower part of the Hamar would have been inundated at a level corresponding to 1789. Table 3.1.9.45 summarised damages caused by *Storofsen* at the western side of Lake Mjøsa at Toten, Snertingdal and Biri (Laudal, 1951), and in Valdres at Vang, Slidre, Aurdal and Land. These districts suffered also from slides and inundations as listed in Table 3.1.9.5 and 3.1.9.6, but the losses of farmland and buildings were less than in Gudbrandsdalen.

Drammenselv

Valdres is a part of the Drammenselv catchment and includes mountaneous districts bordering to Jotunheimen in the north and the mountains towards Vestlandet in the west. The floods in River Begna has been documented in Otnes (1982b). Although *Storofsen* was by far the largest flood in the upper Begna, there are no information about *Storofsen* downstreams the boundary between Oppland and Buskerud counties in 1789 except in the tributary from Hedal, where a slide killed 7 people. One farmer drowned in River Vinjarelv at Aust-Torpo in Land and another perished at the farm Landmark in Nord-Aurdal. Several people were invalided by the flood in Valdres. In 1792 a large snowmelt flood occurred in the Etna and Dokka catchments. The review of the damages in Land and Aurdal after *Storofsen* was held after the 1892 flood, and the damages are therefore the sum of both events.

In the tributary Hallingdalselv some damages occurred in Sørbygda at Flå and at Ål. The damages at Sørbygda occurred at x farms and the total damage was estimated. The damage at Ål was the result of a landslide triggered by heavy rainfall.

Table 3.1.9.5 Summary of the damages caused by Storofsen at the western side of Lake Mjøsa and in Valdres.

District	Number of			Number of fatalities			
	farms	small-holdings	Validation (rdlr)	People	Horses	Cattle	Sheeps and goats
Vang	20		3090	0			
Slidre			3460	0			
Aurdal	24		24510	8		19	35
Land	6		15402,48	1			
Biri	21		2561,32	0			
Toten			1501,24	0			
Sum			50525,04	9		19	35

Table 3.1.9.6 Summary of damages to the farmland and losses of buildings at the western side of Lake Mjøsa and in Valdres.

District	Fields (mål)		Grassland (mæling)		Buildings	
	ruined	Damaged	ruined	damaged	Ruined	Damaged
Vang	17,25	15,75	44,5	28,5	20	4
Slidre	18,75	19,25	68,2	53	13	3
Aurdal	132	253,25	326	621,5	106	16
Land	102,75	282	235	673	52	23
Biri	11,5	33	112	15	31	5
Toten	6,34	95,92	2,67	156,33		
Sum	288,59	669,17	788,37	1547,33	222	51

Numedalslågen

River Numedalslågen suffered from damages at 50 farms upstreams the mining town Kongsberg. Several properties in the the western side of the valley suffered from landslides caused by the heavy rainfall. The farms obtained an average deduction of 35,5 percent.

Storofsen caused damages at Skien because of failing dams at Eidet. The lower part of the town was inundated. Further upstreams at Tinn farms suffered from landslides.

Further west River Vegårdselv inundated an iron work at Nes, timber booms were taken in River Nidelv and in River Otra.

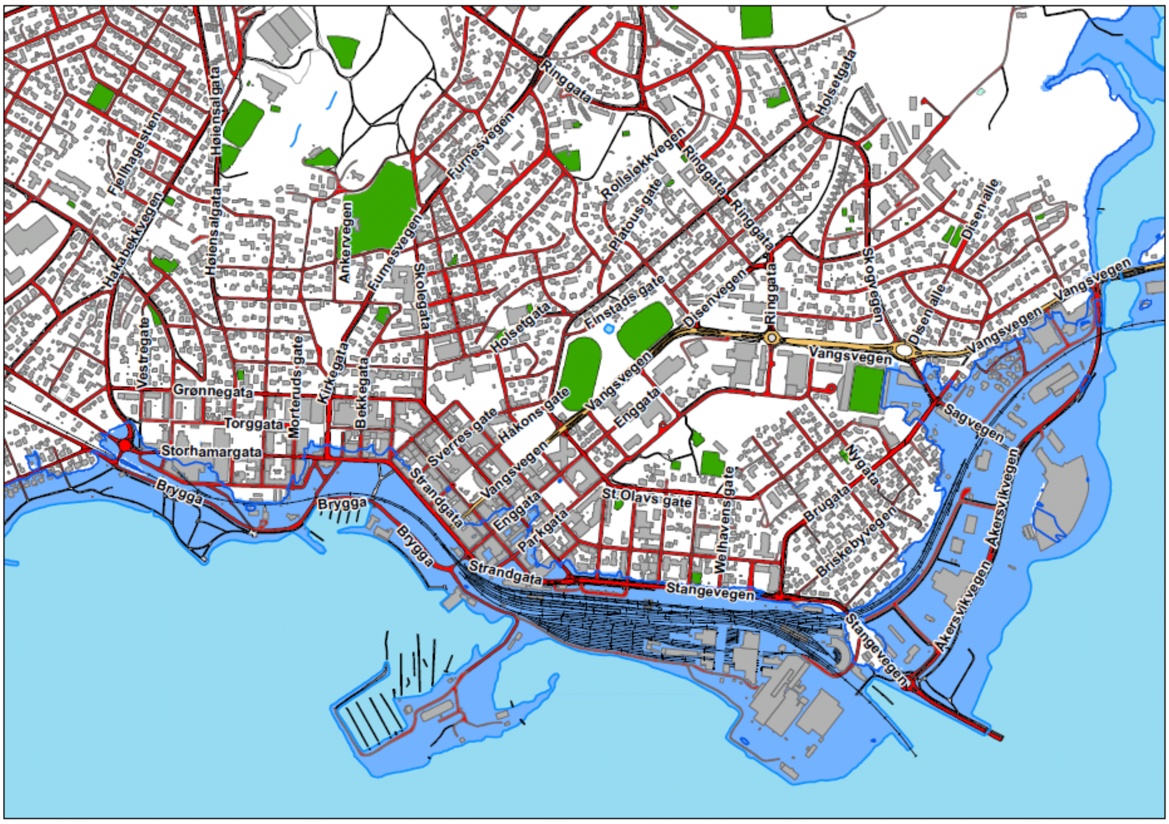


Figure 3.1.9.3 The part of the present Hamar which would have been inundated by the level of Storofsen.

Floods in rivers at Vestlandet and Trøndelag

River Breimselv flows from the glaciers Jostedalsbre and Myklebustbre westwards to the Gloppenfjord. Lake Myklebustvatn is located on the northern branch of this river. I 1789 it was written that the inhabitants of the farm Myklebust had to access the farm buildings on horseback because of the flood in the lake. The flood was most likely caused by extreme melting on the glaciers, resulting from strong foehn winds caused by the extreme rainfall east of the water divide.

River Rauma flows northward from the water divide at Lesja to the Romsdalsfjord at Åndalsnes. The upper part of this river did also flood, although less than further south. River Driva flows from Dovrefjell northward to the village Oppdal, and westwards through Sunndal ending in the fjord at Sunndalsøra. Storofsen was the most severe of all known floods in this river. Table 3.1.9.6 summarises the flood damages in this river.

Table 3.1.9.6 Summary of damages from Storofsen in River Driva.

District	Number of farms	Percentage deduction	Loss (rdlr)
Hov parrish	15	22,2-89,7	3543
Romfo parrish	21	25-83,3	9349
Oppdal	12	16,6-94,4	

The damages at Driva has been documented by Rise (1947), Sande (1981). Several tributaries were temporarily blocked by landslides, followed by subsequent dam failures. Farmland was inundated and more than 50 buildings and 20 mills were taken by the flood.

River Surna flows westward from the water divide to River Orkla to Surnadalsfjorden. Hyldbakk (1957) mentions that several farms suffered damages from Storofsen along River Surna.

River Orkla flows from the water divide to River Folla, and the northwest part of the upper Glomma westward and later northward to the Orkdalsfjord a branch of the Trondheimfjord. Storofsen caused extensive damages in River Orkla, see Table 3.1.9.7. Several islands in the river used for producing hay disappeared because of erosion. Farmland near the riverbanks were covered by thick layers of sand and gravel as well as logs and other debris. The flood broke through the flood protection works and inundated the copper mines at Kvikne. These mines were never reopened after the flood. Further downstreams the flood caused severe damages to many farms by eroding islands in the river used for farming, deposing sand, gravel, trees and other debris of the farmland and damaging or destroying many buildings. Five bridges were taken by the flood (Grefstad, 1929; Hoff, 1945; Hagen, 1952).

The rainfall penetrated also across the water divide from River Orkla into the catchment of River Gaula through Soknedal towards Støren. Eight farms were granted deductions in River Gaula. The farms were not able to feed more that half of the farm animals after the flood.

Table 3.1.9.7 Summary of damages from Storofsen in River Orkla.

District	Number of farms	Percentage deduction	
Orkdal	26	17-58	
Meldal	66	10-100	
Rennebu	10	20-72	
Kvikne	8		
Sum	110		

3.1.10 The large flood at Østlandet in 1827.

A major spring flood occurred in the large rivers at Østlandet from Trysilelv to Skienselva in 1827. River Glomma started to rise in late March. The flood was primarily caused by snowmelt, but ice contributed to damages at Elverum 20-21 April. The spring flood from the lowland culminated in mid April. The water level decreased until 5 May, when the melting started in the alpine part of the catchment. The flood peaked in the first days of June.

Flood damages

The flood caused severe damages at Storelvdal close to the junction between River Glomma and the tributary Imsa (Sætren, 1904; Fosvold, 1937). The River Imsa carried a lot of logs, trees and rock as the flood set in. The river was split into two channels, where the northernmost was the main channel. This channel filled up with the material, forcing the water to flow through the southern channel instead. The main road as well as as several bridges was destroyed. Farmland was eroded; the farm Nordre Messelt was almost completely devastated.

The ice run 20 -21 April caused damages at Haug and at Strandbygda at Elverum. The flood peaked 30 May, causing a large riverbank failure at Indset. The water level was said to be 2 1/2 alen below the level of Storofsen and 1/2 alen below the level in 1773 (Kvernmoen, 1921). The water level was 1,44 meter lower than in 1789 at Grindalen according to Sætren (1904). There were riverbank failures at Foss at Brandval, the outlet of River Norsåa at Vinger and at Snekkermoen and Os at Odal (Helland, 1902).

Captain Gerhard Schive conducted daily water level measurements at Minne at the outlet of Lake Mjøsa 1824-1827 as a part of a project to map the potential for building a system of weirs and locks along River Vorma as basis for traffic by steamships. The 1827 flood culminated between 5 and 10 June 1827 in Lake Mjøsa. The water level referred to the local scale at Hamar brygge was about 8 feet below the level of Storofsen. The population living along Vorma stated that the 1827 and the 1808 floods were the largest since Storofsen.

The water level in Lake Øyeren rose to 28 feet 11 inches, approx.5 feet below the level of Storofsen (Johnson, 1861). Several houses were inundated at Skien. The timber boom at Funnemark was damaged, but the flood did not cause riverbank failure in Telemark.

3.1.11 The spring flood at Østlandet in May 1846.

A large spring flood occurred in Rivers Glomma, Drammenselva, Numedalslågen and Skienselva. The flood had been studied by Johnson (1861) who compared it with the large flood in 1860.

Initial conditions

The winter 1845/1846 is one of several winters with abundant snowfall. Mild weather caused numerous avalanches in the west in February. The spring remained cold until May.

The flood

The temperature rose abruptly in May. A heavy rainstorm from Østerdalen to the mountains at Hallingdalen co-incided with intense snow melt. The water levels of the rivers at Østlandet started to rise fast. The flood level at Grindalen at Elverum peaked 1,57 meters below the level in 1789 (Sætren, 1904). The flood peaked at Solør 24 May, 17-18 feet or 5,3 meter above the normal low flow datum at Norsfoss. The flood penetrated over the flood plain into the lakes east of Glomma as the flood protection works failed. Drifting timber was deposited on the fields. Water from Glomma floded into Lake Storsjøen where the flood peaked 25-27 May.

The flood in lowland rivers around Lillehammer culminated 24 May, but the contribution of meltwater from Jotunheimen caused the water level in Lake Mjøsa to rise until 18-23 June when the lake peaked at the level of 19 feet 8 inches at Minne. The flood peaked at Sarpsfossen 1-2 July at a level exceeding the 1827 flood. The flood culminated in Drammenselva, Numedalslågen and Skienselva 24 May (Johnson, 1861).

Flood damages

The flood caused severe riverbank failures at Flisa where several farms were considered for relocation (Kanalvæsenets historie 2, 1881a). Large areas were inundated along River Glomma at Odalen. The flood magnitude at Nor was comparabel to the flood in 1850. The riverbank failed at several locations.

3.1.12 The spring flood at Østlandet and Trøndelag in 1850.

A large spring flood occurred in Rivers Glomma, Drammenselva, Nidelva at Aust-Agder and Orkla and Gaula in Trøndelag.

Initial conditions

The winter 1849/1850 is one of several winters with abundant snowfall in the mid 19th Century. Mild weather in the west caused slush avalanches and ice run floods in February and March from Nordfjord to Nordmøre.

The flood

The snowmelt started in May at Østlandet. The resulting flood peaked at Storelvdal 25 May at a level exceeding the level of the large flood in 1934 by 10 cm. At Elverum the flood peaked at 1,14 meters below the level of Storofsen, 0,8 feet below the flood in 1773 and 10 feet above the level in 1827. The flood peaked at Grue 26 May. The flood from Mjøsa through Vorma, delayed the flood at Lake Øyeren, which peaked 17-18 June at the local level 13,6 meter (3 meter below the level of Storofsen). Lake Øyeren is said to have extended upstream in River Nitelva to Rotnes.

Flood damages

The damages at farmland in Os and Tynset were fairly small, mostly because the land on the floodplain had not been taken into use for farming. Landfastøya at Alvdal was inundated, and this was also the case from Storelvdal downstream to Åmot. The main road was only visible above the water at a few locations. Several wooden bridges crossing tributaries such as River Imsa were lifted from their fundaments by the water. Many homes had to be abanoned for longer periods. There were severe riverbank failures at Messelt, Mellem-Rustad, Stai, Koppangsøyene, Grundset, Åset and in Søkkunna. The flood deposited a large quantity of sand on much of the farmland, at other location the soil had been washed away. It was neccessary to redo the spring work in the fields, sowing grain and spreading fertilizers anew (Kanalvæsenets historie 2,1881a; Andersen, 1996).

The flood caused also widespread inundation at Elverum. Most of the houses on a large peninsula was surrounded by water. The flood was also large at Hof and Grue. There were riverbank failures at Brandval and in Solør-Odal (Mandt, 1953). Some farmers succeeded in building dikes which kept the water away from their farms.

The flood was also large at Bjørkelangen. Vittenbergbrua at Hovin was destroyed (Kiær, 1885; Sætren, 1904). Four persons is said to have perished there. The flood removed a wooden bridge at the outlet of Lake Øyeren at Mørkfoss (Nygaard, 1991).

The flood was severe at Østfold, where an old factory building at Hafslund was partly destroyed by the river. A log slide was partly taken by the river at the other side of the water fall at Borregård. A ferry overturned downstream the waterfall, carrying four persons onboard. One man was saved, the others drowned.

A major riverbank failure occurred at Hokksund caused by Drammenselva (Kanalvæsenets historie 5, 1881c). Flood protection works were also damaged along River Gaula.

3.1.13 The spring flood at Østlandet in 1853.

Water level data are available at some locations from Hokksund to Vikersund in the lower part of Drammenselva. These data show that a large spring flood occurred there in 1853. The flood was also among the larger floods in River Glomma at Lake Øyeren, but 2,5 meters below the level in 1850 (Medby, 1968). There is no record of flood damages upstream Brandval, where some severe river bank failures occurred (Mandt, 1953). The floods seem to have been more severe from Drammenselv to Skienselv. The flood destroyed a bridge at Sør-Aurdal (Kanalvæsenets historie 5, 1881c).

3.1.14 The large flood in 1860 - Storflaumen or Ofsen

The large flood in 1860 is among the largest floods which have occurred in southern Norway. The flood occurred in the western part of River Glomma, River Drammenselv, River Numedalslågen, River Skienselv, River Arendalselv, River Orkla and River Mandalselv. The extreme melting conditions caused also floods from the water divide towards the bottom of fjords in west Norway, in River Sima, River Lærdalselv and River Årdalselv. The catchments affected by the flood is shown on the map in Figure 3.1.14.1. Johnson (1861) has documented the flood extensively.

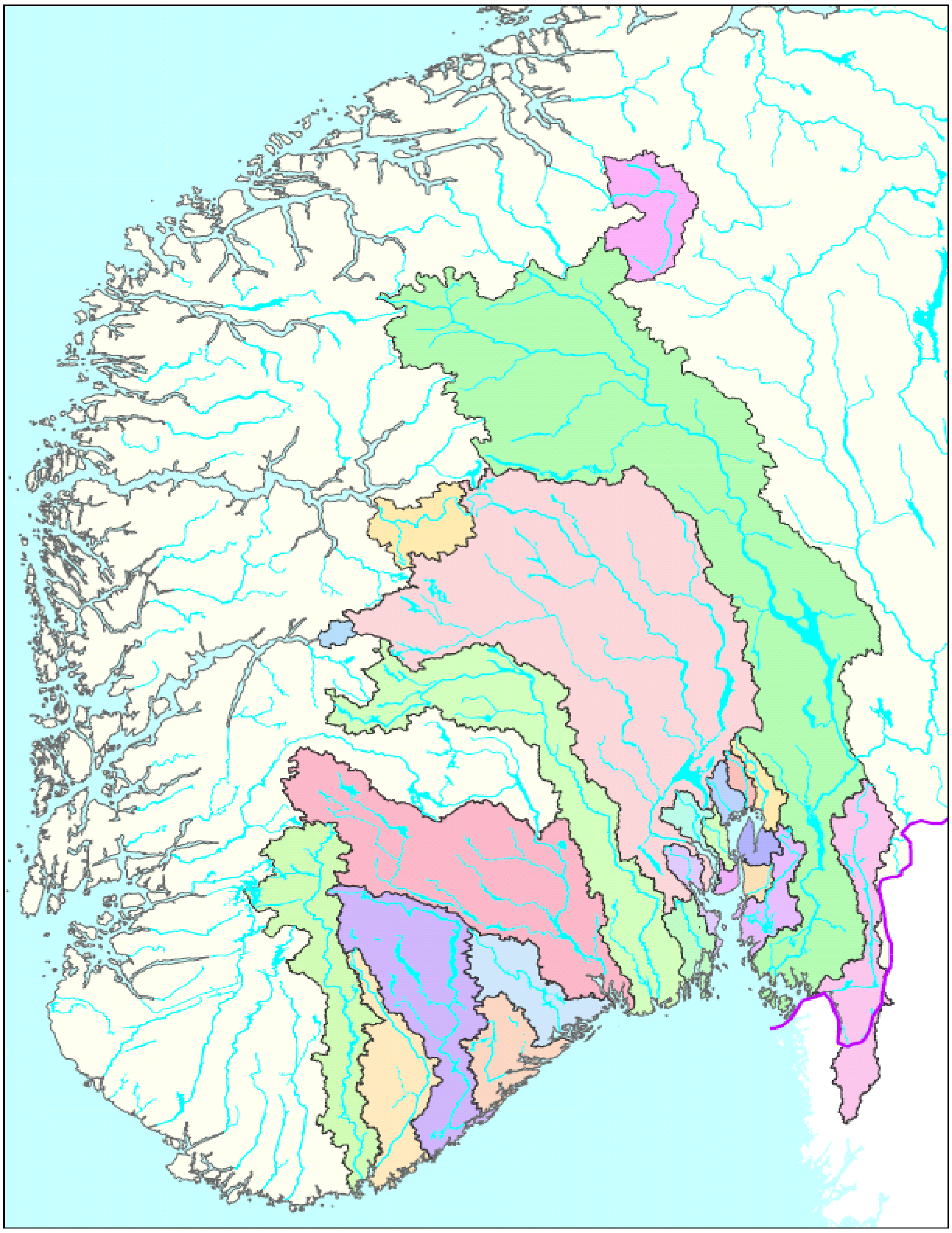


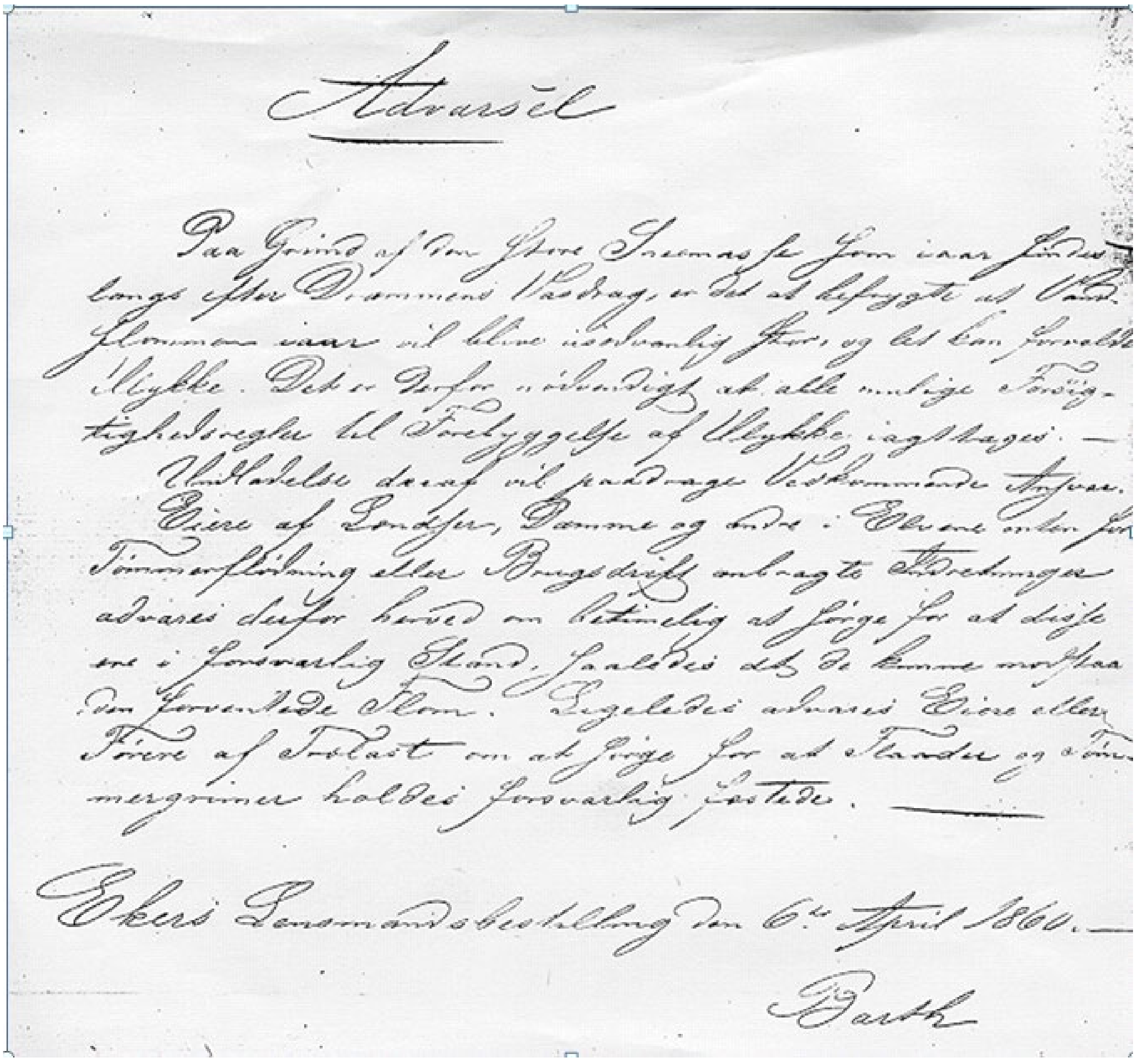
Figure 3.1.14.1 The catchments affected by the 1860 flood in Norway.

Initial conditions

The winter 1859/1860 was severe with heavy snowfall in southeast and southern Norway. The snowfall was less along the eastern branch of River Glomma through Glåmdalen and Østerdalen. Ongoing work at the Strue brigde in River Nidelva near Arendal was prevented by the exceptional amount of snow. The probability of a large spring flood was considered to be high, especially in River Drammenselv and Numedalslågen. Large quantities of timber were contained by timber booms in the large rivers in east Norway. This timber could cause severe damage if the booms failed. The county governor in Buskerud instructed a local police chief, Barth, to issue a warning to owners of timber booms, locks, piers and other constructions in the rivers about the expected flood, see Figure 3.1.14.2. The warning was issued 6 April 1860, more than two months before the flood culminated. A similar warning was later issued by the police in Oppland, prohibiting timber floating until the expected flood was over.

This warning corresponds to reports of the initial conditions prior to the start of the spring flood as produced by the flood forecasting service today, but the warning may be considered as the first attempt of flood warning in Norway.

The spring was cold, but the temperature rose to +3°C or more from 27 April at altitudes around 700 meters above the sea in the Glomma basin. The snowmelt had started, and by mid June most of the snow had melted in the lowlands.



Advarsel

Paa Grund af den store Snemasse som i aar findes langs efter Drammens Vasdrag, er det at befrygte at Vandflommen i aar vil blive usædvanlig stor, og let kan forvolde Ulykke. Det er derfor nødvendigt at alle mulige Forsigtighedsregler til Forebyggelse af Ulykke iagttages. —

Undladelse deraf vil paadrage Vedkommende Ansvar.

Eiere af Lendser, Damme og andre i Elvene anlagte for Tömmerflötning eller Brugsdrift anbragte Indretninger advares derfor herved om betimelig at sörge for at disse ere i forsvarlig Stand, saaledes at de kunne modstaa den forventede Flom. Ligeledes advares Eiere eller Förere af Trælast om at sörge for at Flaader og Tömmergrimer holdes forsvarlig fastede. —

Ekers Lensmandsbestilling den 6te April 1860. —

Barth

Figure 3.1.14.2 The flood warning note issued by the local police chief in Eiker prior to Storflaumen in 1860.

The flood

The meteorological and hydrological conditions causing the flood is described in Johnson (1861). Figure 3.1.14.3 show observed water levels in River Glomma, River Drammenselv and River Skienselv.

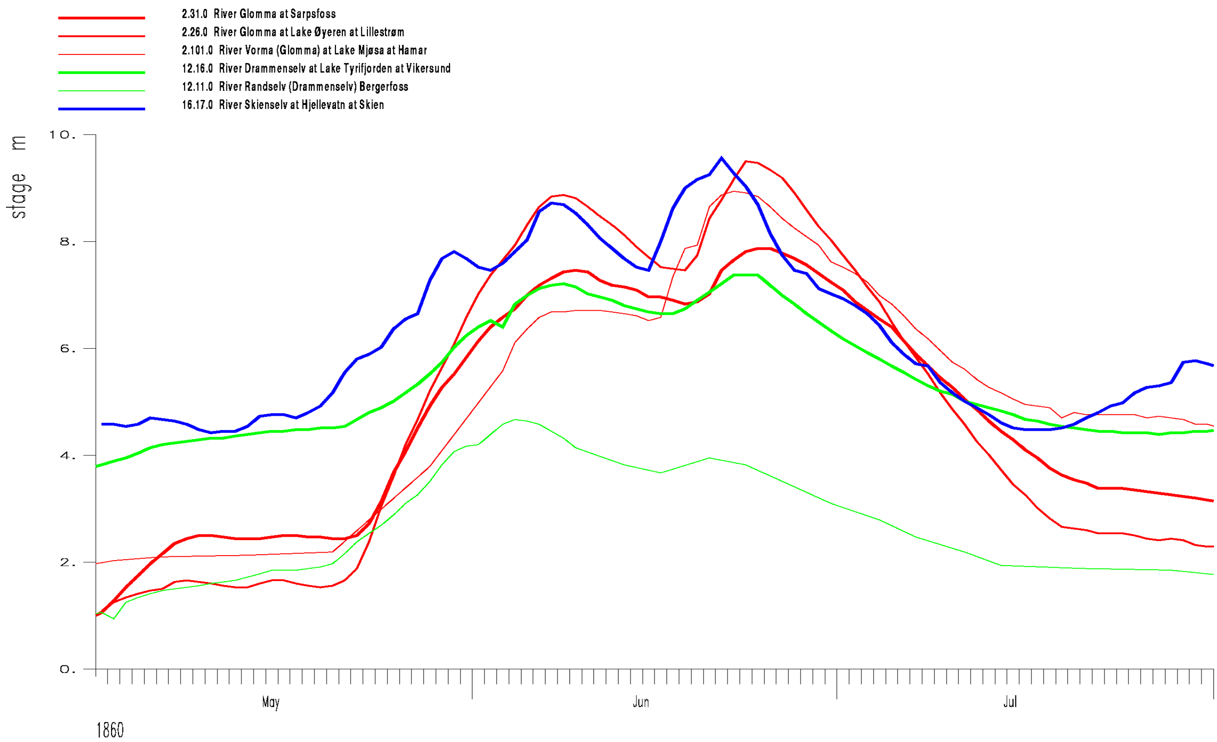


Figure 3.1.14.3 Observed flood levels in River Glomma, River Drammenselv and River Skienselv during the flood in 1860.

The flood started 19 May and lasted until Mid July as a result of the exceptionally large snow volume present. The flood volume must have exceeded the volume of Storofsen several times because of the extreme duration of the flood. The flood had two peaks, one in early June and the second larger in the second half of June. The first peak was mostly caused by snowmelt, the second occurred after a heatwave and thunderstorm moving in from southeast from Agder to Gudbrandsdalen 14-18 June. Reanalyzed weather maps (NOAA reanalysis 2.000) show two anticyclones, one was located at the Atlantic Ocean westwards from the Azores and the other located over the Mediteranian and southern Europe 14 June. These anticylones were embedded in warm air masses. A low with a cool kernel was located over northwestern Britain, extending to the Norwegian coast. Warm and humid air was streaming from the Bay of Biskay northestward across the North Sea to the Oslo fjord. Between the warm and humid air from the south and the cooler air to the northwest a quasistationary front was located over eastern Norway. The rainstorm was accompanied by strong wind from the south. Høgåsen (1998) estimated the temperature at 1300 m.a.s.l. in Oppland and Hedmark to approx. 13° C, causing optimal condition for melting based on observed temperatures in Oslo. As under *Storofsen* the circulation pattern was stable for several days. The first rainstorm 14-15 June affected mostly rivers west of Oslofjorden, such as River Otra and Numedalslågen. The warmer air masses from the south penetrated over most of Southern Norway by 16 June causing the inland rivers to rise 17-18 June both from intense snowmelt and intense rainfall.

Glomma

The snow storage was considerably less in the eastern branch of River Glomma in Østerdalen, and the resulting flood was therefore smaller than further west. River Nidelv in Trøndelag had an exceptionally small spring flood in 1860, indicating a small snow storage available for melting. The flood started to rise in the mountain streams after one or two days. River Otta peaked 17-18 June, see the flood stone at Lalm in Figure 3.1.14.2. Two farms were taken by the flood in the tributary Finna at Vågåmo as the river went bankfull. The discharge from River Otta exceeded by far the discharge from the upper part of River Gudbrandsdalslågen where the snow volume was less and the temperature started to rise two days later.

Figure 3.1.14.4 The flood stone at Lalm showing the level of the largest floods in River Otta. (Photo: L. A. Roald)

Downstreams Otta the flood inundated the main road between Otta and Sjoa. Kleiven (1908b) has documented the flood in Gudbrandsdalen.The flood reached the level of the new main road, which was being built at Ringebu, partly damaging the construction. Based on the experiences of the flood the level of the new road was raised to a safer level. The flood started to rise at Lillehammer 15 June. The Brunlaug Bridge at Fåberg was taken by the flood 17 June (Aftenposten, 1860; Lillehammer Tilskuer 1860). The main road in Gudbrandsdalen was flooded from 16 June. The steamboat *Skibladner* was later used to tow the floating bridge to the shore.

Figure 3.1.14.5 Flood mark at Lillehammer June 1860.

Lake Mjøsa rose to a level at Nes church estimated to just one foot under the peak level of *Storofsen* 20-21 June. The railway station at Eidsvold was flooded from River Vorma 21 June. The flood rose into the buildings at Strandgaten at Hamar, Hedmarks amtstidende (1860). Figure 3.1.14.6 show Strandtorget at Hamar during the flood.

The flood caused damages at lowlying farms, towns and villages around Lake Mjøsa, and threatened to erode the farm Minne at the outlet of Lake Mjøsa, and 100 men worked on securing the riverbank. The wheelboat *Skibladner* was used to transport rocks from the Toten hills to provide the crew trying to save the rive bank at Minne. Floating logs was one of the main causes of failing bridges. A raft of 600 logs destroyed the bridge across River Vorma at Eidsvoll, where the railway station was flooded from River Vorma 21 June.

The eastern branch of River Glomma suffered no damages, but downstreams the junction with River Vorma, further damages occurred. The village Lillestrøm was inundated as shown in Figure 3.1.14.7. The flood rose to the level of the railway bridge at Lillestrøm, and a steamship took over the transport of people and goods from the railway. Lillestrøm became for the first time the location of flood tourism, as people from the capital Kristiania came by train to see the flood. The water level in the lakes Mjøsa and Øyeren are shown in Figure 3.1.14.8.

The discharge at Sarpsfossen rose to 2956 m^3/sec 8 June. After a temporary drop in the water level the flood rose to a peak value of 3181 m^3/sec 24-25 June. The flood threathened sawmills at the industrial town Sarpsborg. Two men trying to save the construction were taken by the flood and drowned.

The stages and estimated discharges at gauging station and lakes in Glomma is summarised in Table 3.1.14.1.

Table 3.1.14.1 Estimated peak water levels and discharges in lakes in River Glomma during the flood in June 1860.

Station	River/Lake	Stage (meter)	Discharge (m3/sec)
Sarpsfoss	Glomma	7,87	3180
Mørkfoss	Øyeren	12,55	4150
Årnes	Glomma	8,5	4300
Hamar	Mjøsa	10,00	
Losna	Lågen	7,00	2800
Olstappen	Vinstra	5,95	469

Lalm	Otta	2,29	1585

The flood destroyed 114 bridges in Oppland County and caused damages to many roads. Eyevitnesses saw at least 20 buildings floating in River Gudbrandsdalslågen

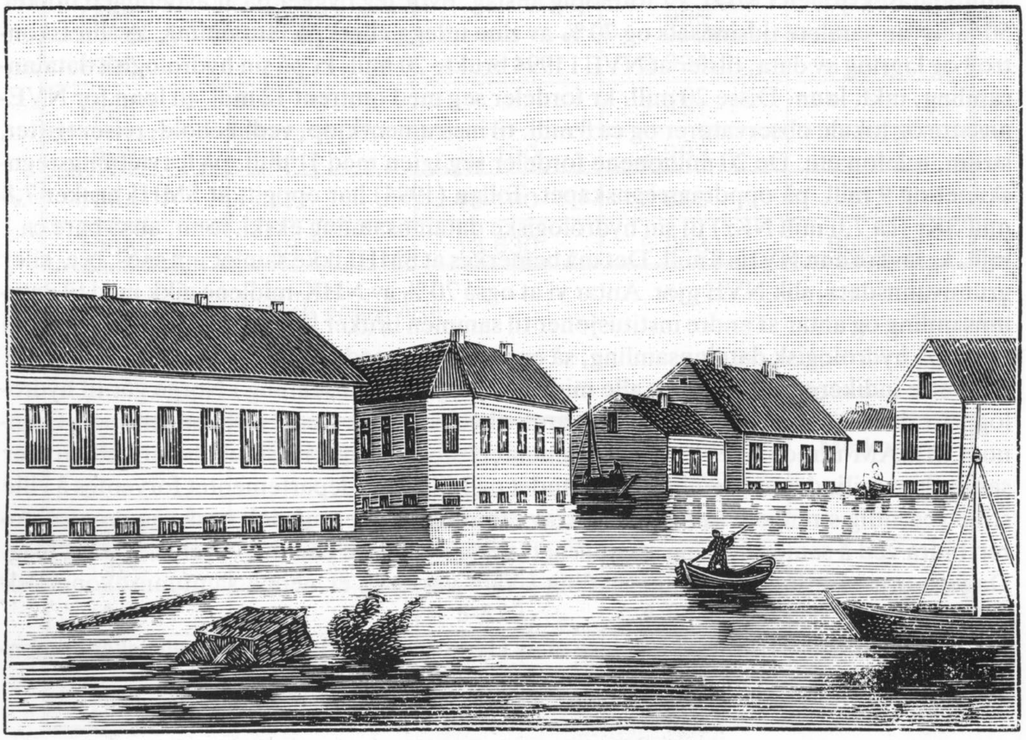


Figure 3.1.14.6 The flood at Strandtorget in Hamar in 1860. (Source: Illustrert Nyhetsblad).

The farmers at the lower part of the Glomma catchment suffered also from a second rainfall flood occurring in late August and early September, as shown in Figure 3.1.14.7. This flood was the highest observed so late in the year in River Glomma, causing damaged crops to the farmers near Lake Øyeren.

Figure 3.1.14.7 The inundation of Lillestrøm in June 1860. (Source: Woodcut published in Skillingsmagasinet).

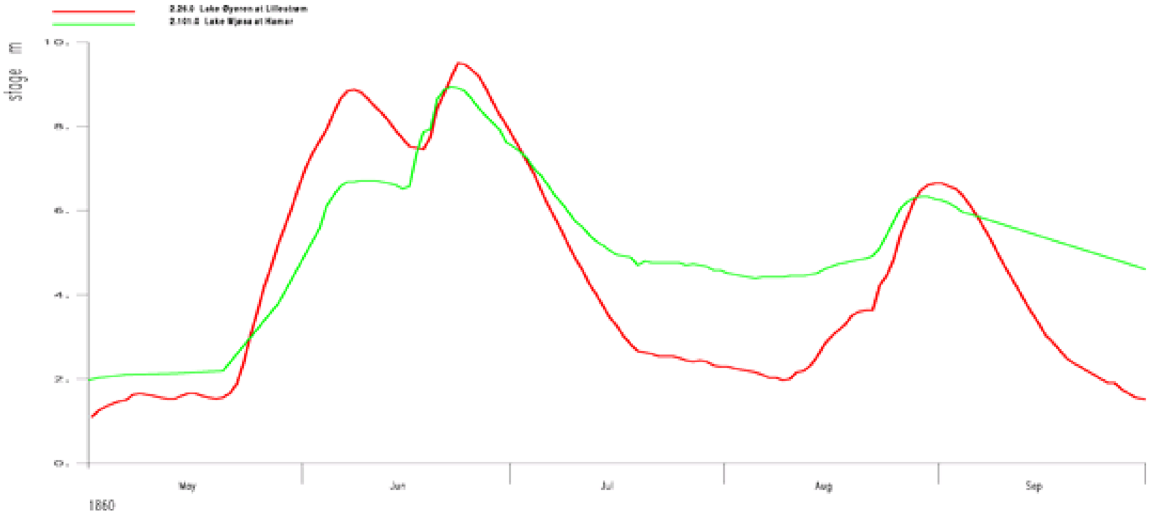


Figure 3.1.14.8 Flood levels of the two floods in 1860 observed in Lake Øyeren at Lillestrøm and at Lake Mjøsa at Hamar.

Lierelv

The flood in River Lierelv was probably also among the largest floods known in the river. The river shifted to a new riverbed to the fjord further east.

Drammenselv

The upper parts of River Drammenselv in Valdres suffered from intense snowmelt simultaneously with River Otta. River Drammenselv comprises of several branches. The easternmost branch, River Randsfjordelv with the tributaries Etna and Dokka, peaked already in early June, and contributed less to the flood in the main river.

River Begna joins River Randselv at the town Hønefoss upstream Lake Tyrifjord. The flood destroyed most of the bridges near Hønefoss. Several people fell into the river, and one girl drowned. The five bridges Tveitebrue, Alabrue, Øyebrue and Bogetunbrue on the main road at Vang municipality were destroyed by the flood. Another six bridges on private roads were also taken. The flood ravaged 134 daa farmland and 408 daa grassland at Vang municipality and 324 daa farmland and 2229 daa grassland in Sør-Aurdal municipality.

Downstream Lake Tyrifjorden River Snarumselv joins the main river from the west. Upstreams Lake Krøderen the river changes name to River Hallingdalselv. The 1860 flood is the largest known flood in this river, and farms at the valley floor suffered damages from inundation. The flood levels were marked at some of locations, near the main road, but most of these marks are lost when the roads were improved. People living on farms at islands or next to the river was rescued under dramatic circumstances at several places. In the side valley Hemsedal, several smallholdings were struck by slides and four people perished.

The main river started to rise 16 June and rose to a level three feet above the marketplace at the town Drammen 29 June. The timber boom at Kværk upstreams Hokksund contained several thousand logs. If this boom should fail, the drifting logs would devastate Drammen. A telegraph line was set up connecting the authorities in Drammen with the staff at Kværk to provide warnings in case of failure. The boom was re-inforced with 17 huge cables. At the day the flood peaked, 14 of these cables broke, but the remaining cables managed to save the boom from breaking.

The village Hokksund suffered from slides. Some buildings were demolished. After the flood some mudslides occurred on the other side of the River.

Numedalslågen

Intense rainfall caused several slides in the steep hills west of the valley, causing damages to chalets and smallholdings. A slide struch a smallholding on the bank of Lake Norefjord, killing three people. The silver mine at Kongsberg used a lot of timber, as props in the mine as well as for other purposes. The logs were stored in the river at the timber boom "Stadshengslet" upstreams the town. This boom failed releasing 72000 logs into the river and smashing the recently built bridge "Nybroen". Bridges were also taken at Skjønne and Blåflot in the tributary Uvdalselv.

Skienselv

Skien is an industrial town, which was mostly based on sawmill industry in 1860. The Bandak Canal from the fjord through Skien and Dalen at Lake Bandak was completed in 1851. The flood caused damages to properties around the upstreams lake Nordsjø as well as to damages in Skien. These damages were blamed on the construction of dams and weirs in the canal. Landowner took the canal company to court and was awarded compensations for the damages.

Table 3.1.14.2 Estimated peak water levels and discharges in lakes i River Drammenselv during the flood in June 1860.

Lake	River	Stage (meter)	Discharge (m3/sec)
Hokksund	Drammenselv	10,13	
Tyrifjord	Drammenselv	7,37	930
Krøderen	Snarumselv	7,65	1400
Sperillen	Ådalselv	9,70	1050
Strandefjord	Begna	12,53	400
Slidrefjord	Begna	3,52	300

Vangsmjøsa	Begna	2,60	230
Randsfjord	Randselv	5,00	500

Table 3.1.14.3 Estimated peak water levels and discharges in River Numedalslågen, River Skienselv, Nidelva and Otra during the flood in June 1860.

Lake/station	River	Stage (meter)	Discharge (m3/sec)
Labro	Numedalslågen	6,00	1285
Norsjø	Skienselv	18,88	2500
Bøylefoss	Nidelva	7,10	1023
Vallebø	Otra	6,90	

The discharge at Vallebø in River Otra is not known.

Flood damages:

Fatalities:

Sarpsfoss	2 men
Ringebu	1 unknown man
Hønefoss	1 girl (28/5)
Sokna	1 man (7/6)
Begna/Randselva	1 child (13/6) and 1 man (26/6)
Søre Leine farm in Vang	1 girl
Nordland farm in Vang	1 man and a boy (18/6)
Torsetåsen in Hemsedal	1 woman
Tutta in Grøndalen in Hemsedal	1 man, 1 woman, 1 girl and 1 child.
Numedal	3 people perished in slides

Slides:

Upper Gudbrandsdal, Valdres, Buskerud, Telemark, Agder, Rogaland, Hardanger and Sogn og Fjordane suffered from 45 slides (Furseth, 2002).

Losses:

The total losses of the 1860 flood is summarised in Table 3.1.14.4.

Table 3.1.14.4 Losses per county from the extreme flood in 1860. (Source: SSB).

County	Damages (Spd)
Smaalehnenes Amt (Østfold)	5.000
Agershuus Amt (Akershus)	39.675
Hedemarkens Amt (Hedmark)	29.000
Christians Amt (Oppland)	116.643
Budskeruds Amt (Buskerud)	156.336
Jarlsberg og Laurvigs Amt (Vestfold)	1.500
Bratsbergs Amt (Telemark)	14.000
Lister og Mandals Amt (Agder)	2.250
Nordre Bergenshuus Amt (Sogn og fjordane)	4.400
Sum	368.804

Note: The damages reports from the Nedenes (Telemark) and Robyggelaget (Agder) districts are missing. The damages from Akershus, Vestfold and Telemark are incomplete. The total damages were at least 400.000 spd.

Table 3.1.14.4 Flood damages by county in 1860.

County	Number of fatalities	Damages	
		(speciedaler)	(NOK)
Akershus	0	60800	243200
Buskerud	12	156330	625320
Oppland	4	24532	98128
Telemark	0	656	26240
Østfold	2		
Sum	18	248222	992888

Table 3.1.14.5 Flood damages in Buskerud in 1860.

Buskerud	Sum (spd)	Damages (spd)		
District		Bridges	Farmland	Other damages
Eiker	10000			
Drammen	34484			
Ål	4660	1790	1320	1550
Gol	4140			
Nes	11406			
Sigdal	495			
Sum	156330			

Table 3.1.14.6 Damages in Akershus in 1860.

Akershus	Number of fatalities	Damages	
District		(speciedaler)	(NOK)
Fet	0	10308	41232
Høland	0	10083	40332
Aurskog	0	8000	32000
Nedre Romerike	0	34400	137600
Sum	0	60800	243200

The damages in Akershus was partly caused by the second rainfall flood in late August. Some buildings were also damaged by the flood in River Alna in Kristiania.

Table 3.1.14.7 Damages in Hedmark in 1860.

Akershus	Number of fatalities	Damages	
District		(speciedaler)	(NOK)
Hamar	0	8000	32000
Disen teglverk	0		

Table 3.1.14.8 Damages in Oppland in 1860.

Oppland	Number of fatalities	Damages	
District		(speciedaler)	(NOK)
Lillehammer	0	2591	10364
Fåberg	0	5761	33044
Brunlaug bridge	0	5300	21200
Gudbrandsdalen (roads)	0	1800	7200
Sum	0	24532	98128

Floods caused also damages at River Mandalselv, River Sima in Hardanger, River Lærdalselv and in River Årdalselv. The flood destroyed the bridge Steinbrui, halting the traffic on the main road in Lærdal, as well as inundating Lærdalsøyri, causing a major riverbank failure at Mobakkene upstreams Ljøsne and Mo. The floods in the 1860ies caused loss of 5 % of the farmland in the valley. Masses eroded by River Tya upstream Øvre Årdal, filled the riverbed, causing the farms Ve and Farnes to risk being eroded as well.

3.1.15 The spring flood at Østerdalen in June 1867.

River Glomma, Trysilelv, Orkla and Gaula flooded in late June 1867 causing flood damages in the upper parts of the rivers.

Initial conditions

The winter 1866/1867 was cold and with abundant snow fall in northern Østerdalen and in Trysil. The cold weather persisted into most of June, and the snow melt in the mountains did not commence before much milder weather occurred a few days before 23 June.

The flood

A heavy rainfall occurred on the 23 June, causing the rivers to flood in northern Østerdal as well as in Trysil. The water levels rose fast, and the peak was reached in River Glomma 27 June. The flood is described locally as the second largest after *Storofsen* at Trysil. The flood did however mostly affect the uppermost basins. Further downstream they were not among the largest floods in River Glomma. The flood peaked 1,83 meter lower than during Storofsen. Lake Øyeren culminated at the local level 10,57 meter (6,03 meters below Storofsen) and ranks as the fourth highest from 1789 to 1903. The local flood level in 1867 at Sarpsfossen 30 June 1867 was 9,79 meters. This level has been exceeded by several larger floods in the 20th Century.

Flood damages

The flood damages were especially severe along Skårbekken at Trysil. The flood in Glomma caused inundations at Hummelvoll at Os. A local flood in Storbekken caused the farms at Øvre Åseng at Vingelen to be relocated after the flood. The flood penetrated into the village

Tynset. Four farms were later relocated as a consequence of the inundation. Steibrua was damaged at Alvdal, and River Folla caused extensive erosion at Grimsmoen.

The main road was damaged at Tylldal by River Tysla, and River Grøtåa shifted to a new riverbed. Three bridges, Undsetbrua, Desetbrua and the bridge at the priest farm in Øvre Rendalen were taken. River Speka caused severe damages at Brydalen where 50 % of the farmland was covered by sand and gravel. The bridge over River Rena was destroyed by timber at ytre Rød at Åmot.

The Bjølsen district at Elverum suffered from inundation as the flood protection works failed.

3.1.16 The large spring flood in late May 1879.

A major flood occurred at the end of May 1879 at Østlandet and in rivers west of the water divide flowing towards the inner fjords at Vestlandet. The flood was in parts of River Glomma, River Drammenselv, River Numedalslågen and Skienselv at Østlandet. Thre flood was large in River Nidelv (Arendalsvassdraget) and River Otra at Sørlandet, River Lærdøla in the west and rivers in Geiranger and Sunnylven, River Driva, River Surna, River Gaula and River Orkla at Nordvestlandet. Figure 3.1.16.1 show observed discharges during the flood at stations in River Glomma. Some stations were also active in River Drammenselv, but rating curves had not been established as early as in 1879. Figure 3.1.16.2 show observed water levels at stations in River Drammenselv. Observed discharges are shown for stations in River Numedalslågen and River Nidelva in Figure 3.1.16.3.

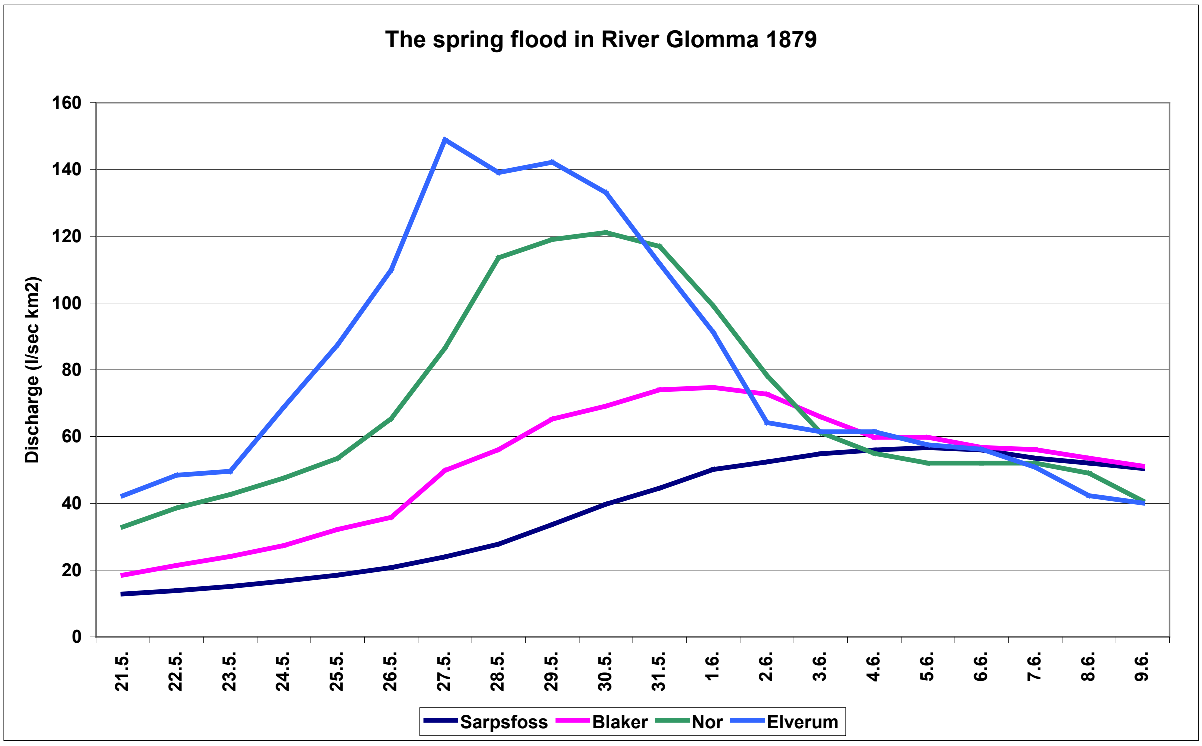


Figure 3.1.16.1 The discharge in River Glomma in 1879

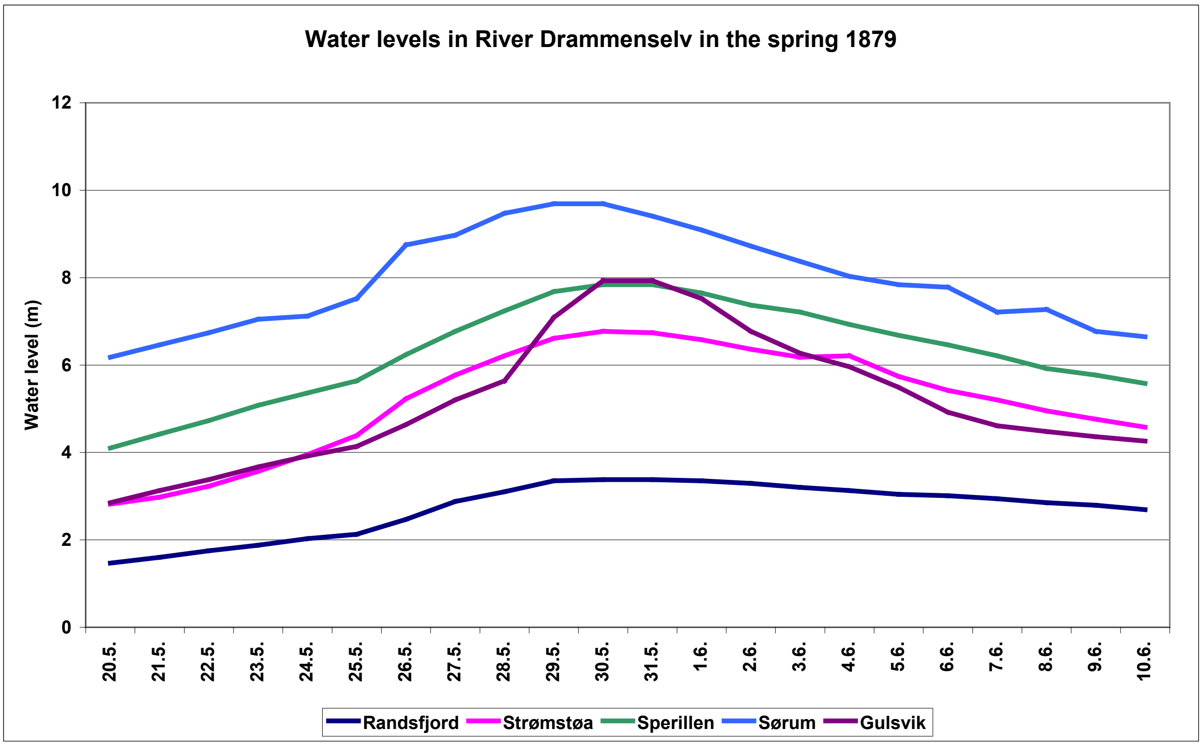


Figure 3.1.16.2 The water levels in River Drammenselv in 1879.

The flood at 2.604 Elverum is the eight largest flood 1872-2014 and the 9th largest in the joined series at 2.2/120/393 Nor (1869-2014).

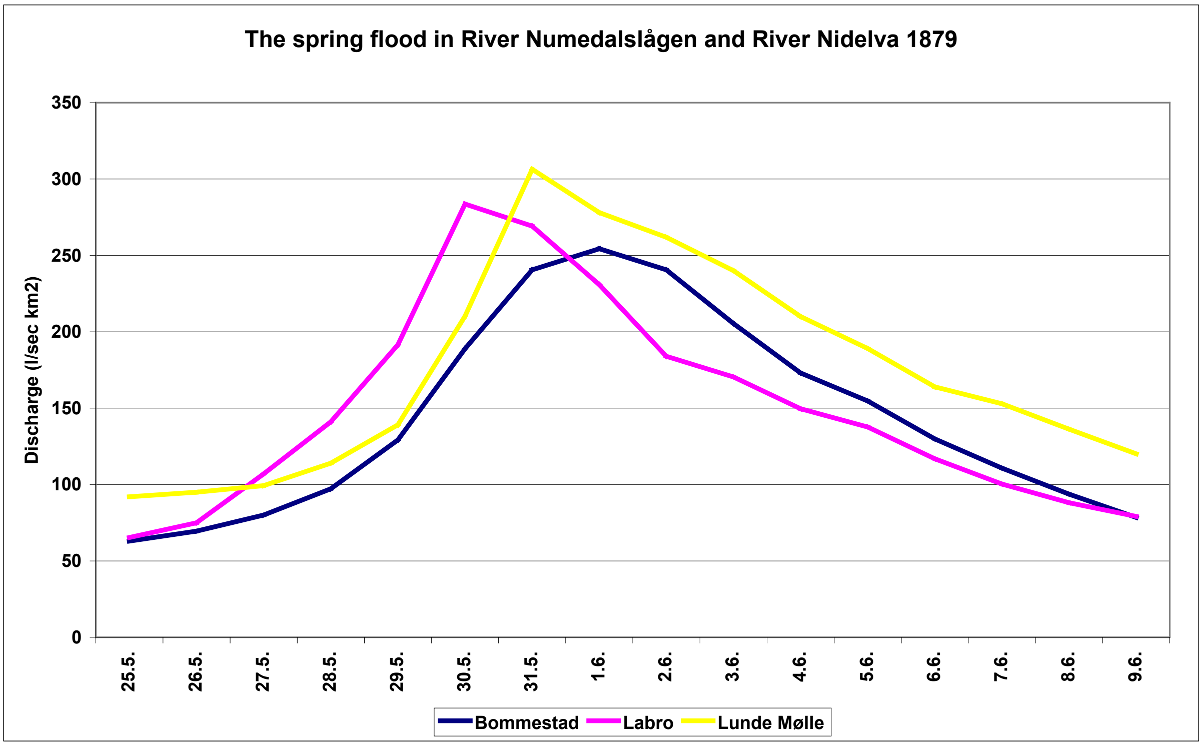


Figure 3.1.16.3 The discharge in River Numedalslågen and River Nidelv in 1879

The discharge was the largest observed at 15.18 Bommestad bru (1879-1926) and at 15.1 Labro (1874-1907). The flood at Labro was probably higher during the extreme flood in 1860.

Cause of the flood.

Initial conditions

The winter 1878-1879 was cold in southern Norway. The temperature deficit at selected stations were ranging from -2,6 to -6,5°C in December, -1,1 to -4,1°C in January, -.1,3 to -5,5°C in February, -0,1 to -1,7°C in March, 0,8 to - 1,7°C in April. The temperatures were close to normal in May and mostly with a small surplus in June. The precipitation was also below the normal, especially in Vestlandet. The deficit was less at Østlandet, with a surplus in May and June at most stations. The snow storage was probably less than normal, but the melting started in the seond part of May and was probably over the peak when heavy showers occurred 1 June.

The weather and flood

A blocking anti-cyclone was located at the Atlantic west of Spain and another over East Europe 30 May- 1 June. The temperatures were high, causing the main snowmelt until a depression moved from Britain and in over Norway with a cold front separating warm air from the cooler maritime air masses. The cold front moved in from northwest over southern Norway 31 May. The flood was initially caused by snowmelt, but intense rainfall in the end of the event caused the flood to peak.

Flood damages

Glomma

Drammenselva

<u>Below Lake Tyrifjorden</u>
Farmland was inundated at several locations in the Eiker municipalities.

<u>River Sokna</u>

<u>Rivers Snarumselv/Hallingdalselv/Hemsil</u>

The flood in River Hemsil destroyed Hesla and Ro bridges. *T. Flatin (1914)*

<u>Rivers Ådalselv/Begna</u>

<u>Rivers Randselva/Etna</u>

Numedalslågen

The flood inundated lowlying farmland and caused landslides. A mill was destroyed at Mykstufoss. Timber floating caused difficulties in many rivers. This was also the case in Numedalslågen at Ulvik (Kristensen, 1911). The bridge at Hvittingfoss was destroyed in the flood in 1879. The wooden bridge was only four years old. Gravel was used to weight down the bridge as the water was rising. Three men and a horse were at the bridge as it failed. The mill at Øvre Foss collapsed at the same time. All three succeded in reaching ashore, two the west and the third and the horse to the eastern bank (Kollandsrud,1939; Lunde,1973; Saga, 1977).

Downstream the dam at Rødberg, a bridge was taken by the flood. Another bridge was damaged at Dokkeberg in the tributary Uvdalselv further west.

River Skienselv

The water level of Lake Gjellevatn in the town Skien culminated 31 Mai 1879 0,3 fot below the level in 1860. The basement of around 70 buildings at Blegebakken and at Gjellen was flooded, and the inhabutants had to evacuate their homes. Several bridges were inundated, and an old sawmill collapsed. The steamship traffic between Skien and Porsgrunn was cancelled as well as the steamship traffic on the lower part of the the canal to Lake Nordsjø. The damages was, however less severe than the previous 1860-flood. The damages occurring in Skien was estimated to 73.104 NOK. Damages to buildings covered by insurances was estimated to 31.140 (Sætren 1903). The inhabitants in Skien applied for lowering the water level at Lake Gjellevatn to prevent similar damages in the future.

Timber floating contributes to the damages in the entire catchment. Further upstreams River Gjøyst, caused severe damages at the priest farm and two other farms, Ullern and Hagtvedt. River Gøyst is a tributary to Lake Tinnsjø, flowing into the northern part of the lake from northwest. The river has caused severe damages several times; in 1860, 1858, 1822 and in 1752. The river catchment is mountainous, and the river carries large amount of sediments. Several of the floods caused numerous landslides, the flood in ,1977).1858 no less than 20 slides. The flood carried away several bridges, among three on the main road. Several roads were also eroded.

Further west the riverbank failed at Kviteseid and River Bøelva caused damages at Seljord.

River Arendalselv/Nidelva

River Otra

The timber boom at Strai broke 1 June 1879. The timber struck the bridge across the brook Tordalsbekken at Kristiansand and caused it to collapse.

River Styviselv at Nærøy in Sogn

Snow accumulated in the riverbed of River Styviselv, forming a snow dam which accumulated meltwater upstreams the farm Styvi. When the dam failed, the floodwave struck the farm buildings, destroying ten buildings and covered a field of 6 daa with rocks and gravel. Fortunately, no lives were lost. The farm was granted a deduction because of the damages.

River Lærdalselv

The flood penetrated also into River Lærdalselv. The farm Grøtøyane was almost cut into two separate parts by the river. The flood protections works were damaged.

River Geirangerelv

Four bridges were taken by the river in late May.

River Driva

River Surna

The flood is listed among the larger floods in River Surna.

River Orkla

The flood caused riverbank failurers at the farms Nervig, Hof and Rømme on the lower reaches of River Orkla. The village Orkendalsøren at Nervig had been protected by flood protection works but shifting riverbeds had caused the flood to penetrate behind the dikes.

River Gaula

The flood eroded the riverbed under the railway bridge at Støren. The farm Bogen suffered from inundation of the farmland.

3.1.17 The autumn flood in Buskerud and Telemark in October 1892.

The early part of October 1892 was wet in the western part of Østlandet and the eastern part of Sørlandet. This caused floods in from River Drammenselv to River Otra. Figure 3.1.17.1 show observed daily rainfall and discharge at stations from Buskerud to Aust-Agder.

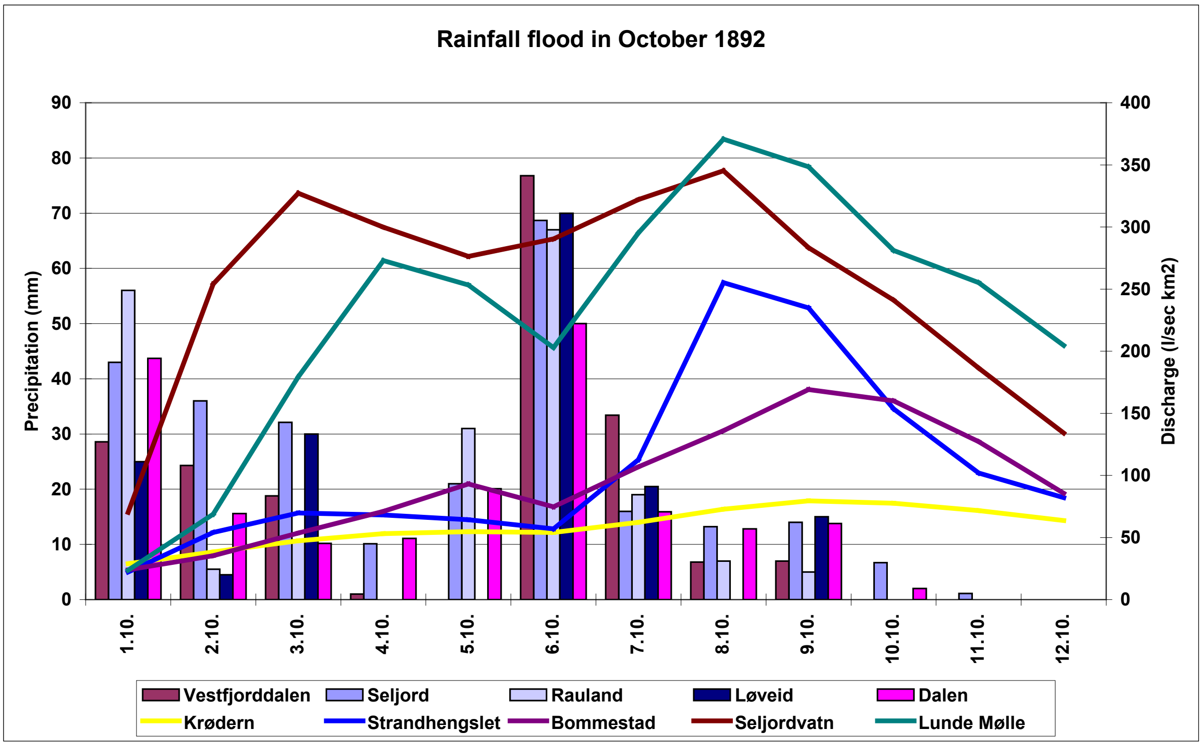


Figure 3.1.17.1 Observed daily rainfall and discharge during the autumn flood in October 1892.

Rating curves had been established at a few stations in Drammenselv, Numedalslågen, Skienselv and Nidelv, but not in Otra where water levels are known at a couple of stations. The flood was large in River Simoa at 12.49 Strandhengslet and in Numedalslågen at 15.18 Bommestad bru where the flood was second largest. The flood in 1927 barely exceeded the flood in 1992.

Long-term water level series exist in River Skienselv at Norsjø and Hjellevatn starting in 1851. The flood ranks as the fourth largest in Lake Norsjø at 16.15 Løveid ovf. only exceeded by the floods in 1927, 1960, 1888 and 1879. The discharge at Løveid was estimated to 2140 m^3/sec or 233 l/sec km^2. The flood at 16.17 Hjellevatn ranks as the fifth largest. The discharge was estimated to 2260 m^3/sec. The flood in 16.34 Totak was less than the spring flood in 1891 and was exceeded by three even larger spring floods 1885-1907. The flood peak in 1897 was 265 m^3/sec or 322 l/sec km^2. Upstream Vrangfoss the discharge was estimated to 873 m^3/sec or 202 l/sec km^2.

The flood was large in River Toke (Kragerøelv) and probably also in River Vegårdselv further to the west. The flood at 19.40 Lunde Mølle in River Arendalselv was probably the largest 1874-2002. The flood was considered as one of the largest spring floods which has occurred in the district.

Cause of the flood

A depression was located over the North Sea with an anti-cyclone in northern Russia with a ridge extending over southern Europe to an anti-cyclone located at the Atlantic. The weather types were **TB** 1-4 October and **TRW** 5-7 October (Grosswetterlagen) and **C** (Lamb.Jenkinsson).

Flood damages

River Skienselv

Buildings and basements were flooded at Blegebakken. The damages in Skien was assessed to 27.525 NOK.

River Arendalselv/Nidelva

The rising water level in River Arendalselv threathened the timber boom as Asdal. Several iron chains were used to anchor the timber. The water pressure finally forced the boom to break 6 October 18.30 hrs, and between 24.000 and 36.000 logs were released into the river. The river split into two channels further downstream. About 12.000 logs floated into the southern channel, where the timber grounded and got stuck. The rest of the logs floated in the other channel and struck the bridge “Vippebro” at 19:30 hrs. This bridge was made of iron and sank to the bottom. A new bridge was built to years later, and this bridge served for 50 years (Aamlid, 1986). Farmland was inundated in Froland.

3.1.18 The large spring floods at Østlandet in 1895 and 1897.

Two large spring floods occurred at Østlandet in 1895 and 1897. The first of the floods took place before the establishment of the Hydrology department and the start of the network for daily precipitation data for hydrological purposes. Some observations were taken during this flood, but the event in 1897 is far better covered by observations. The discharge was observed at several gauging stations in River Glomma, Drammenselva, Numedalslågen and Skienselva in 1897, and meteorological data and some snow observations are also available from this flood.

Initial conditions

January 1897 was cold and dry. February was milder, but the dry weather persisted throughout the month. A lot of snow fell in March, causing a substantial snow reservoir to develop. Figure 3.1.18.1 show the difference between the monthly precipitation and the long-term average. The temperature during the melting period at Dovre is shown in Figure 3.1.18.2.

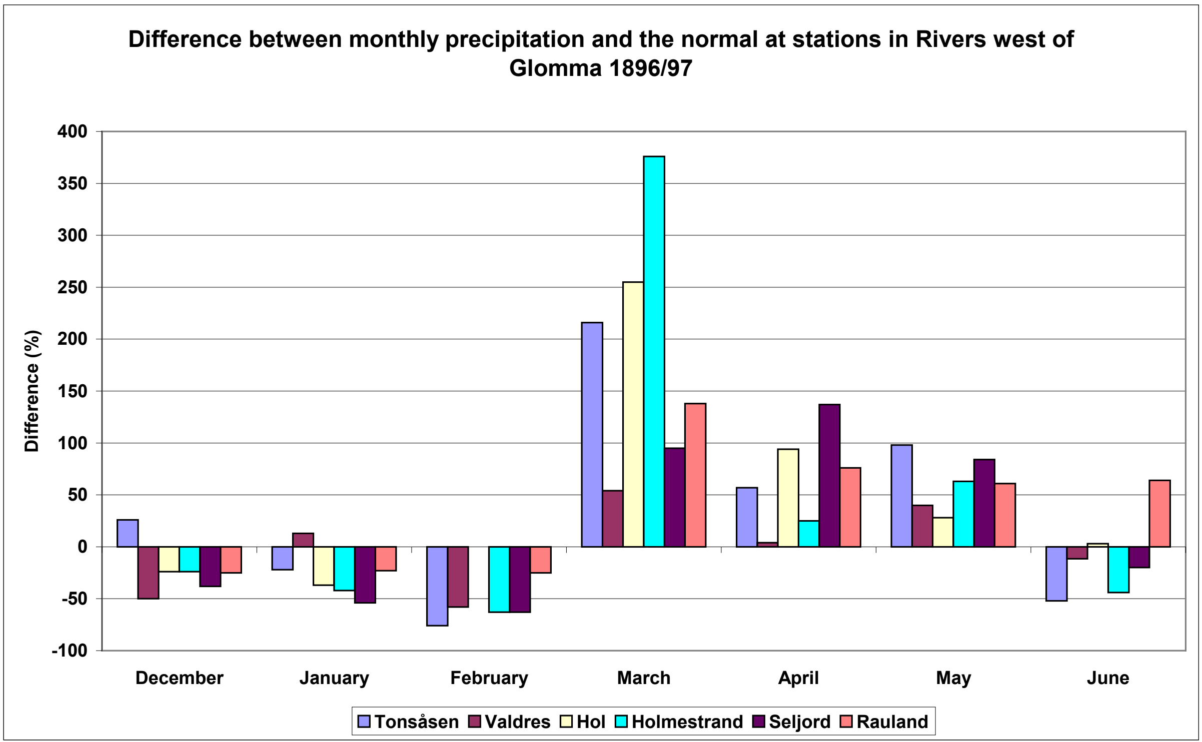


Figure 3.1.18.1 Deviation in the monthly precipitation from the normal in rivers west of Glomma in the winter 1896/1897.

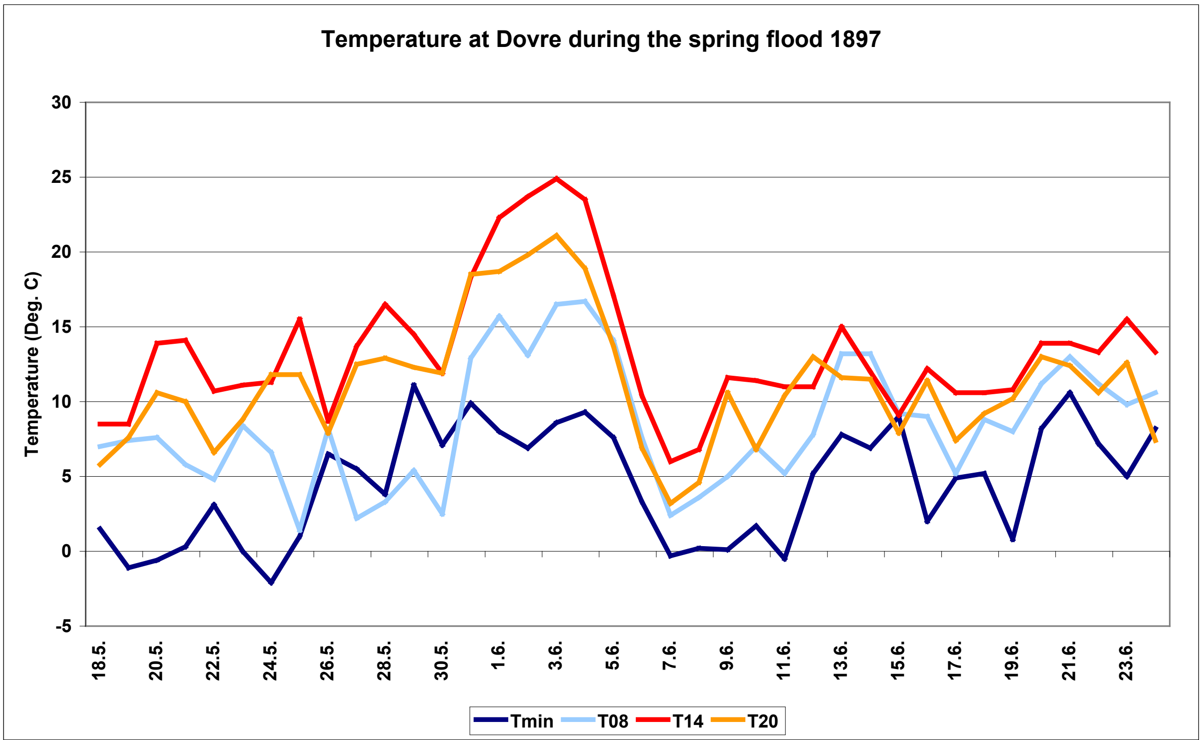


Figure 3.1.18.2 The temperature observed at Dovre during the spring flood in 1897.

The flood

The flood coincided with a heat wave at the end of May and into early June. This can be seen in Figure 3.1.18.2, which show the temperatures observed at Dovre. The heat wave was caused by warm air masses from south-southeast. The warm period ended on 5 June when a depression moved in from Finland and a high pressure are developed further west causing northerly wind and heavy precipitation over parts of South Norway.

Observed precipitation and daily discharge at stations in River Glomma is shown in Figure 3.1.18.3 and on stations in River Drammenselv, River Numedalslågen and River Skienselv in Figure 3.1.18.4. The flood culminated between the 29 and 31 May and one week later at Sarpsfoss at the outlet of Glomma.

In River Glomma the flood ranks as the 9th largest at Elverum 1872-2009, as 9th largest at Nors bru 1851-1935 and sixth largest at Losna 1896-2009. The flood was the second largest at Hen in River Ådalselv, the 14th largest at Lake Tyrifjord at Skjerdal and the sixth largest at in Lake Krøderen in Drammenselv. The flood was the fourth largest in Numedalslågen at Bommestad 1879-1927 and second largest observed at Lake Totak and fourth largest at Lake Seljordvatn 1884-1970 in Skienselv.

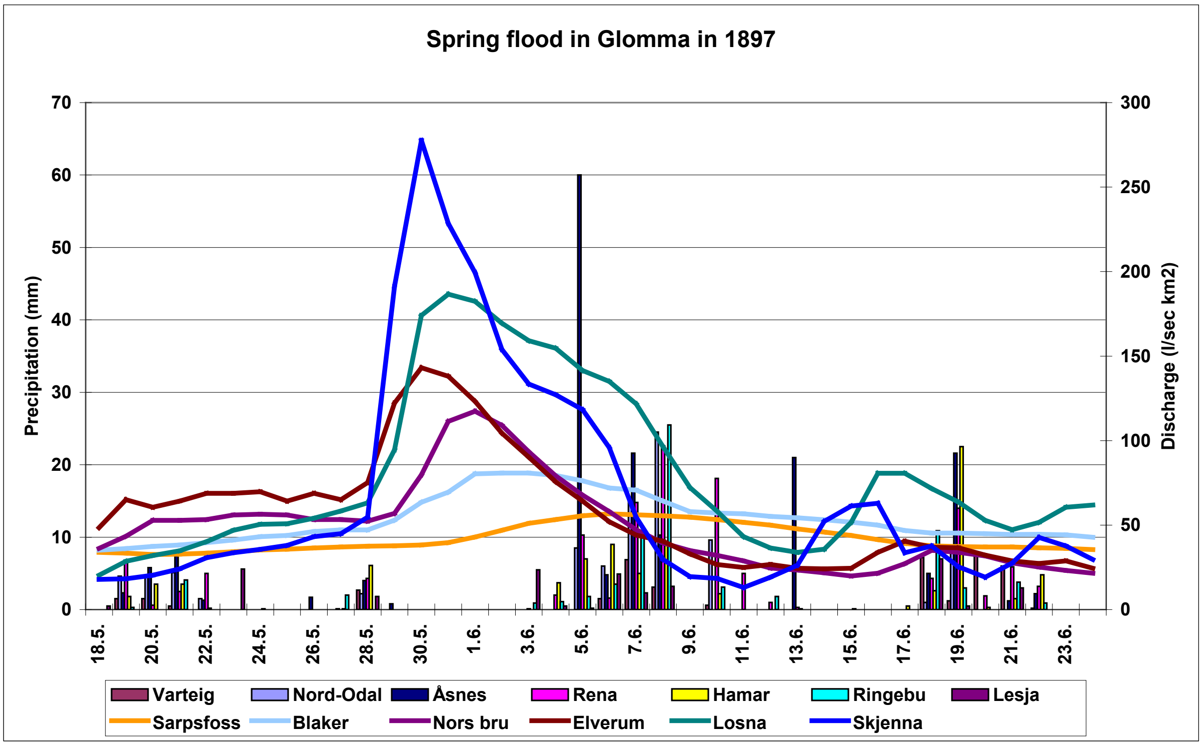


Figure 3.1.18.3 Observed precipitation and daily discharge during the large spring flood in 1897 in Glomma.

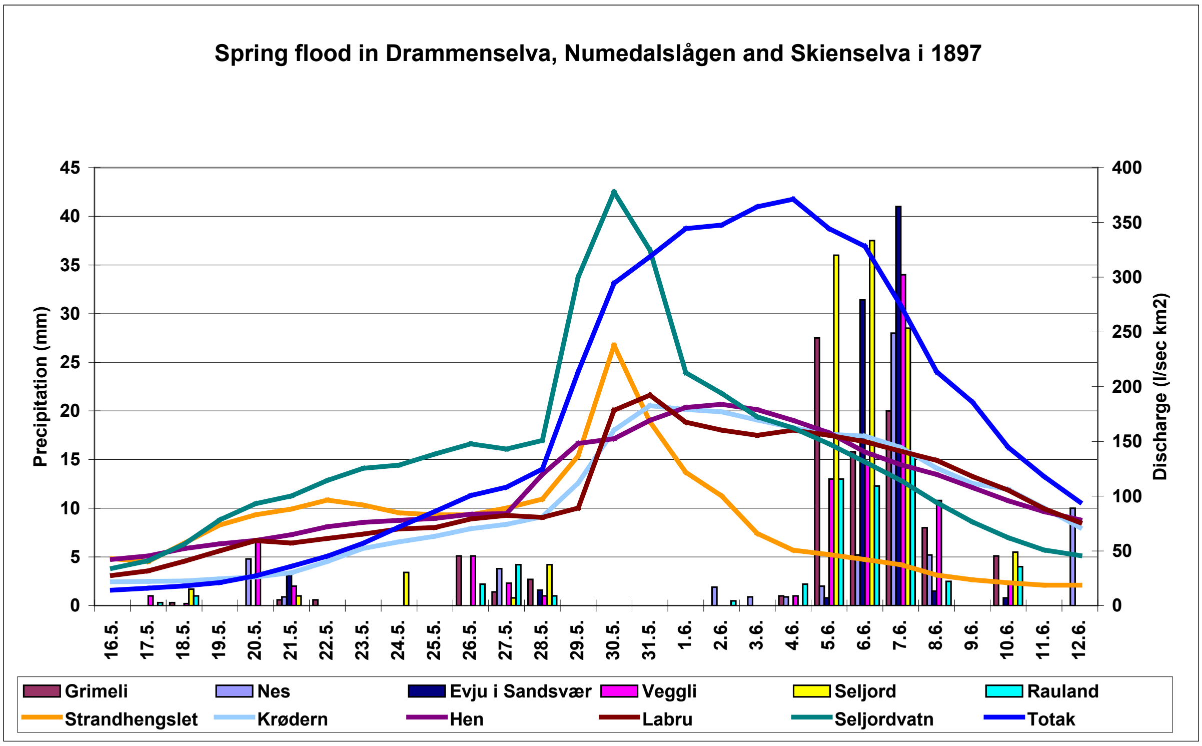


Figure 3.1.18.4 Observed precipitation and daily discharge during the large spring floodin 1897 in Drammenselva, Numedalslågen and Skienselva.

3.1.19 The large spring flood in the lower Glomma in May 1910

A large flood occurred at the lower part of River Glomma and Vorma and in River Drammenselv the southern part of River Begna and River Randselv in May 1910. Daily precipitation in Kristiania and in River Glomma at Langnes is shown in Figure 3.1.19.1.

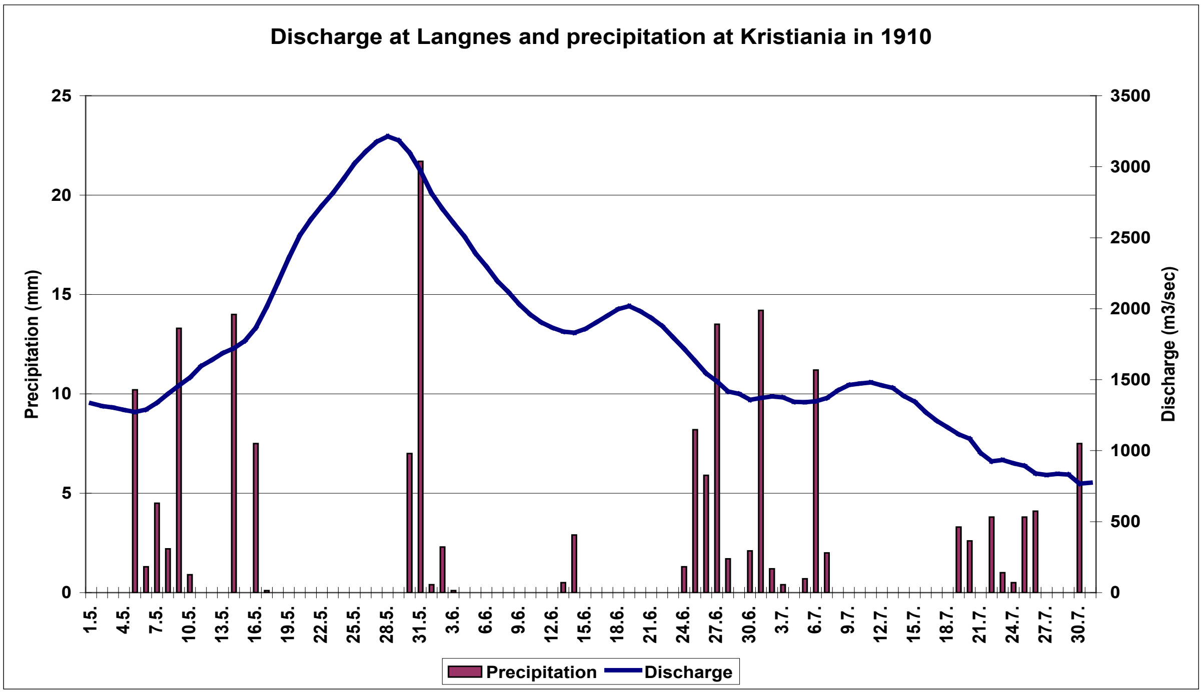


Figure 3.1.19.1 Observed precipitation in Kristiania and daily discharge in River Glomm at Langnes during the large flood in May 1910.

The flood was the fifth largest observed in Lake Øyeren at Langnes since the observation started in 1901. The flood peaked there 28 May with a discharge of 3213 m^3/sec. The discharge was above 2000 m^3/sec from 17 May to 9 June. The flood peaked 24 -25 May at Lake Aursunden (177 m^3/sec), in River Glomma at Stai (1243 m^3/sec), at Elverum 17 May (2075 m^3/sec) and at Nor in Grue 25 May. Figure 3.1.19.2 shows observed discharges at selected locations in River Glomma. The second peak in Gudsbrandsdalslågen was caused by the flood from the alpine part of the catchment. The flood in Østerdalen as shown for Elverum did not have this second peak at all.

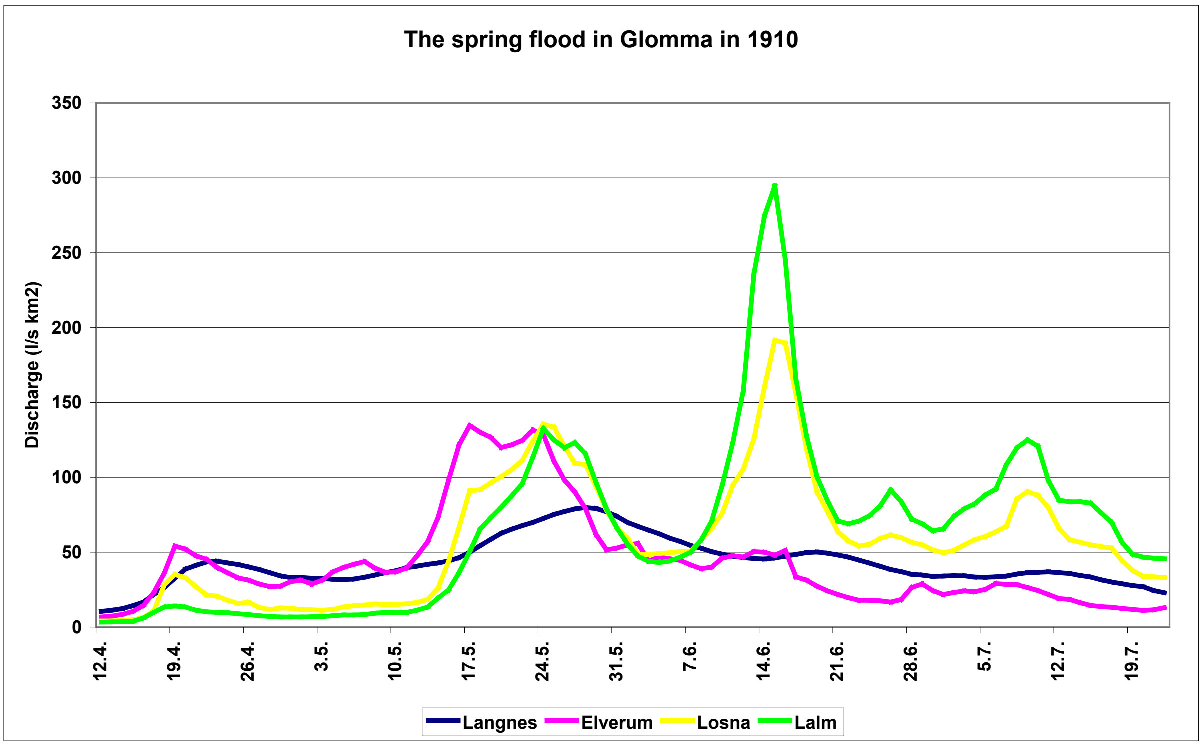


Figure 3.1.19.2 The specific discharge observed in River Glomma at Langnes in Lake Øyeren, River Glomma at Elverum, River Gudbrandsdalslågen at Losna and River Otta at Lalm.

The flood peaked in Lake Mjøsa 25 May but rose later to the level 8,31 meter when the flood from the alpine part of Gudbrandsdalen reached the lake later in the summer. This water level was the largest in Lake Mjøsa since *Storflaumen* in 1860. The flood was large at stations in River Gudbrandsdalslågen, but does not rank among the largest there. The flood observed at Losna ranks as the 10th largest (1896-2011).

The water level observed in Lake Randsfjorden was the highest observed (1869-2007). The flood was the third largest in River Ådalselv at Killingstrykene since 1905. The flood was also large in River Sokna, but the observations did not start in this river before 193x.

Initial conditions:

The winter had a huge surplus of precipitation in February and April in the southern part of Østlandet. The precipitation fell mostly as snow, and at Bjørnholt in Nordmarka a snow depth of 157 centimeter was observed 27 February, and the snow cover lasted until 26 May. At Mago in Nordmarka 188 centimeter was observed 28 February and the last of the snow had melted by 23 May. The observed snowdepth at Gjerdingen in Nordmarka is shown in Figure 3.1.19.3.

Cause of the flood:

Some rain fell prior to the flood as shown in Figure 3.1.19.1, but the flood peaked at a time witout rainfall. The temperatures observed in Kristiania in May 1910 is shown in Figure 3.1.19.4, which show that the flood co-incided with a heatwave. The flood was therefore a snowmelt flood.

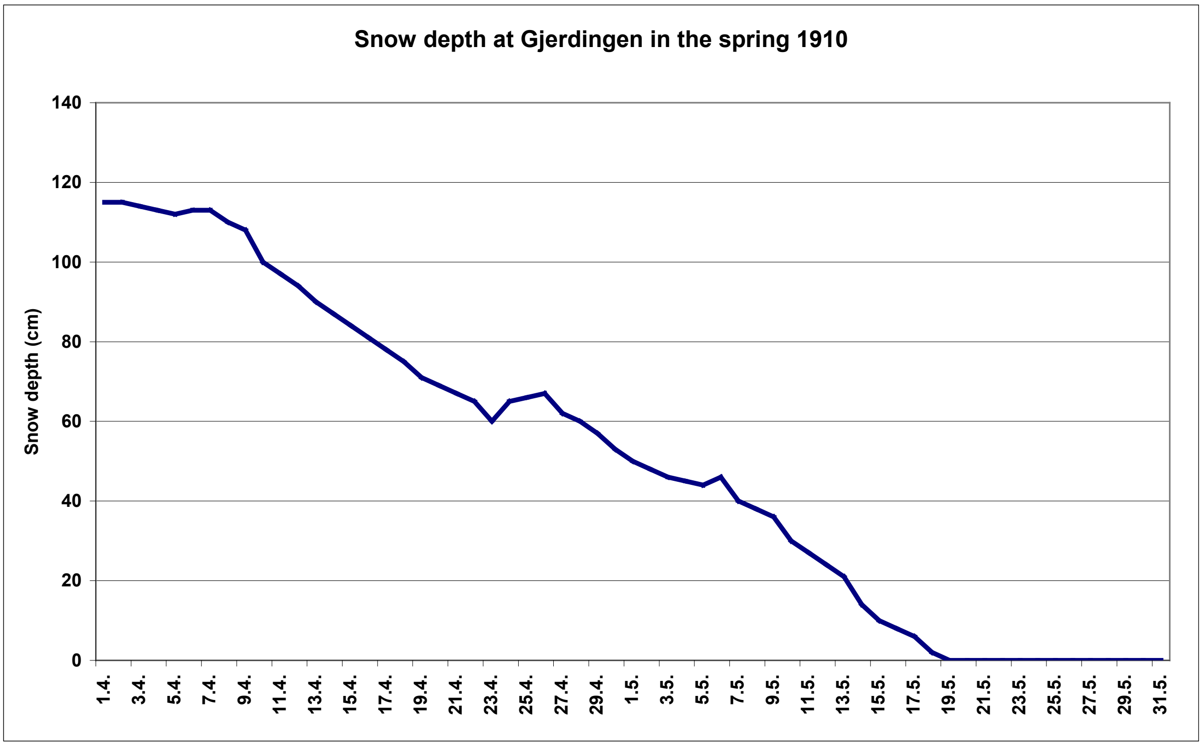


Figure 3.1.19.3 Observed snowdepth in the spring 1910 at Gjerdingen in Nordmarka.

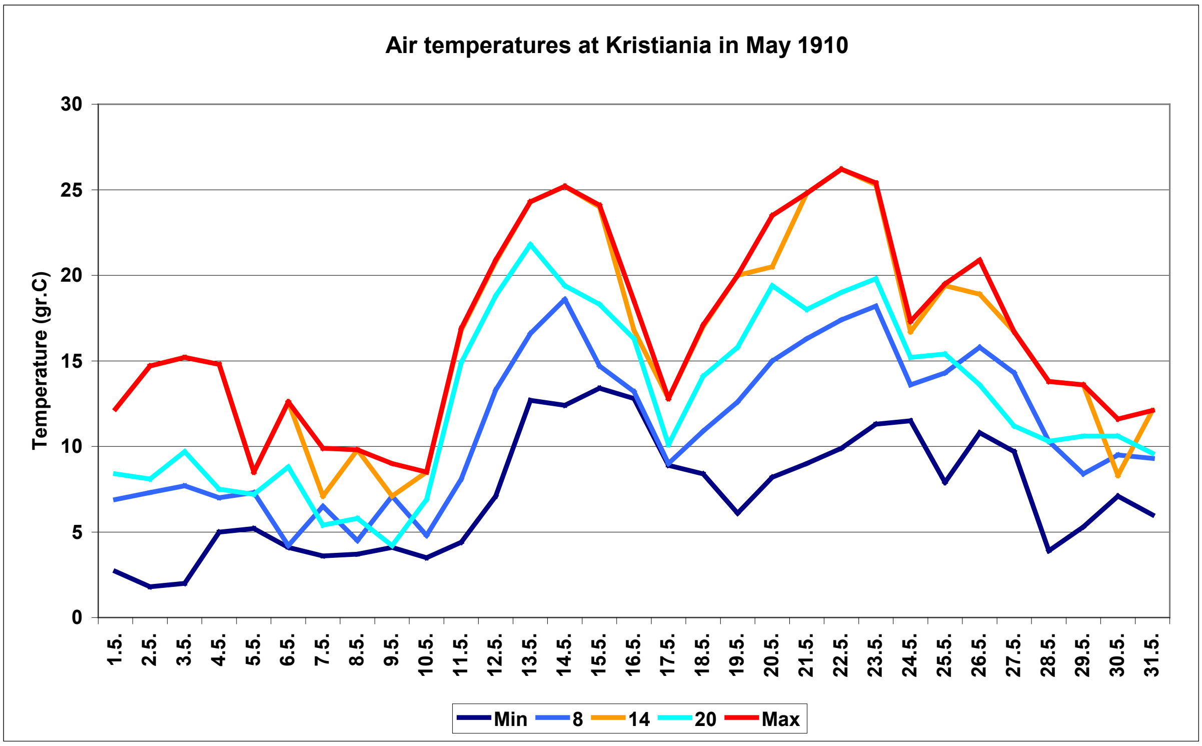


Figure 3.1.19.4 The air temperature observed in Kristiania in May 1910. A second even warmer spell occured in July this year.

Flood damages:

The flood from River Glomma caused the water level in River Nitelv flowing into Lake Øyeren from the north to rise at Lillestrøm. The rising water caused inundations in the gardens and into the basements of buildings close to the lake. Several buildings was evacuated, and when the flood peaked was the streets at Volla and Nesbyen in Lillestrøm inundated. This was also case in the Øya district. Many factories near Øyeren had to stop the production when flood water penetrated into the factory buildings or when the access to the building was inundated. Many grain fields were inundatet, causing the farmers to redo the sping field work for the second time. Drifting logs were also causing problems. Around 240.000 logs came drifting towards the railway bridge at Fetsund, but fortunately the bridge avoided serious damages.

Several newspapers wrote about the flood. Many people travelled to Lillestrøm to see for themselves what was happening. Around 15.000 railway tickets were sold to the spectators coming from Kristiania. The members of the communication and the agricultural committees of the Norwegian parliament (Stortinget) came together with ministers and the director of the Water Courses Directorate.

The flood caused inundation of an area of 18.700 daa, of which 4.200 daa were farmland. The damages were assessed to 143.000 NOK (1910). The muncipality of Skedsmo which includes Lillestrøm, had the damages on houses and gardens assessed to 28.682 NOK (1910). A collection was organised to support the flood victims, and 7000 NOK was collected as well as clothes and food.

The flood caused large landslides at Venabu and next to River Våla at Ringebu in Gudbrandsdalen.

3.1.20 The large mountains flood in Southern Norway in June-July 1914.

The spring flood will frequently occur with two or three peaks during the melting season in catchments which cover a wide range of altitudes. While the flood in the lowland typically occurs in March-April, the flood in the lower mountains frequently arrives in May-June. The flood in alpine catchments peaks usually in June-July, when the temperature is high enough to melt the snow at the highest levels. The most extreme spring floods occur when two or three of these melting periods co-incide, causing the entire catchment to contribute to the flood. This happens usually in years when the flood in the lowlands is delayed because of a late spring. This is typical for flood in many mountain rivers on both side of the water divide between east and west Norway. A large flood occurred in mountains rivers in 1914. Similar floods occurred in 1944, 1950, 1958, 1968 and 1972.

Initial conditions:

The snow storage accumulated during the winter 1913/1914 was relatively high in the mountains of southern Norway. Snow was still present at Hardangervidda at Mogen (950 masl) to the end of May. Much snow was remaining at higher levels both at Hardangervidda and in Jotunheimen.

The flood

Figure 3.1.20.1 show observed daily precipitation and discharge in mountain catchments on both sides of the water divide between East ansd West Norway.

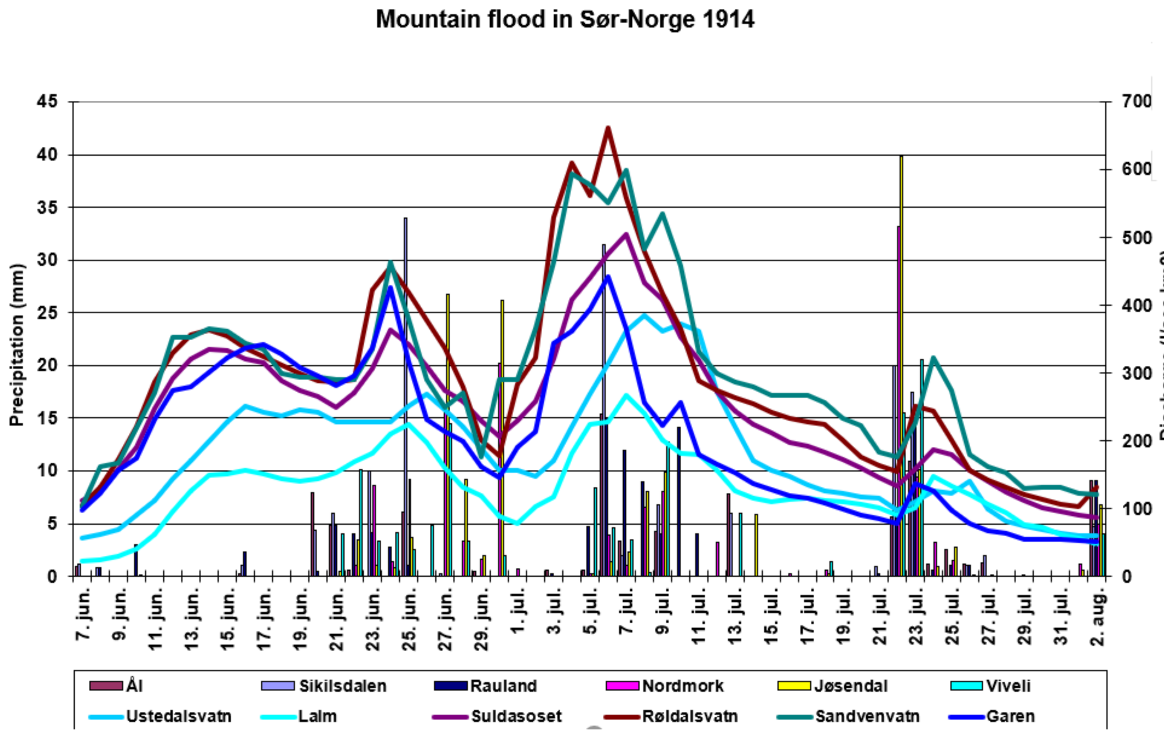


Figure 3.1.20.1 Observed precipitation and daily discharge during the large spring flood in 1914 in Glomma and in rivers draining from mountains to the fjords in West Norway.

The flood ranks as the fourth largest at River Otta at Lalm 1914-2010, in River Usta at Lake Ustedalsvatn 1909-1965, in River Suldalslågen at Lake Røldalsvatn 1913-2005, in River Oldeelv at Lake Oldevatn (903-2010 and at Lake Lovatn 1900-2010. It was the largest inflow flood in River Årøyelva at Lake Veitestrandvatn 1901-2006, and the second largest at River Bjoreio at Garen 1908-1973, in River Aurlandselv at Lake Vassbygdvatn 1908-1980 and in Lake Strynsvatn 1903-2010. The flood was the third largest at Lake Årdalsvatn 1900-2010.

Cause of the flood

Mild air masses flowed towards the mountains from south east of a depression in the North Sea and Norwegian Sea west of Vestlandet. The flood had two peaks, the first occurring 24-25 June caused by rainfall linked to a frontal passage. A weak high caused rising temperatures as shown in Figure 3.1.20.2 until the passage of another front 6-7 July. The flood was caused by a combination of snowmelt at high levels and the rainfall. The weather types 6-7 July were: **HNFZ** and **NEZ** (Grosswetterlagen) and **C** and **W** (Lamb/Jenkinson).

Flood damages

The flood caused damages in Årdal (Ve, 1971). A mill and a bridge were destroyed at Aurland (Ohnstad, 1962).

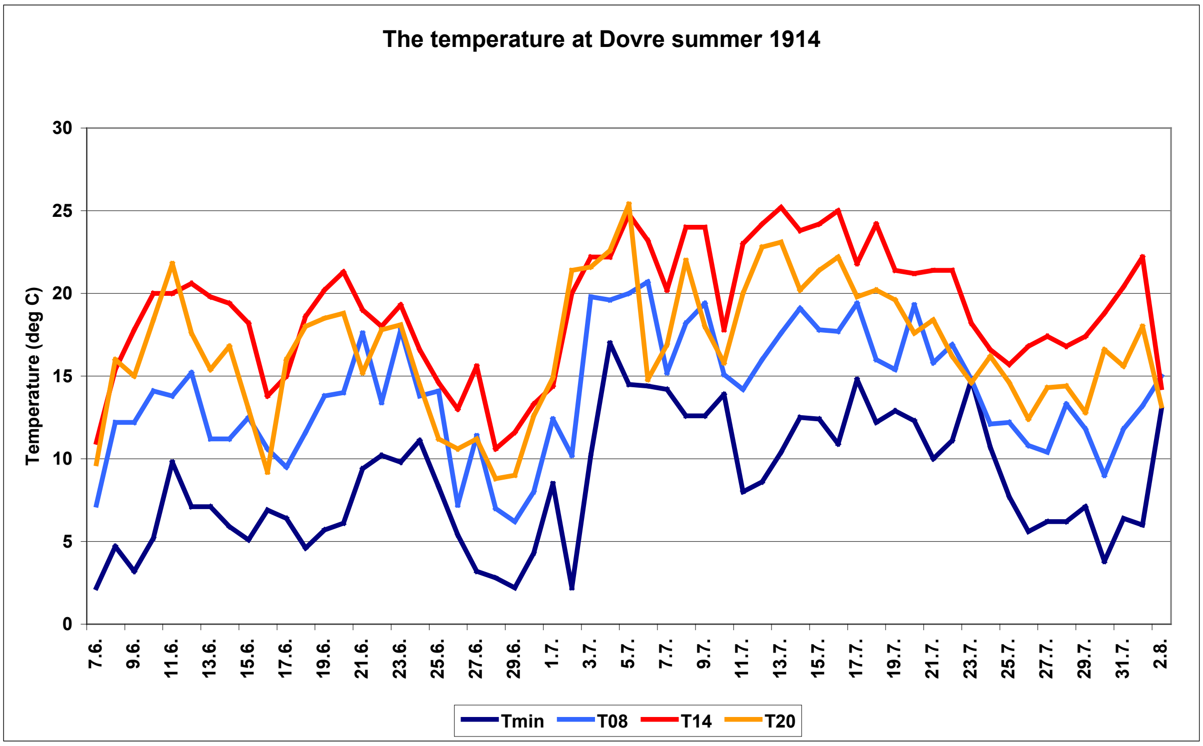


Figure 3.1.20.2 Observed temperature during the large snowmelt flood in 1914 at Dovre.

3.1.21 The large spring flood in East Norway in 1916.

One of the largest spring floods of the 20th Century occurred at Østlandet and Trøndelag in May 1916. The flood magnitudes are comparable with the large spring floods in 1934, 1966 and 1967, and only exceeded by *Vesleofsen* in 1995. The spring flood caused also problems at Bøylefoss at Nidelva in Agder, but later autumn rainfall floods were substantially larger there.

Initial conditions:

The winter 1915/1916 was cold in November and December. The precipitation was about the normal in East Norway. January was mild in east Norway with temperatures ranging between 2 and 4° above the normal. South of Norway the winter was among the coldest on record, causing extremely hard conditions for the armies fighting in Northern France. The precipitation in East Norway was from 15 to 116 mm above the normal. February was slightly milder and March slightly colder than the normal.

The flood:

Observed daily precipitation and discharge in rivers east of Østerdalen and Glåmdalen are shown in Figure 3.1.21.1, in River Glomma at Østerdalen, Glomdalen and Øyeren in Figure 3.1.21.2, in Folldal and Gudbrandsdalen in Figure 3.1.21.3, in River Drammenselv in Figure 3.1.21.4, in River Numedalslågen in Figure 3.1.21.5, in River Skienselv in Figure 3.1.21.6 and in Trøndelag in Figure 3.1.21.7. Observed snow depths at selected stations are shown in Figure 3.1.21.8 and the temperature at Dovre in Figure 3.1.21.9.

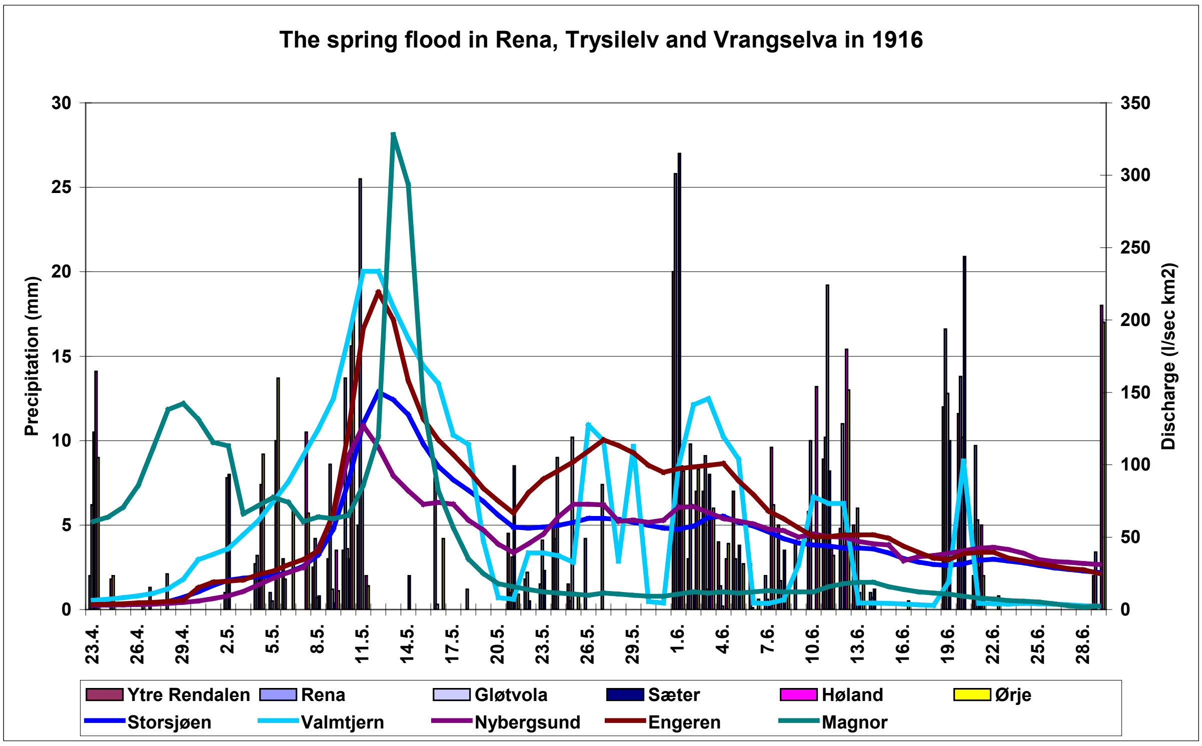


Figure 3.1.21.1 Observed precipitation and daily discharge during the large spring flood in rivers east of Østerdalen in 1916.

The flood was the fifth largest in River Rena at Lake Storsjøen. In Trysilelva at Nybergsund the flood was sixth largest since observations started in 1908. The flood ranks at the sixth largest at Femundsenden since observations started in 1896 and at Lake Engeren the seventh largest. Observations in River Flisa at Knappom started late in 1916 after the flood was over. The largest floods in River Flisa and the rest of the stations along Glomma usually differ because the Flisa catchment is lowlying without inflow from alpine areas. In Vrangselva at Magnor the flood was the largest since the start of observations in 1911.

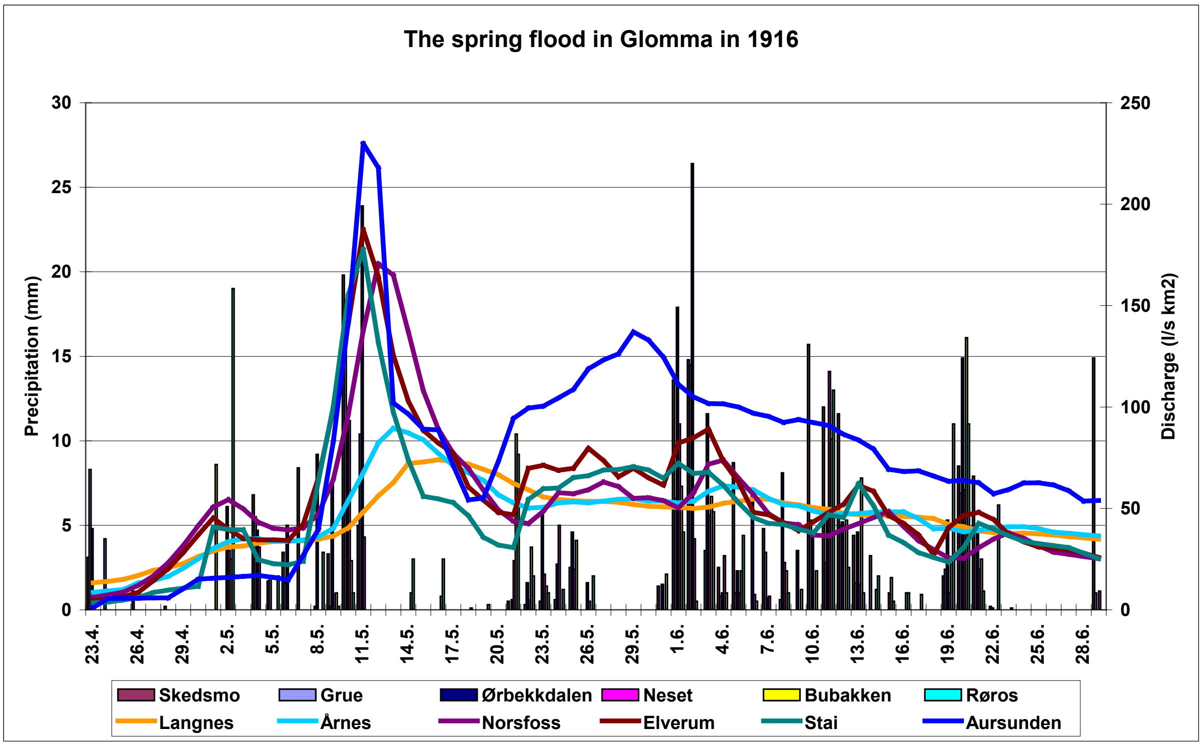


Figure 3.1.21.2 Observed precipitation and daily discharge during the large spring flood in River Glomma in 1916.

The flood was the 32[th] largest at Aursunden, the fifth largest at Stai since 1908, the third largest at Elverum, the largest at Norsfoss 1851-1935, the third largest at Skarnes since 1887, the largest at Årnes 1869-1933 and the seventh largest at Langnes/Solbergfoss since 1902.

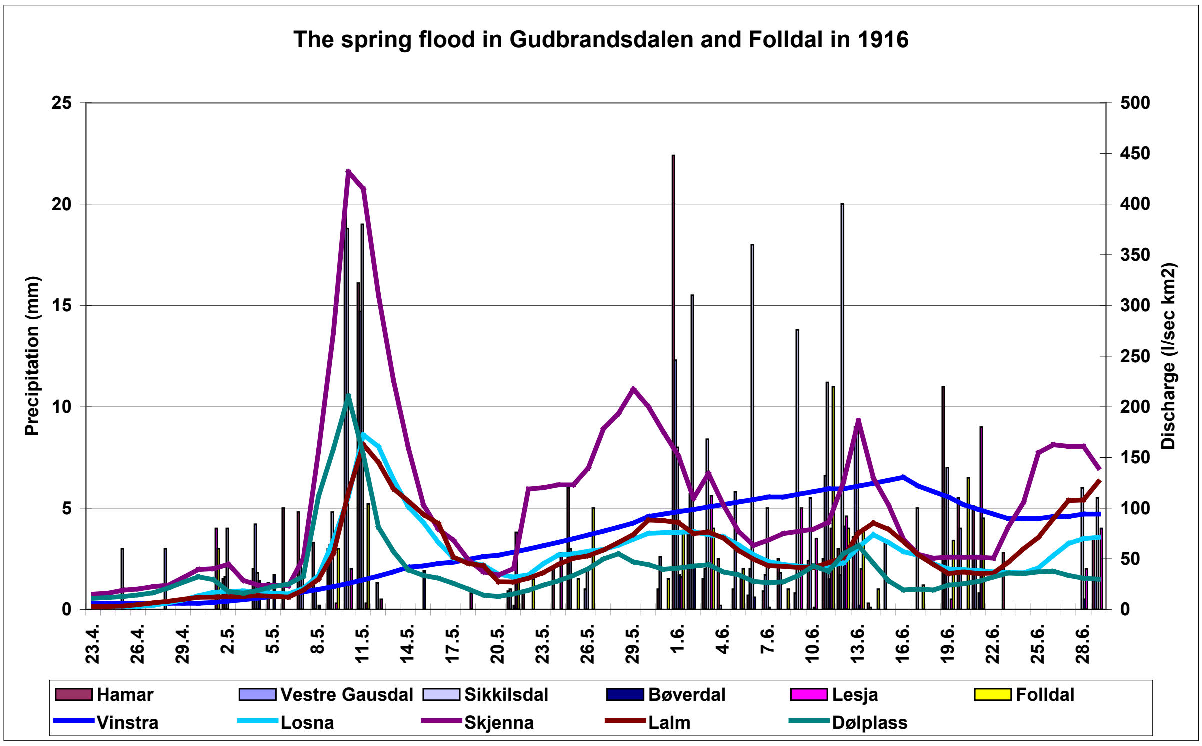


Figure 3.1.21.3 Observed precipitation and daily discharge during the large spring flood in Folldal and Gudbrandsdalen in 1916.

The flood was the 9th largest in Lågen at Losna since 1896, the 13th largest at Skjenna 1879-1921, the 54th largest in Otta at Lalm since 1907 and the 9th largest in Folla at Dølplass.

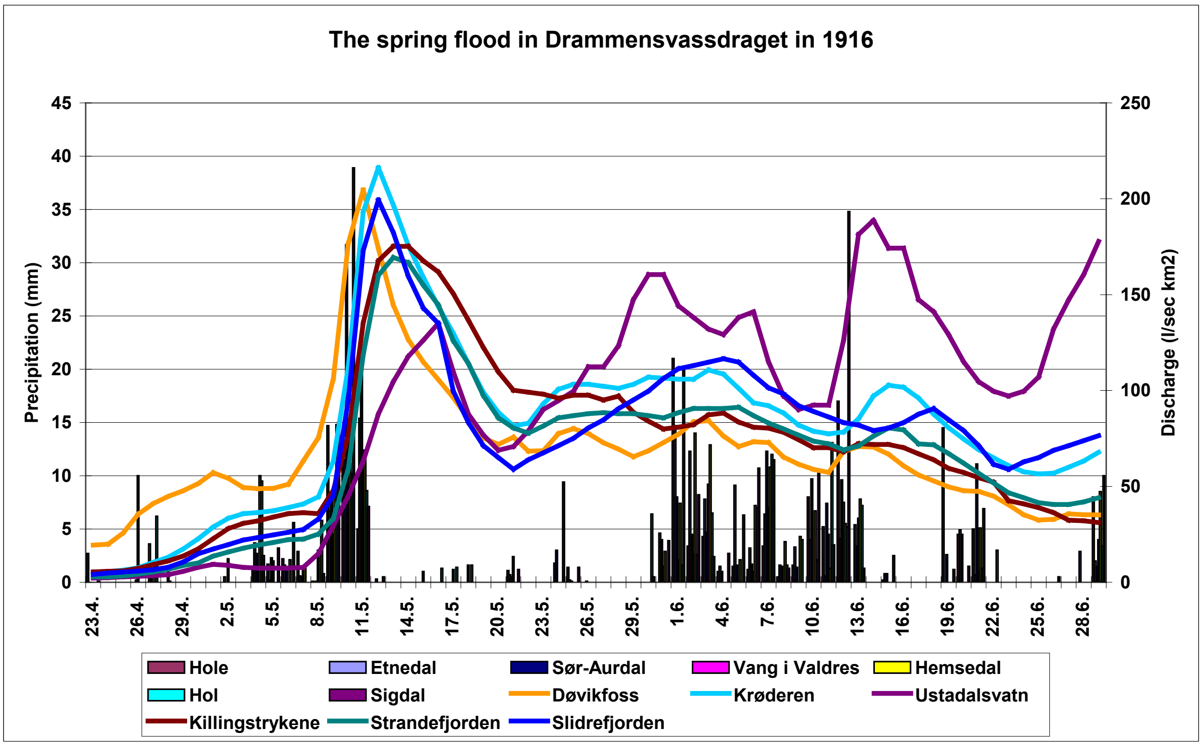


Figure 3.1.21.4 Observed precipitation and daily discharge during the large spring flood in River Drammenselv in 1916.

The flood was the largest observed in Numedalslågen at Bommestad 1879-1927, but the floods in 1879 and 1927 were almost as large. At Kongsberg the flood was the second largest since 1912, only exceeded by the flood in 1927. The flood was the largest 1955-1966 at Dokkeberg in Uvdal.

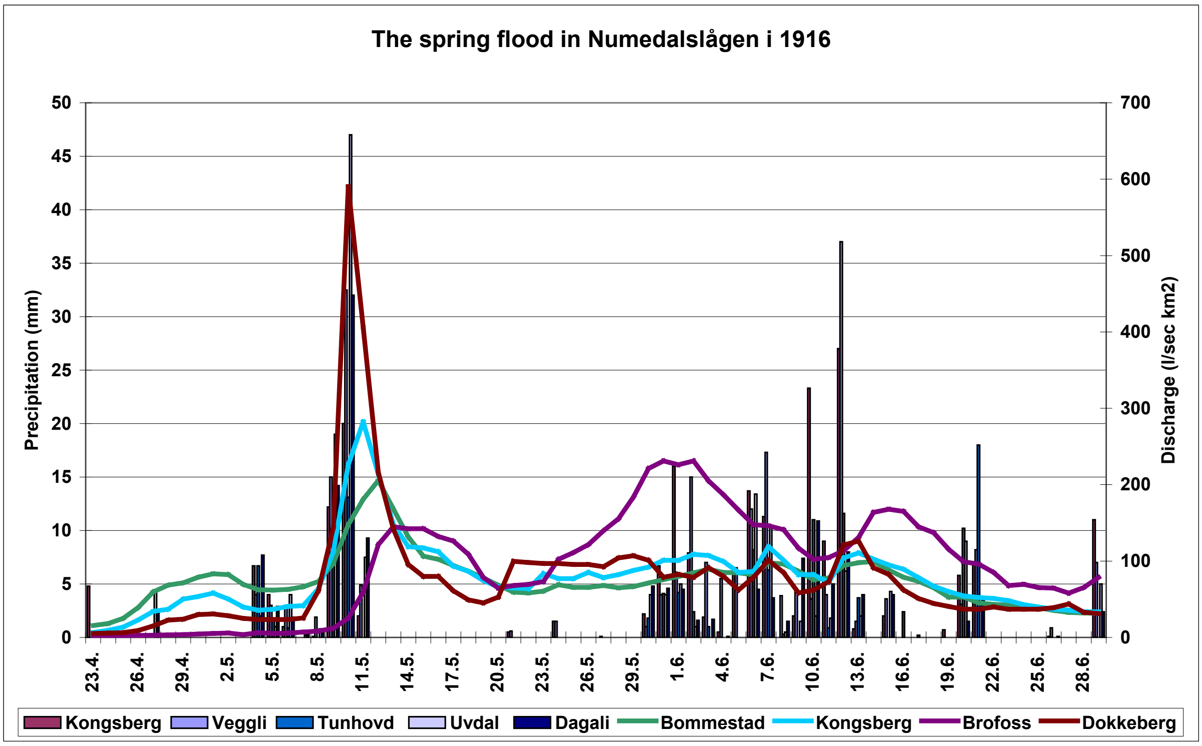


Figure 3.1.21.5 Observed precipitation and daily discharge during the large spring flood in River Numedalslågen in 1916.

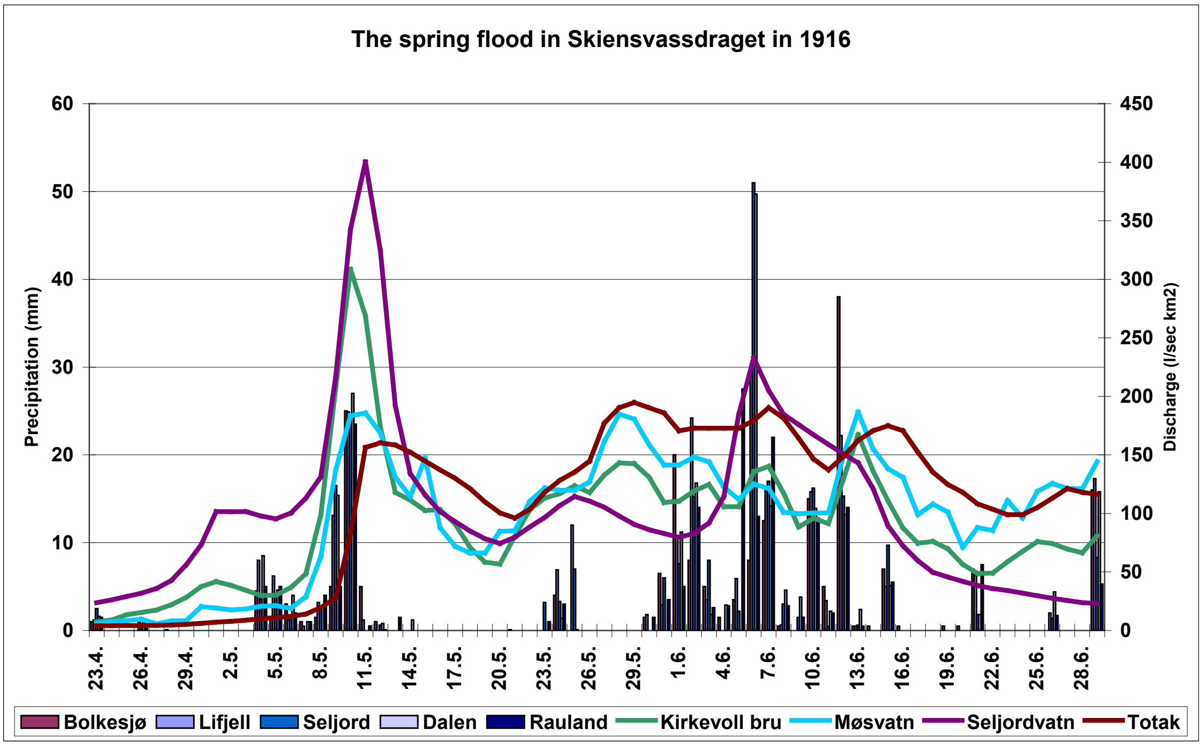


Figure 3.1.21.6 Observed precipitation and daily discharge during the large spring flood in River Skienselv et in 1916.

The flood was second largest at Seljordvatn 1884-1944 and the 49th largest 1885-1958 in Lake Totak. Tinne was strongly regulated in 1916, but at Kirkevoll bru the naturalised flood was the fifth largest.

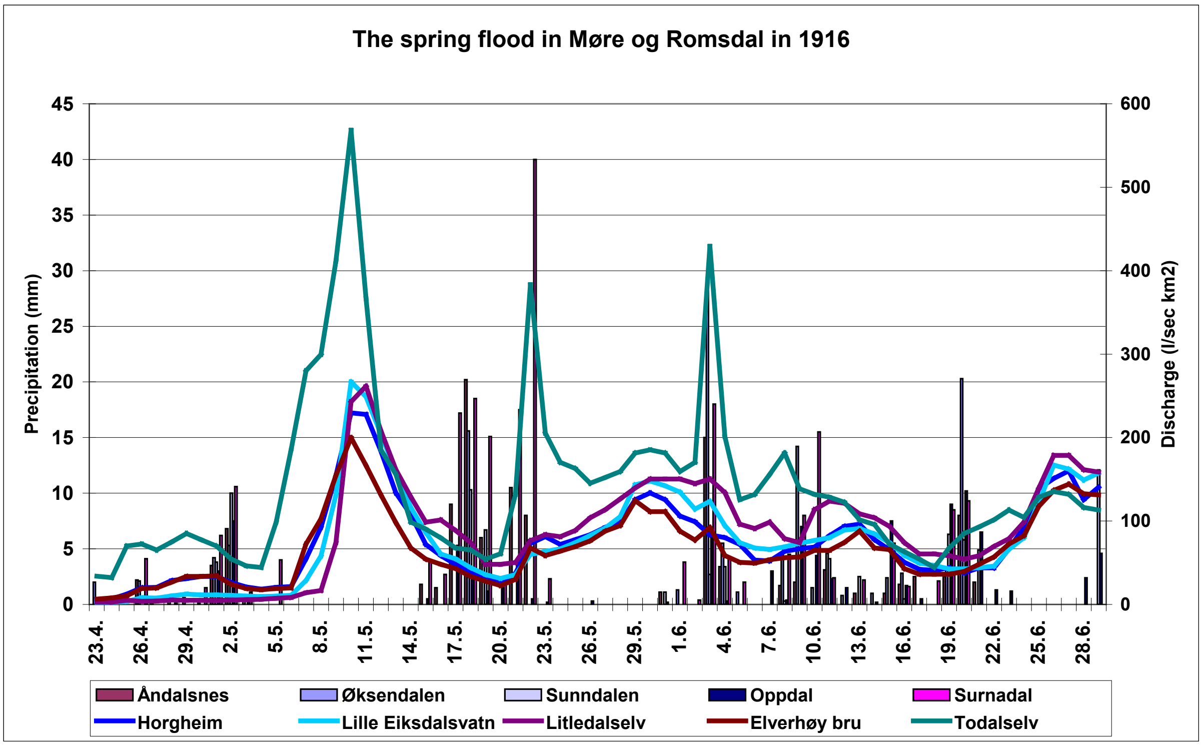


Figure 3.1.21.7 Observed precipitation and daily discharge during the large spring flood in rivers in Møre og Romsdal in 1916.

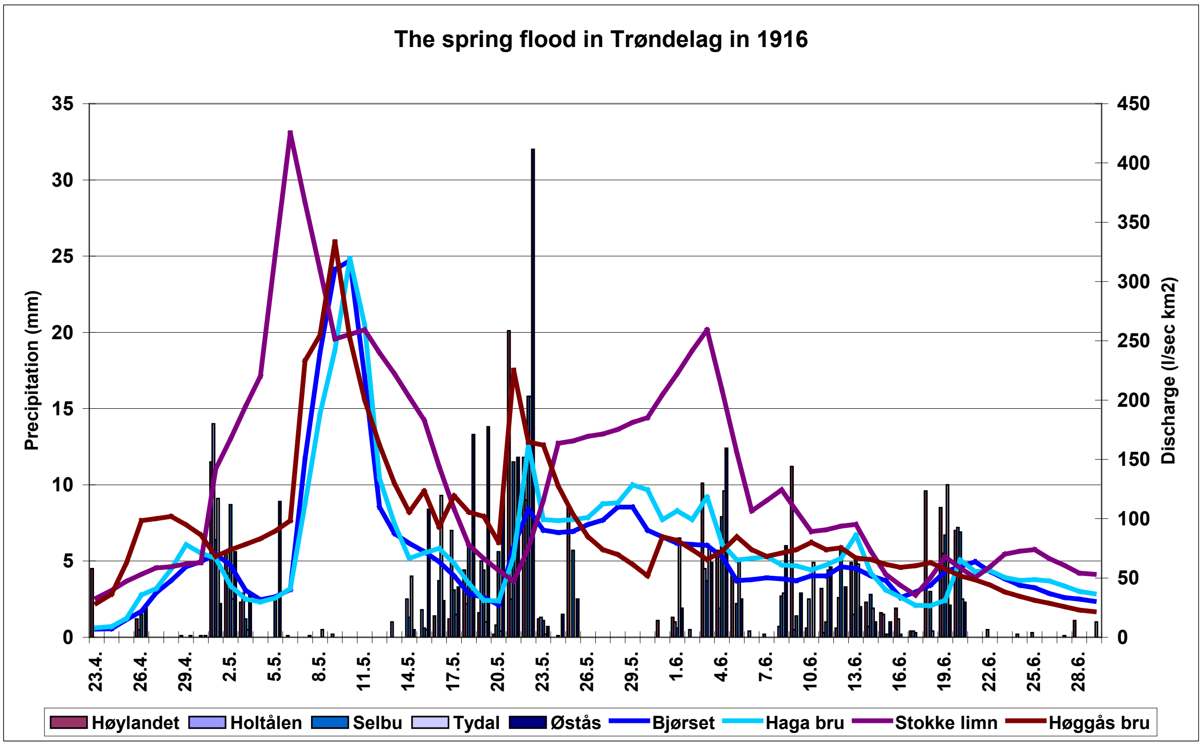


Figure 3.1.21.8 Observed precipitation and daily discharge during the large spring flood in rivers in Trøndelag in 1916.

The flood was the 10th largest in Orkla at Bjørset dam since 1912, the 17th largest in Gaula at Haga bru, the fourth largest in Nidelva at Rathe and the third largest at Stokke limnigraf. The flood was only the 39th largest in Stjørdalselva. The flood was the largest observed 1909-1930 in Verdalselva at Lillelunet.

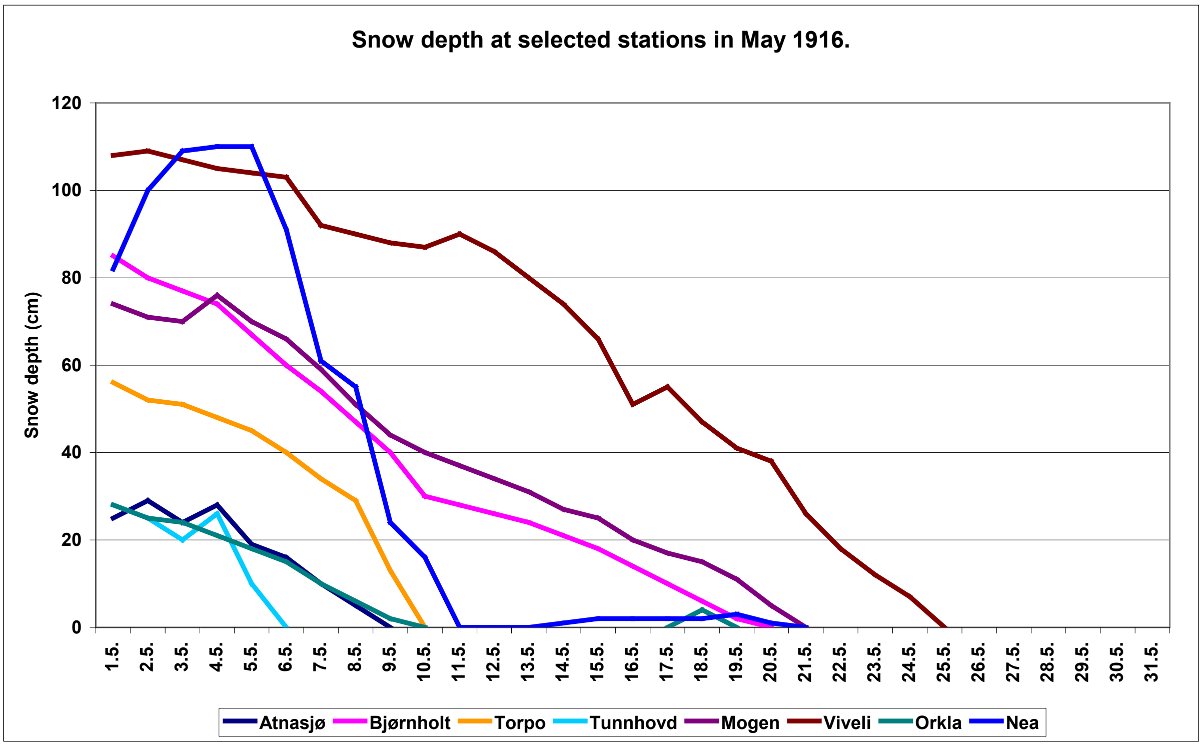


Figure 3.1.21.9 Observed snow depths at stations in Southern Norway in May 1916.

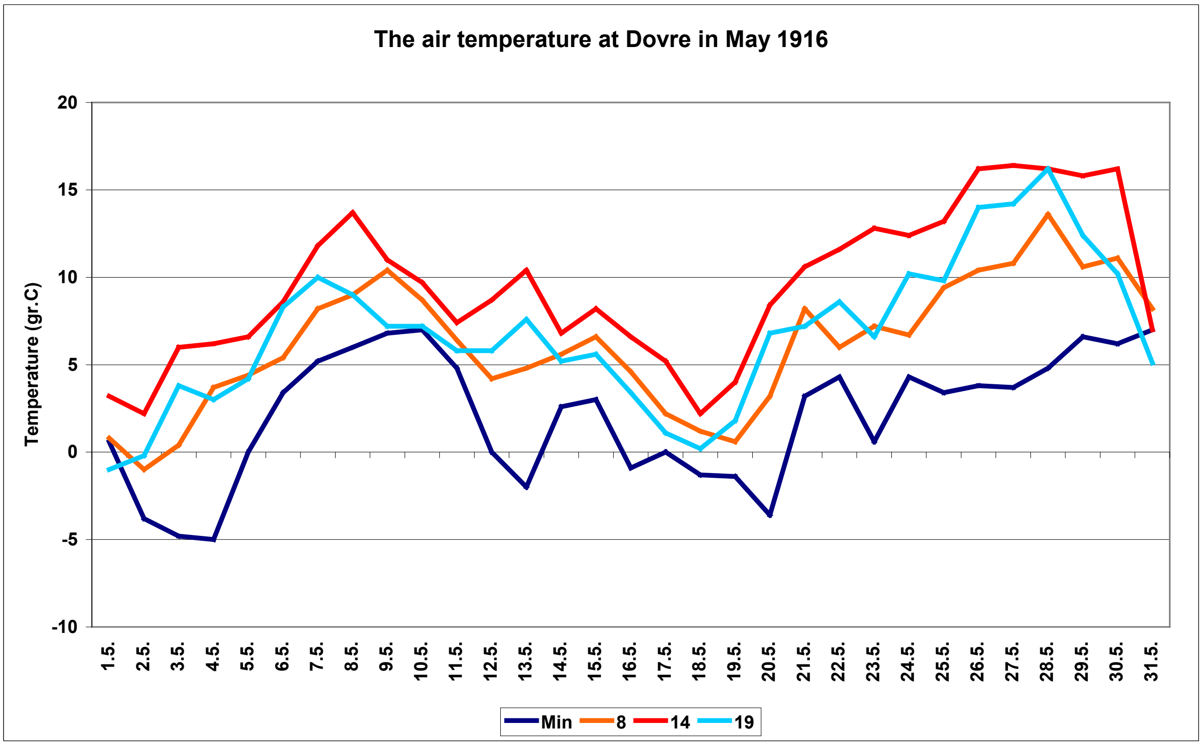


Figure 3.1.21.10 Observed temperature at Dovre during the large snowmelt flood in 1916.

Flood damages:

Glomma: Extensive inundation caused severe damages at Østerdalen. The railway, roads, bridges and timber booms were damaged, and the traffic was blocked for a long time. Much of the floodplain was under water from from Koppang to Stai at Storelvdal including the main road through the valley. The farmland at Koppangøyene had almost vanished. Large fields were completely inundated south of the church. People were compelled to communicate by boats, and many were completely surrounded by the flood water.

The tributaries Skynna and Sorka contributed to the flood at Åmot. Farmland was inundated at Hovind and on other farms. The fields were filled with sand, gravel, logs and other debris as the flood receeded. The flood caused a dam failure at the Osen dam at Rendal. The power station was severely damaged and one woman perished. The paperboard factory at Rena had to stop. The damages at Åmot were between two and three million NOK.

Many farmyards were inundated at Elverum. At Grue inundations caused 36 people to evacuate their homes. The ground floor of the main building at the farm Seim at Solør was also evacuated. The damages at six muncipalities upstream Skarnes was estimeted to 340.000 NOK.

Gudbrandsdalen: The flood was threathening the railway line at Fokstua, and the northbound train had to return to Dombås. The flood in River Otta caused Lake Vågåvatn to rise, and fields were inundated by the lake. River Sjoa destroyed a bridge in Heidal. The flood undermined the railway line at Kvam where a bridge was taken by the flood in Veikledalen. The foundation of a railway bridge was damaged at Ringebu. The wall around the churchyard at Øyer was damaged.

Timber caused serious problems during the flood in 1916 as under other earlier floods. Around 40.000 logs were pressing against the large bridge at Brunlaug at Fåberg crossing over Gudbrandsdalslågen 8 May. 10-12 men tried to remove the logs. The work attracted a lot of spectators. The most foolhardy of the spectators went out on the bridge after a part had failed. Fortunately, everyone was on dry land the day after when the bridge was destroyed, and the remnants drifted out in Lake Mjøsa. A timber boom at Vingsnes at Lillehammer failed also, releasing many thousand logs into Lake Mjøsa.

Drammenselv: The flood caused a dam at the pulp mill at Hønefoss to fail, and two workers were killed.

Numedalslågen: The timber boom at Vittingfoss and at Gravenfoss failed. 9.600 logs were taken by the river, drifting towards Larvik and the fjord. The next day the timber boom failed at Sundby, and another 36.000 logs started drifting southward.

Telemark: Some smaller bridges were destroyed at Sauland and Tuddal. The building in Notodden closest to Lake Heddalsvatn was threathened, but the flood water was contained in the large resevoir upstream River Tinne.

Orkla: Sections of the railway line at Thamshavn was inundated. An 80 year old woman lost her life.

3.1.22 The spring flood in the Dovre region 28 May 1921.

The spring flood observed in River Gudbrandsdalslågen at Lårgård bru/Rosten ranks as one of the largest floods upstream the confluence with River Otta at Sel. The other rivers such as River Rauma, River Folla, River Atna and River Driva had also moderate floods at the time.

Figure 3.1.22.1 show observed precipitation and discharge (daily values) at selected stations in the district.

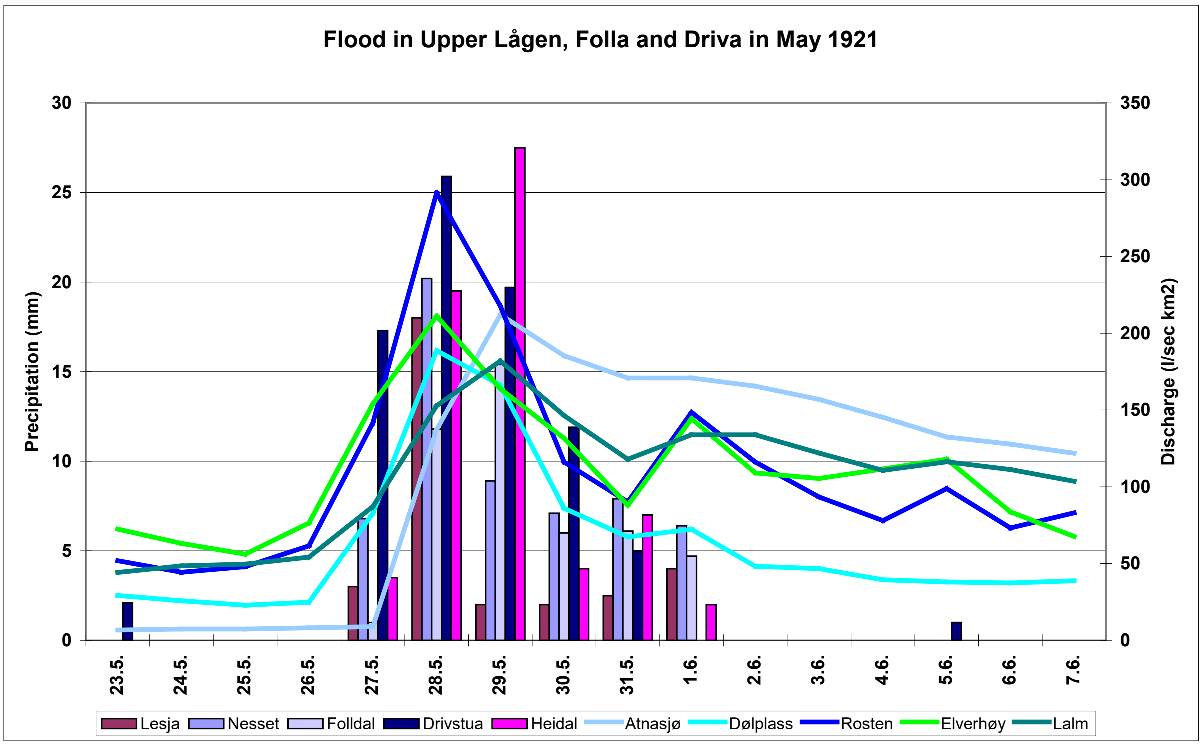


Figure 3.1.22.1 Observed precipitation and discharge in rivers in the Dovre region in late May and early June 1921.

Cause of the flood:

The flood was a combined snowmelt/rainfall flood. Most of the snow had melted in the low mountains when the rainfall started. The snowmelt intensities were moderate prior to the flood since the temperatures were ranging between 0 and 15 degrees as shown in Figure 3.1.22.2.

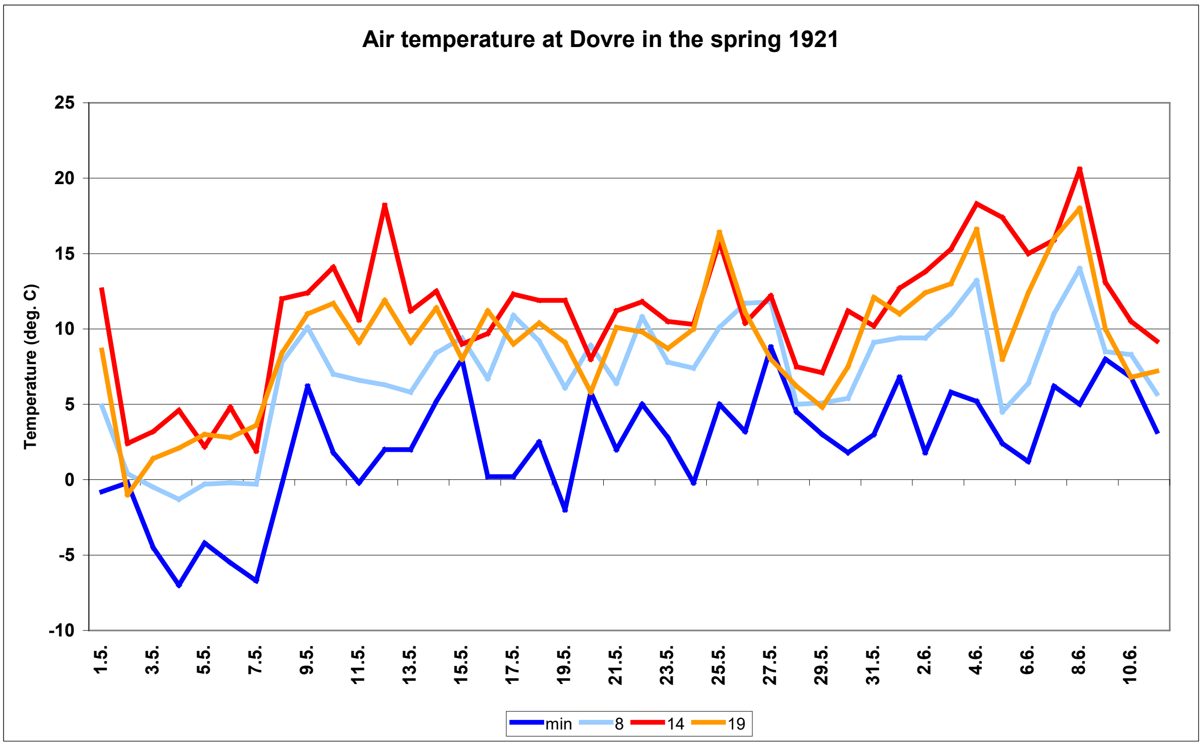


Figure 3.1.22.2 Air temperatures at Dovre in the spring 1921.

3.1.23 The mountain flood in July 1923 on both sides of the water divides of southern Norway.

A late snowmelt flood caused large floods in many rivers on both side of the water divide between East and West Norway in July 1923.

Initial conditions:

Most of the snow accumulated during the winter melted in late May - early June, but snow remained in the alpine areas into July.

The flood:

An anti-cyclone moved in over South Norway at the end of June causing rising temperatures. The temperatures in the mountain were especially high from 7 til 15 July as shown in Figure 3.1.23.1 for Dovre. The period from 16- 17 July was also dry. The resulting flood was therefore caused melting of remaining snow at high altitudes, as shown in Figure 3.1.23.2. The anticyclone moved gradually towards southeast. A low from the Norwegian Sea moved in toward Nordland, causing intense rainfall and local floods in coastal rivers at Helgeland 14 July as a cold front moved in.

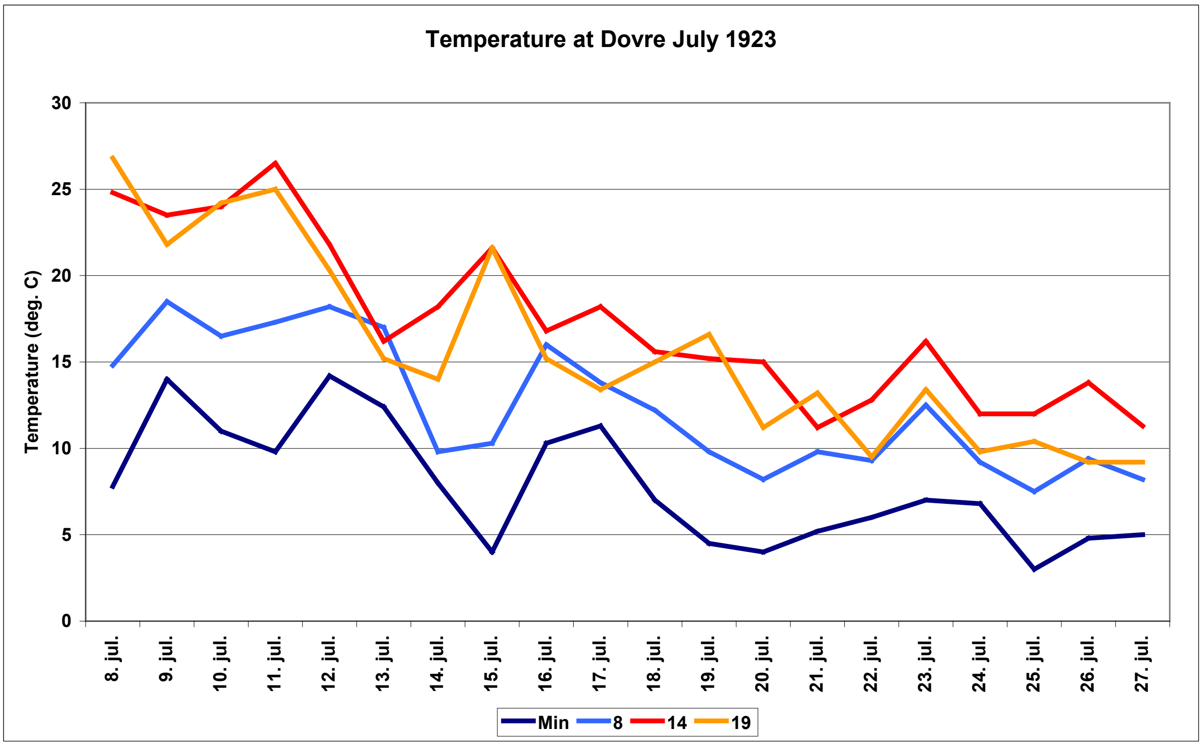


Figure 3.1.23.1 The temperature observed at Dovre in July 1923.

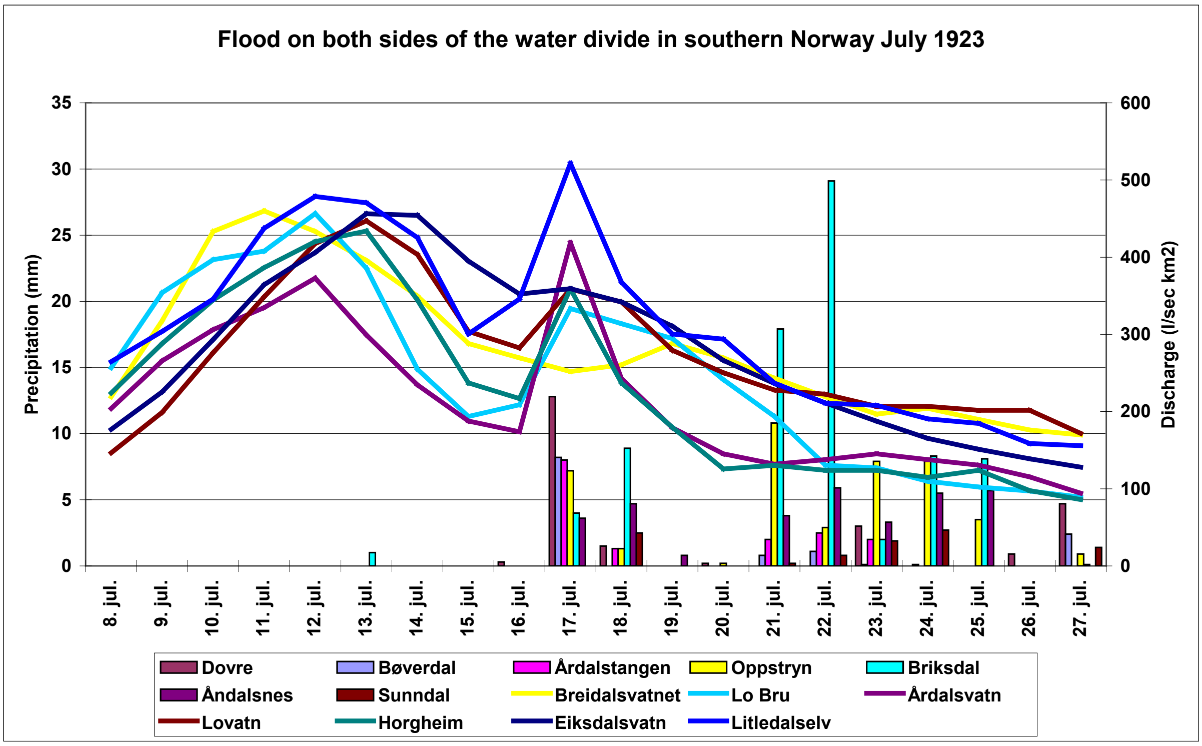


Figure 3.1.23.2 Observed precipitation and daily discharge in mountains rivers at Østlandet, Vestlandet and Romsdal in July 1923.

The flood was the largest observed in River Eira at Lake Eikesdalsvatn 1902-2001, second largest in River Otta at Lalm 1914-2002, and in River Rauma at Horgheim 1912-2008. It was the third largest in River Litledalselv 1912-1960, the fourth largest in River Strynselv at Lake Strynsvatn 1902-2006 and the 11th largest in River Årdalselv at Lake Årdalsvatn.

3.1.24 The severe flood in Gudbrandsdalen, Buskerud and Telemark in June 1927.

In the early summer 1927 suffered Østlandet severe damages from extreme floods. The flood in Gudbrandsdalen was primarily a late spring flood, causing damages from inundation on the floodplain and around the large lakes ie Mjøsa and Øyeren. Snowmelt at high levels in the mountains contributed also to the floods in Buskerud and Telemark, but the main reason was the extreme rainfall 29 June which did not penetrate as far inland as Gudbrandsdalen.

Initial conditions:

The spring and early summer 1927 were cold until mid June. Abundant snowfall in the winter, and the cold spring caused a delayed start of the snowmelt. More preciptation fell in early June at Østlandet, mostly as rain in the lowland, but occasionally as snow in the alpine areas. An outbreak of warm air moved from the Mediterranian toward northwest (Vb-type circulation), but the warm air could not penetrate further north than to Denmark. By 26 June the snowmelt was over in the lowland and in the mountain slopes in the inland valleys. Much snow remained however in the alpine areas, posing a risk of a large flood in Gudbrandsdalen. Rainfall in early June must have filled the ground water reservoir, and the ground was saturated in Telemark before the rainstorm 29 June.

The flood

Some rain fell in Gudbrandsdalen 19-28 June. Varm air moved from a depression over Britain causing very heavy rainfall from Halden, Moss and Ås east of the Oslofjord to Drammen, Sigdal, Numedal and Telemark to Drangedal and Vågsli 29 June. Some rain fell also in upper Setesdal.

At Hakavik at Øvre Eiker and at Kongsberg in fell 98 mm and at Besstul at Gjerpen 89 mm. Other stations in Vestfold observed rainfall ranging from 54 to 79 mm. Most intense rainfall occurred at Rjukan at Tinn where 134 mm regn was observed. At Tuddal 121 mm fell and at Kaldhovd 102 mm. At Løvheim at Hjartdal fell 100 mm, at Rauland 86 mm and at Heggestøl at Vinje 82 mm. The remaining snow in the mountains melted quickly, and rivers and brooks grew as never before.

Figure 3.1.24.1 show observed daily discharge caused by rainfall and snowmelt in River Trysilelv and River Glomma. Figure 3.1.24.2 show daily precipitation and discharge in Buskerud and Telemark. Most of the active gauging stationes during the flood was in regulated rivers. The figures show naturalized floods at stations where the regulation has caused changed flood seasonality and magnitude.

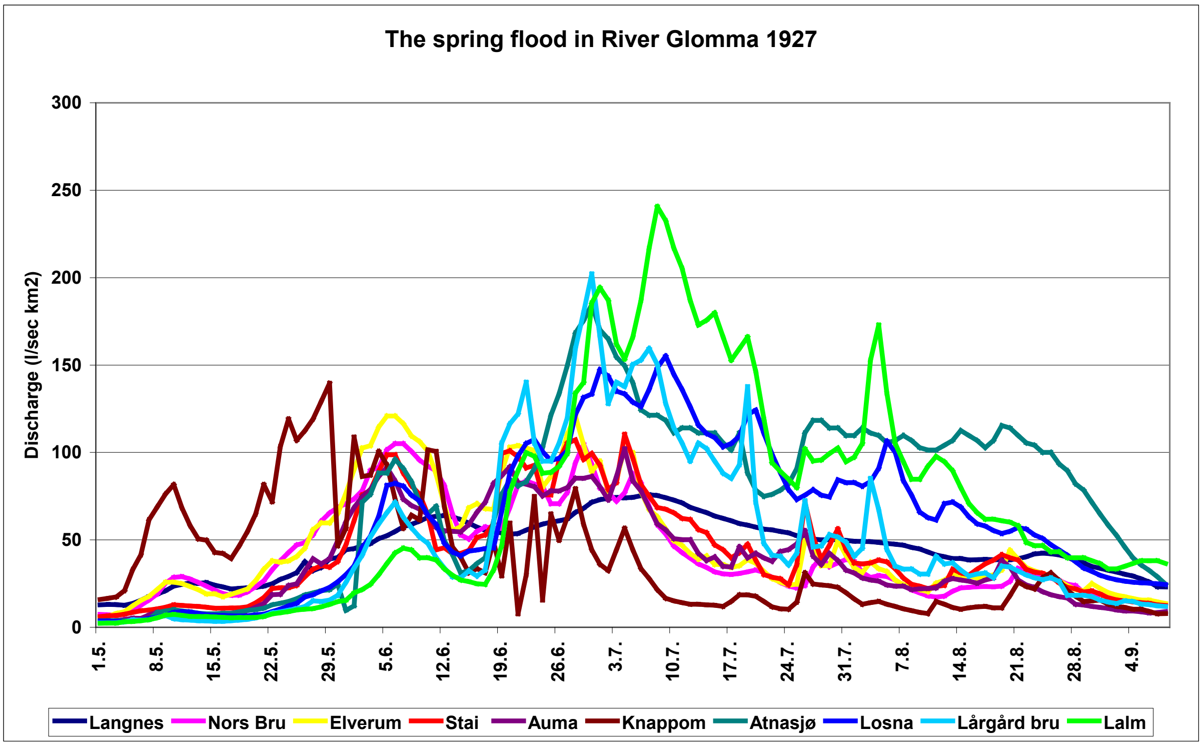


Figure 3.1.24.1 Observed discharge at stations in River Trysilelv and Glomma

The flood in River Flisa and other lowland tributaries was over at the end of May. The flood had two peaks in Østerdalen from Elverum to Tynset 5 and 29 June. The discharge at Elverum was the 23th largest 1871-2014.

The flood in Gudbrandsdalen peaked around 29 June, but the flood from River Otta culminated 9 July, as a result of the heatwave following the extreme rainfall in Telemark. The hot weather caused rapid melting of the snow in the most alpine areas. The flood was largest since the flood in 1860 in Lake Mjøsa and River Gudbrandsdalslågen. The flood ranks as the x largest in Lake Mjøsa, the 15th largest at Losna 1896-1913, the 27th largest at Sel 1917-2014 and the 12th largest in River Otta at Lalm.

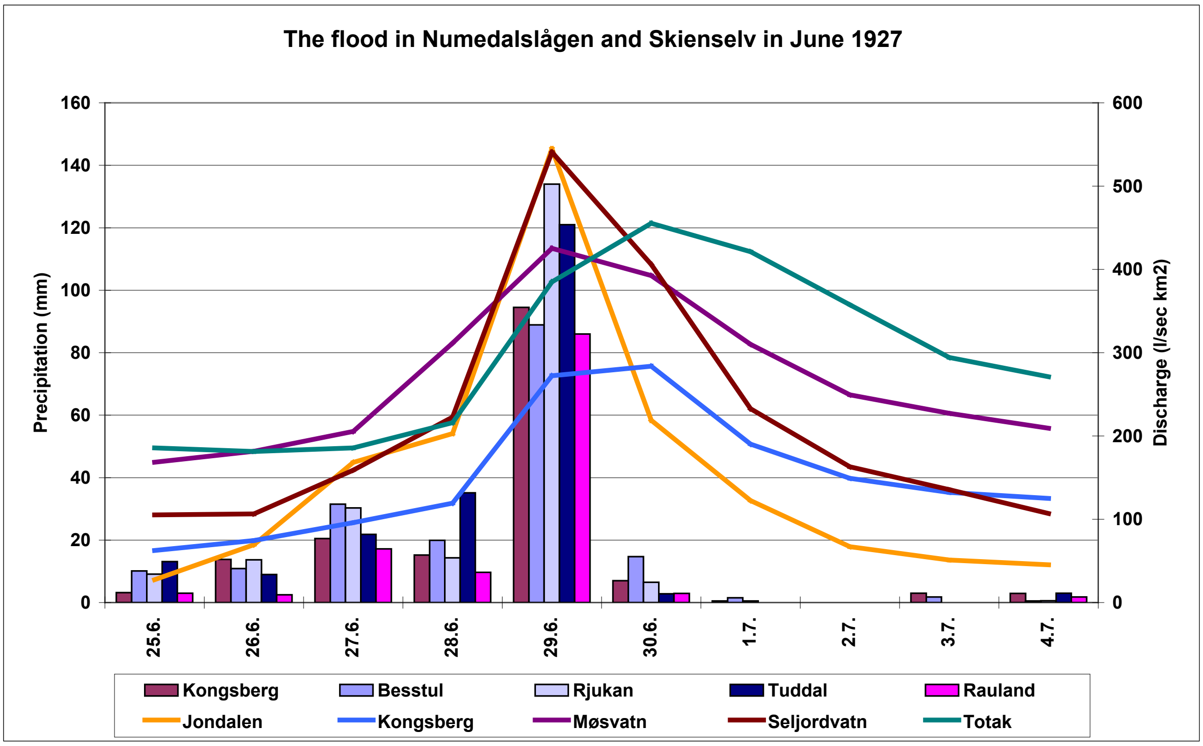


Figure 3.1.24.2 Observed discharge and rainfall at stations in Numedalslågen and Skienselv 25 June- 4 July 1927.

In River Begna the flood was fourth largest naturalised flood 1920-1962, in River Usta fifth largest 1909-1965, in River Hallingdalselv at Bergheim largest 1920-2013, and in River Snarumselv second largest since 1892-2014. In River Numedalslågen the flood was largest 1874-2014. The flood was extreme in River Tinne, Måna, Gøyst and Mår. The flood in River Heddøla at Omnesfoss was second largest when the instrument failed at the station and the largest in River Hjartdøla and in River Bøelva at Seljord. The flood was together with the 1860 flood the largest observed in Lake Norsjø and in Lake Hjellevatn at Skien. Rivers on the west side of the water divide at Hardangervidda did also flood; the flood in River Bjoreio was second largest largest 1908-1975. It was the sixth largest at Lo bru in River Lærdøla 1916-2007.

Aftermath of the flood in Norway

Varm air from south-southeast 4 July caused a heat wave at Østlandet lasting until 16 July. Several days of thunder occurred in Oslo, but no extreme rainfall was observed.
Weather types were: **TRW** (Grosswetterlagen) and **C** (Lamb/Jenkinsson).

The depression over Storbritannia moved southeastward in a Va-trajectory, accumulating meat and humidity from the Mediterrainan before moving nortwest over Germany as a genuine Vb-low causing an extreme flood in the upper reaches of River Elbe in Sachsen 5-6 July. The flood was a major disaster resulting in the loss of 160 people and extensive damages to roads and railways. The total damage in Germany was assessed to 70 million Reichsmark.

Flood damages:

Glomma:

Lillestrøm

Damage at buildings	30.000 NOK
Sawmills – loss of production	112.500 NOK
Farmland, roads and streets	60.000 NOK
Total:	202.250 NOK

Mjøsa:

Large flood at Eidsvoll

Houses and shops in Strandgaten in Hamarwere inundated
All the stocks were removed before the flood.

The harbor at Lillehammer was inundated.
The Mesna cardboard factory had to stop production for 11 days
1000 daa of farmland was inundated at Jørstadvollen

Gudbrandsdalen:

Main road blocked at Vågå from inundation.
200 daa of farmland inundated at Vågå.

Numedalslågen:

Gammelbroen at Kongsberg was taken by the flood and drifted past Skollenborg.
A bridge was taken at Bruhaugen at Rollag with two men. Both men were rescued.

Skienselv:

Rjukan:

Buildings	253.000 NOK
Farms, farmlad and forests	72.867 NOK
Roads and railways	25.000 NOK
Total:	350.867 NOK

250 landslides at Tinn.
6 workers killed by rockfall

Vestfjorddalen and Middøla

Total damages	90.000 NOK

Tinn exclusive Rjukan

Private buildings	9.000 NOK
Roads and bridges	20.000 NOK
Total:	29.000 NOK

Notodden:

Buildings	200 properties	160.000 NOK
Tinfoss iron works		300.000 NOK

One girl drowned

Heddal
Total damages 80.000 NOK

Hjartdal
Total damages 147 properties 79.000 NOK

Tuddal
7 bridges

Seljord and Flatdal
Total damages 51 properties 75.000 NOK

Kanalen at Lunde
Total damages 100.000 NOK

Hovin
Total damages at 16 properties 18.000 NOK

Skotfoss bruk
Total damages at 51 properties 7.000 NOK

Skien

Buildings 120 houses	28.000 NOK
Streets, roads and bridges	15.000 NOK
Total at Skien	43.000 NOK

One man drowned when crossing the river

Porsgrunn
Total damages 78.500 NOK

Summary of the damages at Telemark:

Private properties	815.000 NOK
Roads	400.000 NOK
The Kanal	100.000 NOK
Factories, sawmills, shops etc.	1.500.000 NOK
Total:	2.815.000 NOK

3.1.25 Snowmelt and rainfall flood in mountains rivers at Østlandet in July 1932.

A large mountain flood occurred in rivers draining Dovrefjell and in Ottadalen further southwest in July 1932. The flood was particulary large in the mountains between Lesja, Dombås, Hjerkinn and Drivdalen. Rivers further westward at Nordmøre had floods at the same time.

Initial conditions

In the mild winter 1931/32 a large snow reservoir accumulated at Dovrefjell and at nearby mountain districts. Figure 3.1.25.1 show observed snow depth at Sunndal (200 m.a.s.l) and at Ølset in the Orkla catchment (500 m.a.s.l). Most of the districts are located at higher altitudes than these two stations, and much snow remained into July. The precipitation was low in May and June at Dovre. In May 1932 only 9,1 mm fell at Dombås and 6,1 mm at Fokstugu, while 12,9 mm fell in June at Dombås and 13,1 mm at Fokstugu.

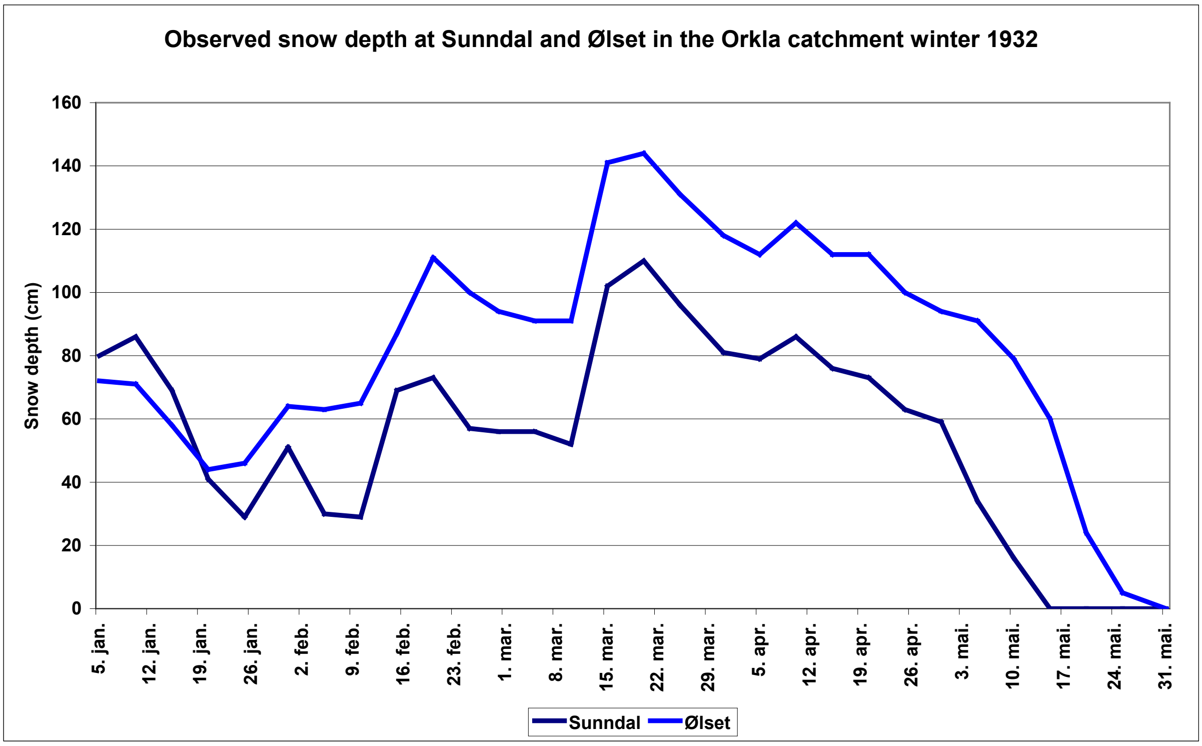


Figure 3.1.25.1 Observed snow depth at Sunndal and Ølset in the winter 1932.

The flood:

The snow melting started late at Dovrefjell in 1932. Temperature data from Oslo and Trondheim show high temperatures during the melting period. The maximum temperatures in June and July were 24,0° 23 June and 22,5° 14 July at Dombås, 20,4° 23 June and 18,4° 14 July at Fokstua and 23,2° 30 June and 23,2° 2 July at Berkåk. July had abundant rainfall in the mountains. At Dombås 109,6 mm fell in July and at Fokstua fell 88,2 mm. Most of the rain fell 4, 7, 8, and 22 July. As shown in Figure 3.1.25.22 some rain fell in the mountains south of the water divide toward Trøndelag.

Between an anticyclonic ridge across Sweden and Finland and a depression in the Norwegian Sea mild oceanic air streamed toward southern Norway 5-10 July. There was heavy rainfall in Valdres, Hallingdal and Telemark 7 July at the same time as the flood at Dovre. Decriptions indicates that foehn occured at Dovre as a result of the heavy rainfall further southwest. The rainfall causing the flood must have been convective and locally intense in the mountains. Rainfall data from the stations operated by the Meteorological institute did not observe extreme rainfall, which must have fallen at locations not covered by the station network in 1932. The weather types 7 July were: **TRW** (Grosswetterlagen) and **SW** (Lamb/Jenkinson)

Figure 3.1.25.2 show observed daily rainfall and discharge at Dovre and Nordmøre and in Figure 3.1.25.3 for stations in River Otta, River Sjoa, River Drammenselv and River Skienselv.

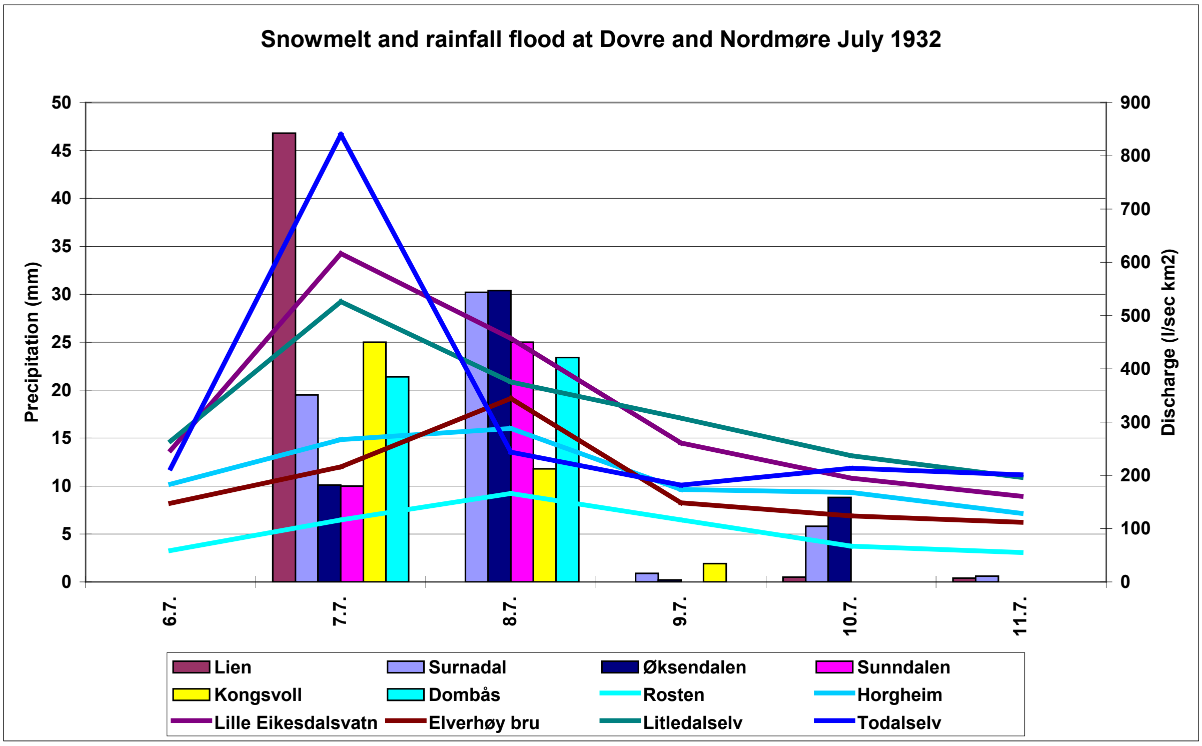


Figure 3.1.25.2 Observed daily precipitation and discharge during the flood at Dovre and Driva July 1932.

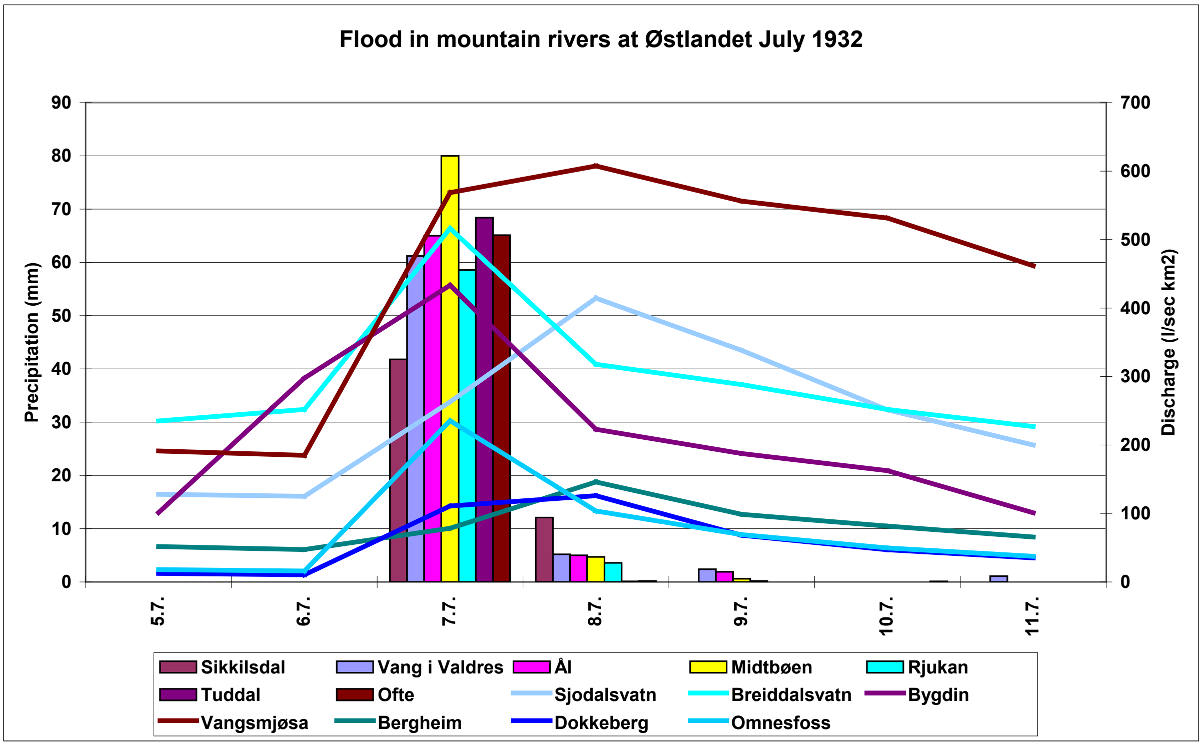


Figure 3.1.25.3 Observed discharge and rainfall at mountains rivers at Østlandet in July 1932.

The flood in River Driva in July 1932 is the second largest flood observed at Elverhøy bru since the observation started in 1908, only exceeded by the August flood in 2003. *Storofsen* must have been much more severe in Driva. The rainfall flood in 1698 and the ice run flood in 1881 may also have been more severe, but no observations exist from these earlier floods. A gauging station was operating at Kongsvoll in 1932, but the station failed during the flood in 1932, probably before the flood peaked. Nevertheless, it is assumed that the flood was the second largest after *Storofsen* in Drivdalen. A new gauging station, Risefoss, was established in Drivdalen in 1934.

The flood was third largest in River Eira at Lille Eikesdalsvatn 1902-2001, second largest in River Litledalselv 1912-1960 and third largest in River Todalselv 1908-1938. The flood in River Gudbrandsdalslågen at Lårgård bru at Sel was moderate, but the flood in the tributary Jora at Dombås was extreme, but this station started to operate in 1966/67, and the water level or discharge is therefore not known from earlier floods. Local descriptions state, however, that the flood in Jora was the second largest known, only exceeded by *Storofsen*. The flood was largest in River Otta at Lake Breiddalsvatn 1917-2014 and fourth largest in River Vinstra at Lake Bygdin 1922-2000. In River Rauma the flood was the largest in 1932, but ranks only as the 33th largest in 95 years.

With exception of the flood in River Hallingdalselv at Bergheim, the snowmelt floods in May-June was larger than the flood in July 1932 in Rivers in Buskerud and Telemark.

Ice runs and failure of dams caused by avalanches at Lake Kaldvellsjøen and at Lake Åmotsvatn have also contributed to the flood and the flood damages.

Flood damages:

Dovre/Lesja:

The extreme snowmelt and rainfall caused avalanches damaging chalets in the mountain valley near River Jora. A mill was taken and was smashed to pieces as it reached the old stone bridge across Jora (Wigenstad, 1987). The bridge across River Grøna at Tungnebben was taken. Three other bridges at Dalsidun in Lesja, Svartdalsbrue, Reindølsbrue and Nyseterbrue, were also destroyed.

Oppdal:

The railway line was damaged near Stølan in Drivdalen, where River Stølå har undermined the line, but temporary repairs were sufficient to maintain the traffic (Dørum, 1989). The suspension bridge across River Driva was damaged on the east side. Most of the bridges in Drivdalen had gone, among those two at Engan, Gottemsbrua, Vikabrua, Bøaseterbrua, Nysæterbrua and Svartøybrua. At Vollan Storbrua survived. A large barn came drifting but did not damage the bridge. The river was also full of drifting trees, which had been taken by the flood. The main road had been totally destroyed from Nestavoll and two kilometer to the south. It took almost three years to repair the road. Meanwhile cars had to be driven by the train past the damaged road. The flood caused also damage to farmland by eroding the riverbanks and inundating fields, leaving sand and gravel when the flood receeded.

3.1.26 The large spring flood in East Norway and Trøndelag in May 1934.

The spring flood in May 1934 was among the largest at Østlandet and in the large inland rivers in Trøndelag ie River Orkla, River Gaula, River Nidelva, River Stjørdalselv and River Namsen. The flood extended to River Vefsna and some other rivers at Helgeland. Some inland rivers at Vestlandet had floods such as River Årdalselv, River Strynselv, River Rauma and River Surna.

Figure 3.1.26.1 show observed daily precipitation and discharge in River Trysilelv and tributaries from the east to River Glomma, Figure 3.1.26.2 for stations in River Glomma from Østerdalen to Øyeren, Figure 3.1.26.3 for Gudbrandsdalen and Folldal, Figure 3.1.26.4 for River Drammenselva, Figure 3.1.26.5 for River Numedalslågen, Figure 3.1.26.6 for Nordfjord and Nordmøre, Figure 3.1.26.7 for River Orkla and Gaula and Figure 3.1.26.8 for Nord-Trøndelag and Helgeland. The flood was comparable in magnitude to the spring floods in 1916, 1966 and 1967, only exceeded by *Vesleofsen* in 1995 in the 20th Century in Glomma. Telemark had also a large spring flood in 1934, but there the rainfall flood 6 August was larger than the spring flood.

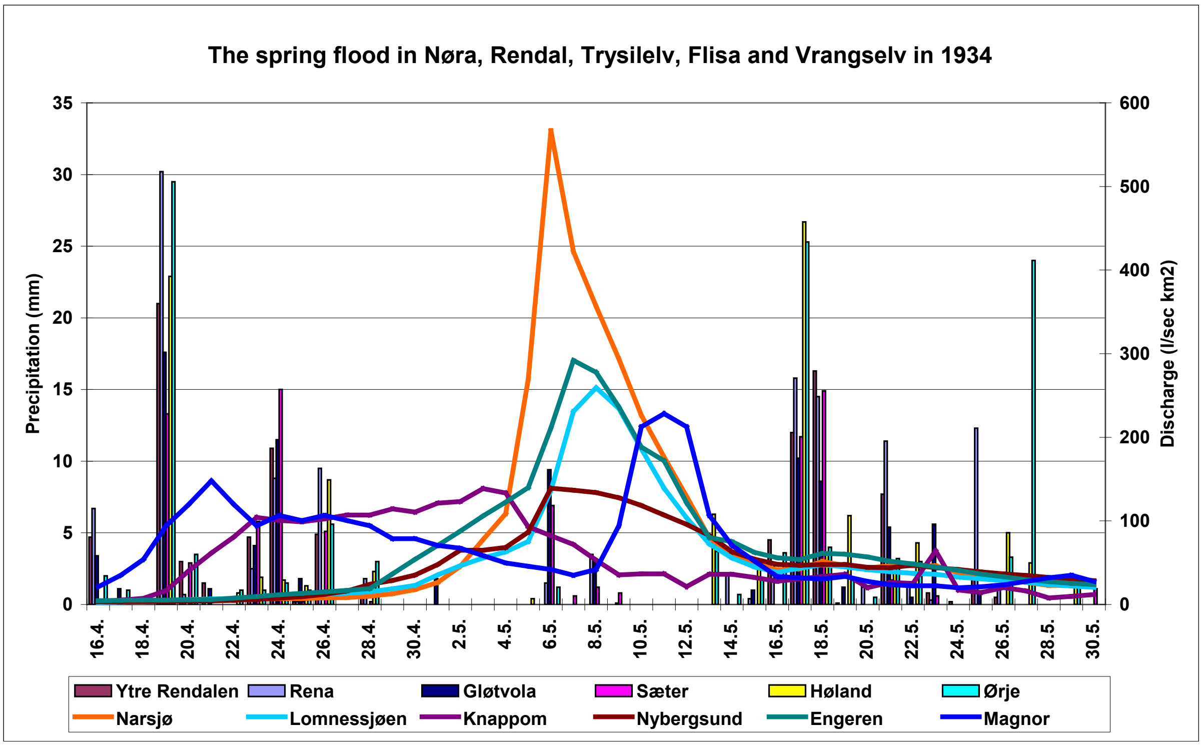


Figure 3.1.26.1 Observed precipitation and daily discharge during the large spring flood in rivers east of Østerdalen in 1934.

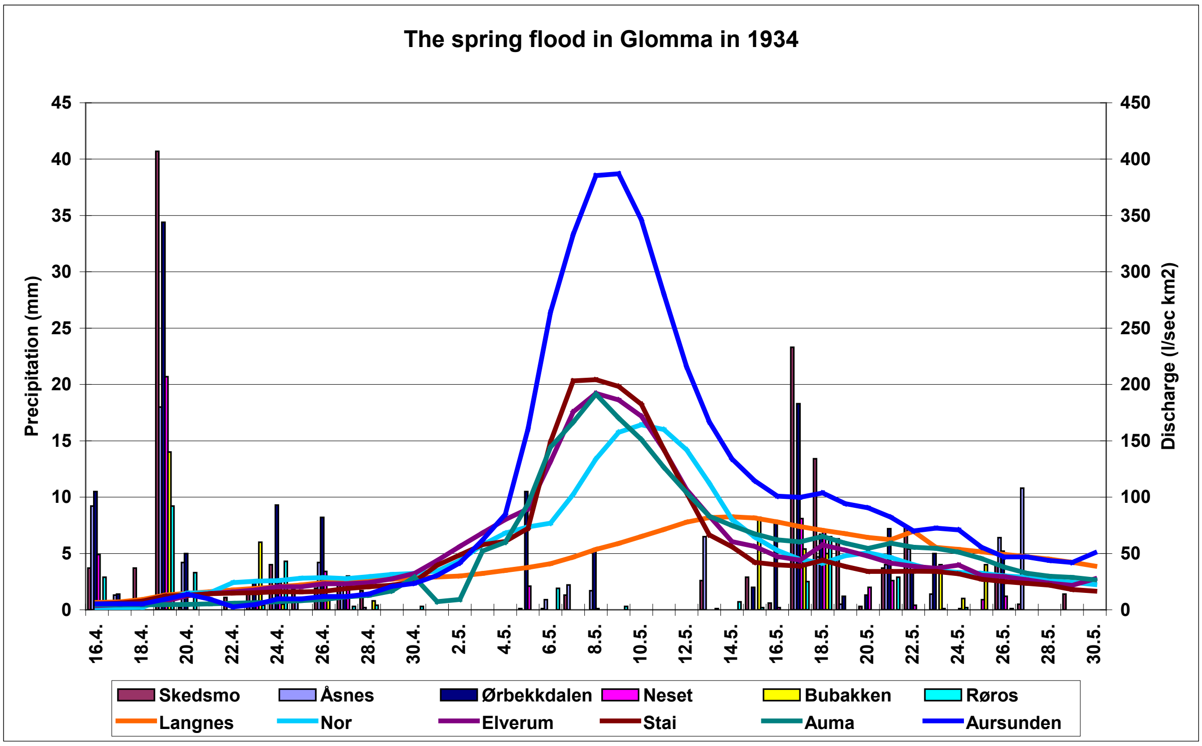


Figure 3.1.26.2 Observed precipitation and daily discharge during the large spring flood in River Glomma 1934.

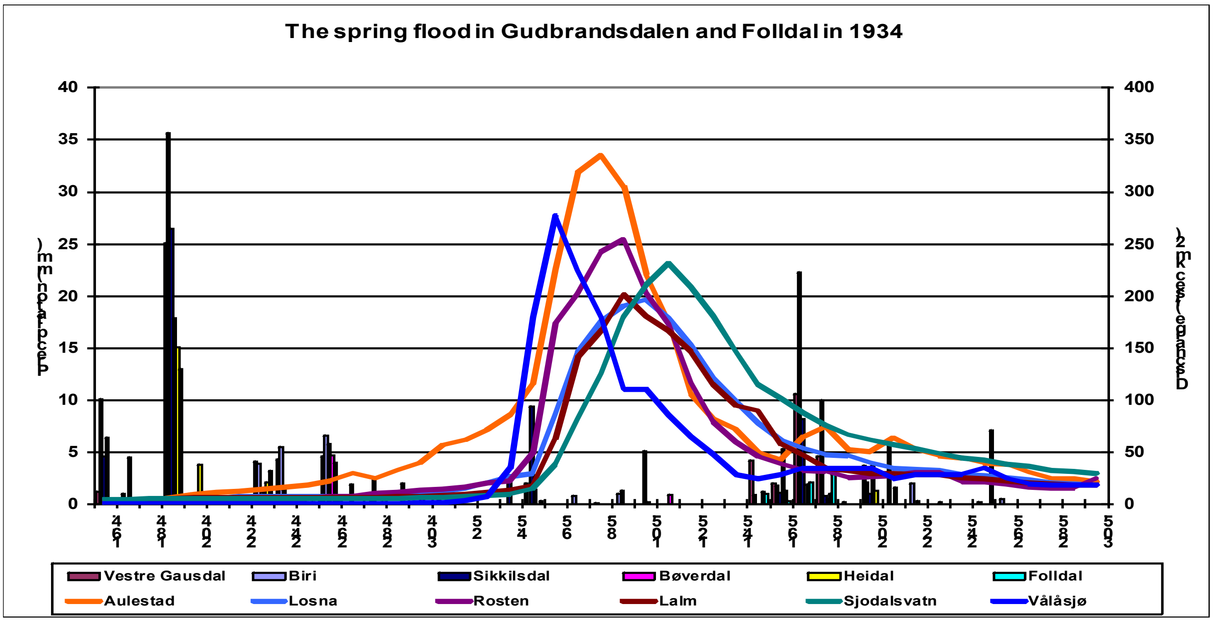


Figure 3.1.26.3 Observed precipitation and daily discharge during the large spring flood\ in Folldal and Gudbrandsdalen in 1934.

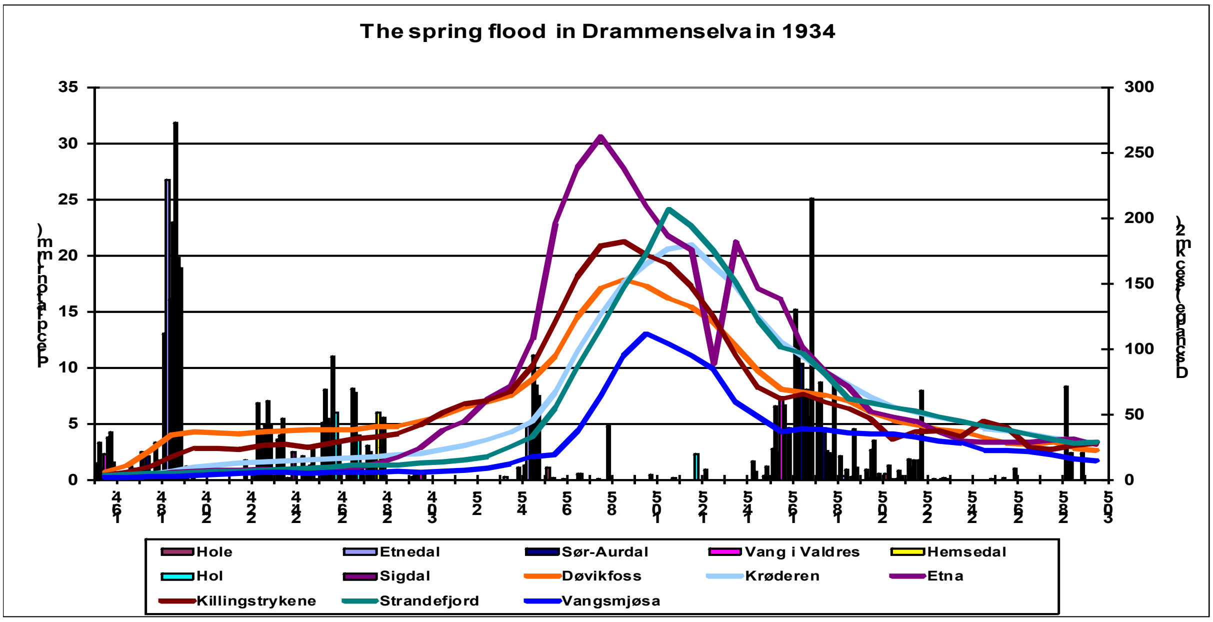


Figure 3.1.26.4 Observed precipitation and daily discharge during the large spring flood in River Drammenselva in 1934.

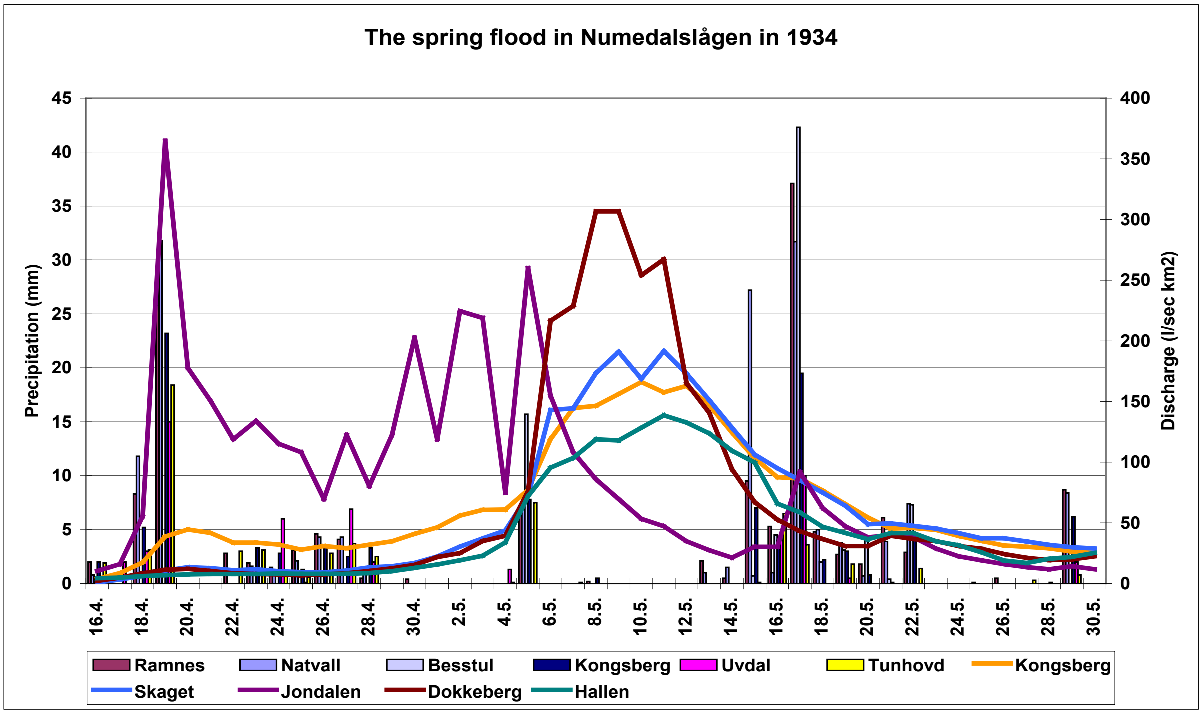


Figure 3.1.26.5 Observed precipitation and daily discharge during the large spring flood in River Numedalslågen in 1934.

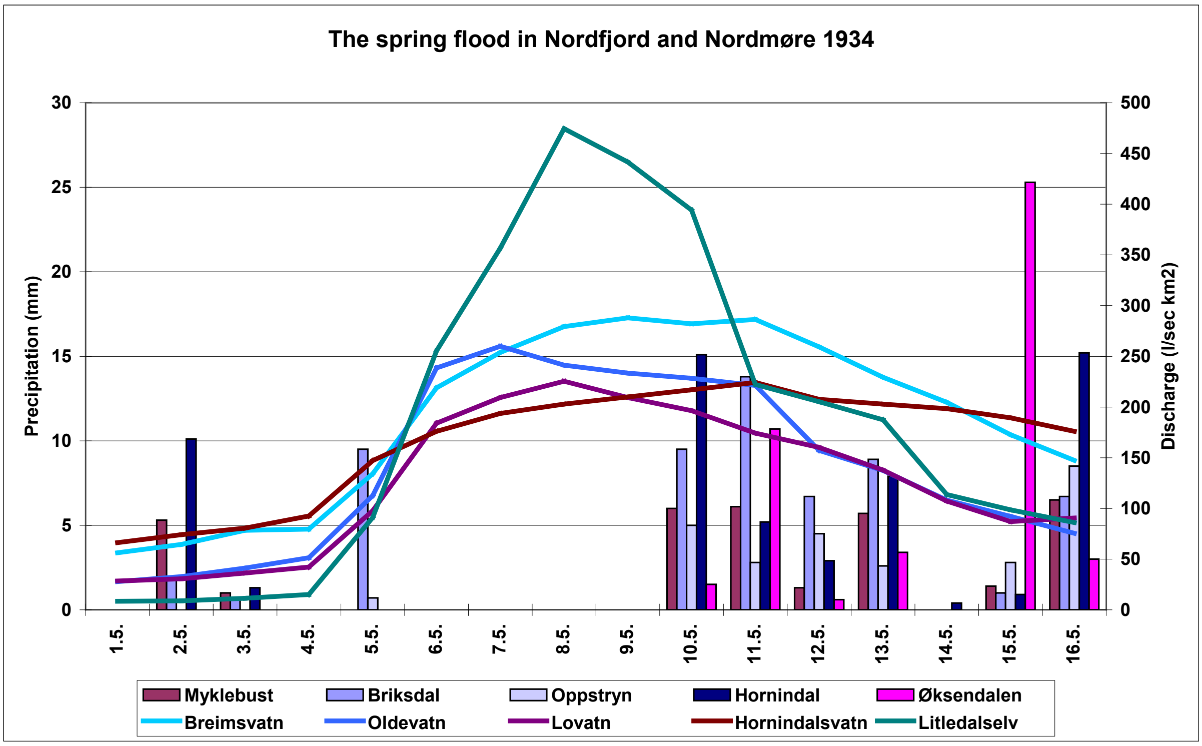


Figure 3.1.26.6 Observed precipitation and daily discharge during the spring flood in 1934 in Nordfjord and Nordmøre.

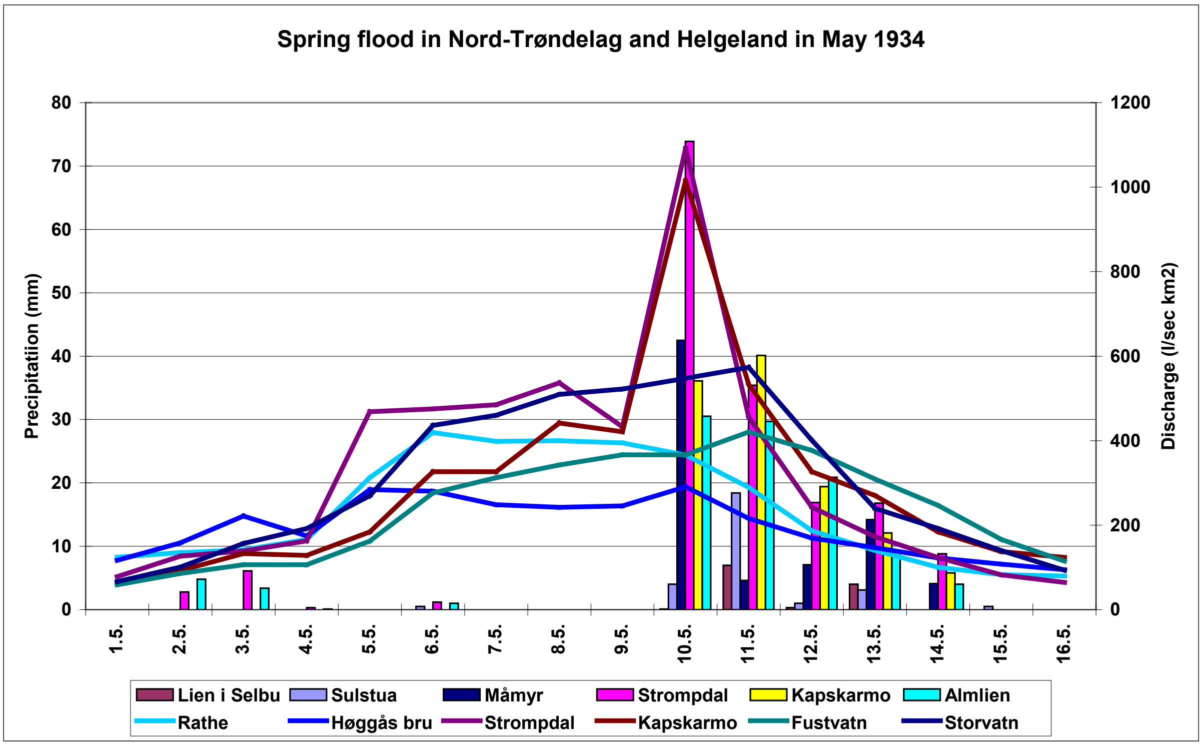


Figure 3.1.26.7 Observed precipitation and daily discharge during the spring flood and 1934 in Nord-Trøndelag and Helgeland.

The flood was the largest in River Glomma at 2.116 Auma 1921-1988 and second largest at 2.119/604 Elverum 1871-2014 and at 2.117/112 Stai 1909-2014, third largest at 2.2/120/393 Nor/Nors bru 1852-2014, largest at Blaker 1869-2008, third largest at 2.126/605 Langnes/Solbergfoss 1902-2014 and fourth largest at the outlet of Lake Øyeren at 2.125

Mørkfoss. The flood was the largest in River Nøra at 2.11 Narsjø 1934-2014, fifth largest in River Folla at Vålåsjøen 1922-2010, in River Rena at Lake Storsjøen 1902-2010. The flood was moderate in River Flisa at 2.142 Knappom 1917-2014. The Flisa catchment is mostly lowlying, and most of the snow had probably melted earlier in the spring. The flood in River Trysilelv at 311.4 Femundsenden 1896-2014 was seventh largest, at 311.6 Nybergsund was sixth largest 1908-2014 and in 311.460 Engeren 1912-2014 the second largest.

The flood was the fourth largest in River Gudbrandsdalslågen at 2.145 Losna 1896-2014 and and at Harpefoss 1933-1960. The flood was 11th largest at Lårgård bru/Rosten 1879-2014. In River Otta at 2.150/25 Lalm 1907-2014 the flood was the 22th largest, and the flood was sixth largest in River Bøvra at 2.268 Marstein/Akselen 1934-2014. River Mesna at Lillehammer, River Hunselv at Gjøvik and River Lena at Toten caused flood damages.

The flood in May in Buskerud and Telemark was the worst spring flood since the flood in 1916 but was exceeded by the large summer floods in 1927, 1934 and 2007 in many rivers.

The flood in River Gaula at Haga bru and River Orkla at Bjørset dam was fourth largest in 1908-2010 and 1912-2010 respective.

Cause of the flood

The flood was primarily caused by melting snow. Before the flood started some rain had fallen. The culmination of the flood co-incided with a heat wave 2-10 May. Snow was remaining at higher levels into May as shown in Figure 3.1.26.8 at some stations at Østlandet and in Figure 3.1.26.9 at Vestlandet and Mid-Norway. The snowmelt was over at low and middle altitudes in April, but snow remained at higher levels in the mountains into May. Figure 3.1.26.10 and 3.1.26.11 show the temperature in Oslo and Trondheim in the spring 1934.

Mild air was streaming from south-southwest over Norway between a depression in the Norwegian Sea and an anticyclone over Finland 5-10 May. Another cyclone was situated in the Atlantic west og Britain and blocking the air transport from west. The weather types were: **TM**/ **WW** (Grosswetterlagen) and **CS**/**SW** (Lamb/Jenkinson) **(Vb-type).**

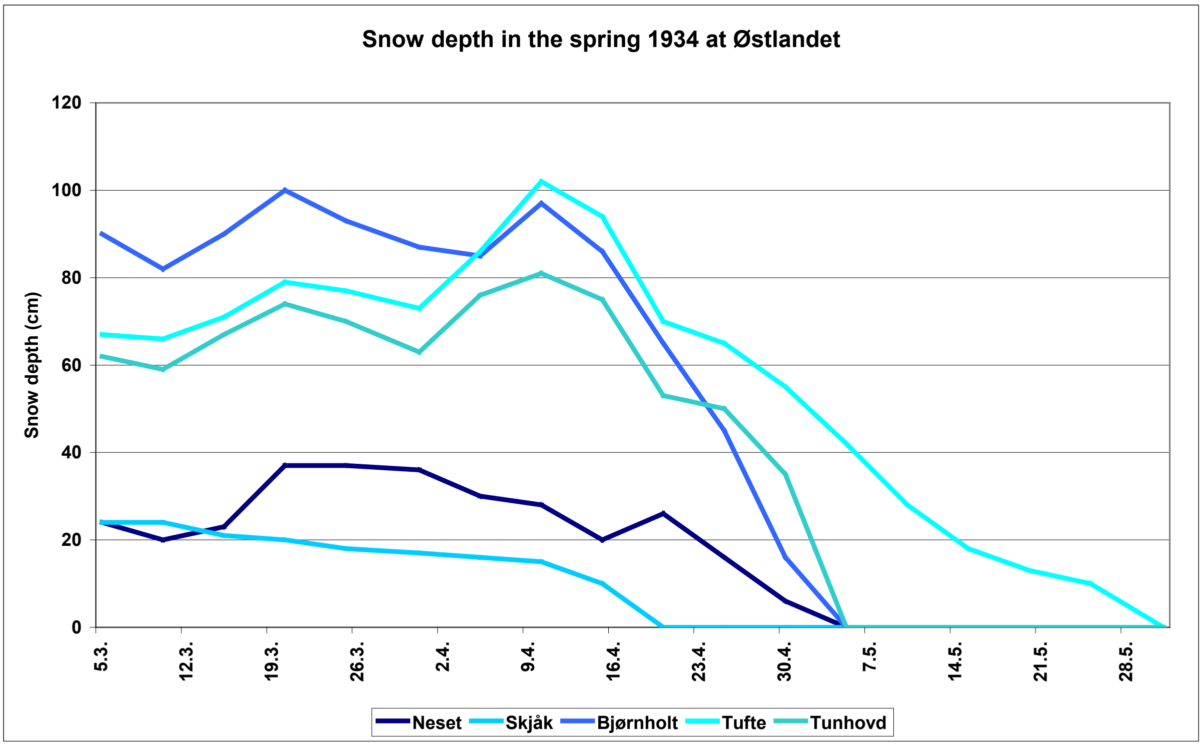


Figure 3.1.26.8 Observed snow depths at Østlandet prior to the large flood in 1934.

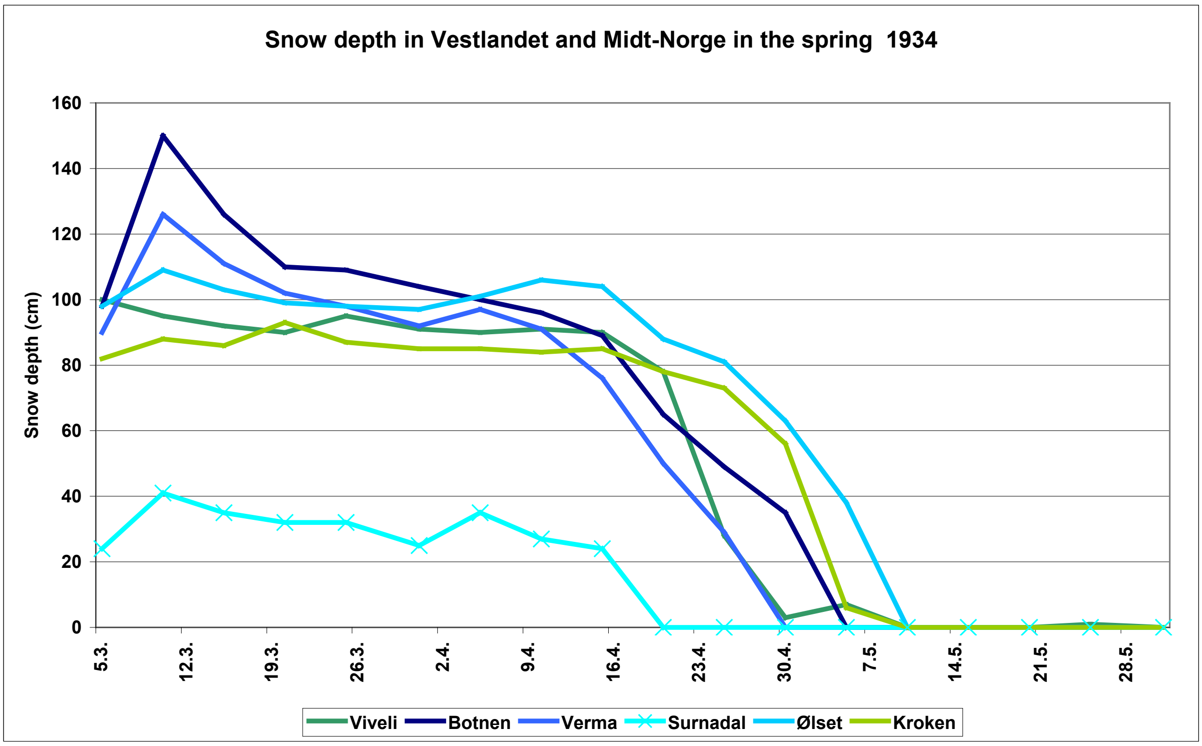


Figure 3.1.26.9 Observed snow depths prior to the large spring flood at stations at Vestlandet and n Mid-Norway in 1934.

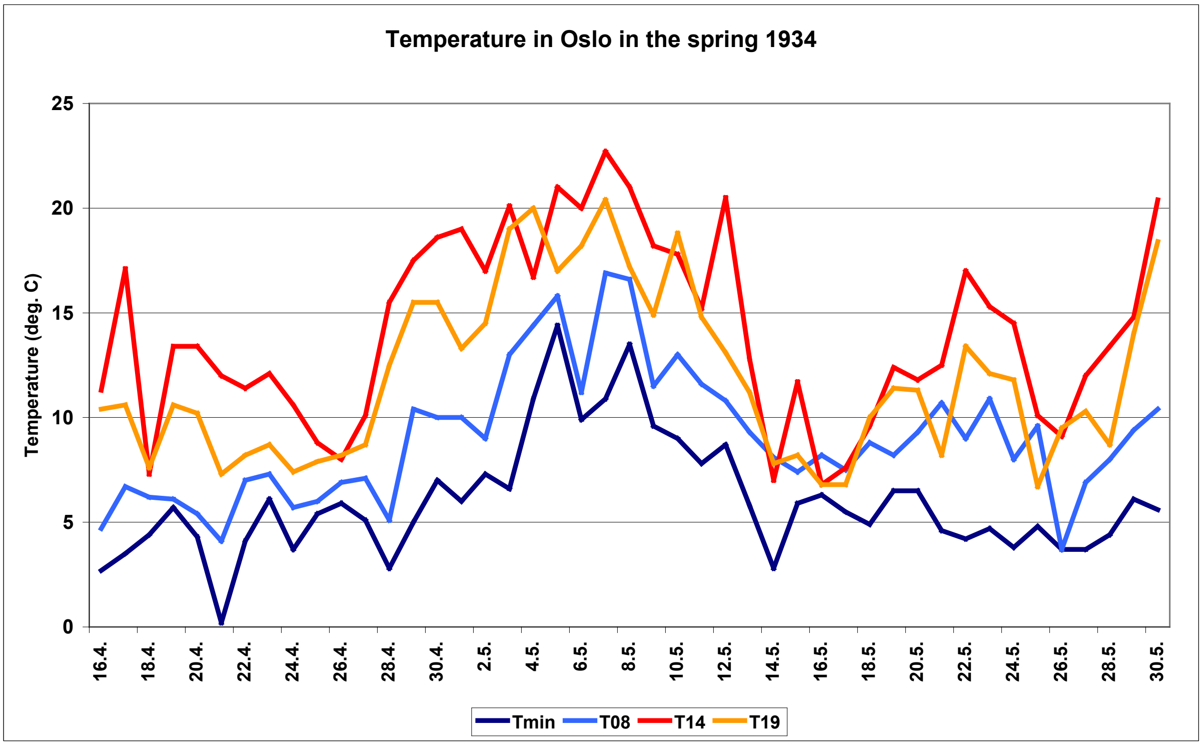


Figure 3.1.26.10 Observed temperatures in Oslo in the spring 1934.
2

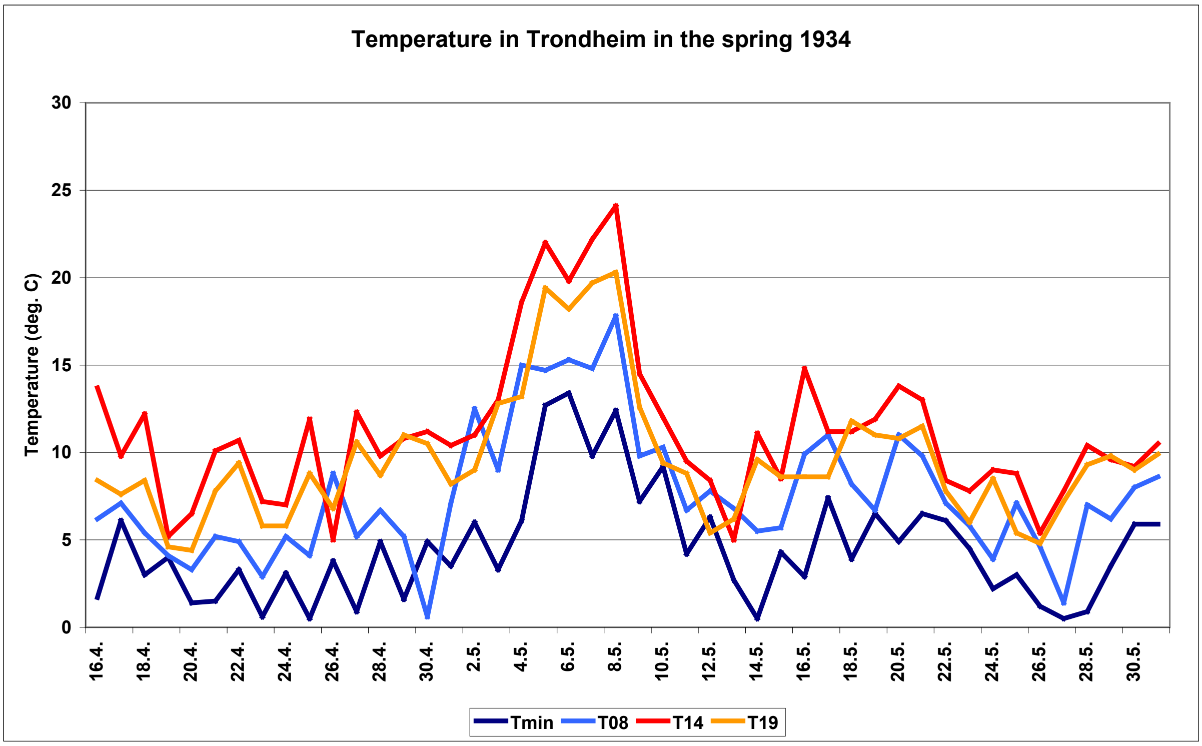


Figure 3.1.27.11 Observed temperatures in Trondhein in the spring 1934.

Flood damages:

Trysil

A property was almost completely destroyed at Trysil, and the loss was assessed to 10.000 NOK.

Østerdalen/Glåmdalen

The intense snowmelt took a bridge over River Hitterelv at Røros at 5:00 on 6 May. Because of further erosion, 30 families were evacuated. The flood started with a major ice run at Koppang. The traffic at railway to Røros was stopped at Rena because of the flood.

The telephone lines were badly affected at Storelvdal, where almost every villages were inacessible for road traffic. 12-15 barns and smaller buildings had been taken by the flood. Åmot power station had to stop operating as the flood water was almost flooding the buildings.

The flood protection works at Heradsbygda was Elverum was opened in the upper end to prevent a total failure at the southern end. Debris caused difficulties by blocking the intake to the dam of the power station at Elverum, and the power line across Glomma at Strandbygda was destroyed.

At Åsnes several square kilometer farmland was inundated. 120 houses at Kirkenear were more or less evacuated.

The railway line of Solørbanen was broken betwwen Roverud and Kongsvinger. Kjeller airport was partly inundated, as well as buildings at Volla at Lillestrøm where flood water had penetrated into the basement.

Gudbrandsdalen

Most of the damages in Gudbrandsdalen were caused by the tributaries to Lågen, not by the main river at the bottow of the valley.

A new sports arena was inundated at Otta.

Storåa at Kvam went bankfull and destroyed the railway line at four places north of the station (Teigen, 2000). River Veikleåa grew, and large rocks and gravel came rolling in the flood water. The houses next to the rivers were evacuated. Veikleåa destroyed a new railway bridge. The flood brought a lot of debris such as trees which got stuck in the riverbed and threatened to build up dams. This was prevented by the use of dynamite. Several houses and gardens were damaged. The traffic was maintained by driving passengers past the locations where the flood had damaged the railway line at Kvam, Sjoa and at Lundamo-Støren where the passengers had to walk some distance carrying their luggage.

The flood caused a football match to stop at Ringebu when the flood carried timber into rhe football field. The main road through Gudbrandsdalen was inundated north of Øyer. It was possible to drive on smaller roads via Fåberg-Gausdal-Tretten.

Mjøsa flooded into the tunnel at Hotel Victoria at Hamar.

Etna-Dokka

The flood was the largest since 1916. The damages were mostly caused by inundation of large areas of farmland. Much timber was floating over the inundated fields. One dam used for flood protection vas damaged at Etna. A timber boom at Tingvoll failed at Dokka, releasing timber into the river.

Sogn

Many rivers in Sogn had large floods. Landslides had damaged farmland and blocked the main road at Ulvisbakken at Filefjell. The road was also blocked of a land slide at Bjøråker. The river was running on the road at Voldum, where farmland was destroyed. At Stønjum much of the farmland was now a stone desert.

Nordfjord

The flood was caused by intense snow melting and rainfall at Stryn, where the main road was flooded at 11 locations 9-11 May. There were also several landslides in Stryn.

Romsdal

A large landslide cut the railway line 3-4 km north of Verma station at the Herschel farm. Another slide at Skiri farm damaged farmland and caused a large inundation at the farm. The families were evacuated at both farms.

Nordmøre

The flood caused extensive damages to farmland at Todalen. At Surnadal three power stations, roads and bridges were destroyed.

Trøndelag

The flood caused damages at River, Driva, River Orkla, River Gaula and River Nidelva. The bridge across Orkla at Svorkmo was partly undermined, but 100 men succeeded in saving the bridge. The water did almost shift to a new channel at Meldal, threathening the railway, Thamshavnbanen. Some tributaries further down stream had shifted into new river beds. The flood in River Gaula was threathening two farms at Singsås. Several farms were evacuated at Melhus.

The flood in River Nidelv at Selbusjøen reached the second highest level in the lake. Only the level of the flood in 1707 was higher. 4 km of the road from Selbu toward Hell was inundated, and the road from Selbu to Tydal was also blocked. The flood caused calso damages at Snåsa.

3.1.27 Rainfall floods in Buskerud and Telemark 6 August and 3 September 1934.

Two large rainfall events occurred in Buskerud and Telemark in the late summer end early autumn 1934. Heavy convective showers caused floods at Tinn and at Gjerstad in west Telemark and Vegårdshei in Aust-Agder 4-8 August. Figure 3.1.27.1 show observed daily rainfall and discharge at selected stations in the district.

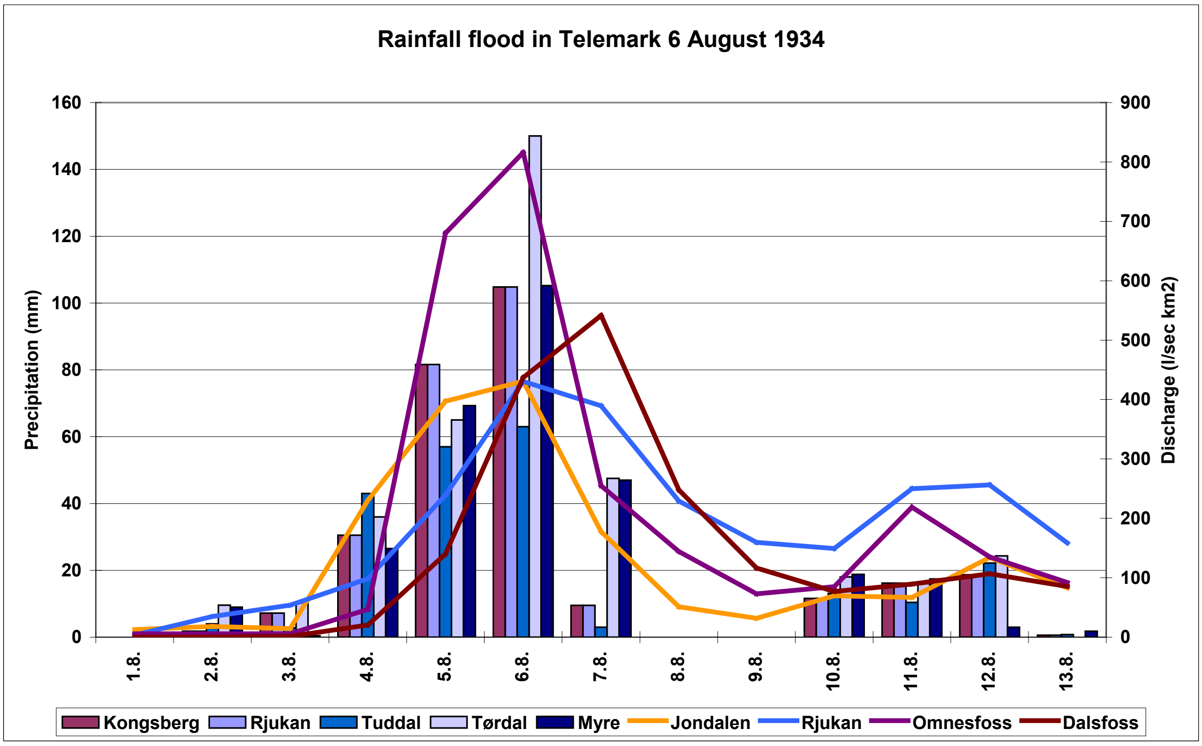


Figure 3.1.27.1 Observed precipitation and daily discharge during the large rainfall flood in Telemark in August 1934.

The flood was the largest observed in River Heddøla at Omnesfoss 1921-2010. The peak of the flood in 1927 was probably larger, but the instrument failed before the peak was reached in 1927. The flood was large in River Hjartdøla and River Bøelva but the floods were not among the largest in these rivers. The flood was second largest naturalised flood in River Drammenselv at Døvikfoss 1912-1990.

A depression was moving northeastward from a position southwest of Ireland across England and the North Sea 1-6 August. A week depression over Polen and Tsjekkoslovakia moved westward towards Germany. Warm and humid air was streaming from southeast over Østlandet on the northern flank of the trough. Weather types were: **WS** (Grosswetterlagen) and **CNE** (Lamb/Jenkinson). The largest one-, two-, three- and four-day rainfall was observed at Tørdal (150/215/262/298 mm) and at Rjukan (105/186/217/226 mm).

The second event 31 August- 3 September

In late August and early September another spell of showery weather with intense rainstorms caused new floods at Sørlandet and the western part of Østlandet. The largest daily rainfall intensities were observed in the catchments of River Vegårdselv and River Gjerstadelv, where no gauging stations were operating at that time. Figure 3.1.27.2 show observed daily precipitation and discharge at some stations during this event.

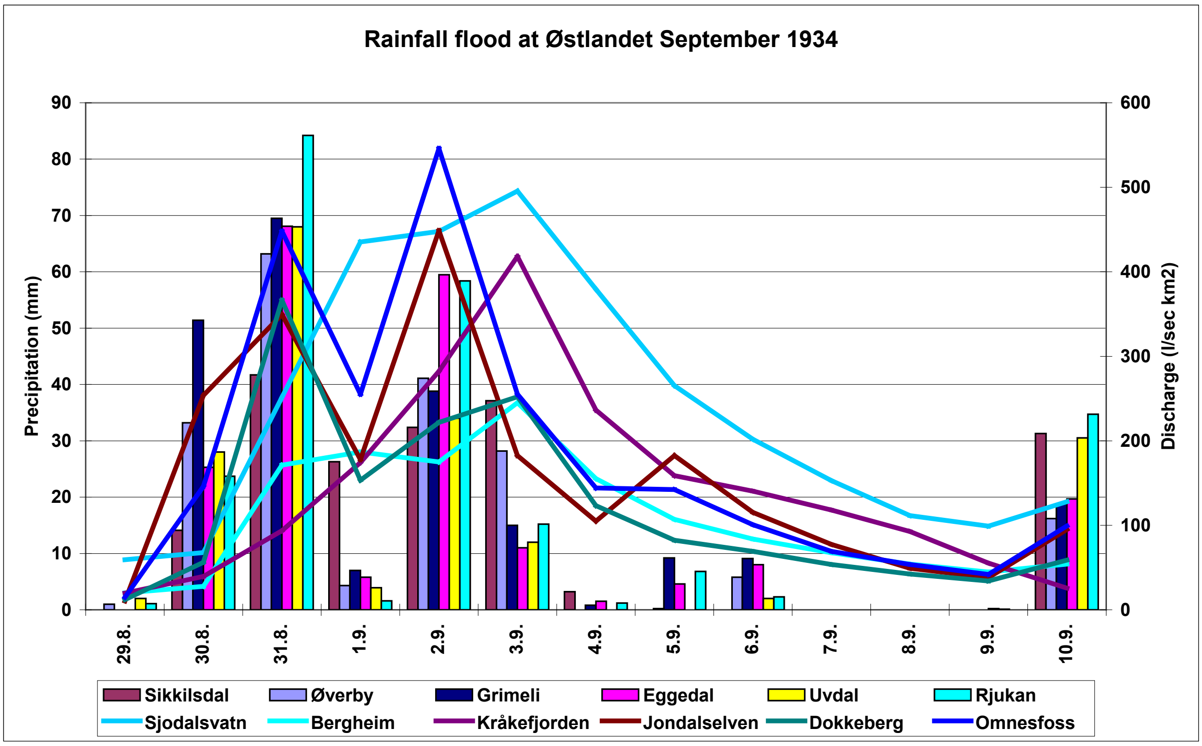


Figure 3.1.27.2 Observed precipitation and daily discharge during the large rainfall flood in Buskerud and Telemark in September 1934.

The flood was the second largest naturalised flood in River Drammenselva at Døvikfoss 1912-1990, fourth largest in River Snarumselva at Lake Krøderen 1889-2007, third largest in River Hallingdalselva at Bergheim 1920-2004. In River Begna the flood was the largest naturalised flood at Killingstrykene 1905-1995 and at Lake Fløafjord second largest 1921-2002. In River Simoa at Lake Kråkefjorden the flood was the largest 1930-2001. In River Numedalslågen the flood was fourth largest naturalised flood 1874-2007, in River Jondalselv fifth largest flood 1919-2010 and in River Uvdalselv at Dokkeberg fourth largest 1915-1966. In River Skienselv and in smaller tributaries to River Drammenselv the flood in September was less than the flood 6-8 August 1934.

Between 30 August and 4 September, a depression was situated between Scotland and Iceland with secondary depressions in the North Sea. An anti-cyclonic ridge extended southwestward from Northern Russia towards the Atlantic. An air stream from east-southeast across Østlandet was causing locally heavy showers. The weather types were **TB**/**WZ** (Grosswetterlagen) and **C**/**SW** (Lamb/Jenkinson).

Flood damages

The first event caused some landslides, blocking the railway between Larvik and Aklangen. The road between Hovin and Tinn was also blocked by slides. Farmland was inundated at Hedal and Rauland, damaging the crops. The pier at Skien was also inundated. The boat traffic at Bandak Canal was also halted.

The second rainfall event caused also houses to be evacuated at Notodden because of fast-rising water level in River Tinne. Farmland next to River Numedalslågen was inundated. The production of the factories was temporary halted. The flood caused 18.000 logs to break a dam in river Begna at Bagn in Valdres. A young boy was killed by the lightening during the thunderstorm.

3.1.28 The large rainfall flood in Telemark and Gudbrandsdalen in August-September 1938.

A widespread rainfall flood occurred at Østlandet in the late summer 1938. The flood was caused by thunderstorms over three days which locally was described as a reminder of the conditions under Storofsen in 1789 and Storflaumen in 1860. The flood is the largest flood observed in River Otta at Lalm 1907-2013. The flood levels are, however, also known under the floods in 1789 and 1860 at Lalm. The levels of these floods were higher than in 1938, but taking the season into consideration, the 1938- flood was probably as extreme at the two most extreme floods in River Otta. The flood was also severe in parts of River Skienelv catchment and large in parts of the catchment of River Drammenselv. These rivers are however strongly regulated, and the reservoirs reduced the flood magnitudes. Figure 3.1.28.1 show observed daily rainfall and discharge in Gudbrandsdalen and Figure 3.1.28.2 in Buskerud and Telemark.

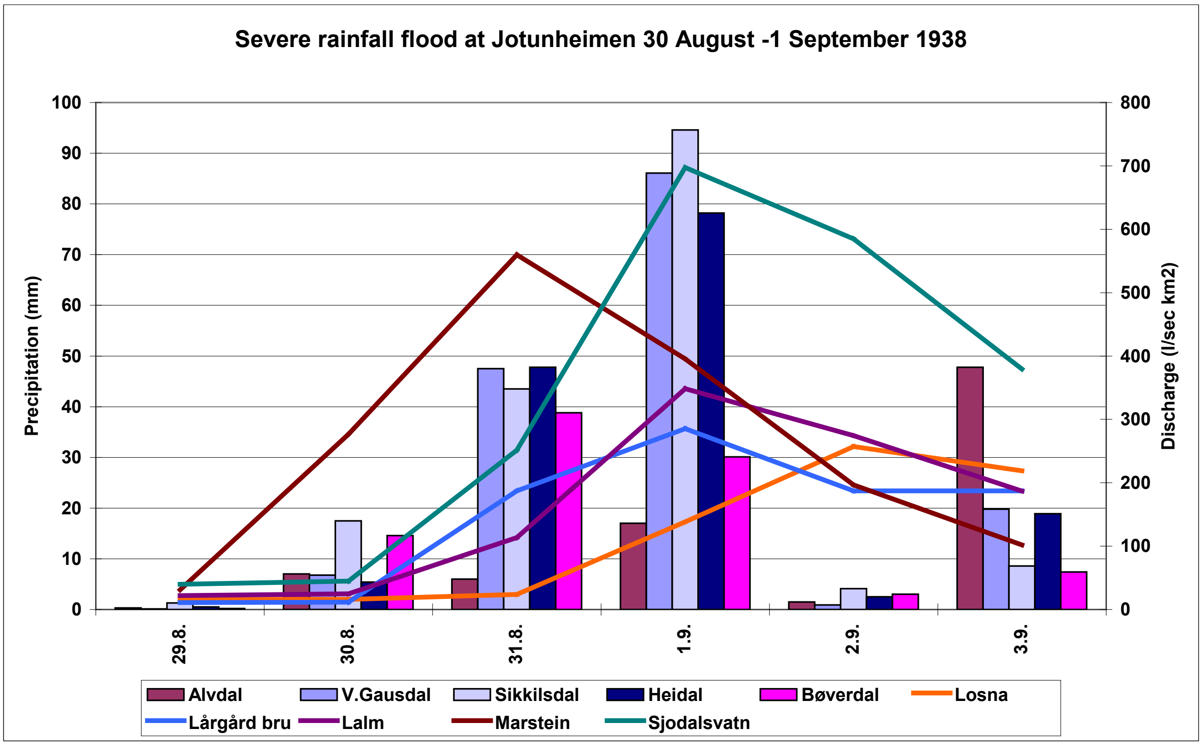


Figure 3.1.28.1 Observed precipitation and daily discharge during the large rainfall flood

in Jotunheimen in August- September 1938.

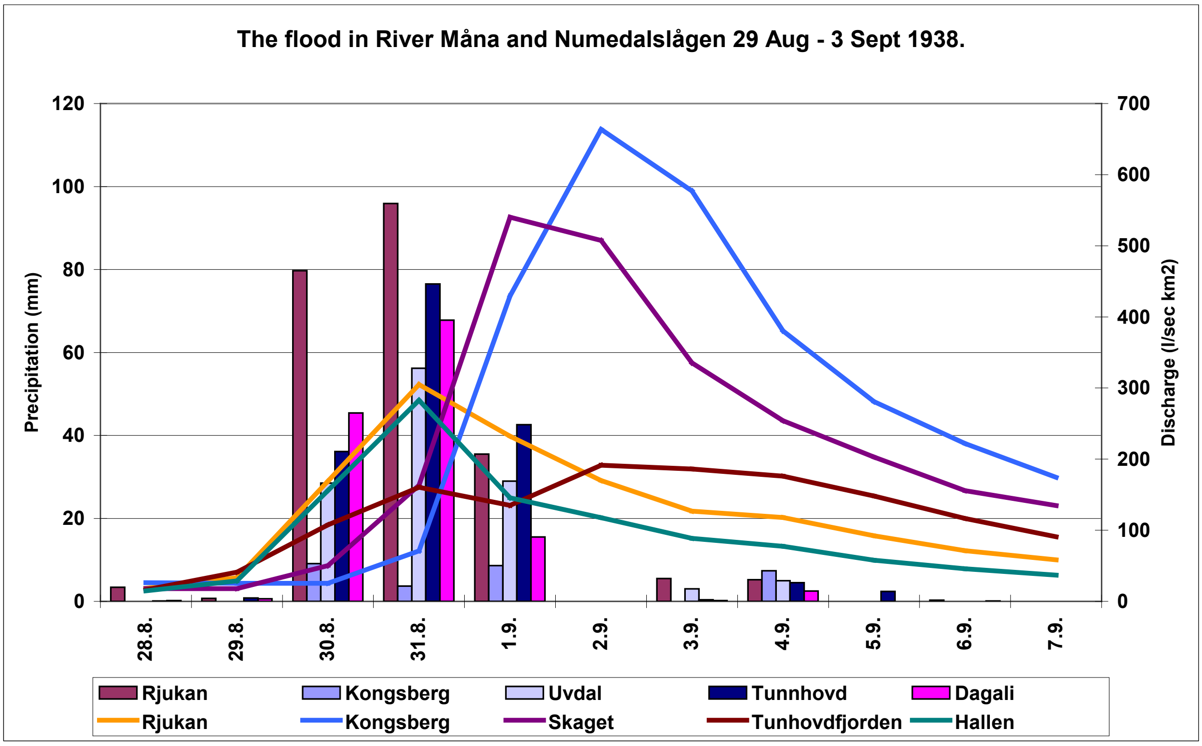


Figure 3.1.28.2 Observed precipitation and discharge (daily values) in Buskerud and Telemark during the flood in August-September 1938.

The cause of the flood:

The flood was caused by a Vb-depression (van Bebber, 1891). In 1938 strong thunderstorms moved in from southeast over Østlandet 29 August. The weather map showed a week depression over Skagerak mowing northwards and was positioned over southern Norway 30-31 August. The depression had the remnants of two old occlusions embedded (Høgåsen, 1998). The air must have been unusually unstable, because of hot air near the ground and very cold air at higher levels. The depression moved gradually southwards, and another depression located further north oner the Norwegian Sea moved southwards across South Norway at the start of September. This depression pulled in varm and humid air masses from east Europe.

The rainfall lasted three days, causing flood in Telemark, Buskerud and Gudbrandsdalen. Most of the rain fell west of Gudbrandsdalen from Gausdal til Ottadalen. Rainfall penetrated also over the water divide to the inner fjord districts of Vestlandet from Kinsarvik to Sunndalsøra. 60 mm or more rainfall was observed at several stations west of the water divide. Warm air in combination with the rainstorms caused large melting at some glaciers at high altitudes. The one- and three-day rainfall at Rjukan was 95,9 mm and 211,1 mm (30 August-1 September). The three-day rainfall at Bygdheim in Hemsedal was 180,2 mm, at Beitostølen 161,6 mm, at Sikkilsdalen 155,6 mm and at Skjåk 87,5 mm.

Flood damages:

Gudbrandsdalen:

River Gudbrandsdalslågen inundated the floodplain from Lesja to Lake Mjøsa causing damages to farms, the railway line and the roads. Most damages occurred from the middle and upper part of the valley. The flood caused damages at the village Fåvang was estimated to 100.000 NOK. At Ringebu 100 farms suffered damages. Houses came floating in the river at Vinstra. At Kvam the severe spring flood in 1934 caused severe damages from the flood in Veikledalen. Flood protection works established after this flood protected Kvam in 1938 from damages of the same magnitudes as the damahes downstream and further upstream.

The damages in Gudbrandsdalen were assessed to 957.959 NOK. The most severe damages occurred at Vågå totalling 469.000 NOK. The damages of 182 properties at Vågå were assessed to 299.262 NOK. Damages to the roads in Vågå were estimated to 80.000 NOK, in Lom 22.000 NOK and in Heidal 92.000 NOK (Kolden, 1988). Damages in Lesja were described in Einbu (1998).

The damages at Ringebu were assessed to 90.000 NOK, at Øyer to 3.600 NOK and at Vestre Gausdal to 1.750 NOK. Kvam escaped the 1938 flood without serious damages, because for the work on the flood protection works after the disastrous spring flood in 1934.

Hallingdal:
The main road blocked at Flå. Smaller rivers and farmland were inundated. The flood caused loss of timber. Landslide from Skogshorn caused damages at Hemsedal. The road from Gol through Hemsedal to Lærdal was blocked.

Dokka and Etnedal:
A girl killed by lightening in Etnedal. River Åseta destroyed two bridges in Øvre Etnedal. Several thousands daa of farmland were inundated. Three roads were closed. Several buildings in the Dokka villages had their basement flooded, and their orchards were damaged. Several thousen of logs were taken by the flood. The damages at Etnedal was estimated to 100.000 NOK.

Valdres:
Record high water level in Lake Øyungen in Øystre Sildre. A power station was partly damaged as water broke into the stations through the windows and the door into the machine room. The damages was estimated to 10.000-20.000 NOK. The bridge on the road between the Bygdin Hotel and Bygdisheim taken by the flood.

Numedal:
The main road to Dagali severely damaged at Sønstebø in Uvdal. All logs left in the tributaries to River Numedalslågen moved downstream into Lake Norefjord.

Telemark:
Extreme thunderstorm in Telemark, worst in Drangedal. More than 1000 lightening was counted in just one hour at the Skiensfjorden. The basements of the bulidings at Notodden were inundated, and the streets turned into rivers. The artificial silk factory at Notodden was struck by lightening. Power cut at Svelgfoss and Lienfoss power stations. Surplus inflow to Lake Møsvatn was released throuhj the Rjukanfoss waterfall. A tornado struck down forest at Laksefjell.

River Vendeåi inundated a road in Hjartdal. A cemetry and 4000 daa of farmland was inundated at Flatdal at twenty farms. Most of the crops were destroyed at thirteen of these farm with an estimated value of 200.000 NOK.

3.1.29 The spring flood in South Norway in June 1939.

In June 1939 mountain catchments at Østlandet, Vestlandet, in Nordland, Troms and Finnmark was simultaneous affected by a large spring flood 19-20 June. Figure 3.1.29.1 show observed daily precipitation and discharge in catchment in Østerdalen and Gudbrandsdalen, in Figure 3.1.29.2 in Valdres and Hallingdal, in Figure 3.1.29.3 in catchment around Hardangervidda and in Figure 3.1.29.4 in Troms and Finnmark. The spring flood in rivers flowing to the west from Hardangervidda is shown in Volume 3.1.29.3.

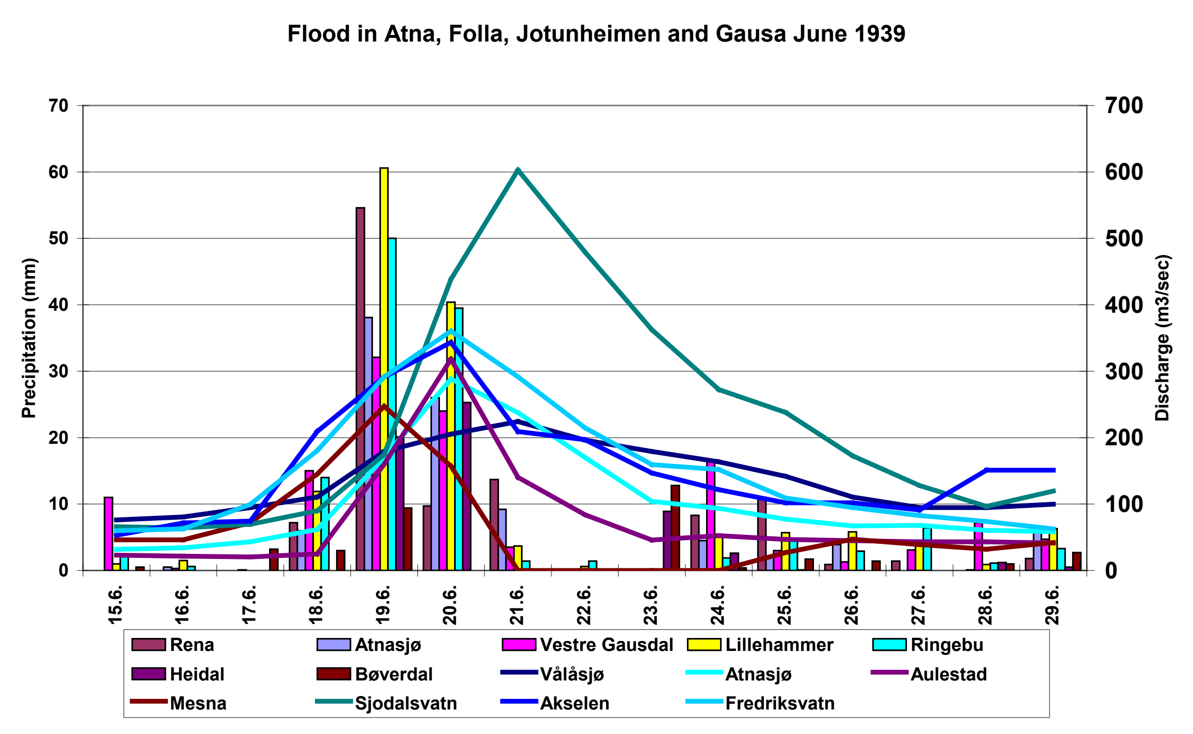


Figure 3.1.29.1 Observed precipitation and daily discharge in Atna, Folla, Jotunheimen and Gausa in June 1939.

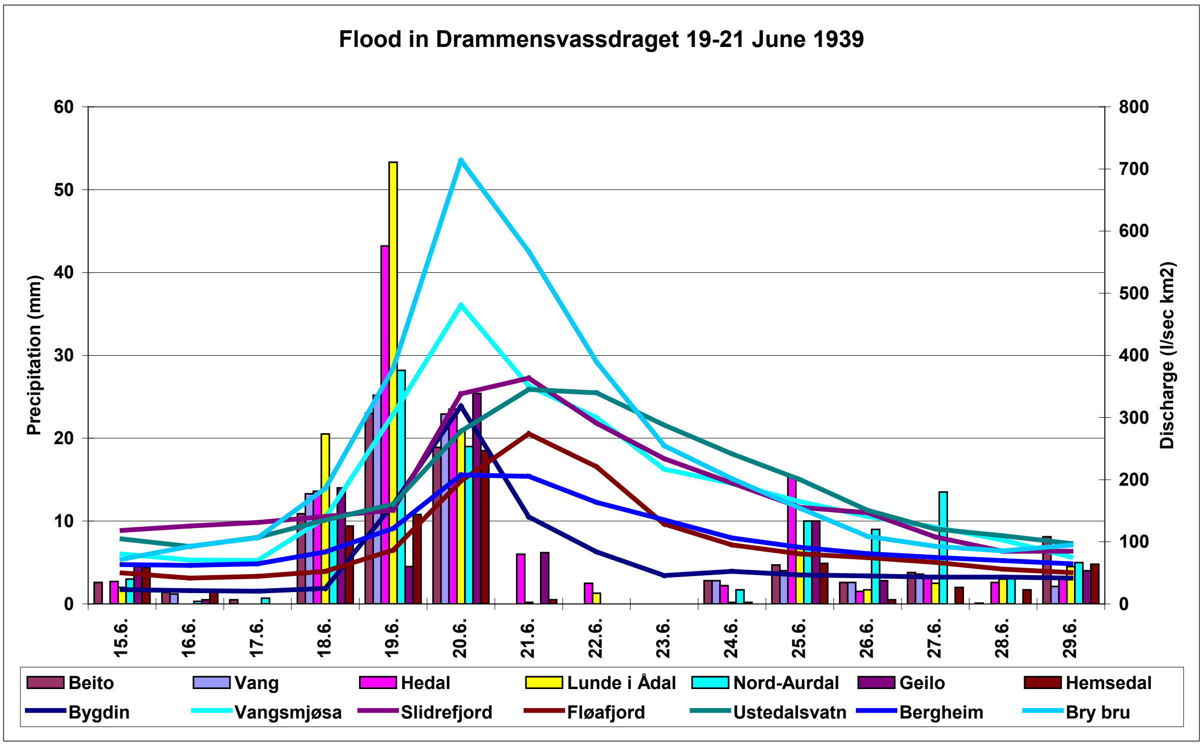


Figure 3.1.29.2 Observed precipitation and daily discharge during the flood in Drammenselv and Hallingdal in June 1939.

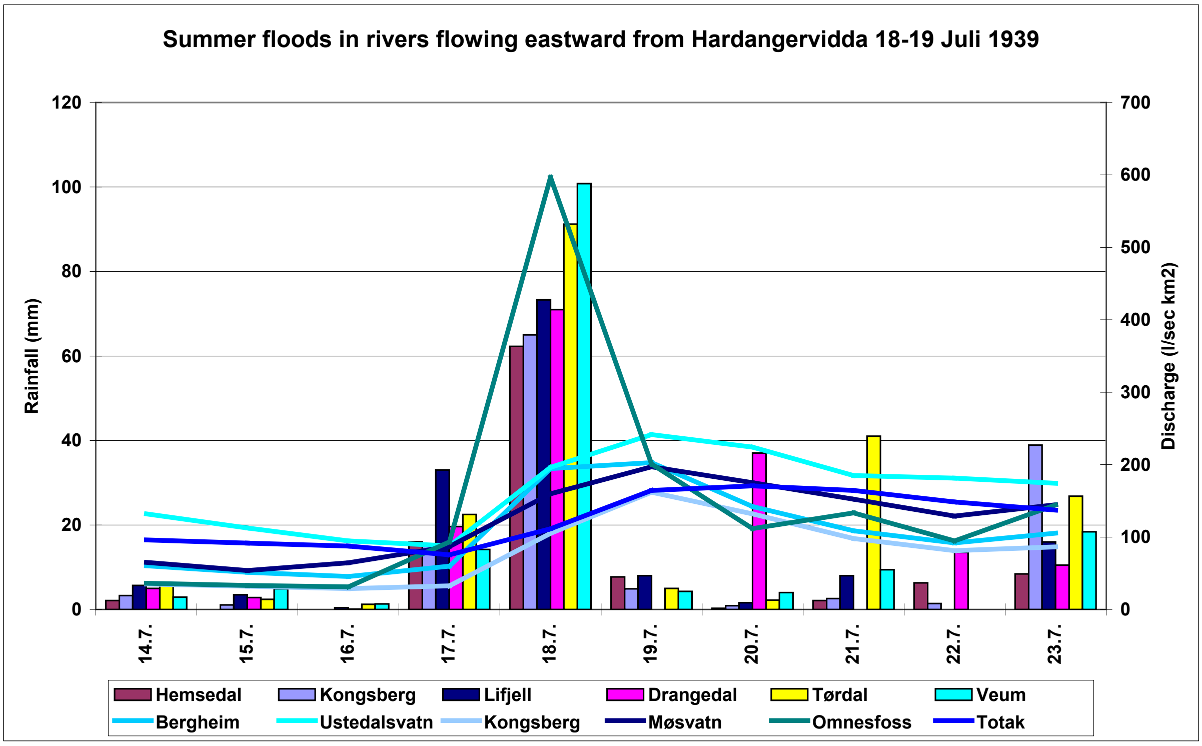


Figure 3.1.29.3 Observed rainfall and daily discharge in rivers draining Hardangervidda to the east during a summer rainfall flood in July 1939.

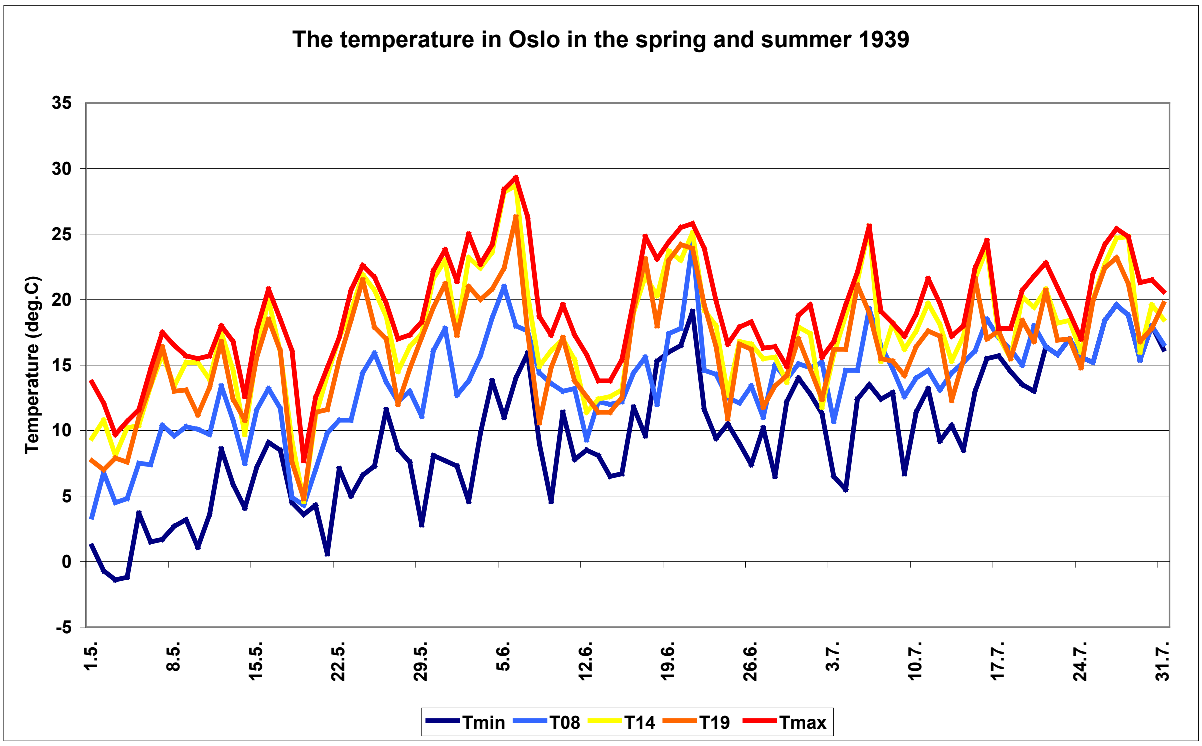


Figure 3.1.29.4 The observed air temperature at Oslo in the spring and summer 1939.

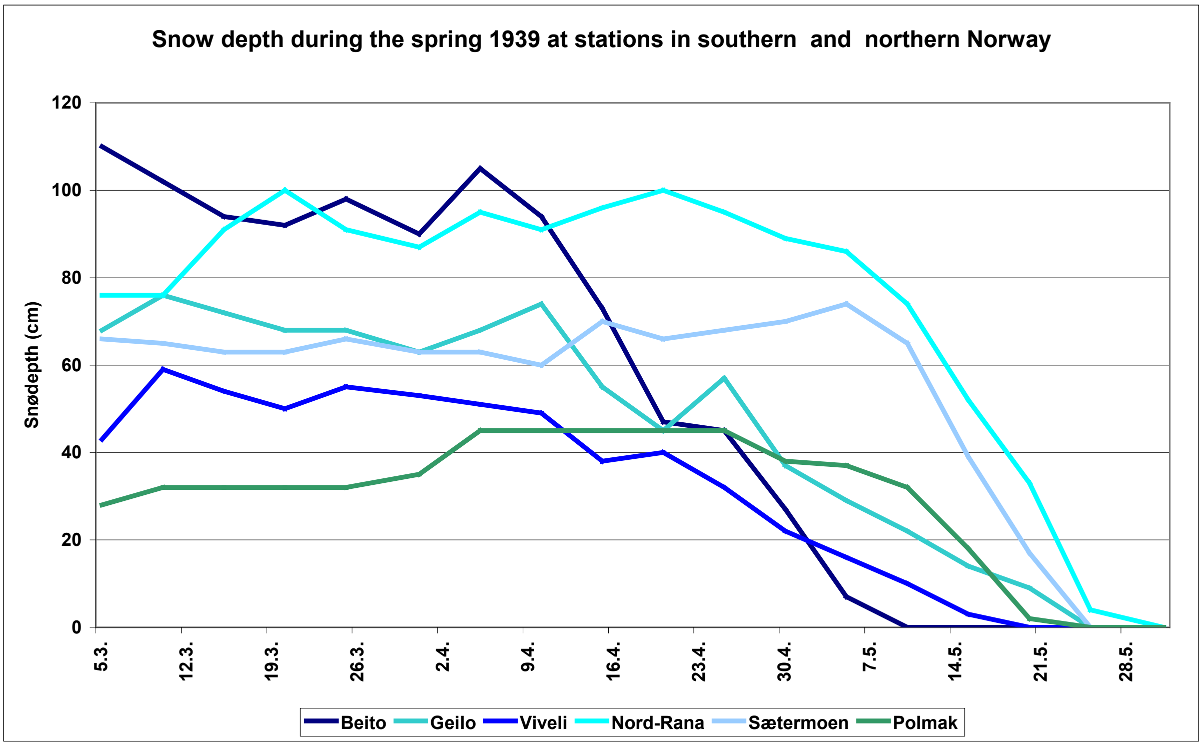


Figure 3.1.29.5 Observed snow depths at stations in South and North Norway prior to the large spring flood in 1939.

The flood was fourth largest in River Atna in Lake Atnasjø 1916-2011, second largest in River Lågen at Harpefoss 1933-1960, third largest at Losna 1896-2010, second largest in River Sjoa at Sjodalsvatn 1930-2010, fourth largest in River Bøvra at Marstein/Akselen 1934-2010, seventh largest in River Otta at Lalm 1907-2010, fourth largest at Lake Fredriksvatn 1934-2005 and 13th largest in River Gausa 1929-2010.

The flood was the largest naturalised flood since 1921 in River Begna at Fløafjord and in River Vinstra at Bygdin and the seventh largest in River Usta at Ustedalsvatn. Det var den sixth largest in River Hallingdalselva at Bergheim 1920-2010 and the 9th largest in Lake Krøderen 1889-2010.

Cause of the flood:

The flood was caused by heavy rainfall on the top of the snowmelt. The temperatures during the spring at Oslo is shown im Figure 2.1.29.4 and the snowdepth at selected station in the mountains in Figure 3.1.29.5. The flood peaked 21 June as a result of the rainfall 18-19 June. The second mountain flood 18 July was caused by the rainfall 17-18 July.

The rainfall in June was caused by an anti-cyclone with a warm kernel was located over the Kola penninsula with a ridge extending southwestwards over much of av Norway. A depression was located at the North Sea woving from the Norwegian Sea north of Great Britain. The rainfall 18-20 June was caused by weak secondary depressions in Skagerak. The temperature in North Norway 21 June fell as a cold front moved in.

The weather types were: **WW/HNA** (Grosswetterlagen) and **C/CNE/NE** (Lamb/Jenkinsson).

3.1.30 The mountain flood in South Norway in June 1950.

The largest spring flood observed in rivers west of the water divide to the Sørfjord in Hardanger occurred in June 1950. Some of the rivers flowing eastwards at Hardangervidda and from the water divide to Sogn had also floods, but generally less extreme than the floods in the rivers to the west. Figure 3.1.30.1 show observed daily rainfall and discharge in some of the rivers to the east.

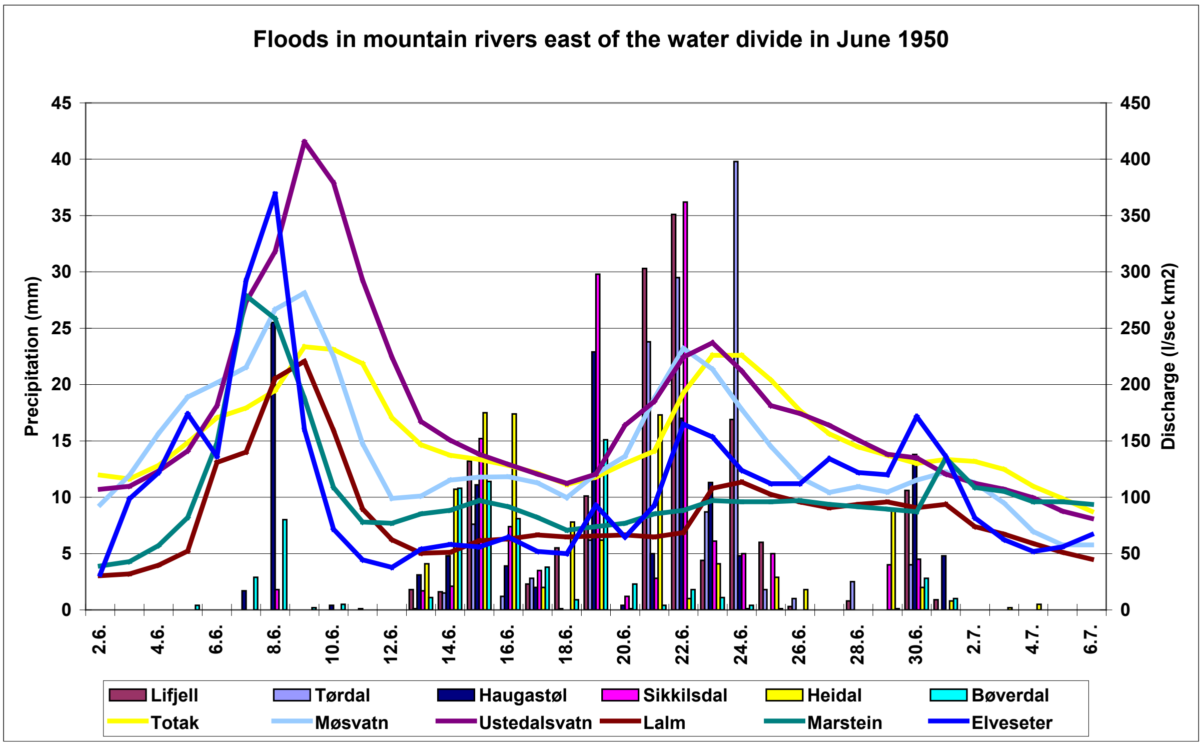


Figure 3.1.30.1 Observed rainfall and daily discharge in mountain streams draining eastwards in June 1950.

Cause of the flood:

Initial conditions

The winter was mild at Sørlandet, otherwise the winter temperatures were close to normal.

The flood

The peak of the flood coincided with a warm and dry spell between 1- 12 June. The peak occurred 8 June coinciding with a local rainstorm at Haugastøl. The warm period was succeeded with a spell of rain 13- 25 June. There was a secondary peak 23 June, but this was lower than the earlier peak.

3.1.31 The mountain flood in South Norway in July 1958.

The spring flood was late in the season in 1958 in Gudbrandsdalen. Consequently, the alpine districts in Jotunheimen contributed heavily to the flood. Figure 3.1.31.1 show observed daily rainfall and discharge observed at stations in Gudbrandsdalen. Floods occurred in many other rivers draining westwards from the water divide to the bottom of the fjords in West Norway ie in Hardanger, Aurland, Lærdal, Årdal, Romsdal and Sunndalen. Figure 3.1.31.2 and 3.1.31.3 show observed daily rainfall and discharge at stations in some of these rivers.

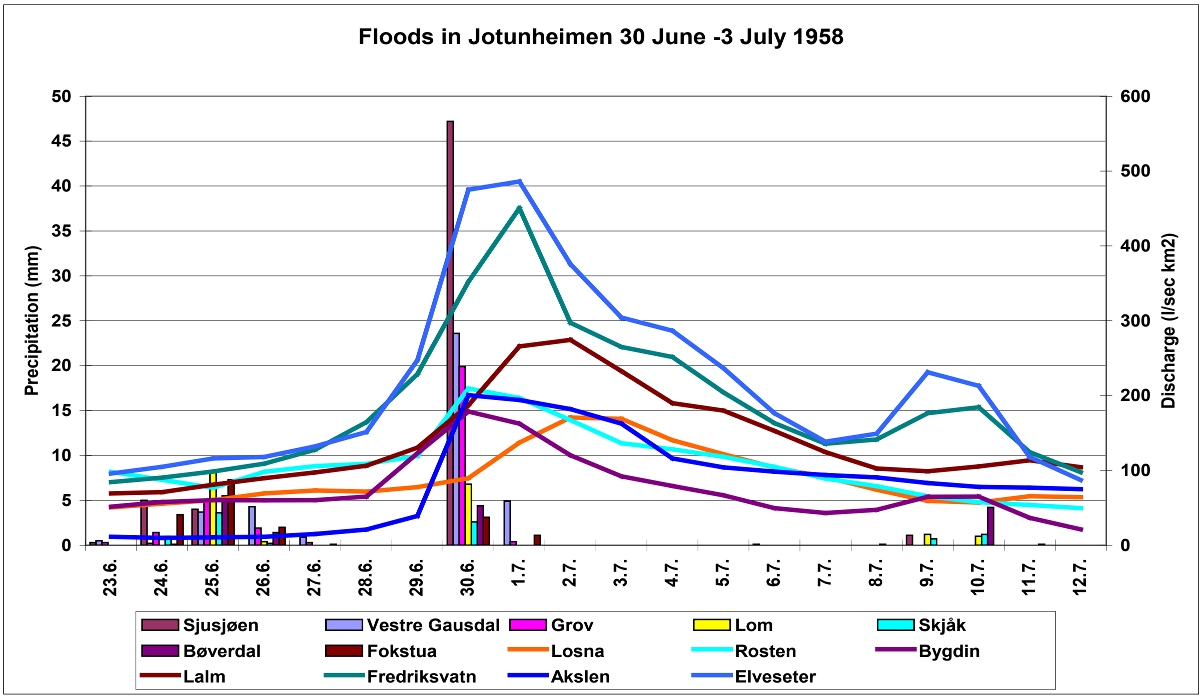


Figure 3.1.31.1 Daily rainfall and discharge in Gudbrandsdalen during the flood in 1958.

The flood was the largest observed in River Otta at Lake Fredriksvatn 1933-2001, second largest at Lake Breiddalsvatn 1917-2002 and fourth largest at Lalm 1907-2014. The flood was third largest in River Vinstra at Lake Bygdin 1923-2014. The flood was less extreme in River Gudbrandsdalslågen except at Harpefoss where it was the third largest 1933-1960. At Rosten at Sel the flood ranks as the 28 largest and at Losna further downstreams as the 10th largest 1896-2014.

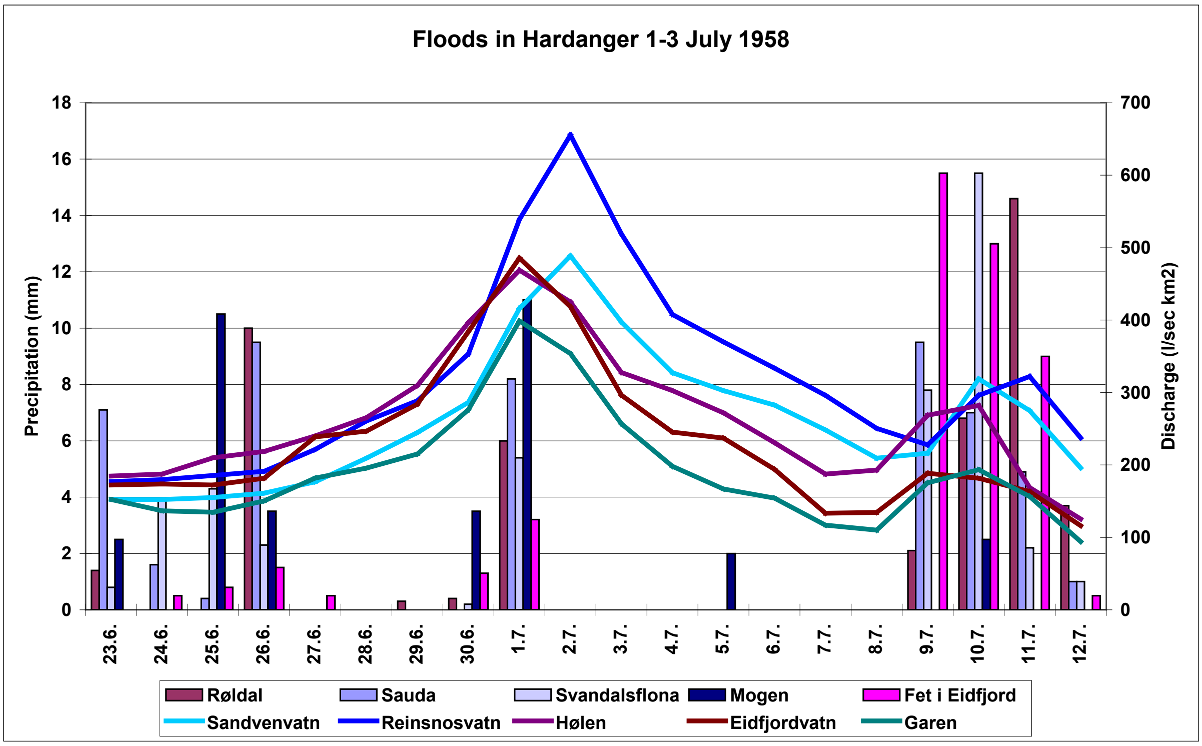


Figure 3.1.31.2 Daily rainfall and discharge in Hardanger during the flood in 1958.

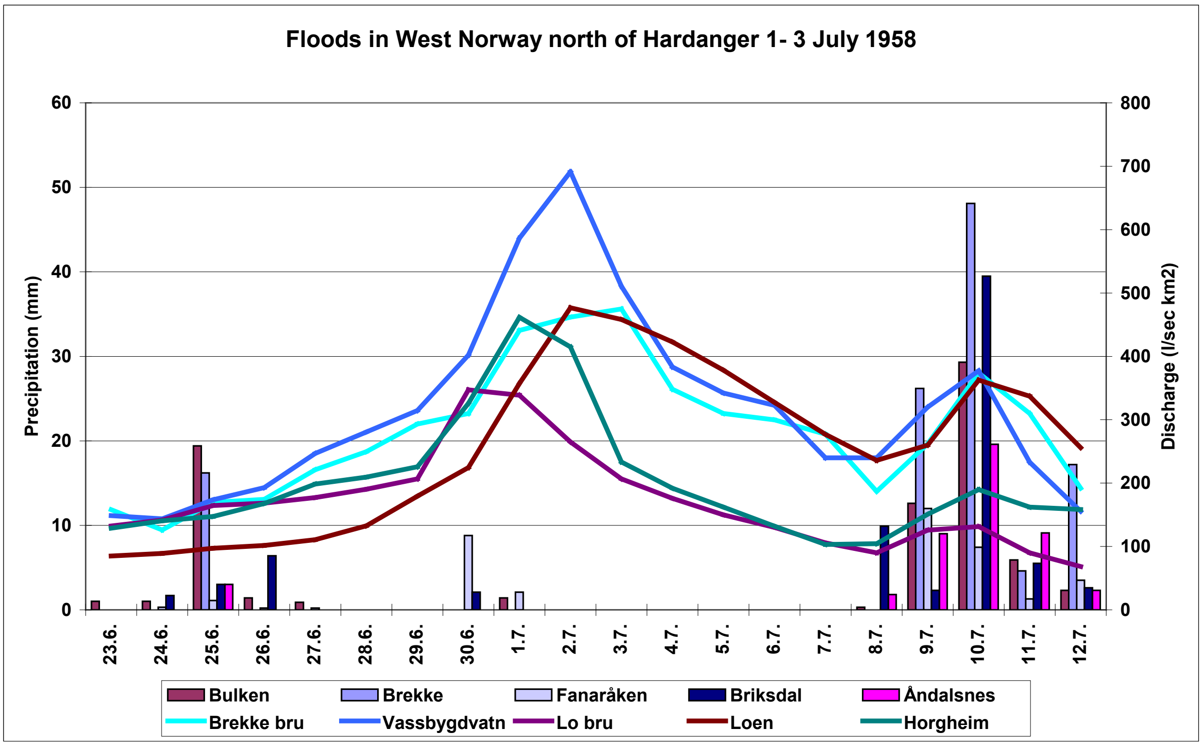


Figure 3.1.31.3 Daily rainfall and discharge in rivers in West Norway during the flood in 1958.

The flood was the largest observed in River Austdøla at Lake Reinsnosvatn in Hardanger 1917-2013 and in River Rauma 1912-2013. The flood was second largest in River Aura at Lake Lille Eikesdalsvatn 1907-1982 and in River Grøva at Bruøy 1949-1990. The flood was rhird largest in River Veig at Viveli 1915-2013, in River Eio al Lake Eidfjordvatn 1928-1914 and in River Aurlandselv at Lake Vassbygdvatn 1908-1980.

Initial conditions:

The temperatures were close to normal during the winter 1957/58, but with a surplus of snow in the mountains in January and February while March had a deficit. There was a large surplus in preciptation in May. The spring flood culminated at the end of May in the lowlands. The remaining snow in the mountains was sufficient to cause a lage flood in many rivers fed from the alpine catchments in case of a sudden warming.

The cause of the flood:

Some rain fell in the mountains 30 June - 1 July, most in the northern part of Gudbrandsdalen. After the rainfall the temperatures started to rise. Figure 3.1.31.4 and 3.1.31.5 show the observed temperatures in Oslo and Bergen during the flood. The temperatures were as high in Trondheim too.

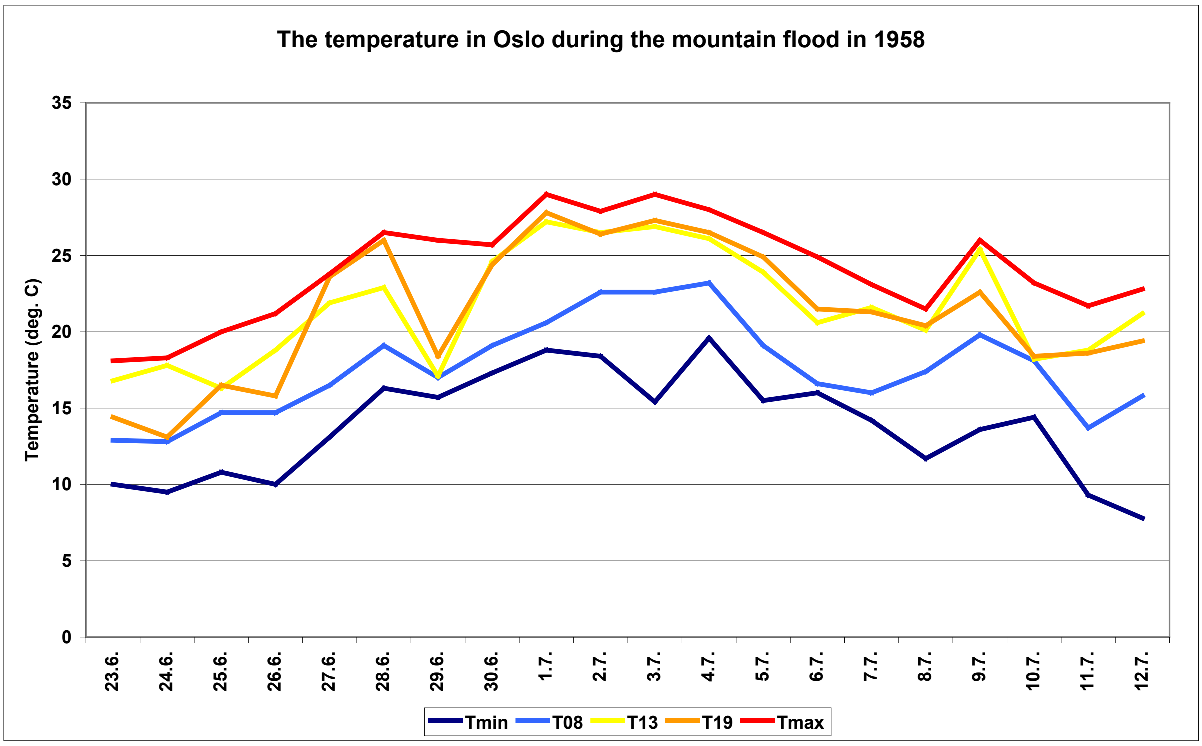


Figure 3.1.31.4 Observed temperatures in Oslo during the mountain flood in 1958

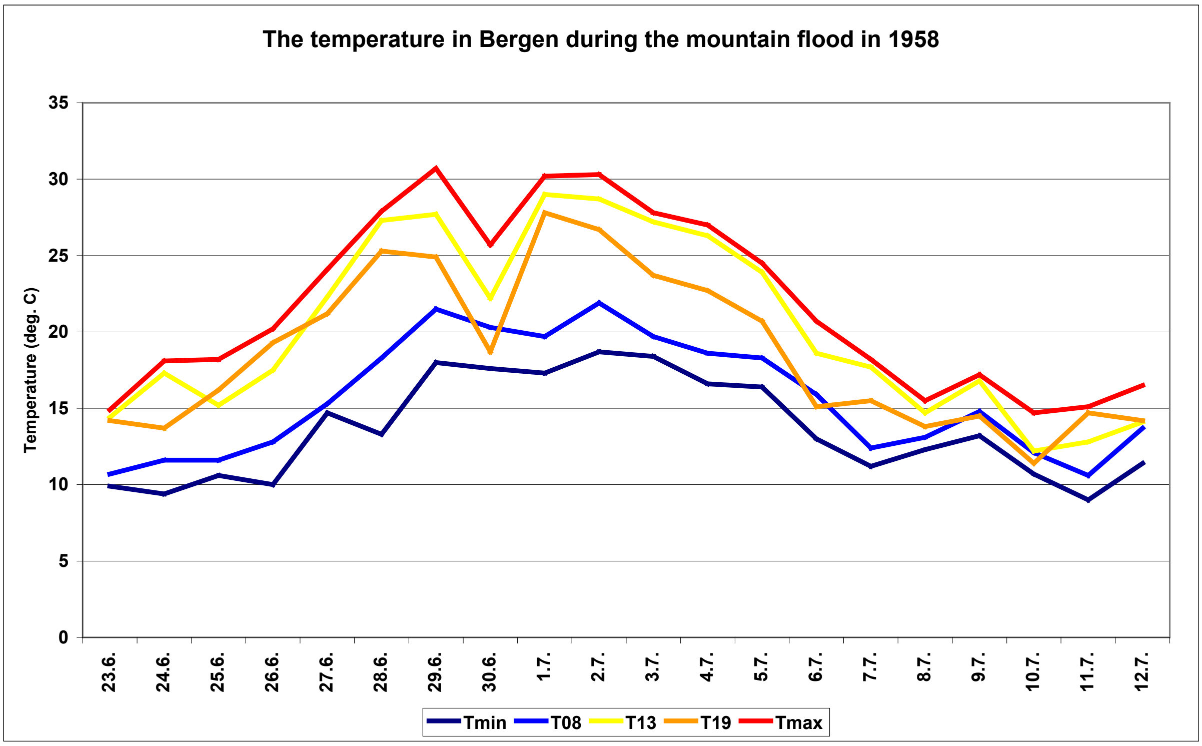


Figure 3.1.31.5 Observed temperatures in Bergen during the mountain flood in 1958

Between a depression over the Baltic States and Poland and an anti-cyclone over Great Britain varm airmasses was streaming towards South Norway from east-southeast. The rainfall 30 June - 1 July was caused by a frontal passage from east ahead of the warm air. This wearher is typical for a Vb-situation although the rainfall associated with the front was less than during other events of this type. After the frontal passage an anticyclone developed over South-Norway. The flood was primarily caused by melting of the remaining snow at high altitudes. The rainfall prior to the heatwave can also have contributed to the flood.

A depression moved in from south toward Great Britain and the North Sea bringing cooler maritime air masses toward South Norway causing heavier rainfall from 9 July causing the temperature to drop more than 5 degrees in the mountains which terminated the heatwave and the flood. At that time most of the remaining snow in the mountains had melted.

The weather type 30 June to 3 July were classified as: **HFA**, **HFA**, **HNZ**, **HNZ** (Grosswetterlagen) and **SE**, **CE**, **E**, **CE** (Lamb/Jenkinson).

Flood damages:

The damages were mostly linked to difficulties with communications, but farmers also suffered from inundated fields, and many buildings had the basements filled with water. Total cost was estimated to several hundred thousand or possibly 1 mill. NOK.

Hedmark
Railway line was temporary closed at Tangen south of Hamar because of a derailed train.

Gudbrandsdalen
Rv 50 blocked at Ringebu. Traffic diverted to minor roads. Trees and some farmhoused were standing in water on the flood plain at several locations from Lesja to Lillehammer.

Rv 160 was blocked between Vågåmo and Grotli because of inundation near Lake Vågåvatn and at several locations in Skjåk. Bus lines were temporary replaced by a motorboat. Several local roads in Skjåk were blocked by swollen minor brooks. Rv 120 through Bøverdalen was blocked 15 km from Lom and at Lake Bøvertunvatn.

River Finna moved large boulders, but the flood protection works succeeded in containing the flood within the river channel.

The railway traffic was maintained on Dovrebanen with some difficulties. Raumabanen was inundated at two locations at Lesja.

Romsdal
The main road Rv 185 was blocked by inundation at Seterbøen, Halsa, Horgheim, Hole and Skiri from River Rauma. The water depth at Seterbøen was 3 meter over the road. Snow plows were used to clear roads from the debis. The railway line was inumdated at two locations, and timber and debris accumulated on the line. Passengers to Åndalsnes were taken by train to Oppdal and transported by bus through Sunndal. All potato fields and grass land were destroyed because of the inundation with subsequent deposition of gravel and sand.

Lærdal
The flood protection work next to River Lærdøla was damaged at a length of 125 meter at the farms at Ljøsnegard. 50 men with eight lorries worked to repair the damages.

3.1.32 A rainfall flood at the southern part of Østlandet 11–12 November 1961.

Heavy rainfall caused floods in several small lowland rivers at Østlandet in November 1961. The station network was less developed in smaller rivers prior to 1966/1967. Observed daily rainfall and discharge are shown in Figure 3.1.32.1 for two lowland catchments in River Jarenelv and River Sokna near Lake Tyrifjord in Buskerud. Many other small rivers within the district had floods, but these rivers had no observations as early as in 1961.

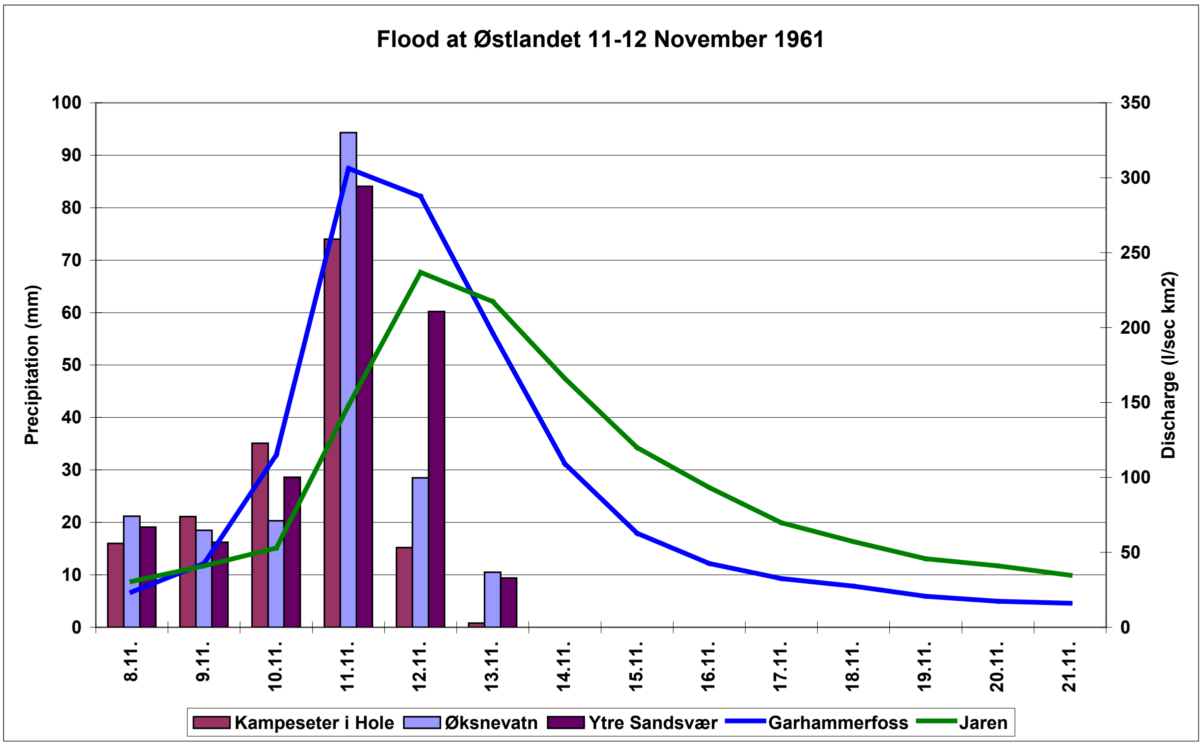


Figure 3.1.32.1 Observed daily rainfall and discharge in small rivers at Østlandet 11 – 12 November 1961.

The flood was the largest on record at 12.72 Jarenvannet 1924-1990 and in River Sokna at 12.114 Garhammerfoss 1937-1978.

Cause of the flood

The distribution of the snow cover 11 and 12 November is shown in Figure 3.1.33.2. The lowland catchments west of Oslo had not yet accumulated a snow cover. The flood was therefore caused by rainfall, not snowmelt in the lowlands. Snow melt has however contributed to the flood in catchment at higher altitudes further west. Figure 3.1.32.3 to 3.1.32.5 show the distribution of temperature, snow melt and precipitation at Østlandet 11 and 12 November. Melting snow contributed to the flood at higher levels further west and north.

Figure 3.1.32.2 The water equivalent of snow at Østlandet 11 and 12 November 1961.

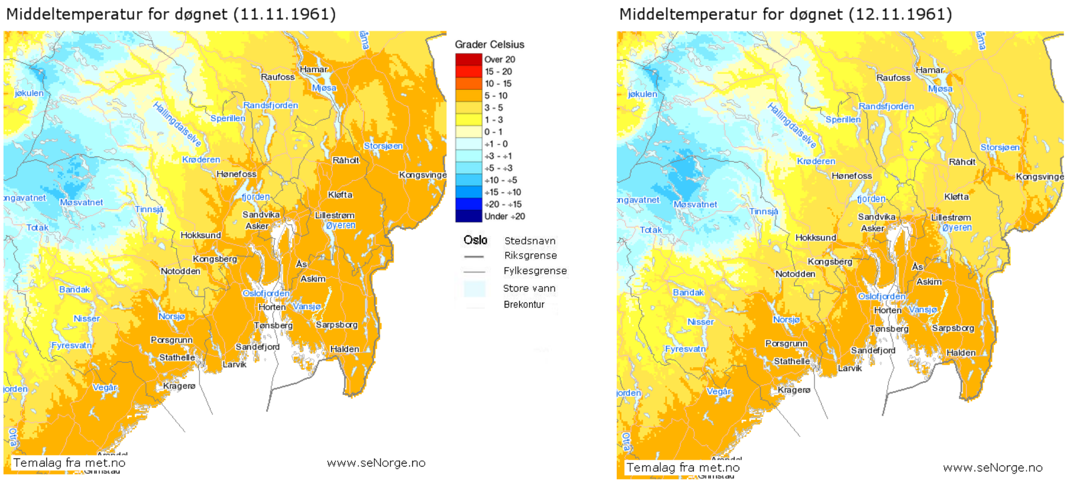


Figure 3.1.32.3 The temperature at Østlandet 11 and 12 November 1961.

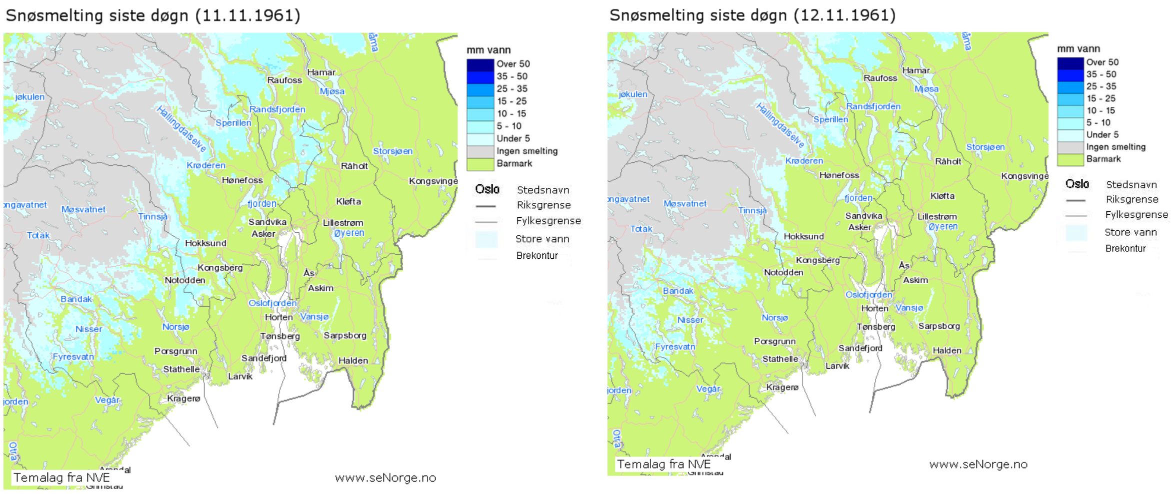


Figure 3.1.32.4 The contribution from melting snow to the flood at Østlandet 11 and 12 November 1961.

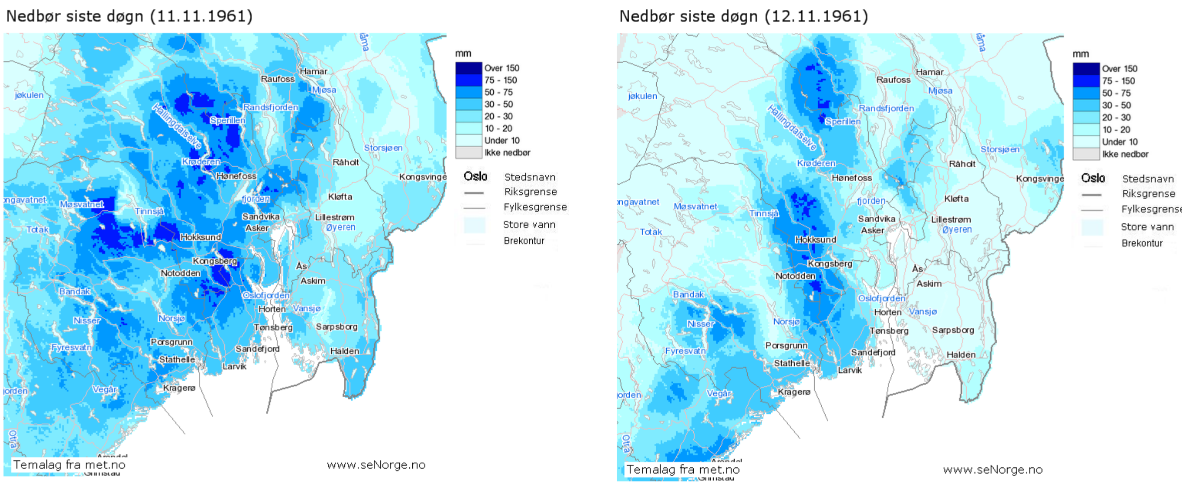


Figure 3.1.32.5 The distribution of the precipitation at Østlandet 11 and 12 November 1961.

The weather type:

Blocking anti-cyclones were located at the Atlantic southwest of Great Britain and from the Kola Peninsula to Novaja Zemlya. Warm air masses were streaming northwestward from the Black Sea region towards Norway and the Norwegian Sea. A depression was extended from the North Sea to Denmark and Germany. The polar front extended from Nord-Troms over Bottenviken, Finland to Russia was stationary and without any cyclogenesis. A string of depressions moved along the polar front on the southwest flank of the warm air stream. The depression moved across southern Norway. The weather type lasted several days and is typical for the Vb-type circulation causing heavy precipitation at Øst- and Sørlandet. The weather types were classified as **TRW** (11) and **HNFZ** (12) (Grosswetterlagen) and **E** (11) and **ANE** (12) (Lamb/Jenkinson).

Flood damages:

Heavy precipitation fell in Agder, Telemark, Buskerud, Akershus, Sør-Oppland and in Gudbrandsdalen. The rainfall lasted five days at some locations at Telemark where fields, grassland and roads were inundated. Rv 350 through Drangedal was closed. The roads in Numedal were damaged at several locations. Traffic on RV 7 beween Hønefoss and Sokna was also halted. Five families were evacuated at Åmot at Modum because of the flood. In Bærum River Lomma flooded over the riverbanks. The same happened at Lake Harestuvann, where the railway line was broken. The water damaged RV 70 at Gran railway station where several buildings were damaged. River Mesna flooded in the district near Lillehammer. Melting snow and rainfall flooded the roads at several locations in Gudbrandsdalen, preventing the traffic through the valley.

3.1.33 The spring flood in East Norway in May 1966

Between the 1940s and 1965 few if any large spring flood occurred in southern Norway. Two large mountain floods occurred, one in 1944 and one in 1958, but these floods did not cause damage in the lower parts of the main rivers.

Initial conditions:

The winter 1965/1966 was the coldest winter on the average in east Norway since the Meteorological institute started to publish regional summaries in 1875. No single month this winter was the coldest, but the cold weather started in November and lasted into April. There were no mild spells during the winter, allowing a substantial snow cover to develop as well as ice to form in inland rivers. Figure 3.1.33.1 show the water equivalent of the snow cover 19 May close to the culmination of the flood. Most of the snow fell at high elevations east of the alpine districs next to the water divide. The mountain ridges between the main valleys in the east had a large surplus of snow compared to the most alpine region.

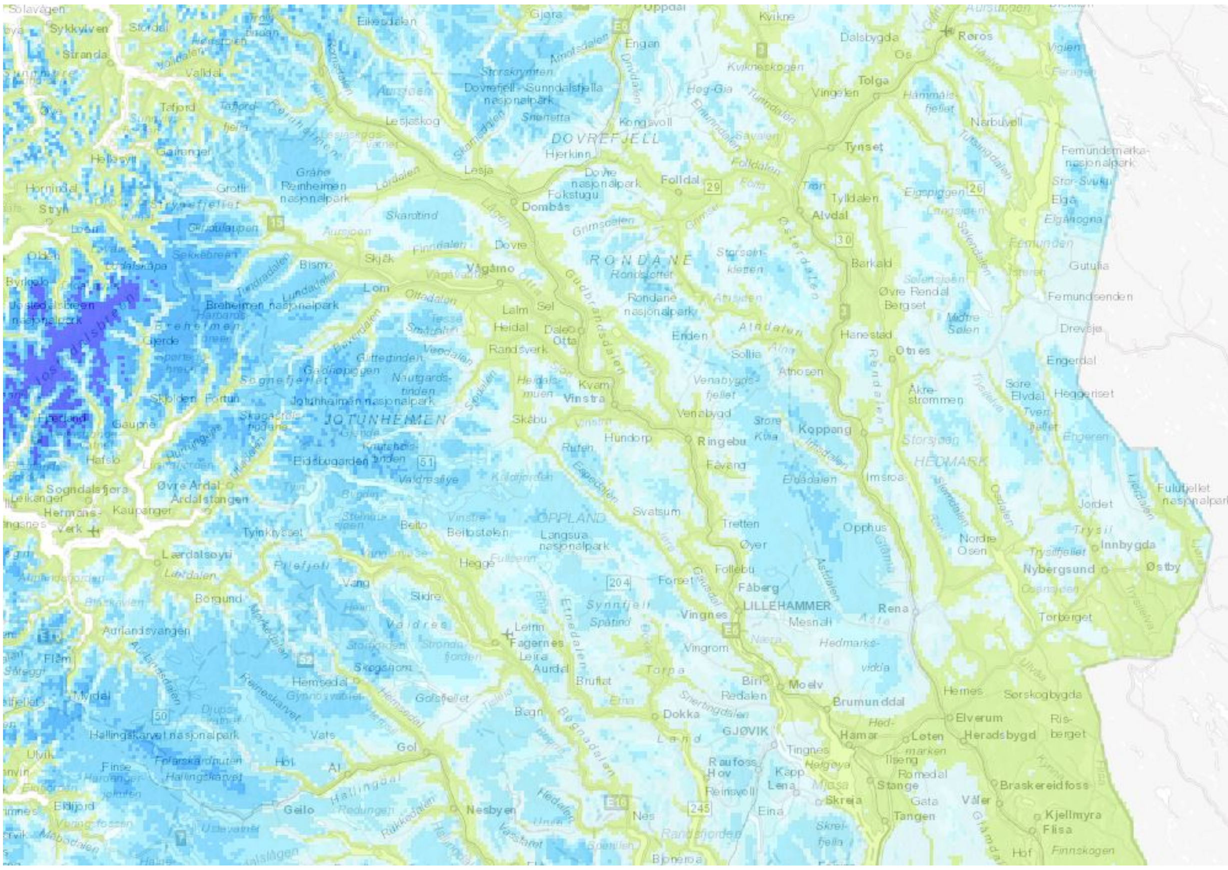


Figure 3.1.33.1 The water equivalent of the snow cover in East Norway 19 May 1966.

The flood:

River Glomma

The temperature started to rise in early May, initiated the largest spring flood in River Glomma since the flood in May 1934. The flood was especially large in Nord-Østersdal and in Gudbrandsdalen. Ice runs occurred 2-3 and 5 May at Koppang at Storelvdal. Figure 3.1.33.2 show observed discharges at gauging stations in the mainstream in Østerdalen and Glåmdalen. The flood culminated 18-21 May in the eastern branch and Glomma. The flood magnitude was estimated to have a return period of 100 years. At Elverum the flood peaked at a discharge of 2600 m^3/s 20 May, and in the tributary Atna at 159 m^3/s or 342 $l/s\ km^2$. The flood in Atnasjø was the second highest 1917-2011.

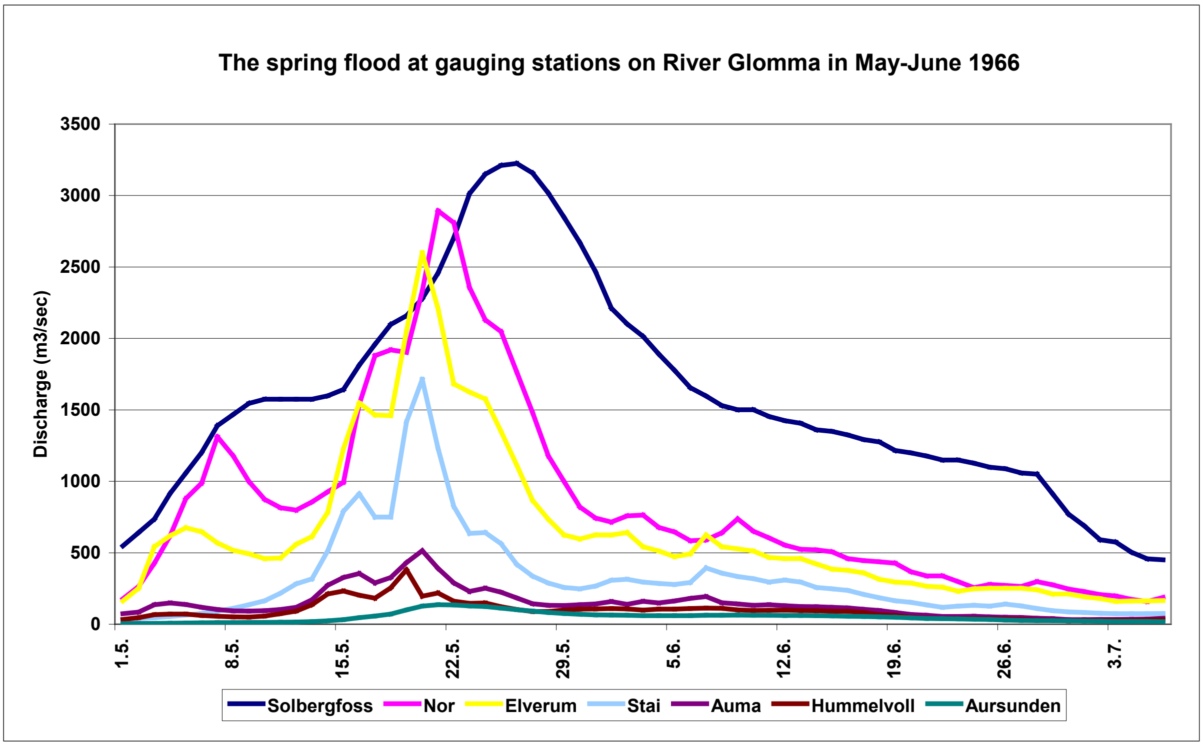


Figure 3.1.33.2 Observed discharge (daily values observed at gauging stations on the main River Glomma.

The peak of the flood co-incided with rainfall 19 - 24 May as shown in Figure 3.1.33.3 for gauging stations in tributaries west and in Figure 3.1.33.4 for stations east of Østerdalen. The flood ranks as fourth largest at 2.116 Auma and 2.604 Elverum, third largest at 2.112 Stai 1917-2014.

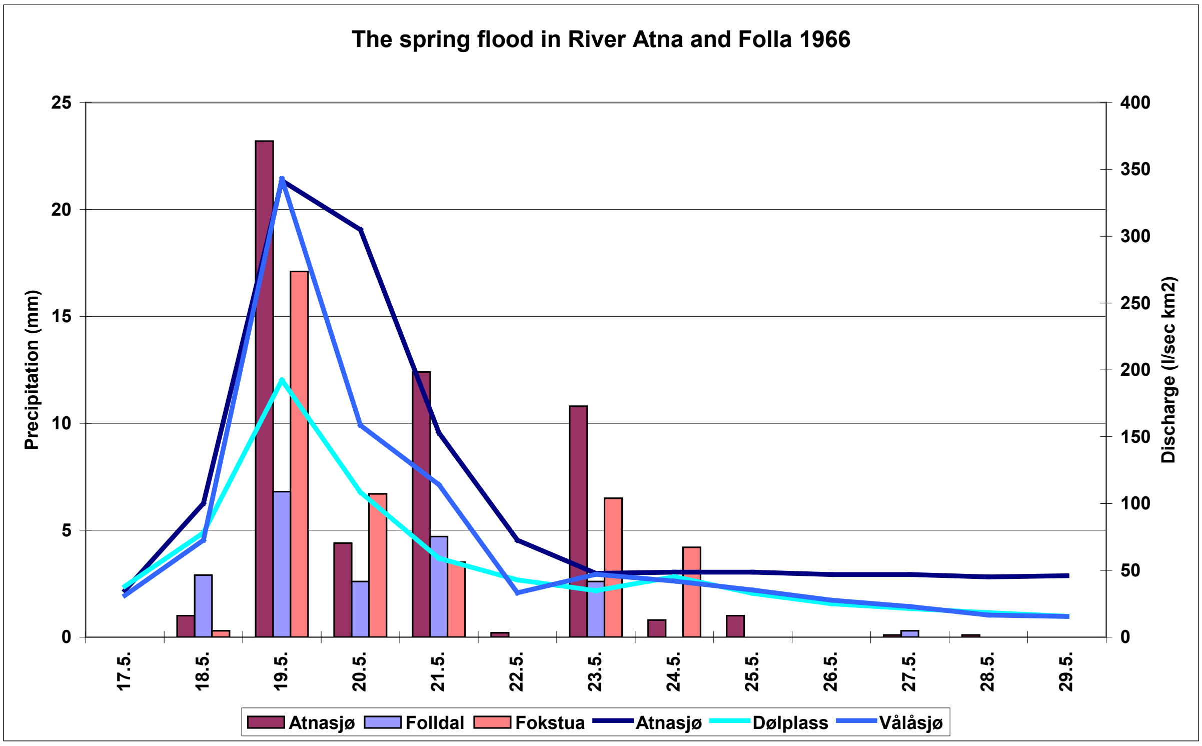


Figure 3.1.33.3 Specific discharge (daily values) and precipitation on River Atna and Folla during the spring flood in 1966.

The flood was second largest annual flood in River Atna at 2.32 Atnasjø 1917-2014, seventh largest in River Folla at 2.129 Dølplass 1908-2014 and second largest at 2.9 Vålåsjø 1923-2014.

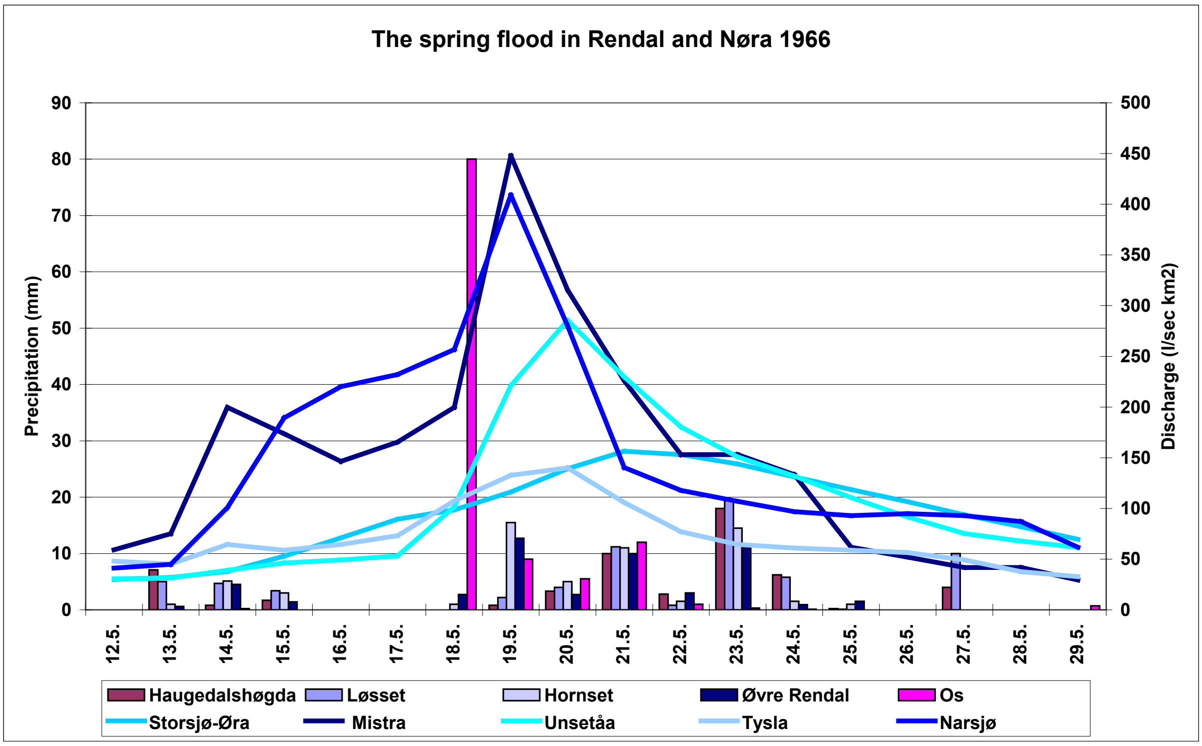


Figure 3.1.33.4 Specific discharge (daily values) and precipitation at stations on River Rena and Nøra during the spring flood in 1966.

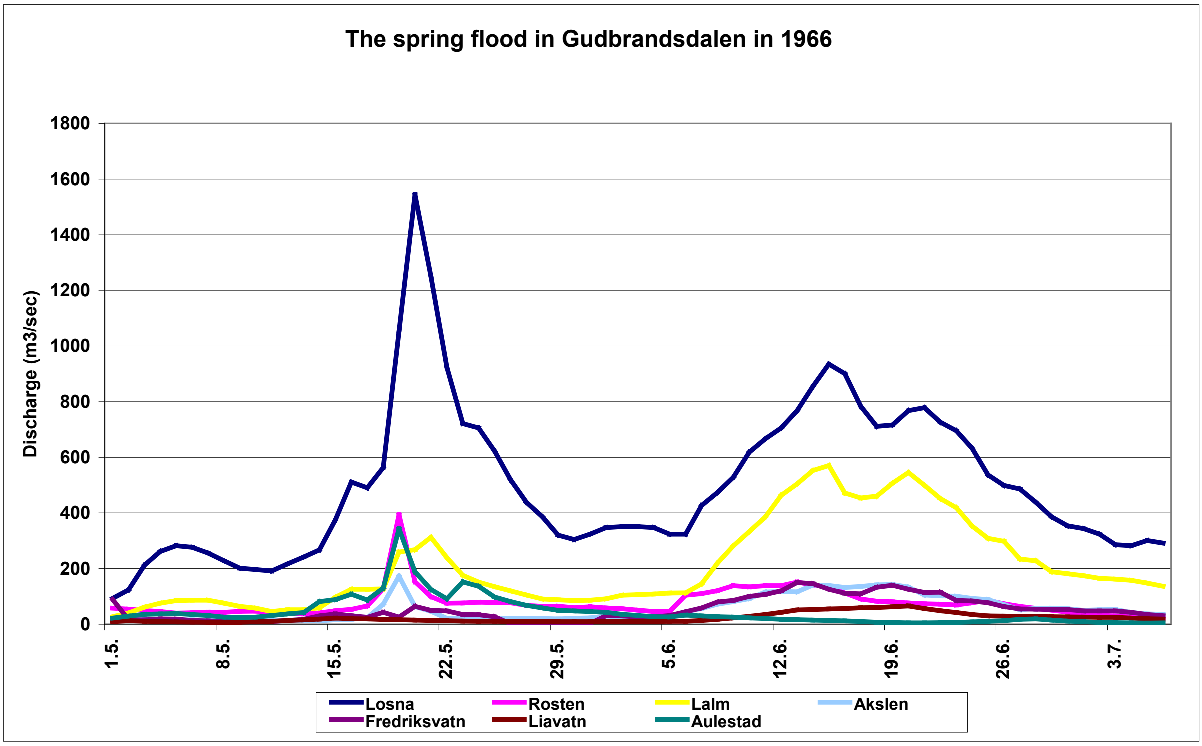


Figure 3.1.33.5 Daily discharge at stations in Gudbrandsdal during the flood in 1966.

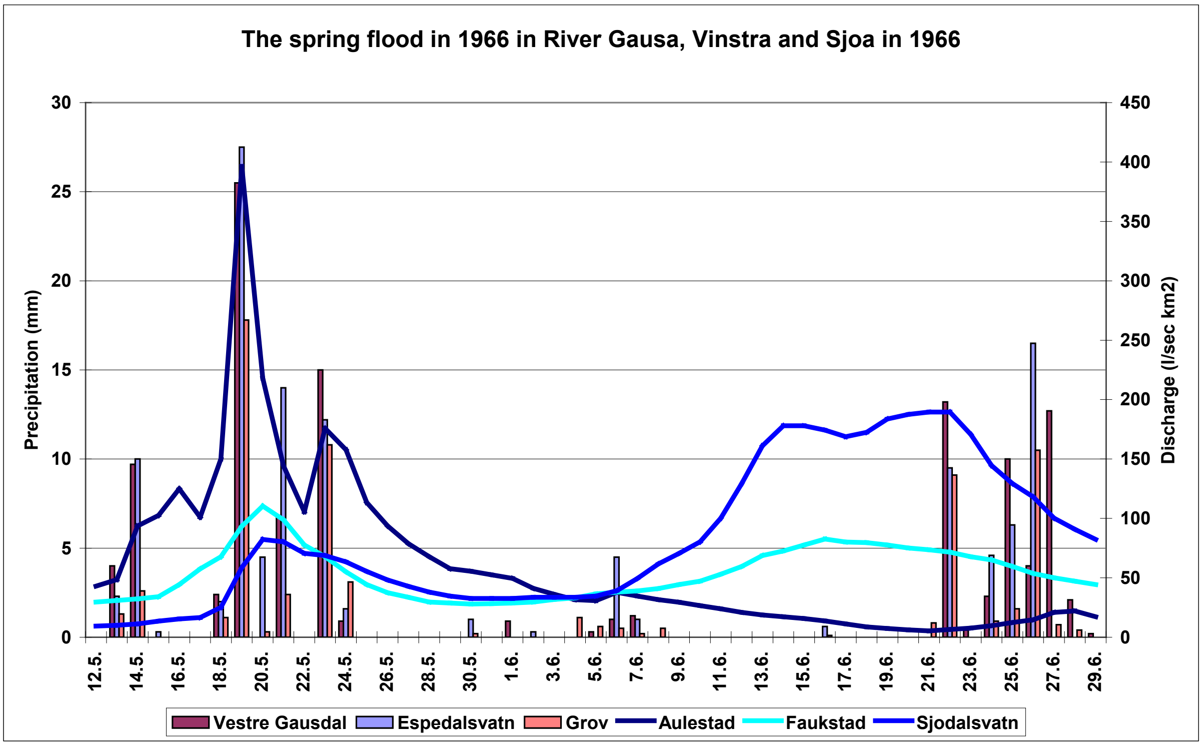


Figure 3.1.33.6 Specific discharge (daily values) and precipitation at stations on River Gausa, Vinstra and Sjoa during the spring flood in 1966.

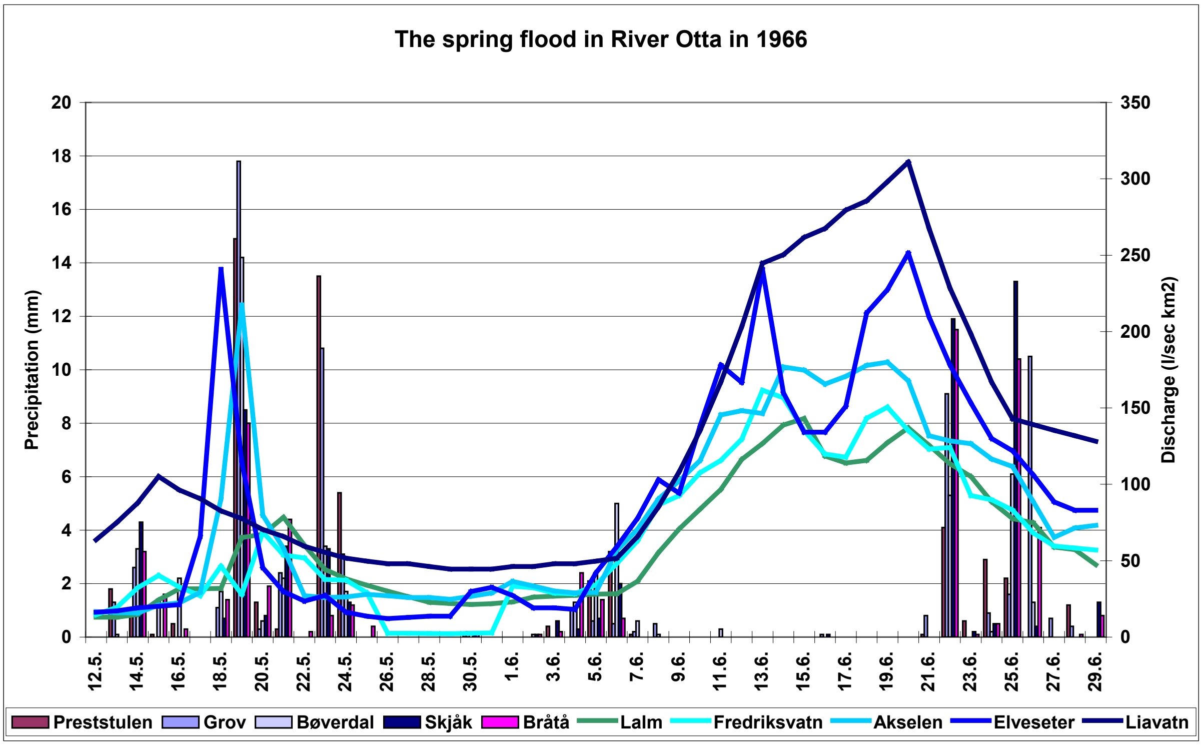


Figure 3.1.33.7 Specific discharge (daily values) and precipitation at stations in the Otta and Nøra catchments during the spring flood in 1966.

River Trysilelv

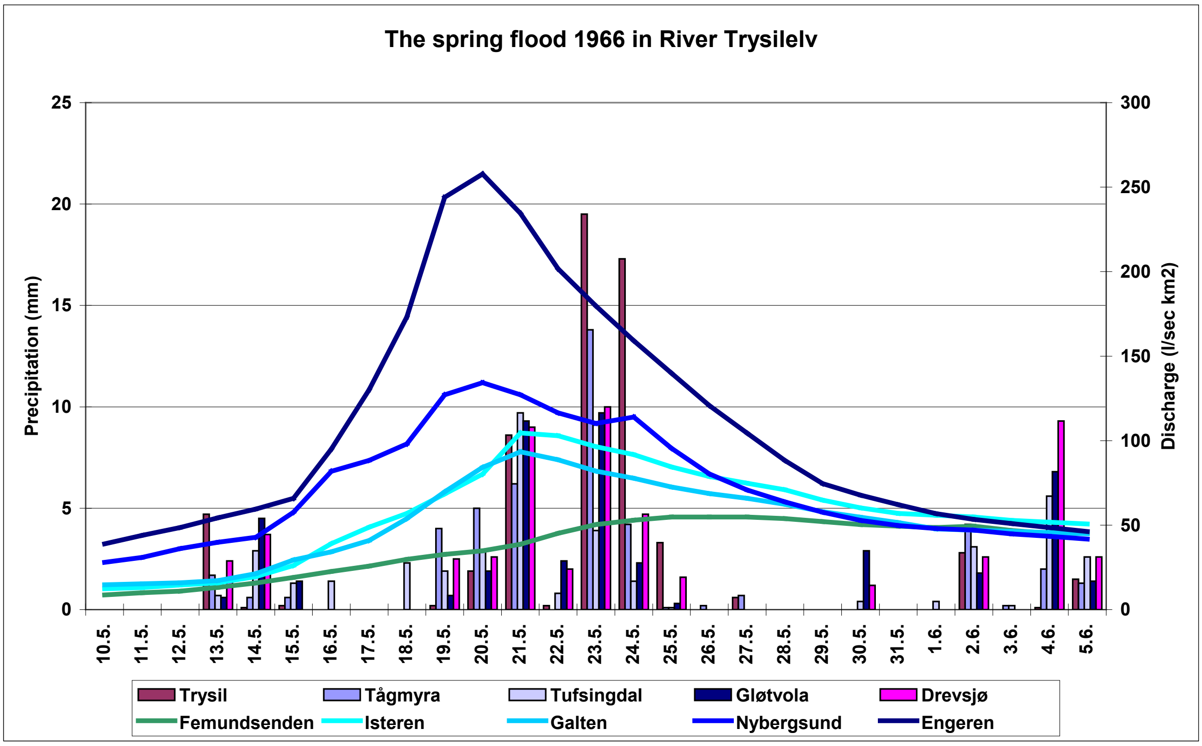


Figure 3.1.33.8 Specific discharge (daily values) and precipitation at stations on River Trysilelv during the spring flood in 1966.

The flood was seventh largest at 311.4 Femundsenden 1896-2014, the fourth largest at 311.6 Nybergsund 1909-2014 and the fifth largest at 311.460 Engeren 1912-2014.

River Drammenselv

The spring flood in 1966 does not rank among the largest in the main branches of River Drammenselv except at some catchments not affected by regulations. Figure 3.1.33.9 show observed specific discharge and precipitation at some of these stations in River Simoa, Rukkedøla, Vindedøla, Etna and Dokka.

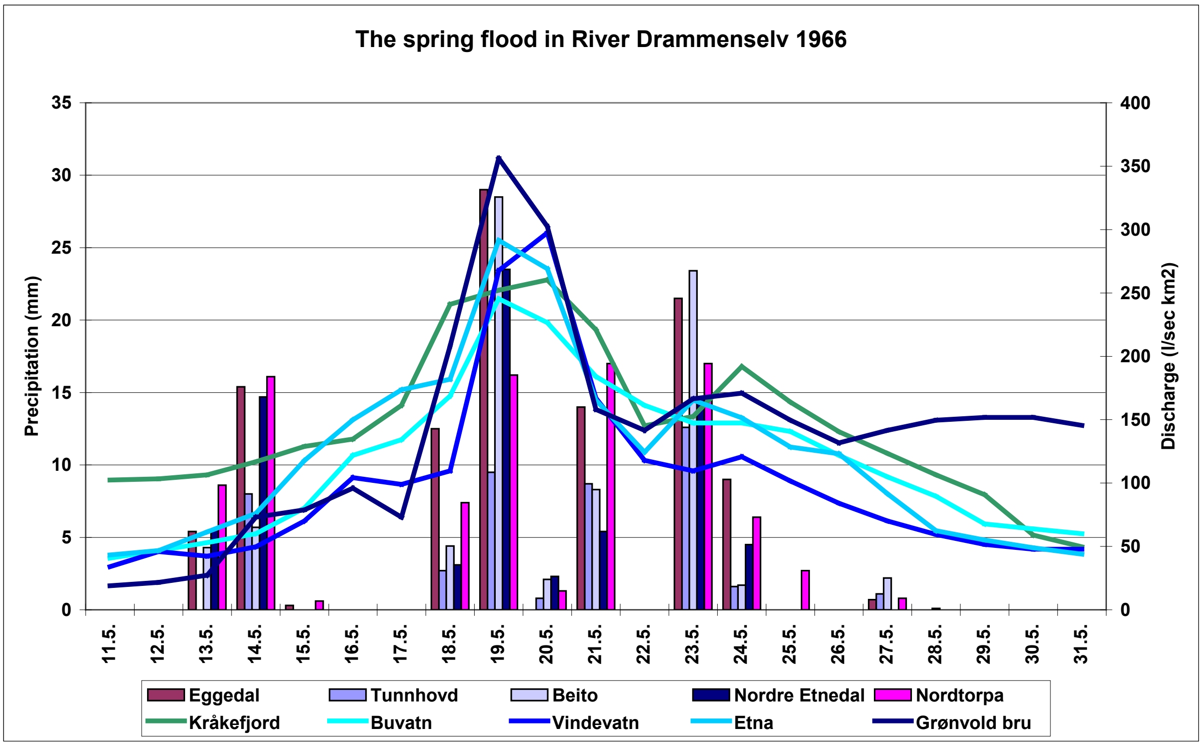


Figure 3.1.34.9 Specific discharge (daily values) and precipitation at stations on River Drammenselv during the spring flood in 1966.

The flood was eight largest in River Simoa at 12.113 Kråkefjord 1931-2014, largest in River Rukkedøla at 12.150 Buvatn 1962-2014, sixth largest in River Vindedøla at 12.92 Vindevatn 1920-2014, fourth largest in River Randselv at 12.228 Kistefoss 1916-2014, third largest at 12.70 Etna 1919-2014 and second largest in River Dokka at 19.8 Grønvold bru 1960-1989. With exception of Kistefoss, the flood peaked at 19 or 20 May at these stations.

River Numedalslågen

The flood was the fourth largest at 15.49 Halledalsvatn 1962-2014, a lake close to the water divide to Hallingdal.

River Skienselv

The flood was second largest at 16.66 Grosetvatn 1949-2014, 9th largest at 16.51 Hagadrag 1885-2014 and fourth largest at 16.75 Tannsvatn 1955-2014.

Flood damages:

<u>Østerdalen/Glåmdalen:</u> The ice runs 2-5 May caused damages at eight farms at Storelvdal. RV25 was blocked at Stai where several thousand daa of farmland was inundated. The subsequent severe flood damaged additional five farms between Stai and Koppang.
The tributaries Atna, Snødøla, Vulua and Imsa caused all damages in 1966. The railway to Røros was blocked between Rena and Tynset. 12-13.000 daa of farmland was inundated at Grue.

Vorma/Mjøsa/Gudbrandsdalslågen: River Einbugga blocked E6 in the village center of Dovre. Riverbank failure took place in River Fossåa at Sør-Fron. E6 was inundated ar Våla bridge at Ringebu. River Rolla devastated a camping site at Tretten. Strandgaten was inundated at Hamar.

Lillestrøm/Fet: Hundred of basements were flooded. 30-40 houses were surrounded by water at Fet.

Trysil:

Valdres and Land: 4000 daa was inundated at Nordre Land and in Etnedal. The road through Etnedal was closed for cars and busses south of Flatødegård. Many basements in houses suffered flood damages in Valdres, and several local roads were damaged.

Numedal: Several hundred daa farmland was inundated. The flood was a threat to timber booms.

3.1.34 The spring flood in East Norway in late May and early June in 1967.

The population living near Glomma had not anticipated a new severe flood occuring the next year as well.

The cause of the flood:

Initial conditions:

The winter 1966/1967 was also a cold winter with abundant snow fall. The melting started in the lowlands in April. More snow fell, however, in the mountains between Østerdalen and Gudbrandsdalen, where most of the snow disappeared at the end of May. Large amounts of snow remained in the alpine catchments in Jotunheimen, where most of the snow melted late in the summer. Figure 3.1.34.1 show the water equivalent of the snow storage 11 May 1967.

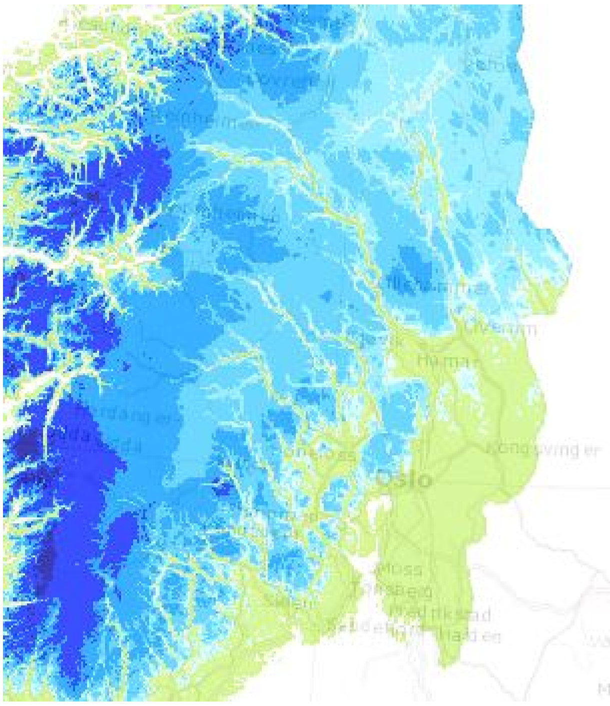


Figure 3.1.34.1 The water equivalent of the snow storage 11 May 1967.

The development of the snowmelt:

Figure 3.1.34.2 The air temperature in Oslo in the spring 1967.

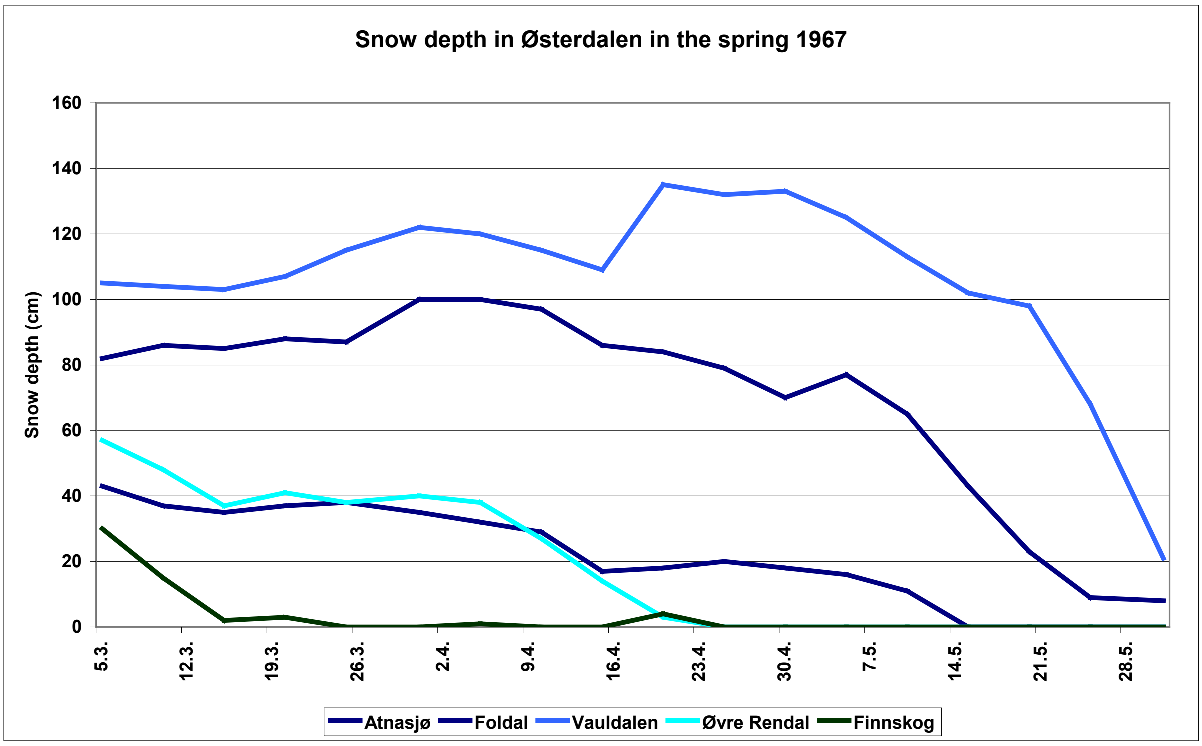


Figure 3.1.34.3 The snow depth in Østerdalen in the spring 1967.

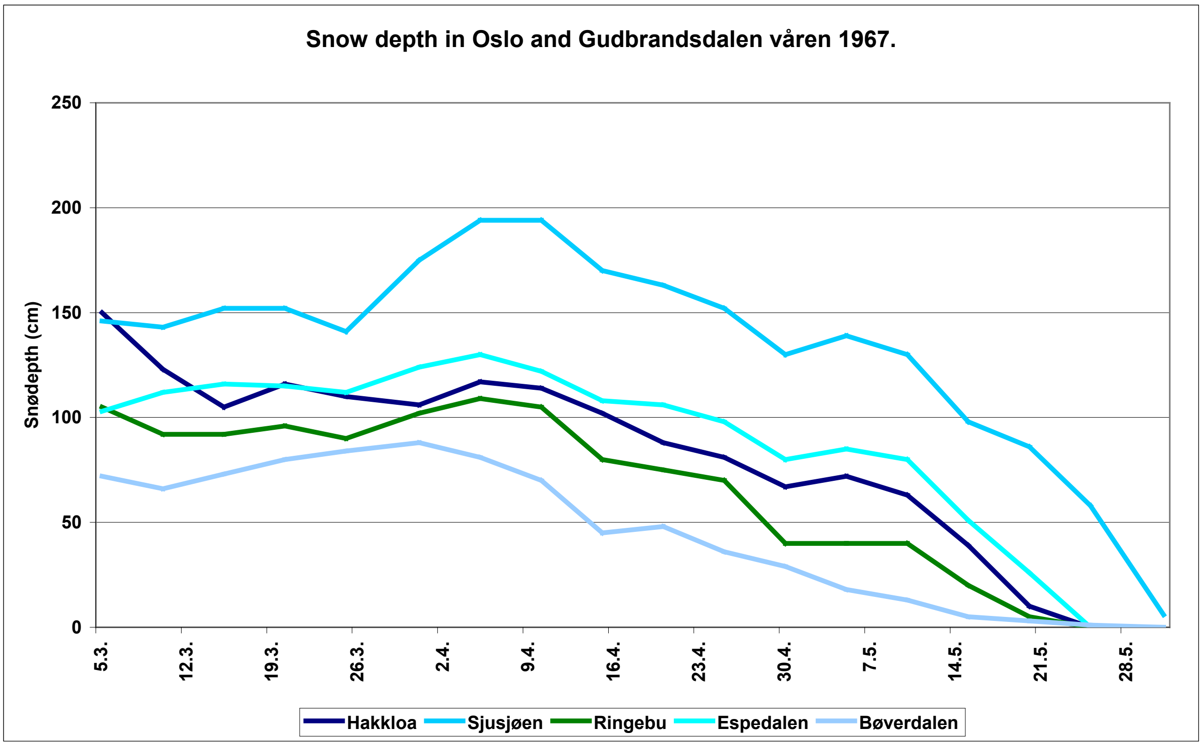


Figure 3.1.34.4 The snow depth in Gudbrandsdalen and in the Oslo district in the spring 1967.

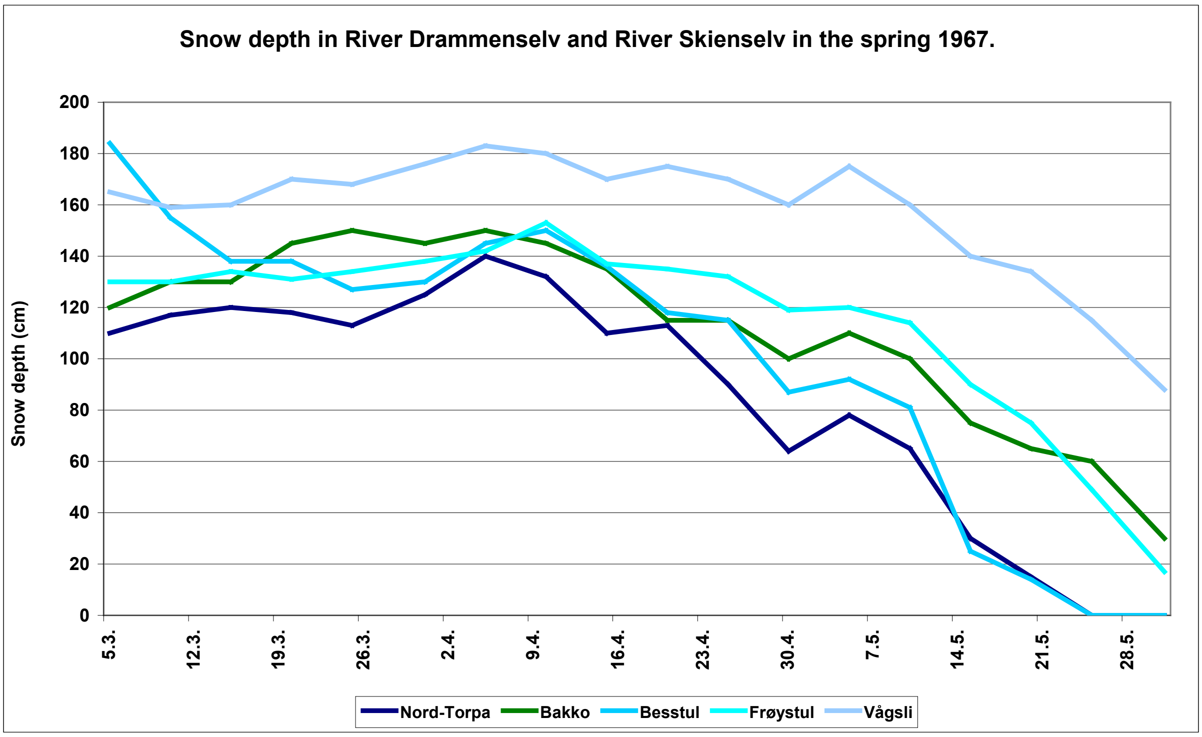


Figure 3.1.34.5 The snow depth in Buskerud and Telemark in the spring 1967.

The weather conditions:

Varm air masses penetrated from southeast over Mid- and North Norway. A low was situated over the North Sea and Great Britain and cold air masses covered southern Norway. Some rain fell 25-27 May in the frontal zone between the warm air to the north and the cold air to the south. More rain fell 1-2 June. The amount of rainfall was generally small except at some locations close to the border of Sweden. The snowmelt combined with the precipitation caused flood in Glomma, Trysilelva, Drammenselva, Numedalslågen, Skienselva, Sira, Orkla, Gaula, Nidelva and Stjørdalselva 25 May-3 June.

The flood:

River Trysilelv and River Rena

Figure 3.1.34.6 show observed rainfall and discharge (in specific units) for stations in River Trysilelv and in River Rena. Some additional stations were operating in River Trysilelv in 1966 and the discharge in m^3/sec is shown in Figure 3.1.35.7.

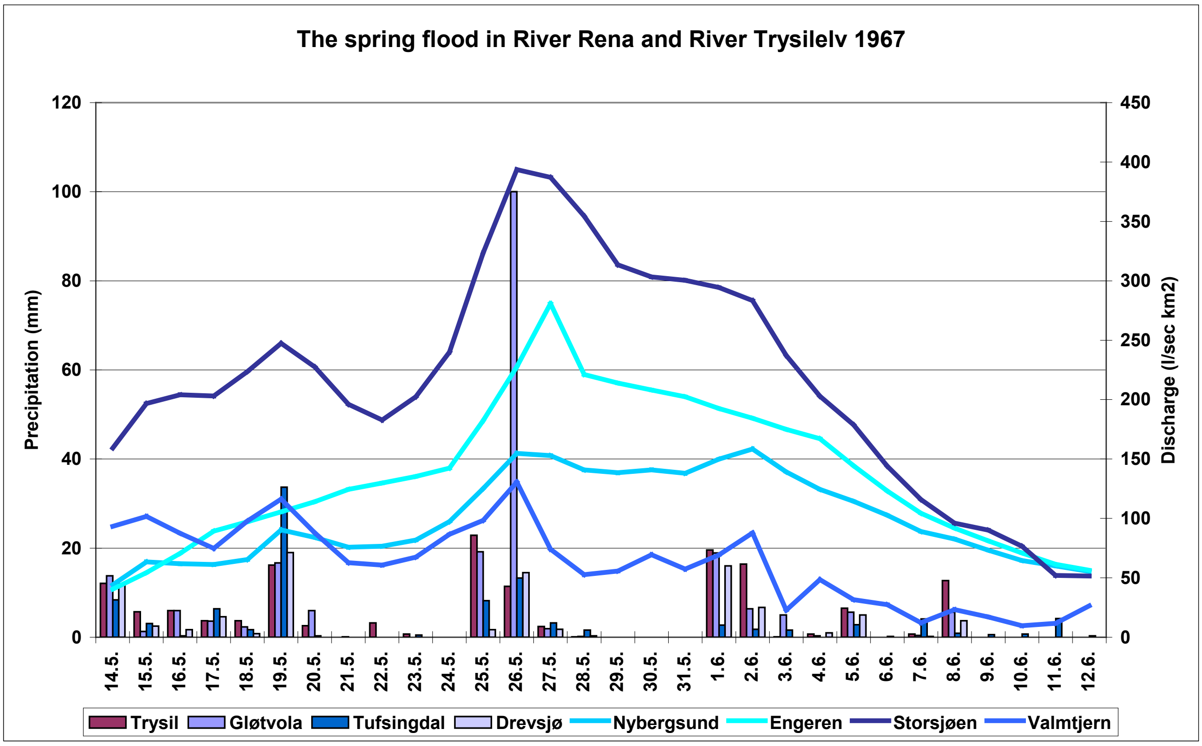


Figure 3.1.34.6 Observed precipitation and daily discharge during the large spring flood in rivers east of Østerdalen in 1967.

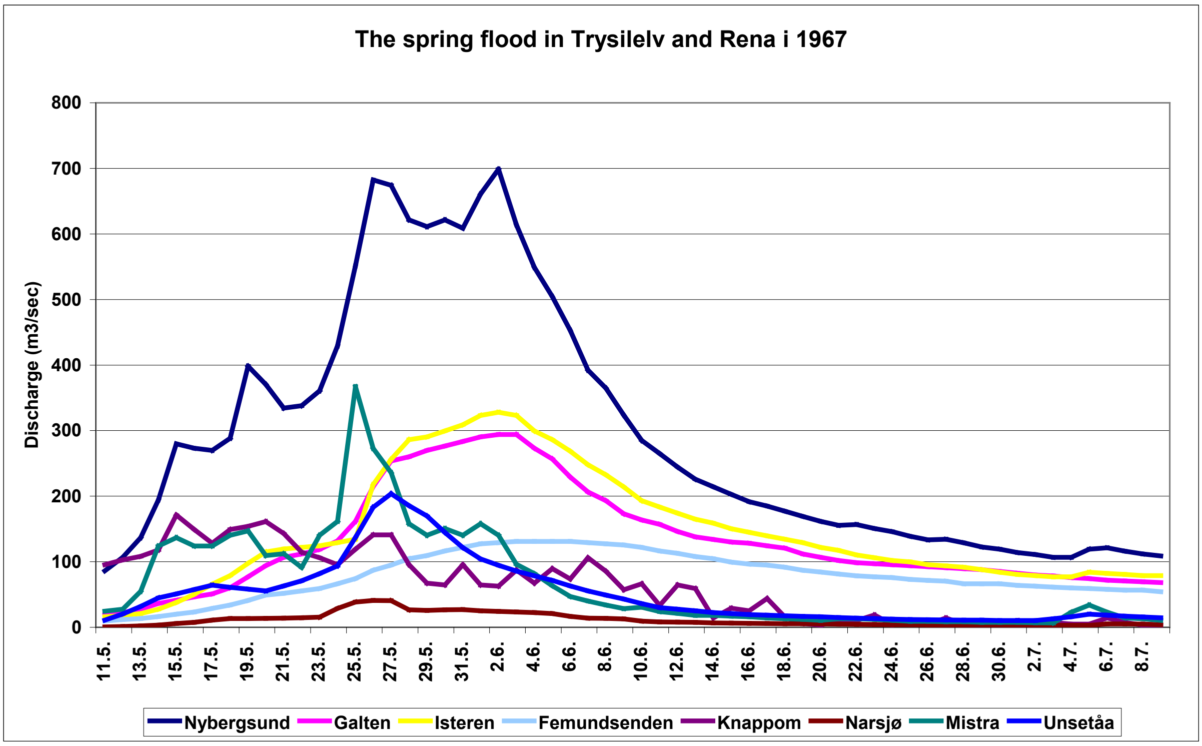


Figure 3.1.34.7 Observed flood (in m3/sec) in River Trysilelv and in tributaries to River Glomma from the east.

The flood was the second largest at Trysilelva.

River Glomma in Østerdalen and Glomdalen to Øyeren

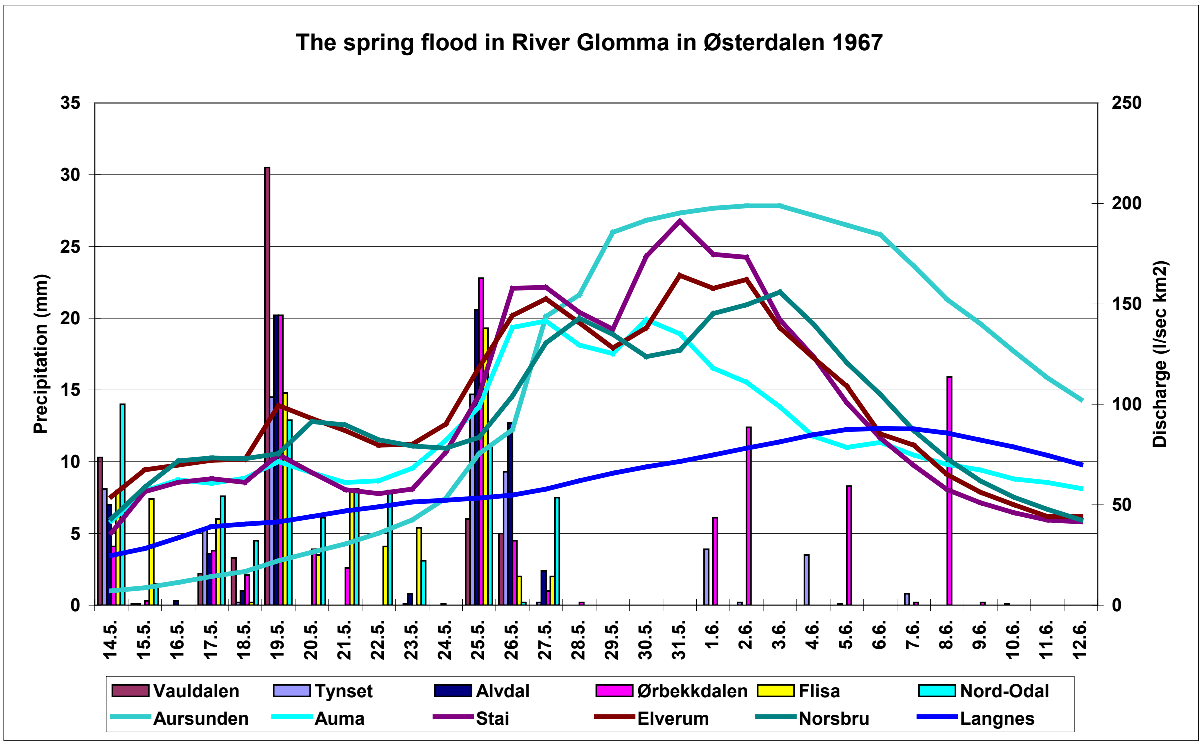


Figure 3.1.34.8 Observed precipitation and daily discharge (specific values) during the large spring flood in the main River Glomma in 1967.

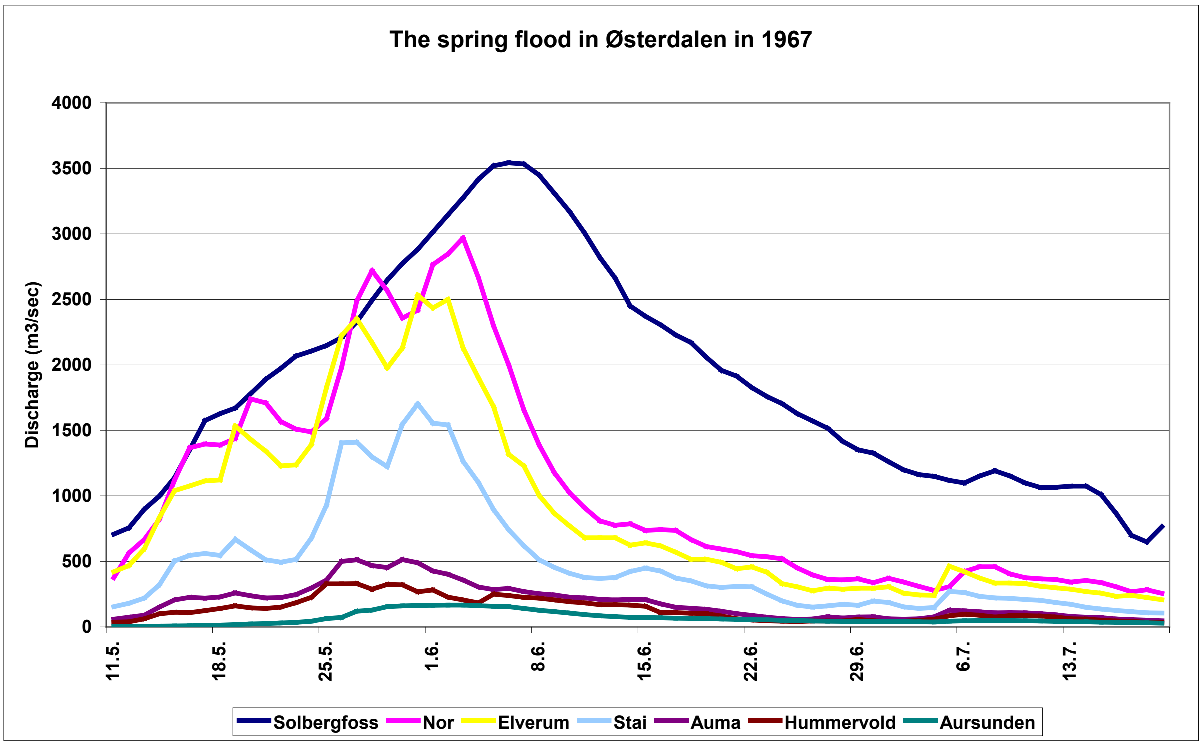


Figure 3.1.34.9 Observed flood (in m3/sec) at stations in River Glomma from Aursunden to Langnes/Solbergfoss in 1967.

At Solbergfoss, downstream Øyeren, the flood was the second largest 1901-2011. The rank was between the third to the sixth largest at other stations in Østerdalen and in Drammenselva. The flood exceeded the level of the 1966 flood at Solbergfoss. The flood was less severe in Numedalslågen and Skienselv, but ranks among the largest observed at River Sira. The flood ranks as the third or fourth largest in River Orkla and Gaula.

The rivers from Jotunheimen such as Vinstra, Sjoa and Otta did not contribute significantly to the flood because the temperature was too low to initiate significant melting of the abundant snow stored at high altitudes. When the melting peaked at the highest altitudes 20 July, many of these tributaries had large floods.

Tributaries to River Glomma

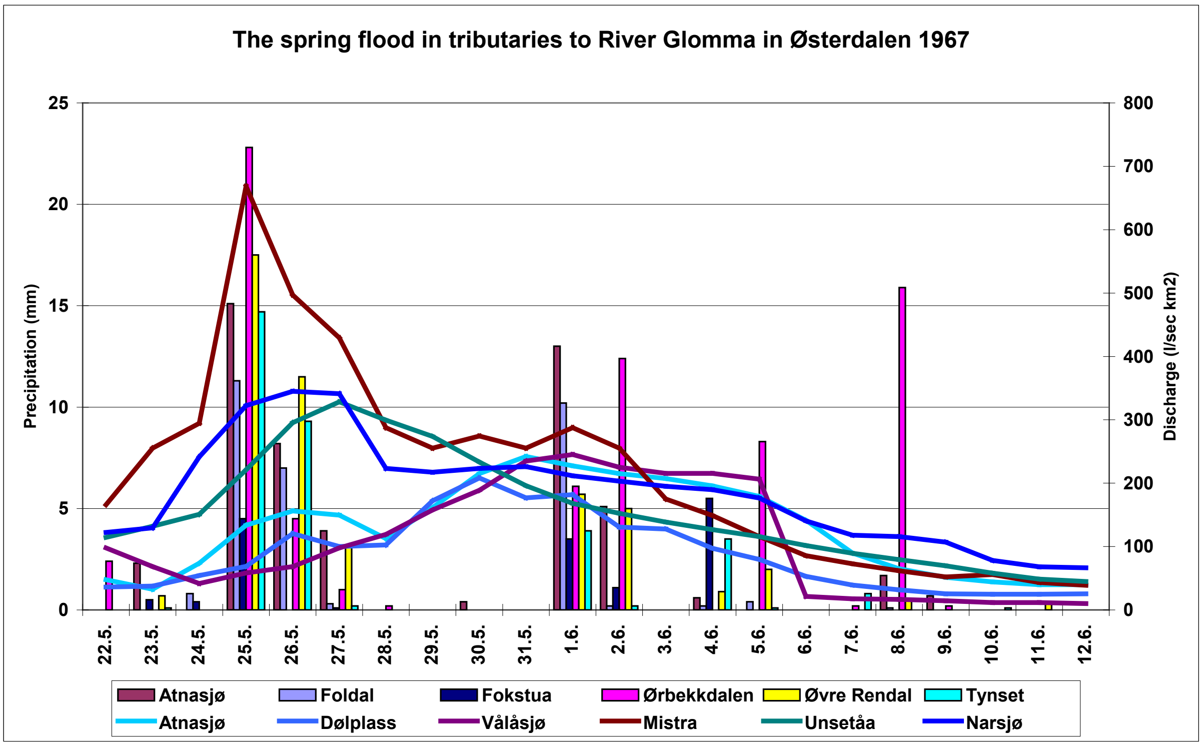


Figure 3.1.34.10 Observed precipitation and daily discharge (specific values) during the large spring flood in tributaries to River Glomma in 1967.

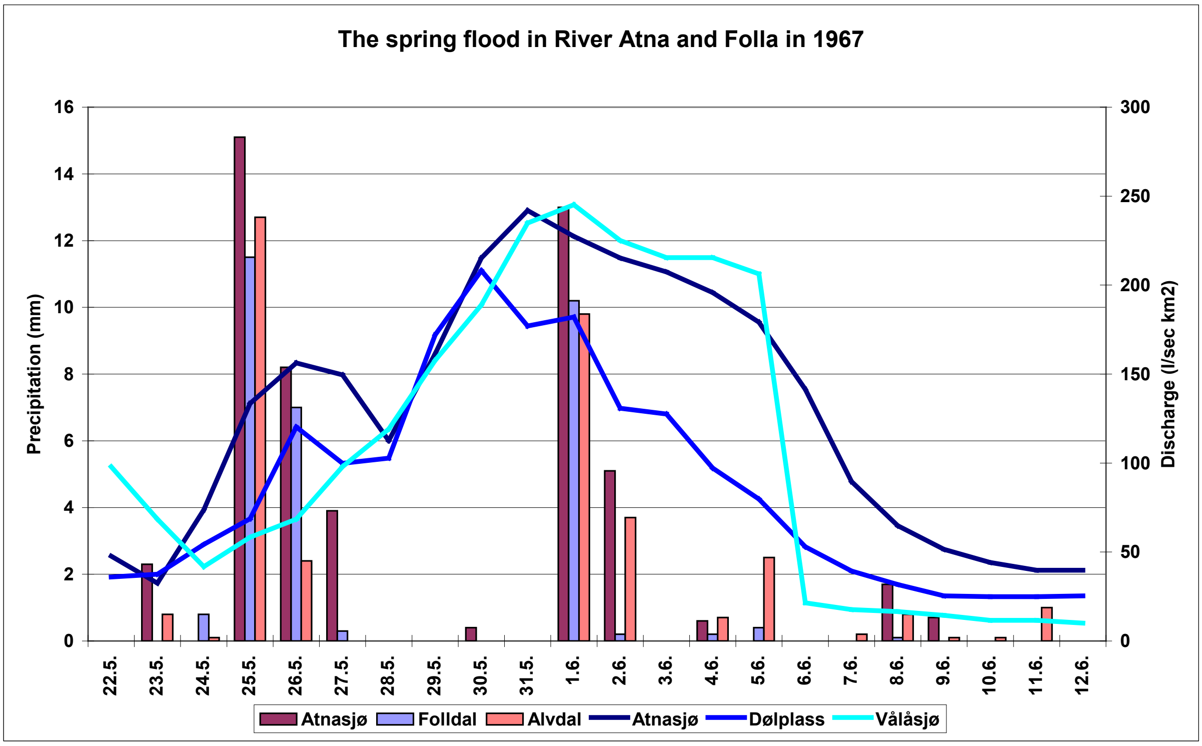


Figure 3.1.34.11 Observed precipitation and daily discharge in tributaries to river Glomma in 1967.

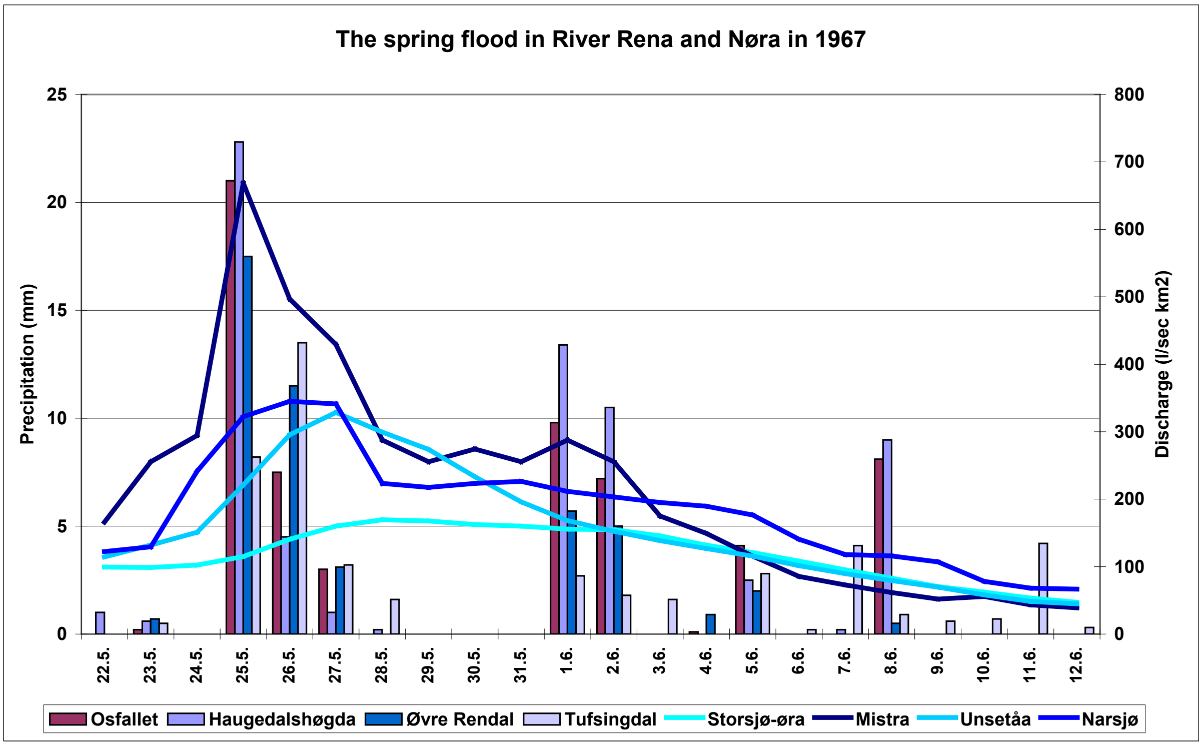


Figure 3.1.34.12 Observed precipitation and discharges to River Glomma in 1967.

River Vorma and Gudbrandsdalen

The flood culminated 1 June in the lower reaches of Gudbrandsdalen. Much snow remained, however, in the most alpine parts of the Jotunheimen catchment. Heavy rainfall in combination with melting snow, caused larger floods in the River Sjoa and River Otta tributaries 19 July and 3 August.

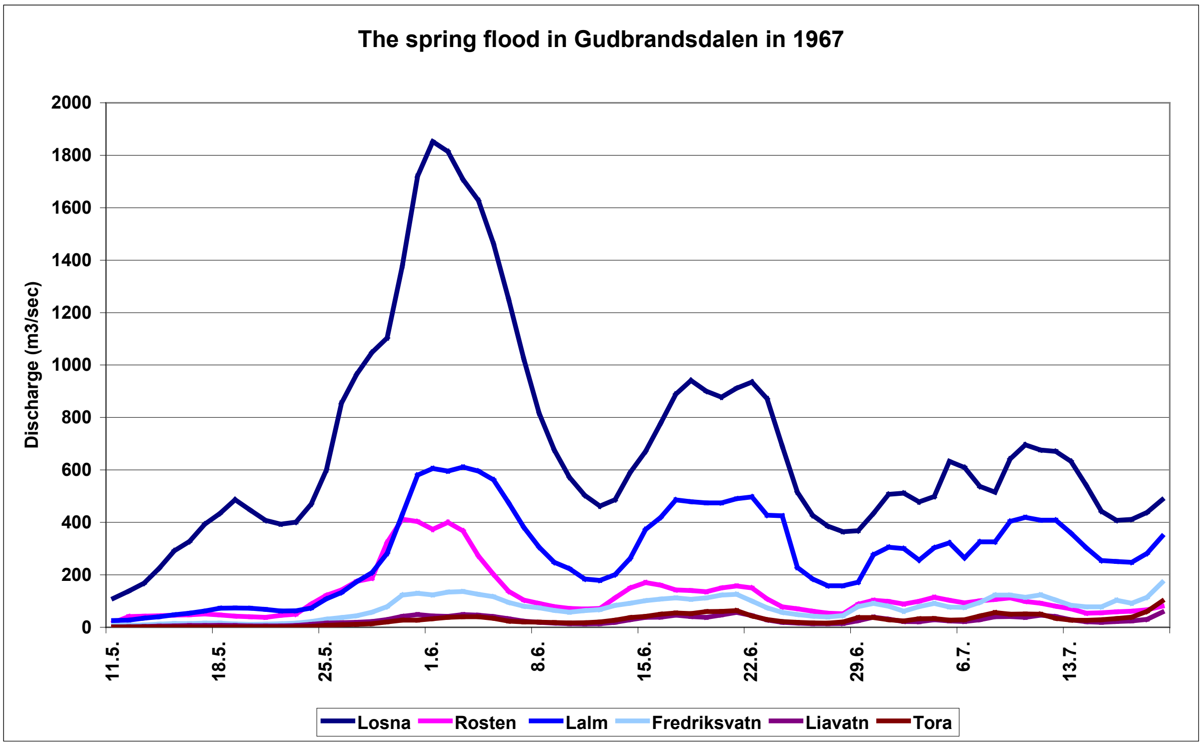


Figure 3.1.34.11 Observed daily discharge (m3/sec) during the large spring flood in Gudbrandsdalen in 1967.

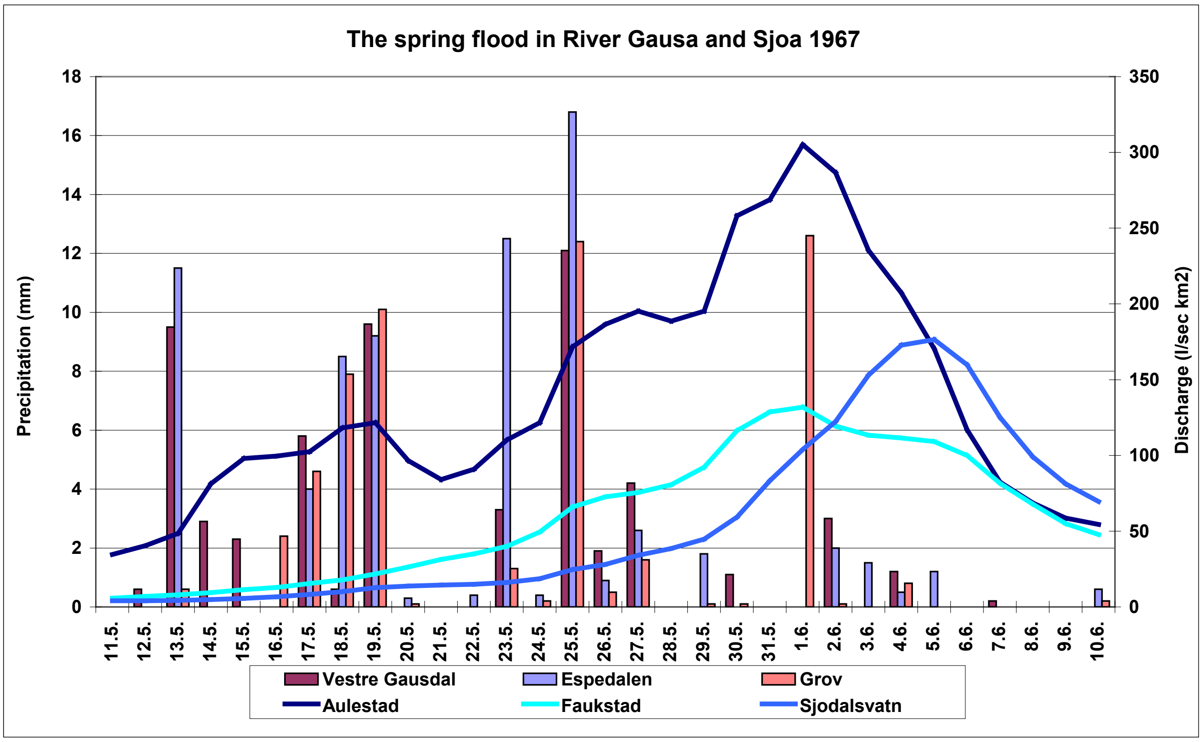


Figure 3.1.34.12 Observed precipitation and daily discharge (specific values) during the large spring flood in Gudbrandsdalen 1967.

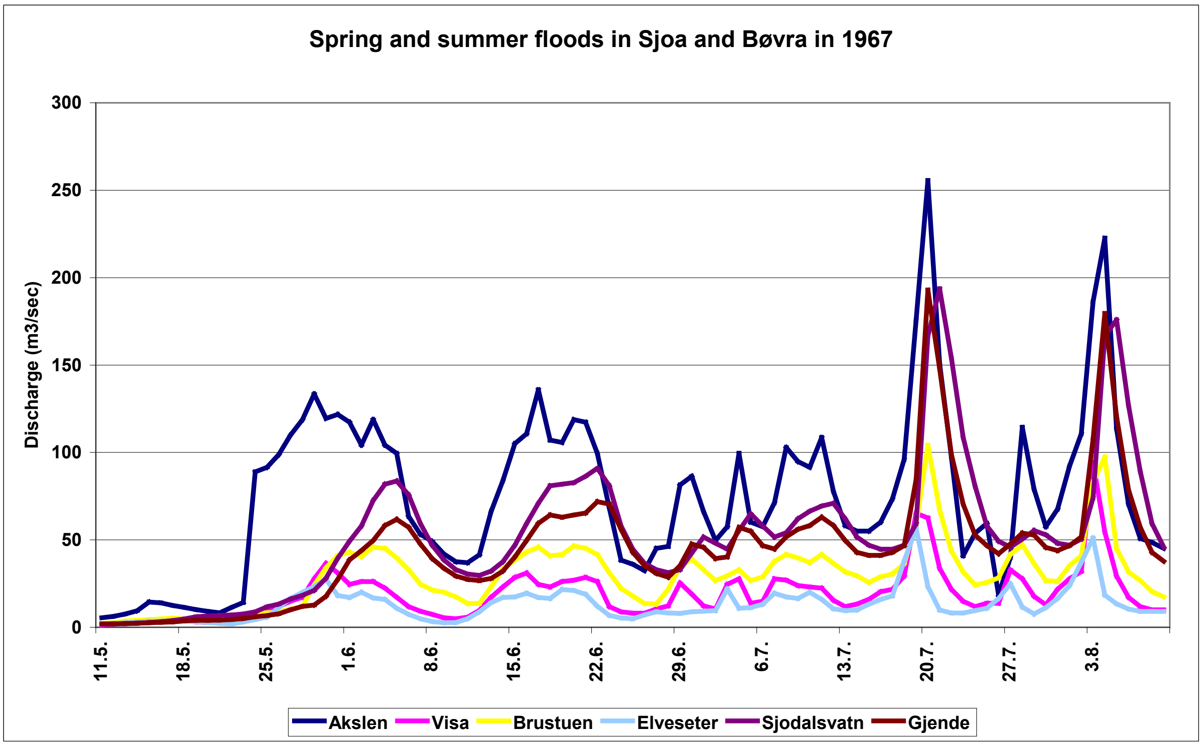


Figure 3.1.34.12 Observed daily discharge during the large spring and summer flood in River Sjoa and Bøvra in 1967.

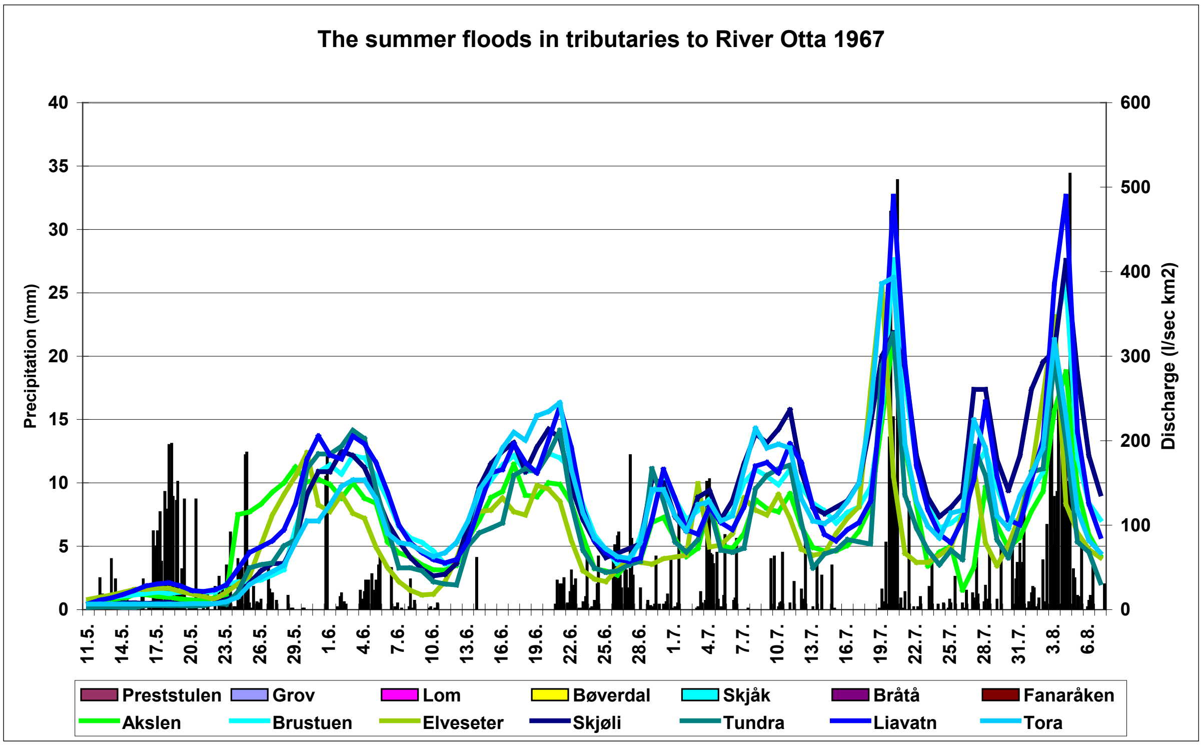


Figure 3.1.34.13 Observed precipitation and daily discharge (specific values) during the large spring flood in Gudbrandsdalen 1967.

River Drammenselv

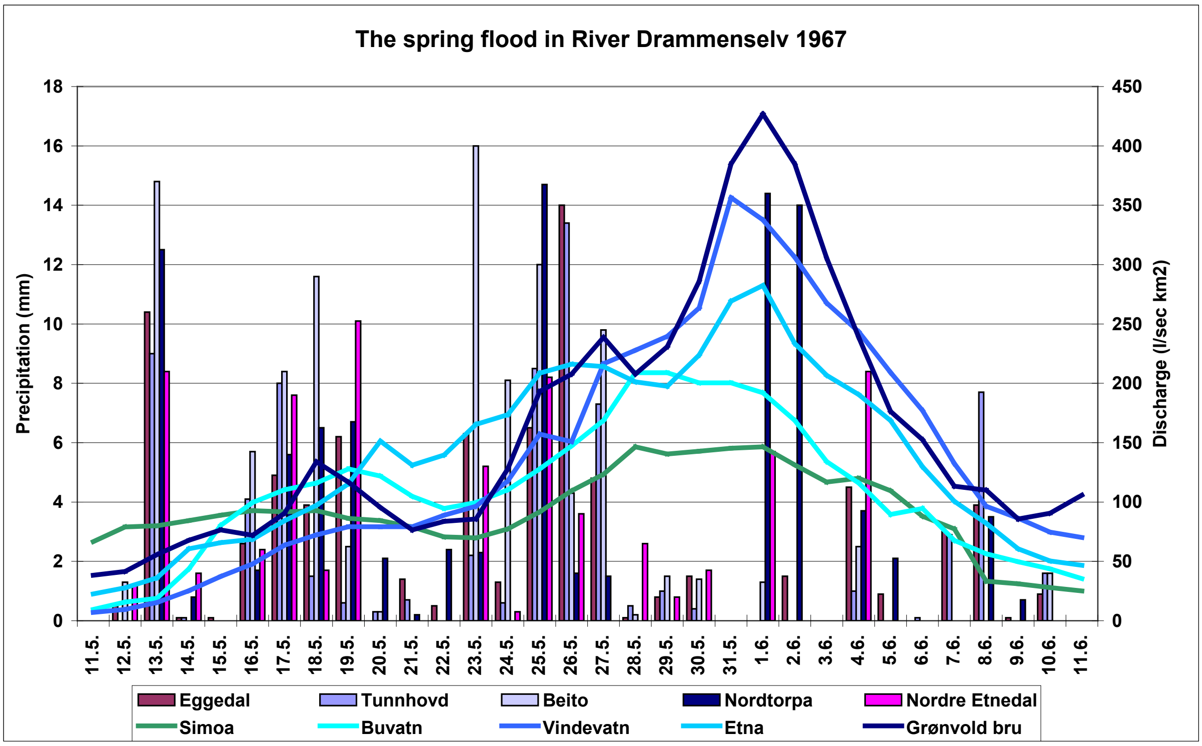


Figure 3.1.34.14 Observed precipitation and daily discharge (specific values) in natural catchments in River Drammenselv during the spring flood 1967.

The flood was sixth larges. 12.68/298 Døvikfoss 1912-2014, fifth largest in Lake Tyrifjord at 12.65 Skjerdal 1887-1999, seventh largest in River Rukkedøla at 12.150 Buvatn 1962-2014, fourth largest in River Begna at 12.290 Bagn 1949-2014, at 12.91 Rudi bru 1919-2014 and 12.70 Etna 1919-2014. The flood was largest in River Dokka at Grønvold bru 1960-1989, second largest in River Randselv at 12.228 Kistefoss 1916-2014 and third largest in River Vindedøla at 12.92 Vindevatn 1920-2014. River Begna is strongly regulated. The natural flood has been reconstruckted by J. Friis (1968).

Flood damages:

Glomma: Eleven farms suffered damages at Storelvdal. The tributary Tresa ran full of sand causing the flood protection work to fail, and the river to shift into another bed. This happened also with the tributary Imsa, causing damages at farms downstream the confluence with River Glomma.

The flood penetrated the flood protection works at several locations at Grue, causing damages of 1,5 mill. NOK. Between Skarnes and Funnefoss and along River Oppstaåa and Lake Storsjøen 9000 daa farmland was inundated. 83 houses, 149 cottages and 48 outbuildings were damaged.

15.000 daa was inundated at Lillestrøm and Fet. Around 1200 houses suffered damages from the flood water. The water reached to the ceiling of the ground floor at some of the houses. Many factories were closed. Roads and railway lines were also closed.

Drammenselva: Several houses at Fagernes had flood water in the basement. 27 cottages, three houses and a store were partly flooded along Lake Sperillen. At Hønefoss some houses had water in the basement at Kvernbergsund brigde. Lake Tyrifjorden reached almost RV7 at

Sundøya at Sundvollen. A moderate increase would have caused the main road to Bergen to close. Several stores had the basement filled with water at Vikersund near the outlet of Lake Tyrifjorden.

Attempts of forecasting the flood levels in 1967.

During the previous floods in Gudbrandsdalen and Mjøsa in 1927 and 1938 knowlegde of the water levels at locations upstreams some vulnerable sites was utilised in estimating the level at the culmination (Aftenposten, 1927), (Klæboe,1938). Hegge (1967) established relationships between the water levels at stations along the main branch of River Glomma by regression analysis. He used these relationships to predict the water leves downstream.

3.1.35 The summer flood in Jotunheimen in 1968.

A large mountain flood occurred in Jotunheimen in early July 1968. The snowmelt from most of the hillsides lasted from 4 to 8 June causing floods in low-lying rivers in Gudbrandsdalen, Trøndelag and at Finnmarksvidda. Figure 3.1.35.1 to 3.1.35.3 show observed daily rainfall and discharge in rivers in Gudbrandsdalen, Ottadalen and Bøverdalen.

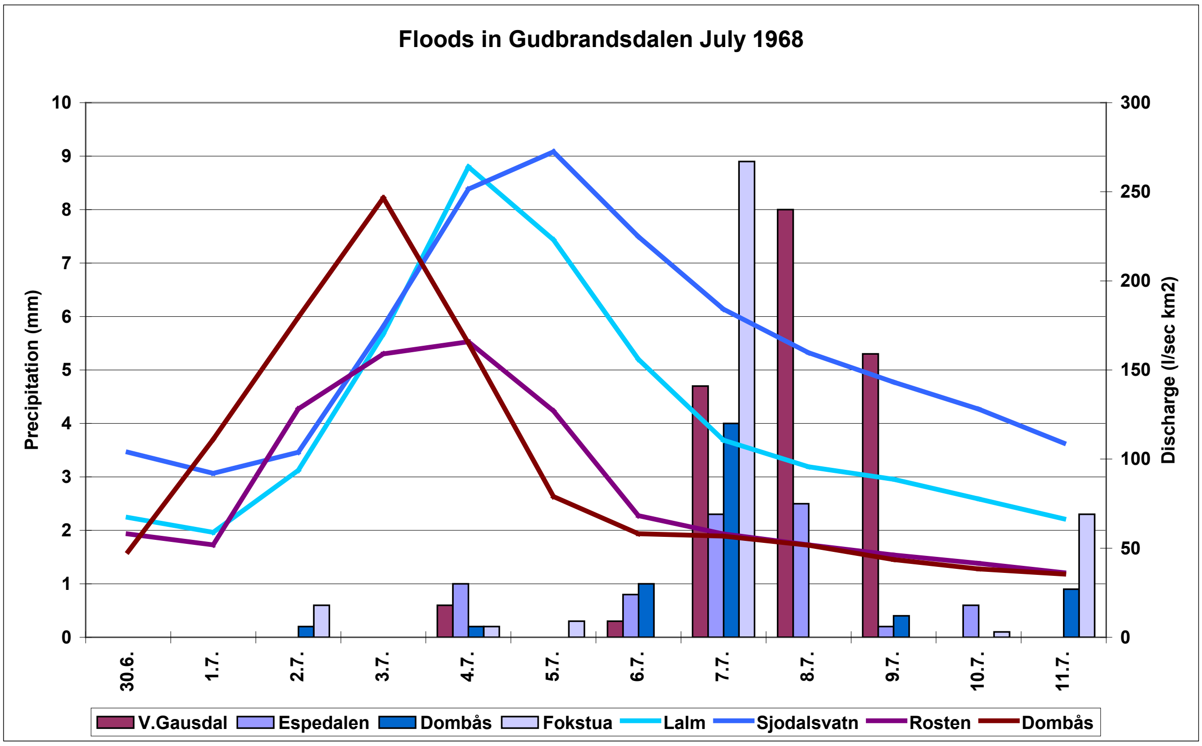


Figure 3.1.35.1 Observed precipitation and daily discharge (specific values) during the large spring flood in Gudbrandsdalen 1968.

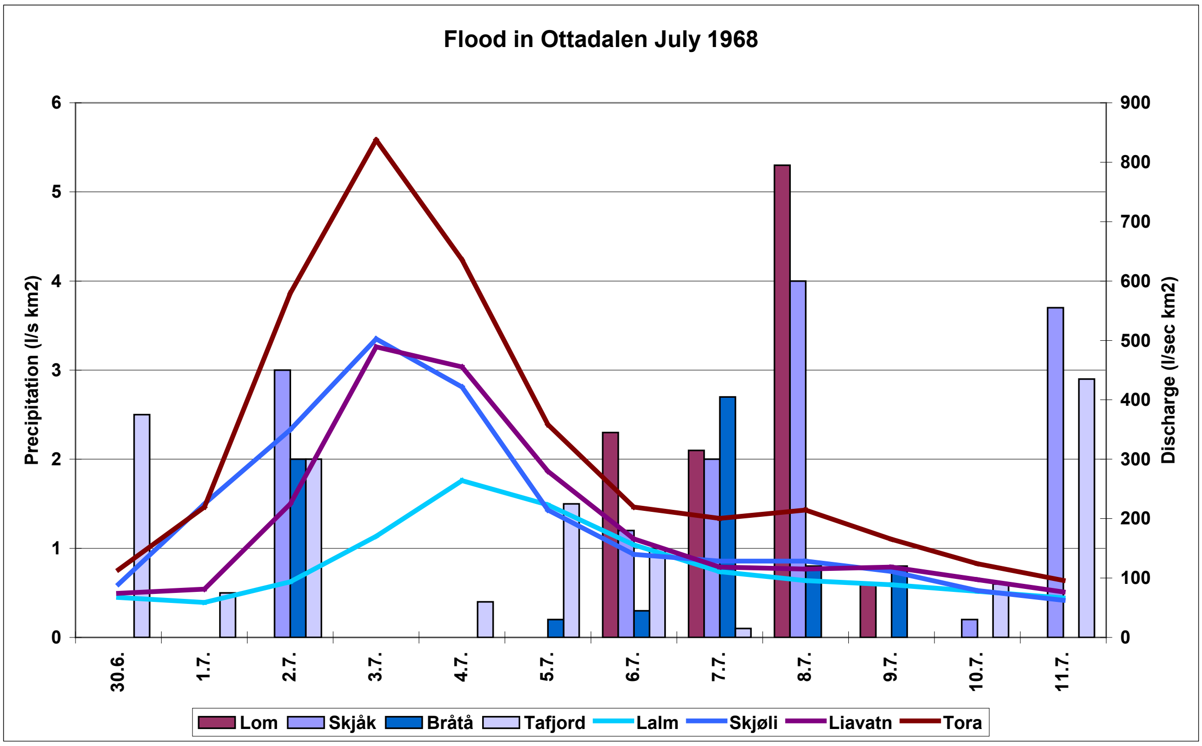


Figure 3.1.35.2 Observed precipitation and daily discharge during the large summer flood in rivers in Ottadalen in 1968.

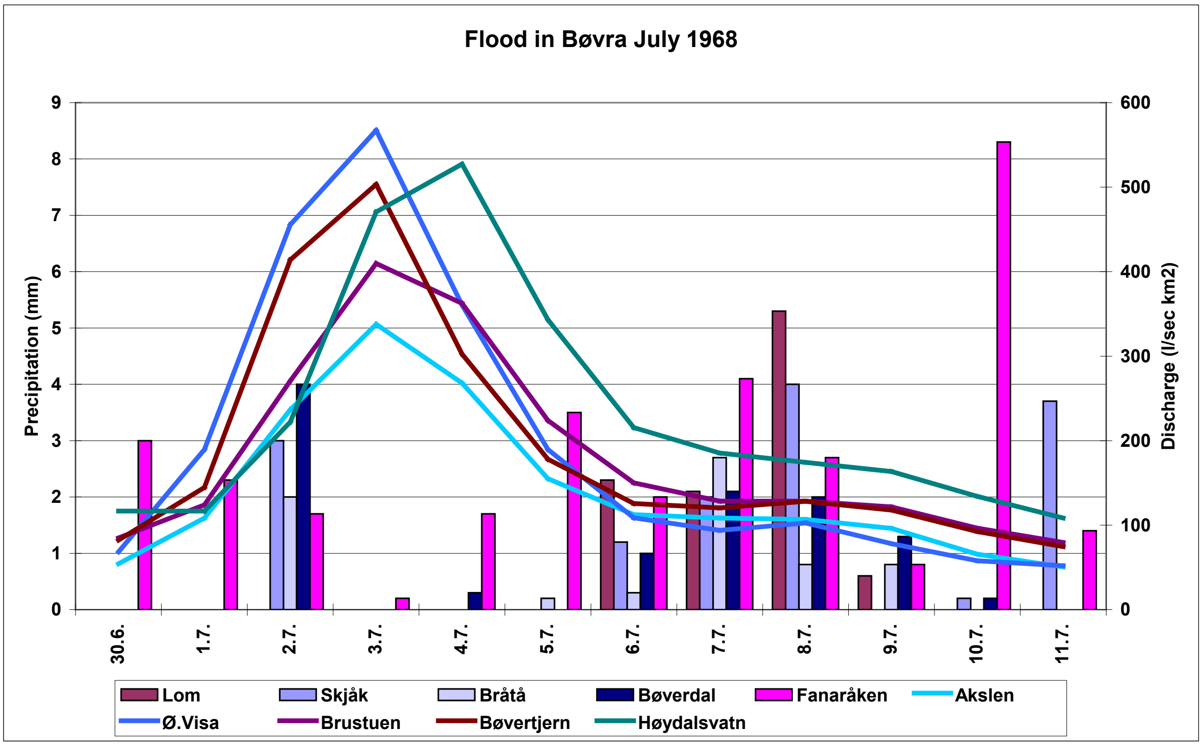
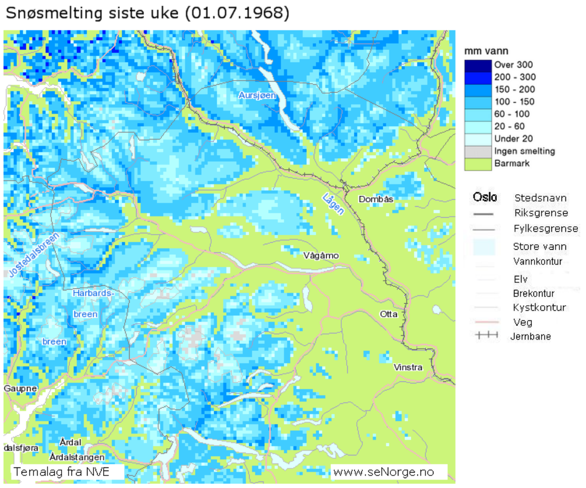


Figure 3.1.35.3 Observed precipitation and daily discharge during the large summer flood in River Bøvra in 1968.

Initial conditions

Some rain fell in Jotunheimen between 24 and 27 July prior to the flood. The temperatur rose from 30 June and reached a peak 3-4 July before more rainfall penetrated from west. Figure

3.1.35.4 a) and b) show that some snow remained at higher levels in the mountains 1 July even though the snow had melted in the valleys. Figure 3.1.35.4a show the estimated snowmelt last week, and Figure 3.1.35.4b show the depth of the remaining snow cover 8 July.



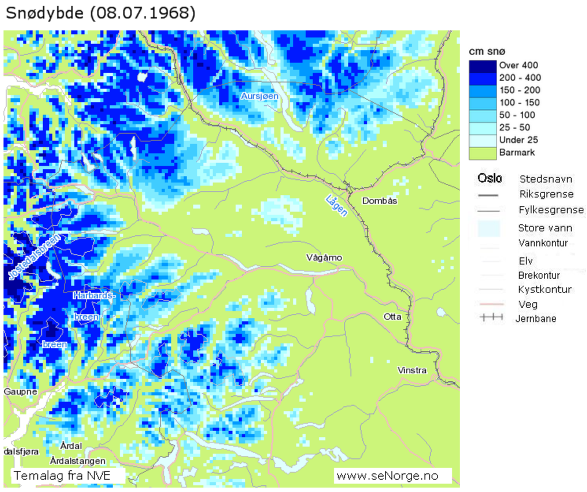


Figure 3.1.35.4a Snow melt last week 1 July 1968
Figure 3.1.35.4b. Snow depth remaining 8 July 1968.

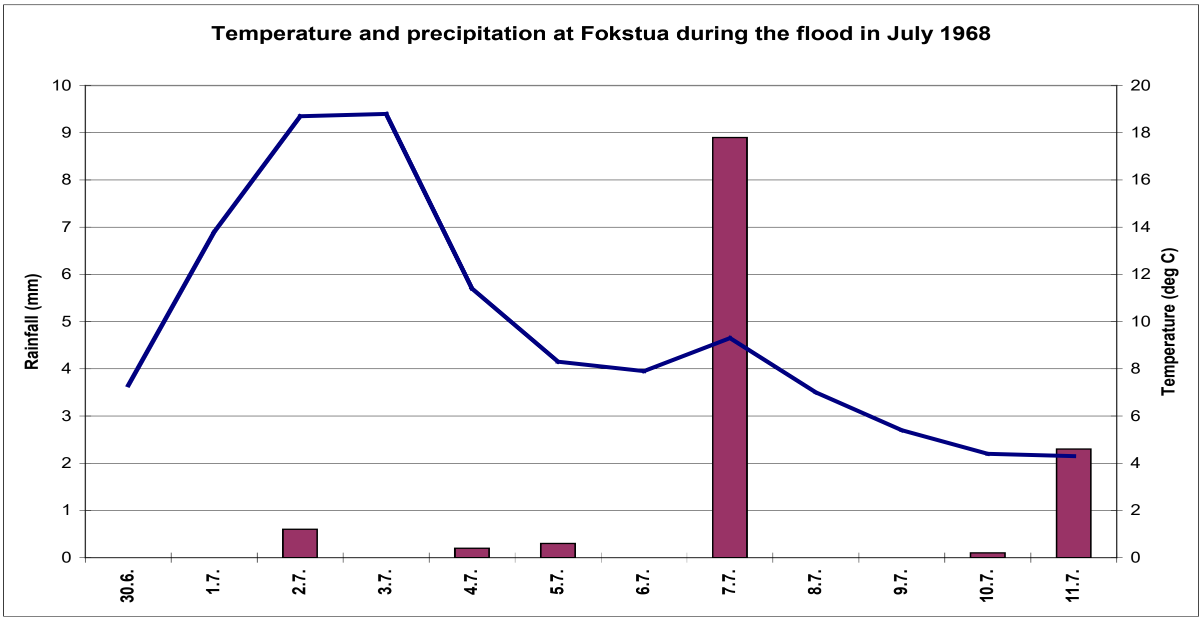


Figure 3.1.35.5 Observed temperature and precipitation at Fokstua during the spring flood at Dovrefjell and in Jotunheimen in early July 1968.

The weather types 2, 3 and 4 July were. **HM**, **BM,** and **BM** (Grosswetterlagen) and **C**, **C** and **W** (Lamb/Jenkinson).

3.1.36 A rainfall flood in Telemark in September 1968.

Heavy convective rainfall caused a flood in eastern Aust-Agder and western Telemark 3-5 September 1968.

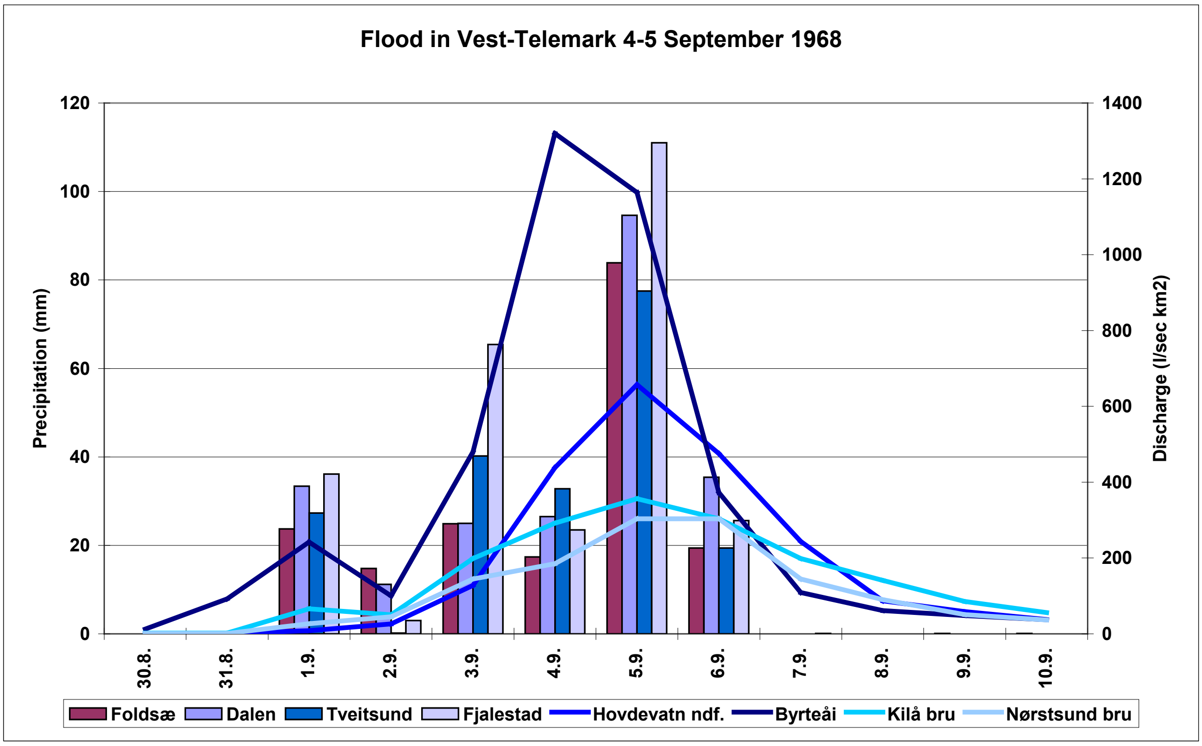


Figure 3.1.36.1 Observed precipitation and daily discharge during an autumn flood in Vest-Telemark in 1968.

The discharge at Byrteåi was the seventh highest daily value observed at the station. This station has very sharp floods and the peak is likely to have been much higher than the dayli mean value, especially in cinvective rainfall. A total of 200 mm rainfall was observed at Fjalestad.

The weather type 2-3 September: **TB** (Grosswetterlagen) and **C** (Lamb-Jenkinson) and 4-5 September: **HFZ** (Grosswetterlagen) and **A** and **S** (Lamb-Jenkinson).

3.1.37 The summer floods in mountains rivers in South Norway in 1972-1973.

A sequence of relativ large spring floods occurred in mountains rivers in Jotunheimen 1971-1973. The largest of these floods occurred in several mountain rivers in South Norway in the summer 1973. River Folla, Atna, tributaries to Gudbrandsdalslågen, Driva, Orkla, Gaula og Nidelva had all moderate to medium floods. Figure 3.1.37.1 show observed daily rainfall and discharge in Østerdalen and Gudbrandsdalen while Figure 3.1.37.2 show observed data in Trøndelag.

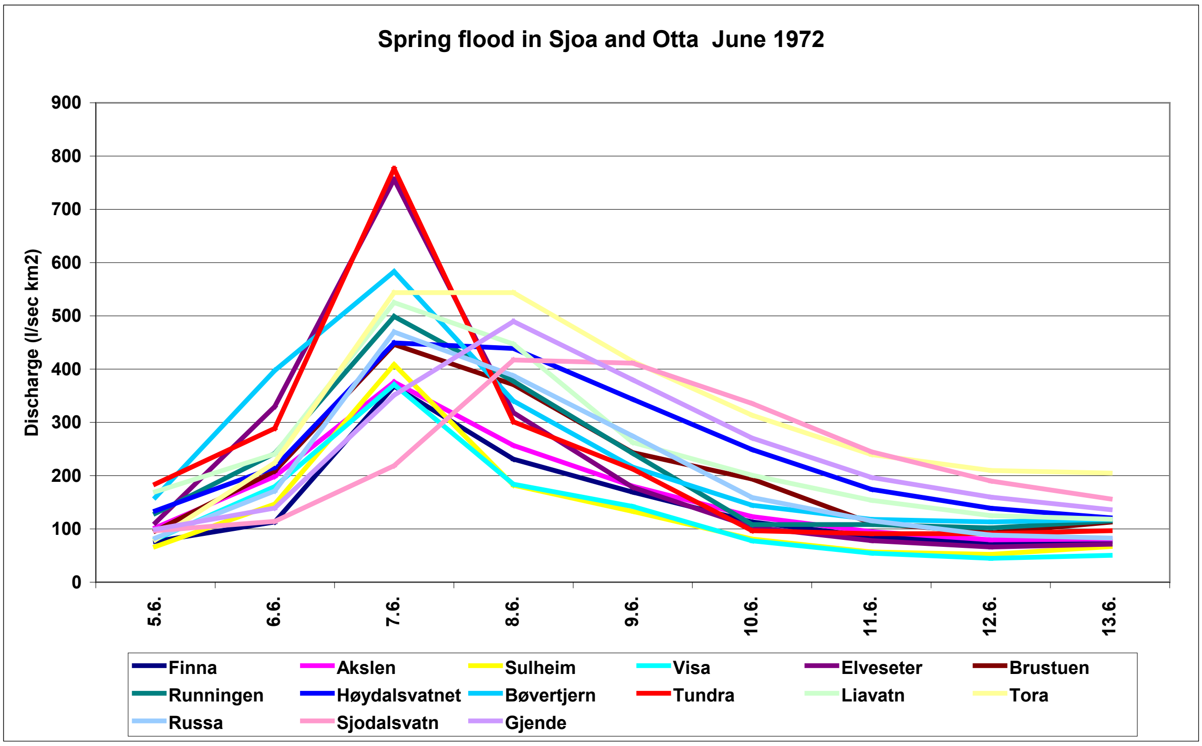


Figure 3.1.37.1 Daily discharge observed in tributaries to River Sjoa and Otta duruing the spring flood in June 1972.

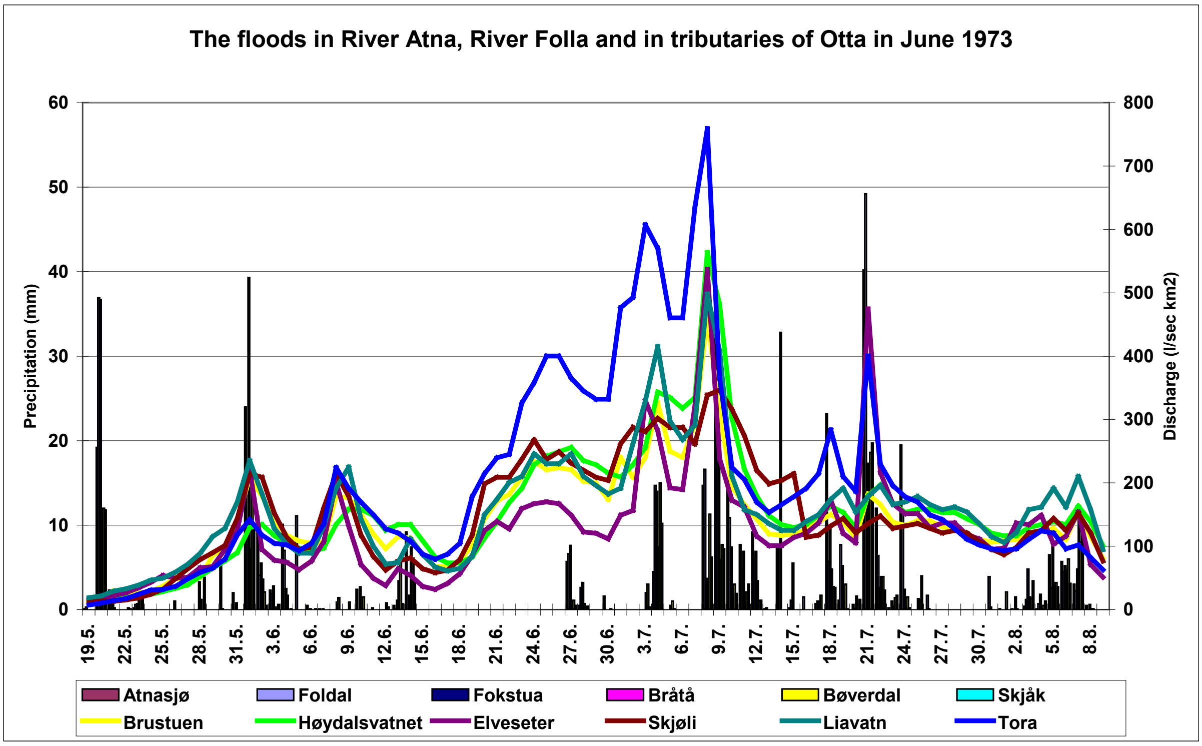


Figure 3.1.37.2 Observed precipitation and daily discharge during the summer flood in mountain rivers in South Norway in 1973.

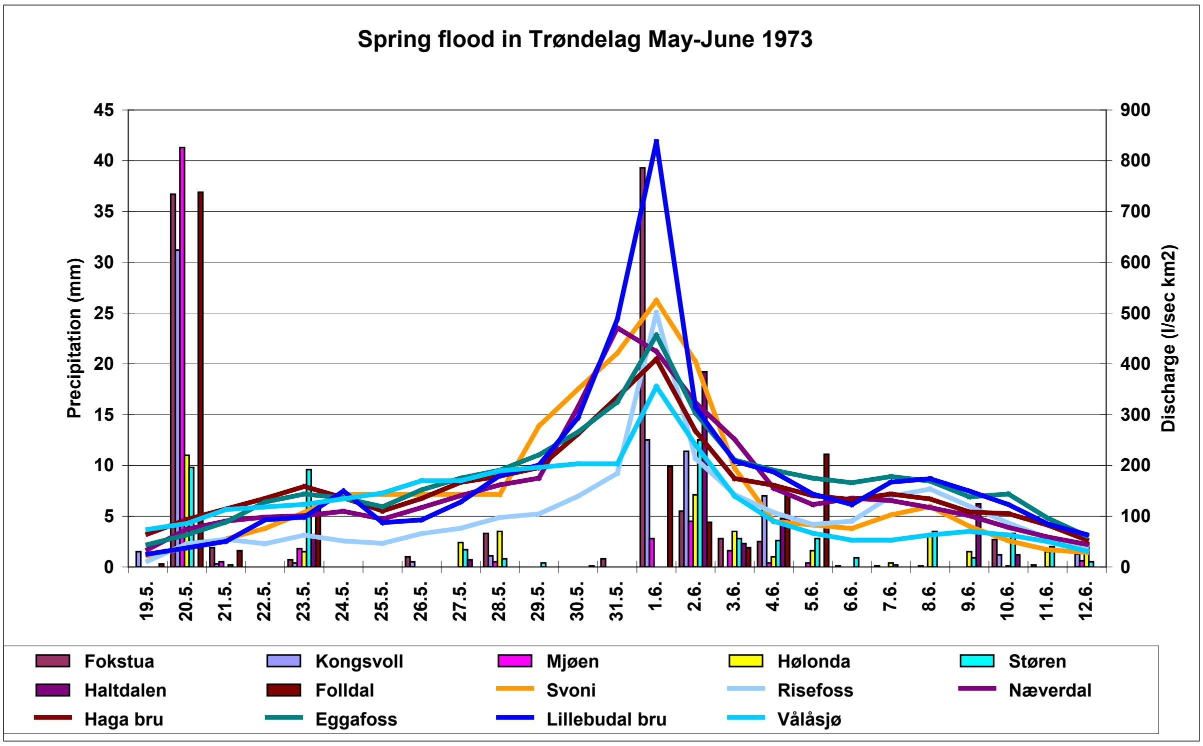


Figure 3.1.37.3 Observed precipitation and daily discharge during the summer flood in mountain rivers in Trøndelag in 1973.

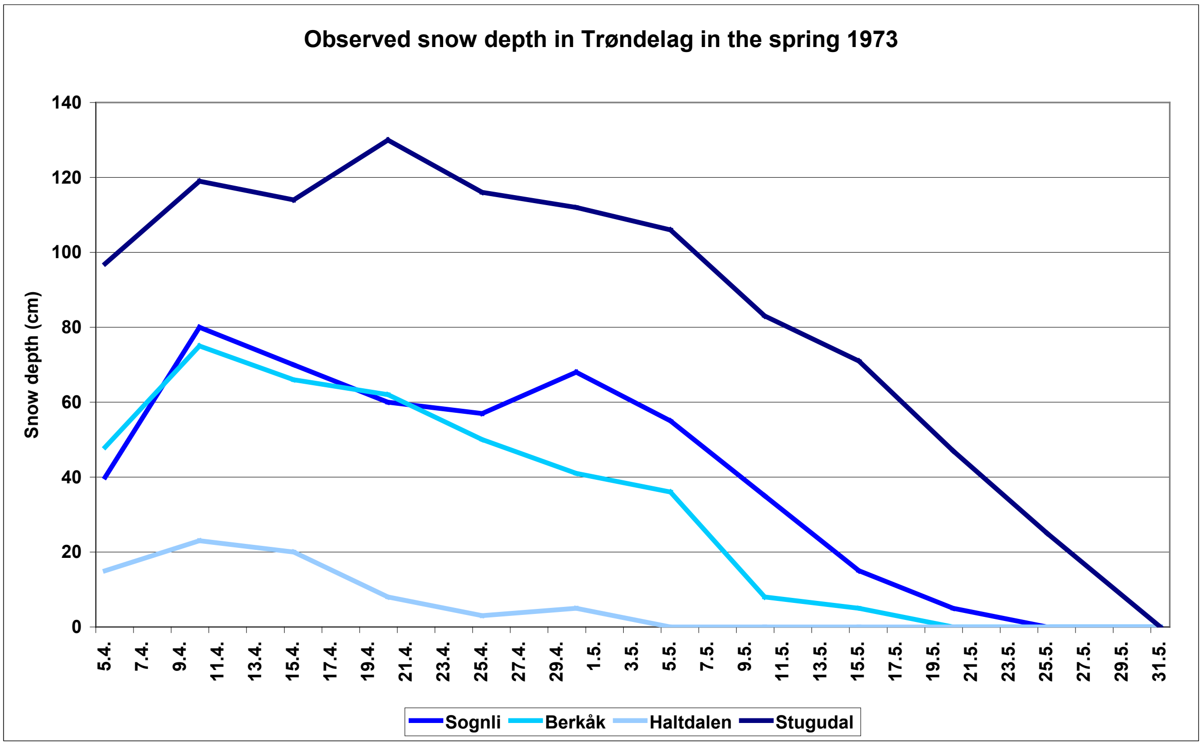


Figure 3.1.37.4 Observed snowdepths during the spring flood in Trøndelag in April and May 1973.

3.1.38 The rainfall flood in mountains rivers in South Norway 1 October 1985.

A late autumn rainfall event caused widespread floods in mountain rivers on both side of the water divide between Østlandet and Vestlandet. Figure 3.1.39.1 show observed daily rainfall and discharge in catchments in Ottadalen. Floods on the west side of the water divide is described in Volume 3.

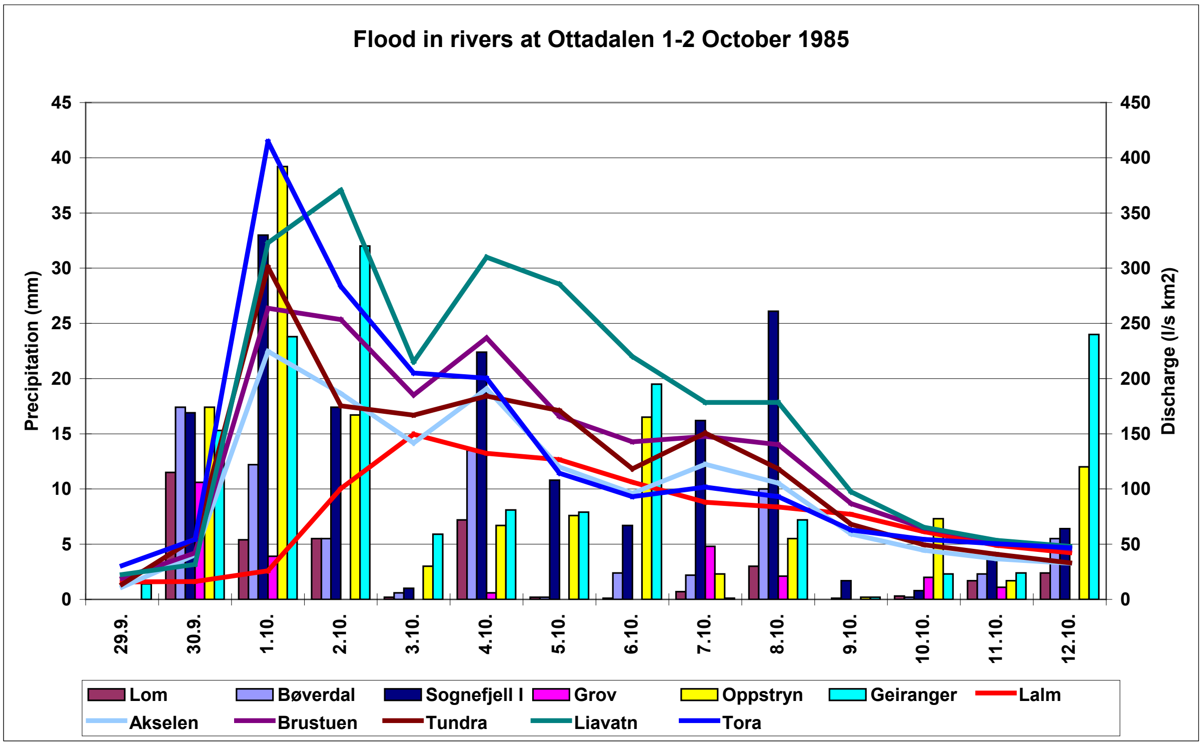


Figure 3.1.38.1 Observed precipitation and daily discharge during the October flood in Ottadalen in 1985.

The flood magnitude was less east of the water divide than on the western side with the exception of River Høya at Lake Høydalsvatn where the highest observed daily discharge 1966-199x occurred.

Cause of the flood:

Figure 3.1.38.2 show the water equivalent i mm of the snow by 1 October and the snow melt the last 24 hours. Initially there was some snow in Jotunheimen. Figur 3.1.38.3 show the distribution of observed precipitation 1 October. The map show that the most severe precipitation fell in a region west of the water divide from Sunnfjord to Nordfjord. Some precipitation fell east of the water divide toward Ottadalen, but the amount declined toward east. The floods occurring in Ottadalen were therefore caused as much from snowmelt as from rainfall.

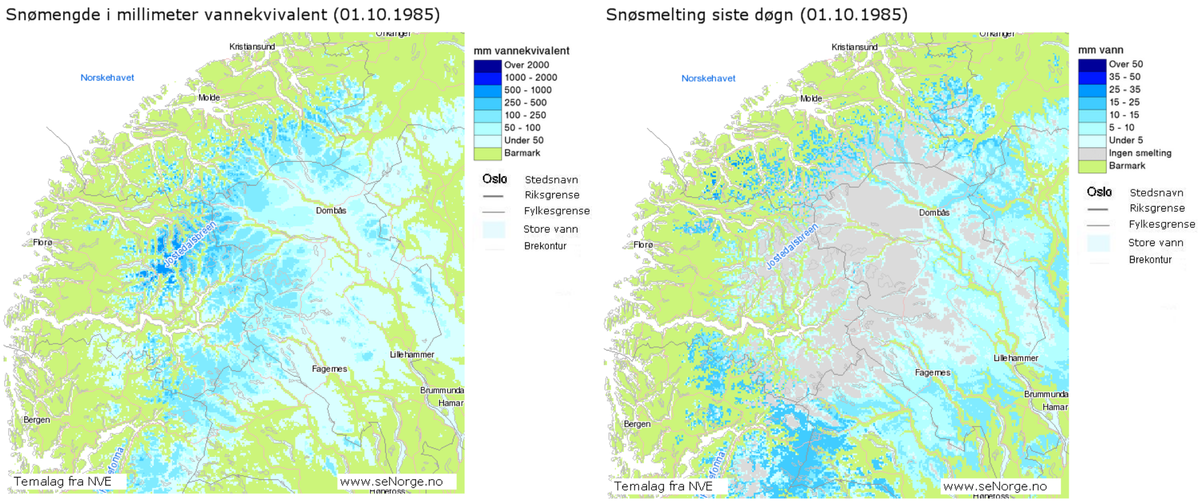


Figure 3.1.38.2 The water equivalent of the snow cover (mm) 1 Oct 1985 (left) and the snow melt since yesterday (right).

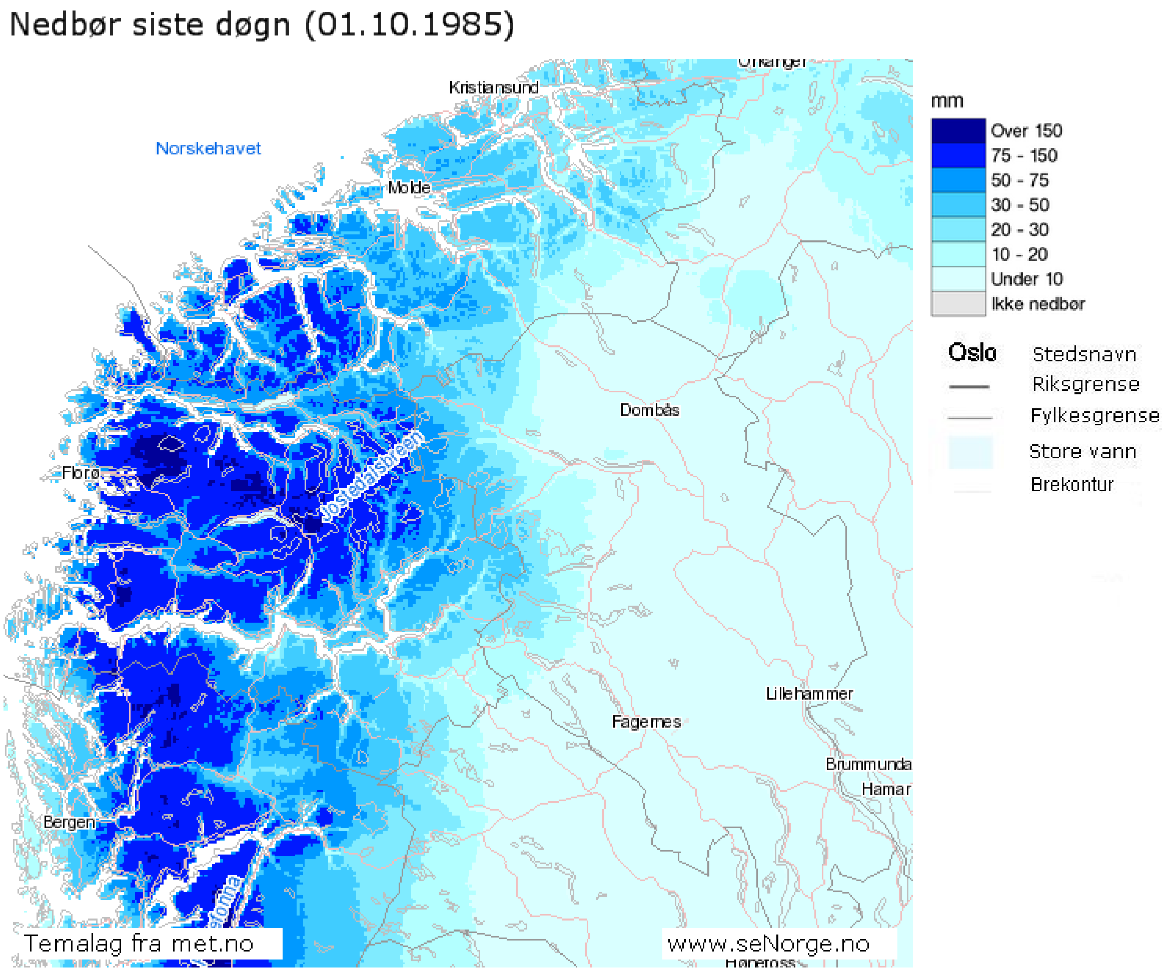


Figure 3.1.38. The distribution of the precipitation 1 October 1985.

3.1.39 The severe flood in Southeast Norway 16 October 1987.

A severe storm caused severe damages in southeast England and northeast France 16 October 1987. The storm moved through the English Channel and northwestwards into the North Sea towards Skagerak and the Oslofjord. The storm caused storm surges and inundation in harbours in coastal towns along the Oslofjord. Smaller rivers close to the coast had large floods at Sør- and Østlandet. The amount of precipitation was not was extreme, but abundant rainfall ahead of the flood had filled up the groundwater reservoir. The storm caused also extensive damages to the forests especially in Hedmark, and the flood caused also several landslides. The event is an example of how different types of damages combine to cause severe losses even if each single type caused mostly moderate damage.

Precursor

The flood was caused by extreme weather ravaging in Southern England. France had a heat wave when a low appeared in the Bay of Biskay 15 October 1987 12:00 UTC. The central pressure was 970 hPa. At 18:00 UTC the low had intensified by 6 hPa. The pressure dropped further as the wind velocity increased. The strengthening of the storm was caused by varm air masses streaming eastward over the Atlantic from Hurricane *Floyd* located east of USA and in combination of a large temperature gradient between the warmt in the Bay of Biskay and cold air masses moving southward from Iceland toward the Iberian peninsula. The position and the fast movement of the low, was linked to an unusually strong jetstream south of 50° N. The trajectory is quite unusual in this region in October.

Hurricane *Floyd* was the third hurricane in 1987, and the first reaching the east coast of USA. The origin was a tropical depression in the western Caribian Sea 9 October. The strength increased to tropical storm 10 October, while moving northwards, crossing Cuba in the evening 11 October. *Floyd* was upgraded to a hurricane 12 October 12:00 UTC. The storm moved now northeastward south of Florida and out in the Atlantic. *Floyd* weakened and turned into an extratropical low which joined a larger polar front cyclone night to 14 October. Figure 3.1.40.7 show the trajectory of Hurricane *Floyd*. *Floyd* was a Category 1 hurricane with a maximum wind velocity of 70 knot.

The low moved toward Great Britain from west, setting up a strong air stream through the English Channel and over Southern England. An intense secondary low appeared over the south coast of England before moving towards northeast. As the low approached Britain, some rain fell ahead of the warm front. Behind the front the wind direction shifted to south-southwest. The depression moved across the south coast of Devon between 01:00 and 02:00 and reached Exeter 02:00. The air pressure was 953 hPa, the lowest in England and Wales in October in 150 years. The center of the depression was located over Somerset levels at 03:00 UTC. Mean wind velocity in the southwest England, the southern part of the Midlands, east England, northern France and the coast of the Netherlands and Belgia was above 15 m/sec eller 34 mph. The strongest winds occurred between kl 04:00 and 05:00 UTC. In a line from Hull to Cardiff the wind increased to Force 10 or storm on the Beaufort scale (24 m/sec or 34 mph). Gusts up to 31 m/sec (81 mph) were measured in the districts suffering the heaviest damages during 3-4 hours. The strongest gusts were observed at Pointe de Roc near Granville in Normandie of 60 m/sec (134 mph), and 54,5 m/sec (122 mph) at Gorleston in Britain. The highest mean wind velocity in an hour was 38 m/sec (85 mph) at Shoreham-by-Sea. Acording to the U.K. Met.office the gusts and the mean wind observed southeast of a line from Southampton through North London to Great Yarmouth had a return period of 200 år. These storms are far more in Northern Scotland than in Southeast England.

Météo France issued a forecast of a strong gale from the Azores to Bretagne at 06 PM 15 October. The first depression did not cause much damages as the wind velocity was only 50- 60 km/hours (31 – 37 mph or 27–32 knot) wind. A much deeper depression reached Ushant west at Bretagne by midnight. The air pressure at the weather station at Brest-Guiapavas værstation was as low as 948 hPa. Other weather stations at Pointe du Raz, Pointe Saint-Mathieu and Penmarch were out of operation because of damages caused by the wind. At Brest the wind velocity was 148 km/hour (92 mph eller 80 knot). The storm center crossed over Bretagne from Penmarch til Saint-Brieuc at 110 km/t (68 mph or 59 knop), with gusts to 187 km/hours (116 mph or 101 knop) at Quimper, 200 km/t (120 mph eller 110 kn) at Ouessant and 220 km/hours (140 mph or 120 knop) at Pointe de Penmarch and Granville. at Ushant and Belle Île ble bølgehøyder at 16 m observed. A storm of a similar strength 1990 struck Frankrike (Tempête Vivian) in 1990, and it happened twice in December 1999.

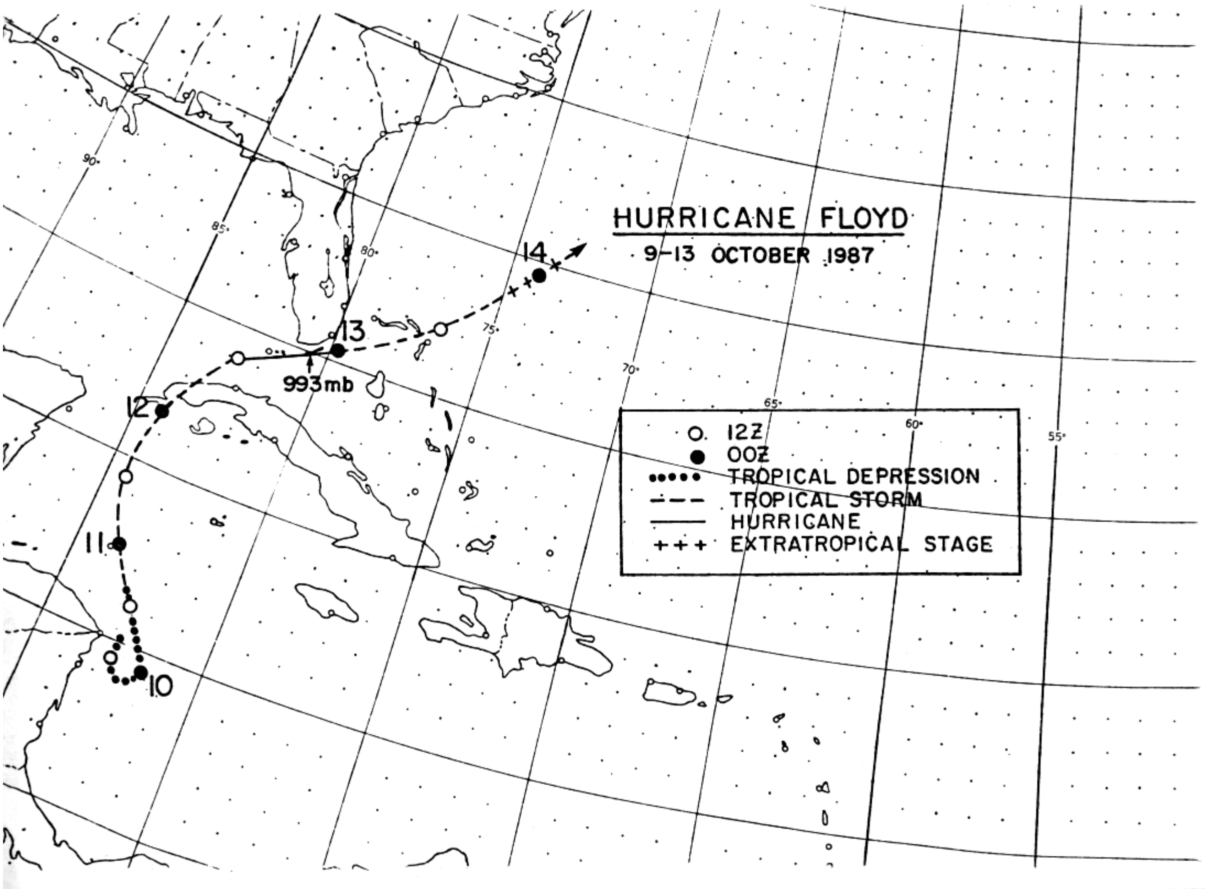


Figure 3.1.39.1 The trajectory of Hurricane Floyd 9-14 October 1987. (Source: National Hurricane Center).

Kl 07:00 the storm moved over the North Sea. The stormen weakened as it was moving northward . The remnants of the depression moved close to the coast of Vestlandet, setting up strong wind from southwest causing a severe storm surge in the Oslofjord. Weather types 16-17 October were: **WW** (Grosswetterlagen) and **C** and **S** (Lamb/Jenkinson)

Prior to the storm abundant precipitation fell in Sør-Norway 6-10 October. Some snow had fallen in the mountains, but little or no snow in the lowlands, as shown in Figure 12. The groundwater reservoar and soil moisture content was moderate 6 October, but the ground was saturated and the groundwater reservoir was filled up by 16 October in southeast-Norway. Figure 13 and 14 show the distribution of the precipitation 16 and 17 October.

The forecasting the storm:

The British Met.Office was critisised for failing to issue correct warning. Prior to the storm some important weather ships in the Atlantic had ceased to operate for financial reasons. These weatherships used to send up radiosonde twice each day providing important upper air data required by the forecasting models.The institute was running two forecasting models at the time, one with coarse spatial and temporal resolution and one high resolution local model. The models lacked essential upper air data from the Bay of Biskay where the storm was developing. One week ahead of the storm the high resolution and the coarse resolution model predicted a severe storm. The forecasts from the two models started to diverge. The duty meteorologist based his forecast on the model which usually gives the most accurate forecast. Unfortunately, this forecast was wrong, while the forecast from the other model was fairly accurate. The meteorologist Michael Fish appeared with a forecast on the Nine o'clock news on the BBC. Han told that a lady on the coast of the Channel had heard a French forecast kysten that she had heard a warning of an expected hurricane at night in the Channel from France. Fish said that no hurricane would appear. This led to a review of the warning procedures of the British Met.Office, which have been documented in reports.

The rainfall and flood in Norway

Figure 3.1.39.2 show daily rainfall and discharge in rivers in Østfold, Figure 3.1.40.3 in Oslo and Akershus, Figure 3.1.39.4 in Sør-Oppland, Figure 3.1.39.5 in Buskerud and Vestfold, Figure 3.1.39.6 in Telemark and Figure 3.1.39.7 in Agder, (Andresen et al, 1987).

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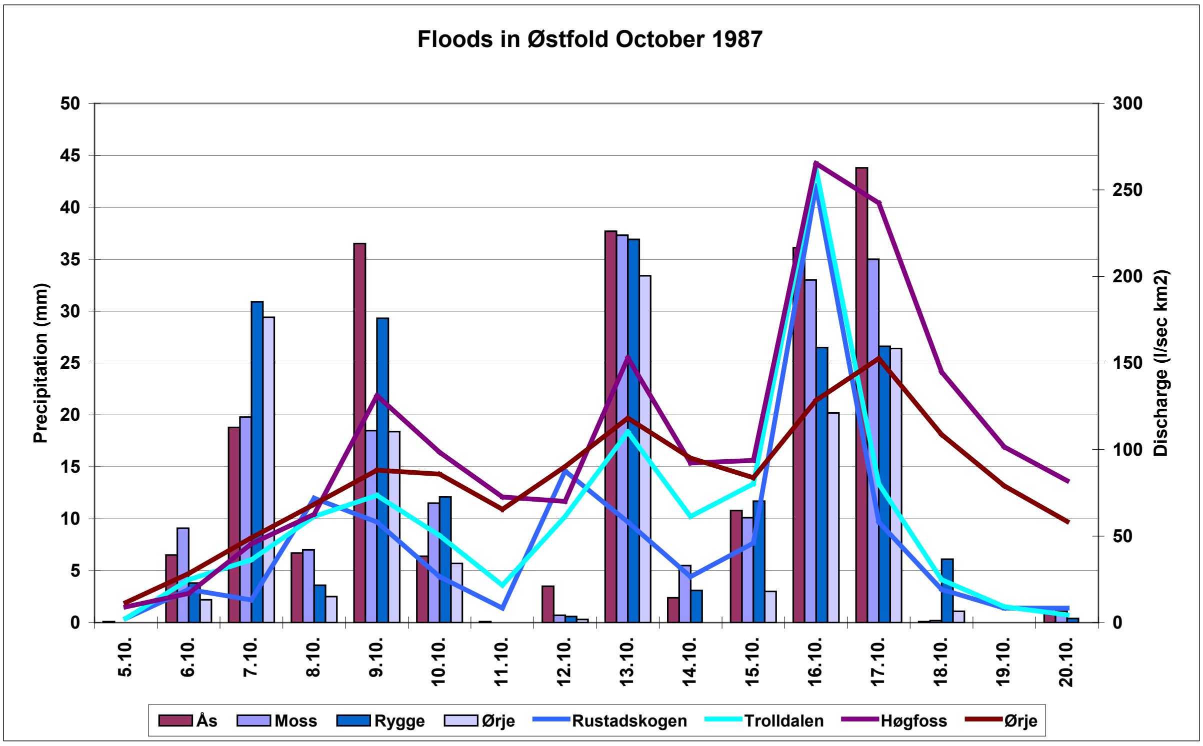


Figure 3.1.39.2 Observed precipitation and daily discharge in Østfold during the rain flood in October 1987.

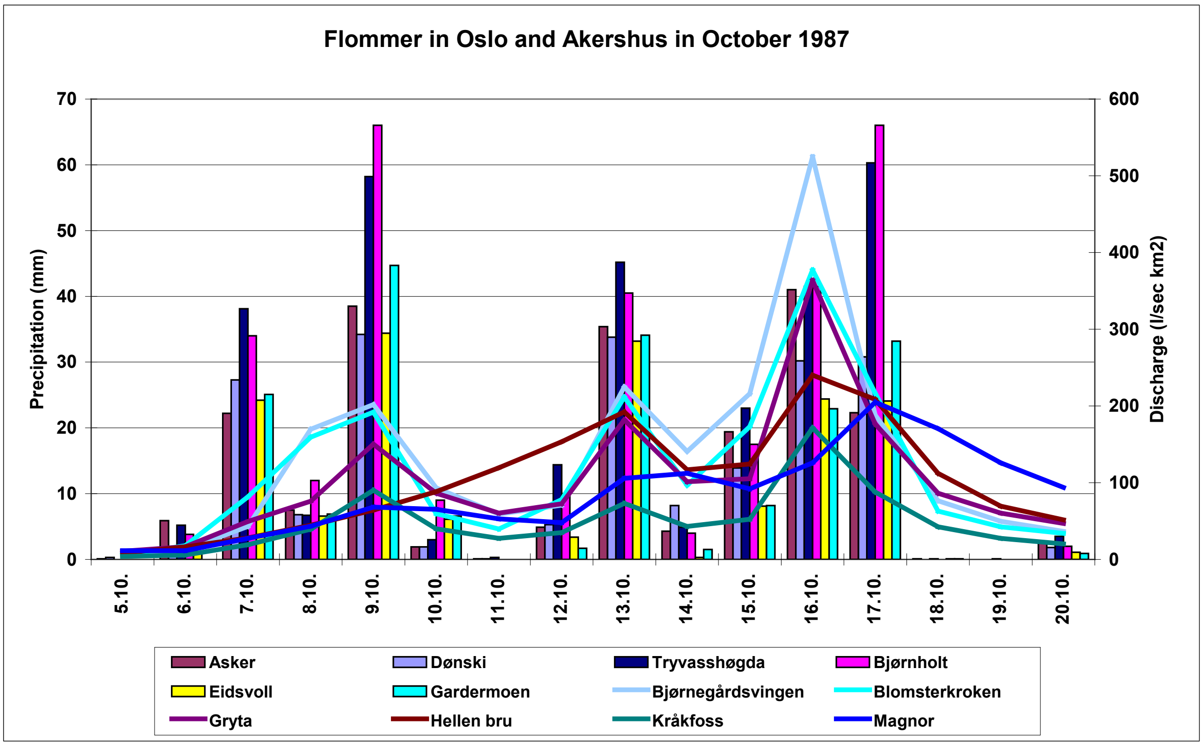


Figure 3.1.39.3 Daily rainfall and discharge (daily values) in Oslo and Akershus during the flood in October 1987.

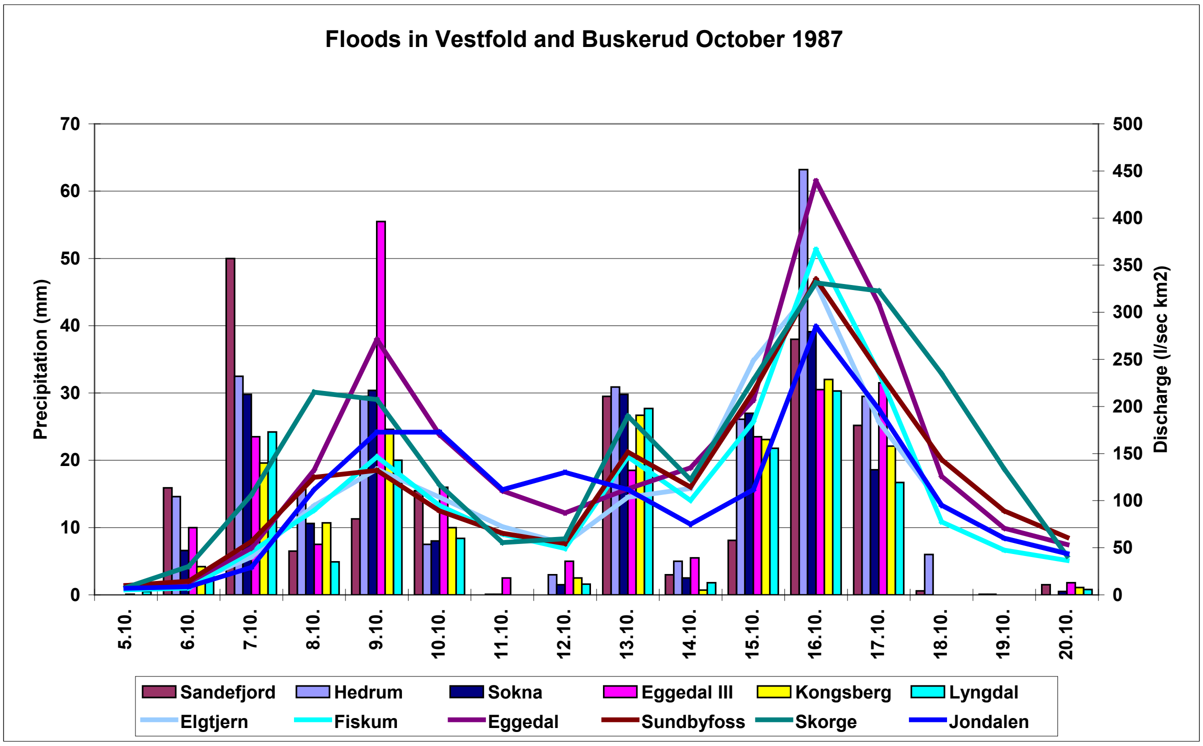


Figure 3.1.39.4 Observed rainfall and discharge (daily values) in Vestfold and Buskerud during the rainfall flood in October 1987.

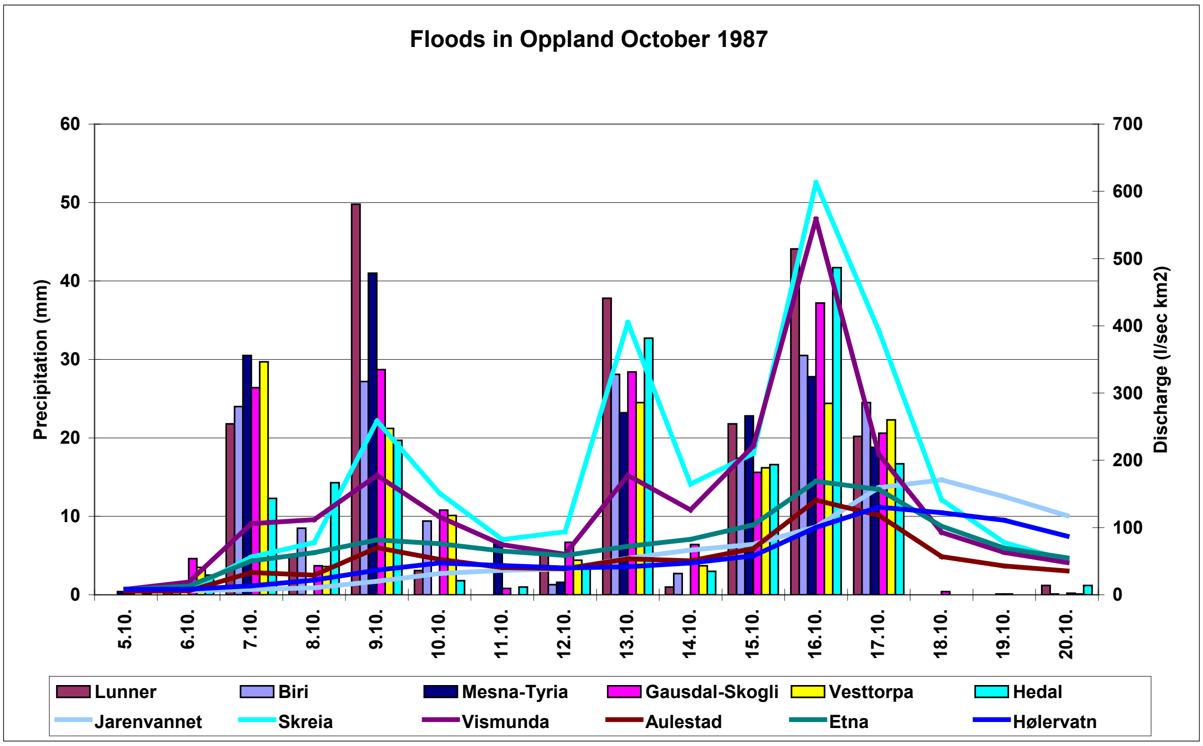


Figure 3.1.39.5 Observed rainfall and discharge (daily values) in Oppland during the rain flood in October 1987.

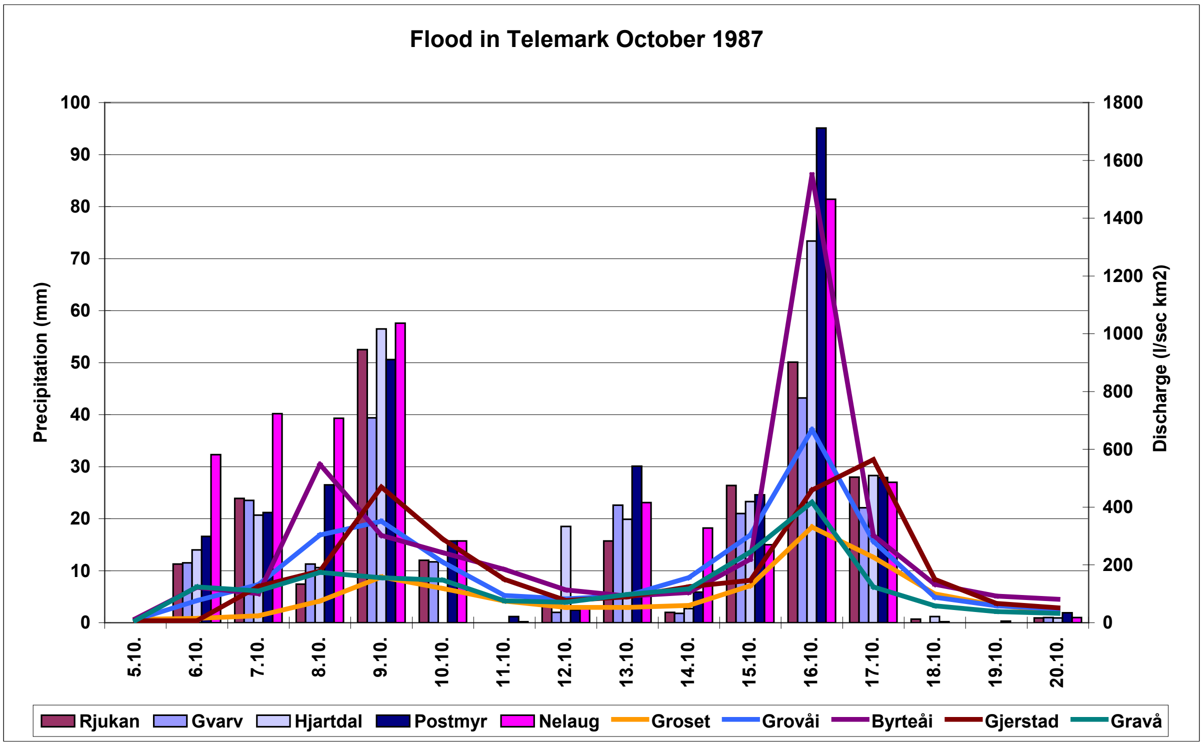


Figure 3.1.39.6 Observed precipitation and discharge (daily values) in Telemark during the rainfall flood in October 1987.

The flood was the largest observed in River Nidelva at Lunde Mølle 1900-2008, in River Tovdalselva at Austenå 1924-2010 and at Lake Flaksvatn 1899-1910. It was among the larger floods in many small rivers at Sørlandet. In River Gjerstadelva the flood was third largest and in River Tjellingtjernbekk fifth largest 1981-2014. The flood was the largest at Tovsliøytjønn 1969-2002. In River Rauåa and River Stigvasså the flood was second largest 1972-2014 and in River Gravå the largest 1970-2014. Further west at Sørlandet, the flood was less extreme.

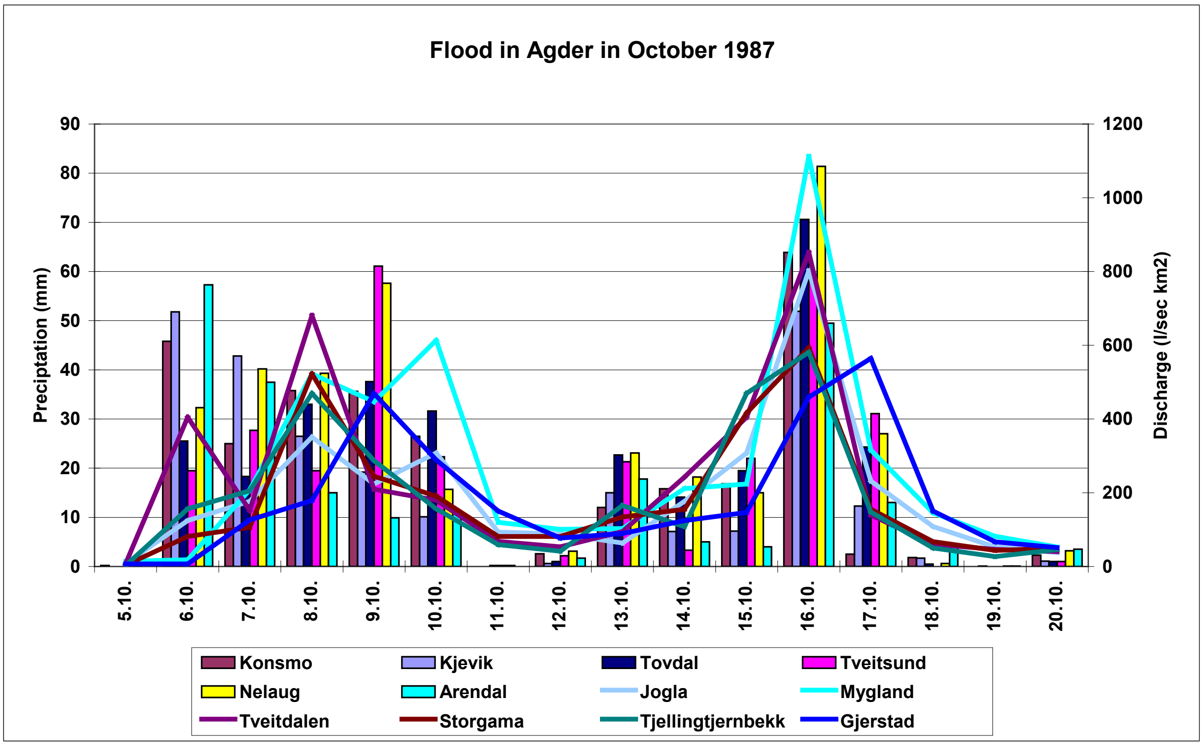


Figure 3.1.39.7 Observed precipitation and discharge (daily values) in Agder during the rainfall flood in October 1987.

The depression moved northwards along the coast of Vestlandet, gradually filling 17 October. Locally there was some rainfall at Vestlandet, most at Kvamskogen 83,1 mm and at Takle 70,9 mm causing small floods in coastal rivers, men these floods were smaller than earlier floods 18-19 September, which neither were among the large floods within the region. The accumulated precipitation in south Norway 11- 17 October is shown in Figure 3.1.39.8.

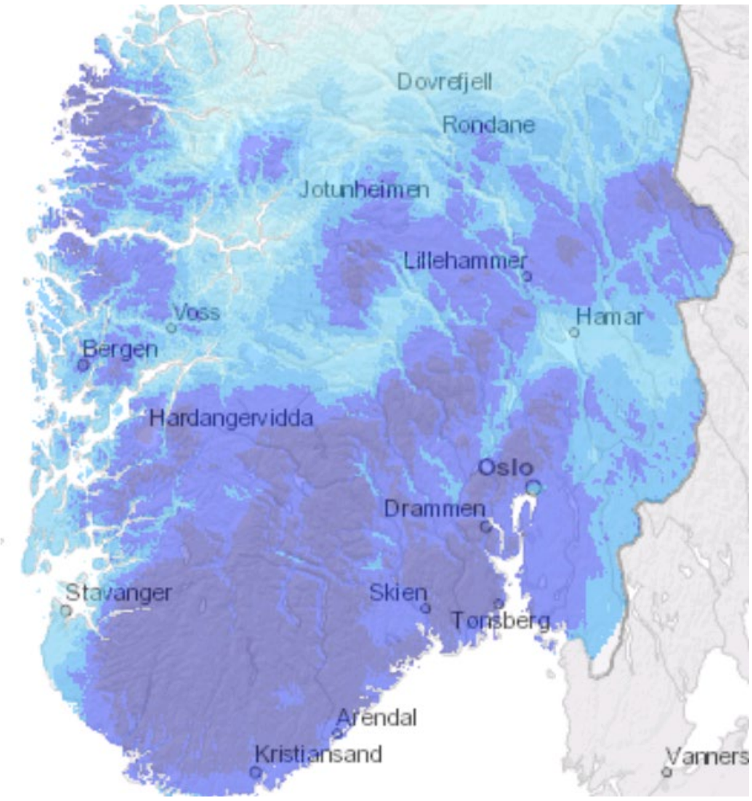


Figure 3.1.19.8 The accumulated rainfall 11-17 October 1987 in south Norway

Flood damages:

The storm moved fast across the North Sea, resulting in gale to storm force wind at the coast of the Oslofjord (Engen, 1987). The storm caused large difficulties for the road- , railway-, and airtraffic. The storm surge in Oslo was 255 cm over datum. Large areas in the port of Oslo, Drammen and other towns at the Oslofjord were inundated. The water penetrated into some hundred buildings in Oslo and Drammen. In Drammen harbour 1000 newly imported cars were inundated in brackish water from the Fjord. These cars were later re-eksported to Island. E 18 was closed at Lysaker because of the storm surge and flood in River Lysakerelven. In Sørkedalen flood in River Sørkedalselva cut the road. Landslides occurred in Sørkedalen and at Skui in Bærum. The wind uprooted a volum at 2 mill m^3 trees. Half of the loss occurred in Hedmark. A 79year old woman drowned in a brook at Svelvik, otherwise no-one was killed or severely wounded. Table 3.1.39.8 show countywise overview over damages resulting from natural causes in 1987.

Table 3.1.39.8 Overview over natural damages in counties affected by the storm in October 1987 according to the cause of damages. (Source: Forsikringstidende, Oslo. Nr. ¾ 1988).

County	Slides	Storm	Flood	Storm surge	Totalt
Østfold	33.600	2.435747	9.662.581	13.311.956	25.443.884
Akershus	591.600	12.163.057	81.422.793	8.449.611	102.627.061
Oslo	160.000	7.716.080	20.947.111	7.342.689	36.165.880
Hedmark	2.435	2.987.045	783.573	35.466	3.808.520
Buskerud	57.380	4.609.177	22.993.674	23.004.566	50.664.797
Telemark	245.510	10.666.368	55.077.825	10.871.512	76.861.215
Aust-Agder	51.808	8.834.109	6.338.789	4.771.318	19.996.024
Vest-Agder	111.813	6.323.462	7.469.033	17.579.341	31.483.649
Sum	1.254.146	55.735.045	204.695.379	85.366.459	347.051.030

The table show that flood was the most important cause of the damages, followed by storm surges and damages caused by strong wind (mostly on forests) as third. The insurance industry considered this event to represent the worst case of damages caused by a combination of all types of natural damages.

The table is based on data from the insurance companies and includes damages on properties covered by insurance against fire and natural disasters. Properties that cannot be insured can also obtain compensation. These damages are covered by av Naturskadefondet (Natural Peril Fund) funded by the the Norwegian state. Compensation for damages of farmland requires a separate insurance. Damages to roads, railways and other infra structures are covered by the State, which is a self insurer. The storm in October 1987 caused total damages of 650 mill. kroner (NOK) (1988).

The storm was in several ways the first modern type of disaster encountered by the insurance industry. Since then several disasters occurred such as severe tropical hurricanes *Hugo* in September 1989 and Andrew in 1992, the flood in River Oder in 1997, the flood in Central Europe in August 2002 and Hurricane *Katrina* in New Orleans in September 2005. Europe suffered from large storms in January and February 1990.

3.1.40 The rainstorm near Lake Mjøsa 3 September 1988.

Heavy rainfall caused local floods in several small rivers at Romerike, at Mjøsa, at Kongsvinger and at Aurskog-Høland 3 September 1988. Figure 3.1.40.1 show observed daily rainfall and discharge at stations in the district affected by the rainfall storm.

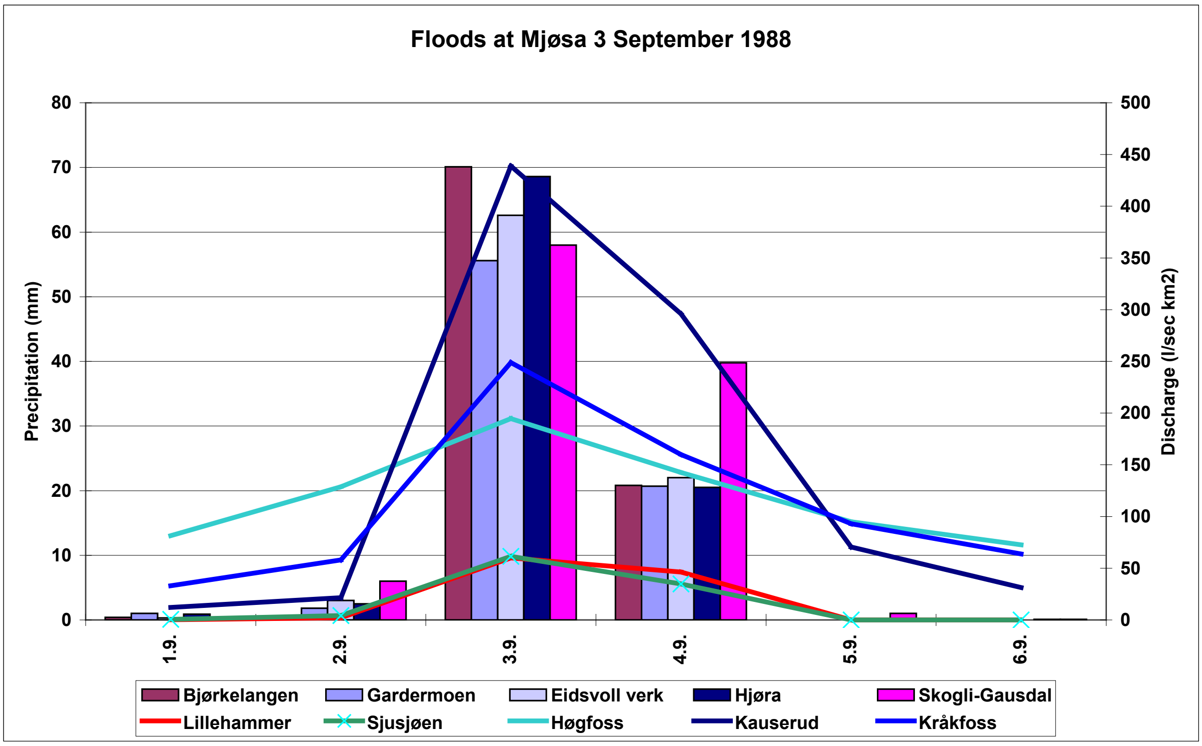


Figure 3.1.40.1 Observed precipitation and daily discharge during the rainfall storm in rivers near Lake Mjøsa in 1988.

The flood was second largest observed in River Rakkestadelv at Stortorp 1979-2002, in River Rømua at Kauserud 1971-2010, in River Lena at Skreia 1986-1995, in River Vismunda 1986-2010 and in River Lierelva at Oppsal 1981-2006. In River Leira at Kråkfoss the flood was third largest 1966-2010. The highest one-day rainfall was observed at Jeppedalen with 88 mm. Figure 3.1.40.2 show the distribution of rainfall at Sør-Østlandet 3 September 1988

Between a low north of Skottland and an anti-cyclone over Russia mild air was streaming from southeast towards Øst-Norway. The rainfall was caused by showers in the frontal zone between the mild air in the east and cooler maritime air from the North Sea. Weather type: **WZ** (Grosswetterlagen) and **W** (Lamb-Jenkinsson).

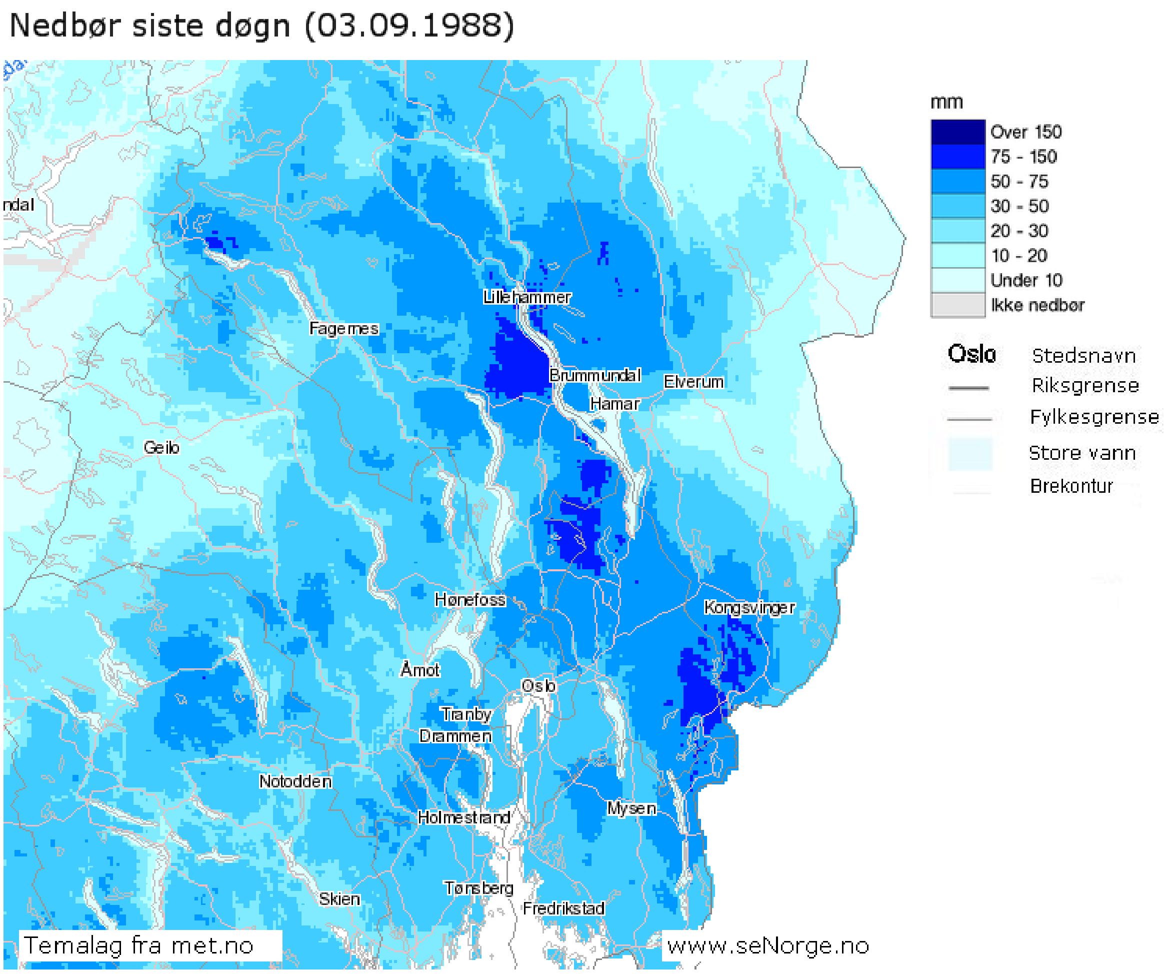


Figure 3.1.40.2 Observed distribution of the rainfall 3 September 1988.

Flood damages:

The flood caused riverbank failures and landslides. Worst damages were near River Vismunda, in Gjøvik and Lillehammer. Estimated damages: 100 mill. NOK (Andersen, 1996).

3.1.41 The spring flood in East Norway and in Trøndelag in June 1995 (*Vesleofsen)*

The spring flood in June 1995 is at many locations the largest and caused more damages than any other flood on record. The flood occurred in several of the large rivers in East Norway, but was most severe in River Trysilelv, River Glomma and in Gudbrandsdalslågen with exception of the alpine western part of the catchment.

Causes of the flood:

The flood resulted from a combination of conditions which each were not extreme. The severe flood was the result of the co-incidence of several moderate factors. The weather types during the most intensive part of the flood 29. May- 4 June were: **TB**, **TB**, **TB**, **TB**, **U**, **SWZ**, **SWZ** (Grosswetterlagen) and **C**, **C**, **C**, **NW**, **NW**, **C**, **C** (Lamb-Jenkinsson)

Initial conditions

The snowfall during the winter 1994/1995 was above normal within most of East Norway. The amount of snow was 100-120 % of the normal at all levels from 400 to 1200 m.a.s.l. with higher values at some locations at the end of April. Glommen og Laagens Brukseierforening estimated the snow reservoir within the Glomma and Lågen basins to be 1230-150% of the normal. Figure 3.1.41.1 show the water equivalent of the snow reservoir 30 April 1995.

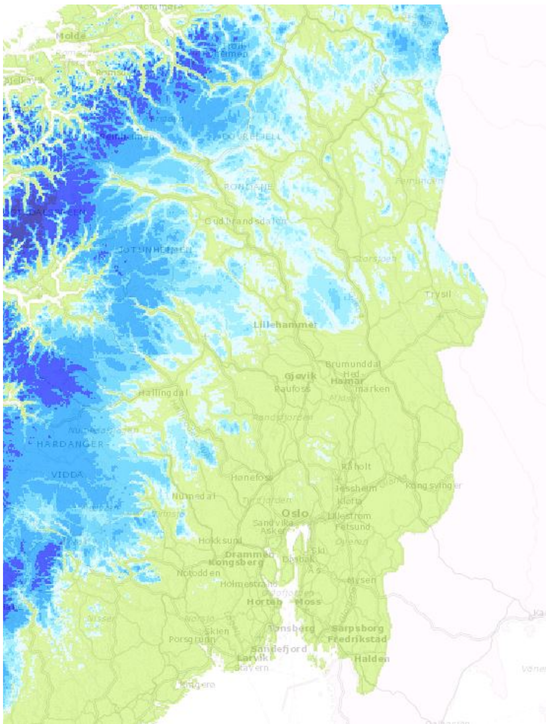
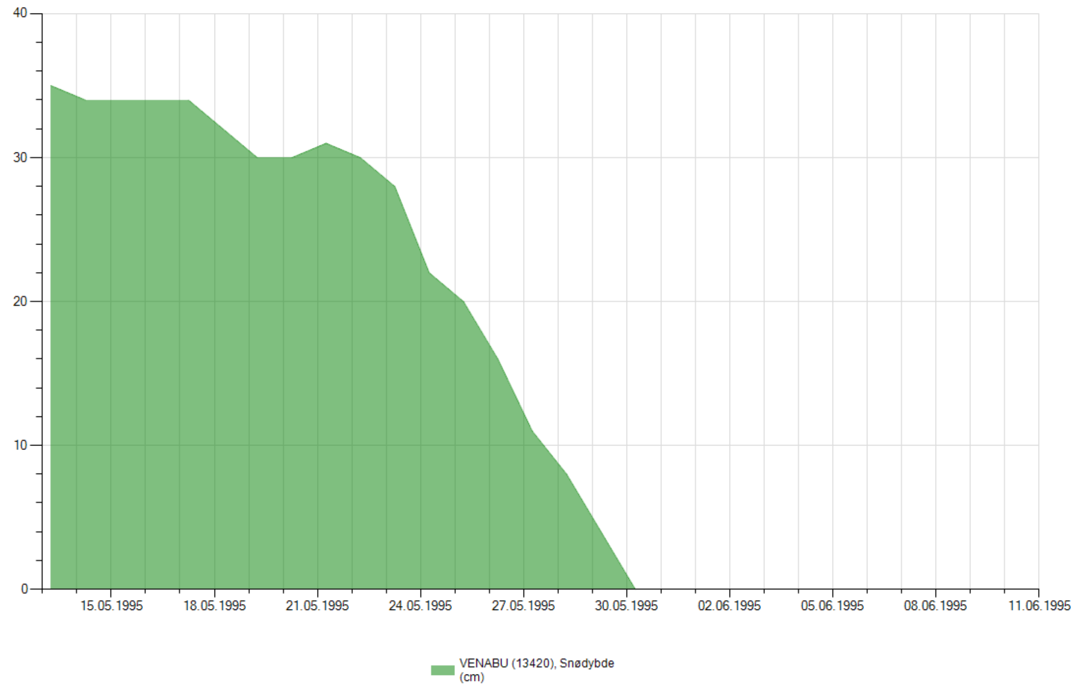


Figure 3.1.41.1 The water equivalent of snow (mm) in South Norway in 30 April 1995.

Low temperatures in most of May caused delayed snowmelt, and the melting occurred only at low levels. The precipitation fell as snow at intermediate and high altitudes causing the snow reservoir to increase at these levels. The temperature rose eventually from 22 May, causing simultaneous snowmelt in forested areas between 300 and 1000 m.a.s.l. and from the mountains. It was estimated that 4000 mill. m^3 snow melted from 25 May to 2 June. The snow melt corresponds to a rainfall of 100 mm distributed over the entire basin. Between 50 and 70 mm rain fell additionally over much of the basin from 28 May to 3 June, a rainfall which roughly correspond to the normal monthly rainfall in the region. Additional rainfall occurred 7- 9 June in catchments west of Gudbrandsdalslågen.



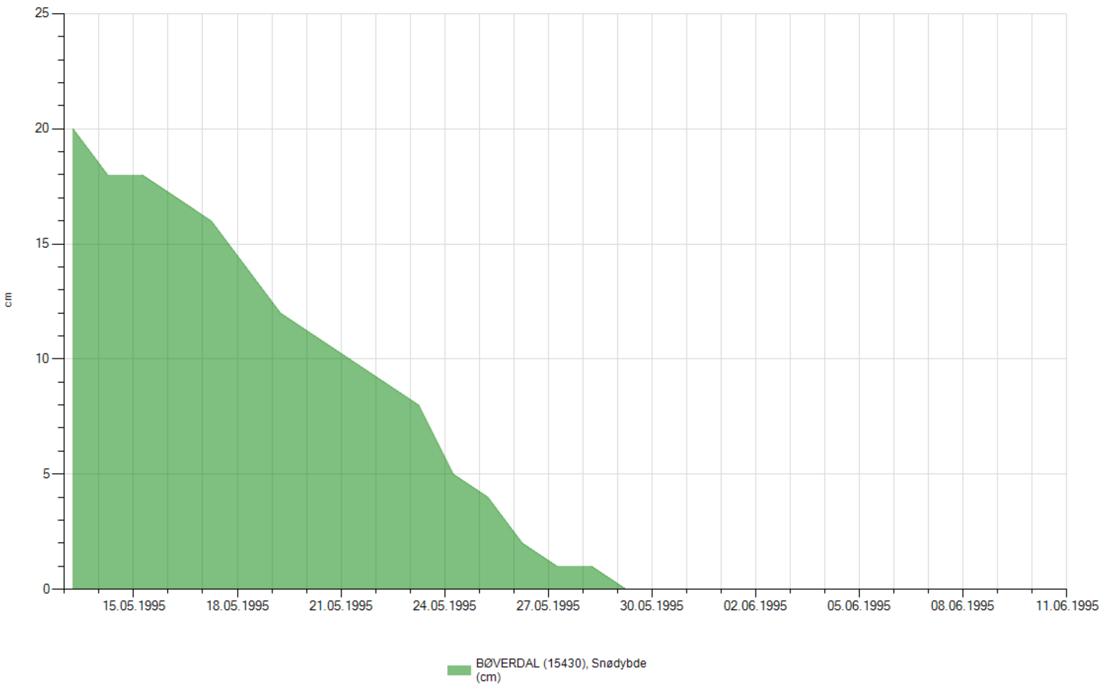


Figure 3.1.41.2 Observed development of the snow cover at a) Venabu in the mountains between Østerdalen and Gudbrandsdalen and b) in Bøverdalen in Jotunheimen.

The flood at Østlandet

River Glomma

The cool weather ended 28 May 1995. A depression was located west of Ireland with an anticyclone located over Finland with a ridge extending southwards over continental Europe.

The temperatures were high to the east and in the boundary zone between the warm continental air mass in the east and cooler maritime air masses the additional rainfall contributed to the flood.

Figure 3.1.41.3 show observed daily discharge at gauging stations along the main branch of River Glomma during the flood. The flood was the largest observed at Elverum (1871-2014). The peak in the mainstream was estimated to correspond to the 200-year flood at some locations.

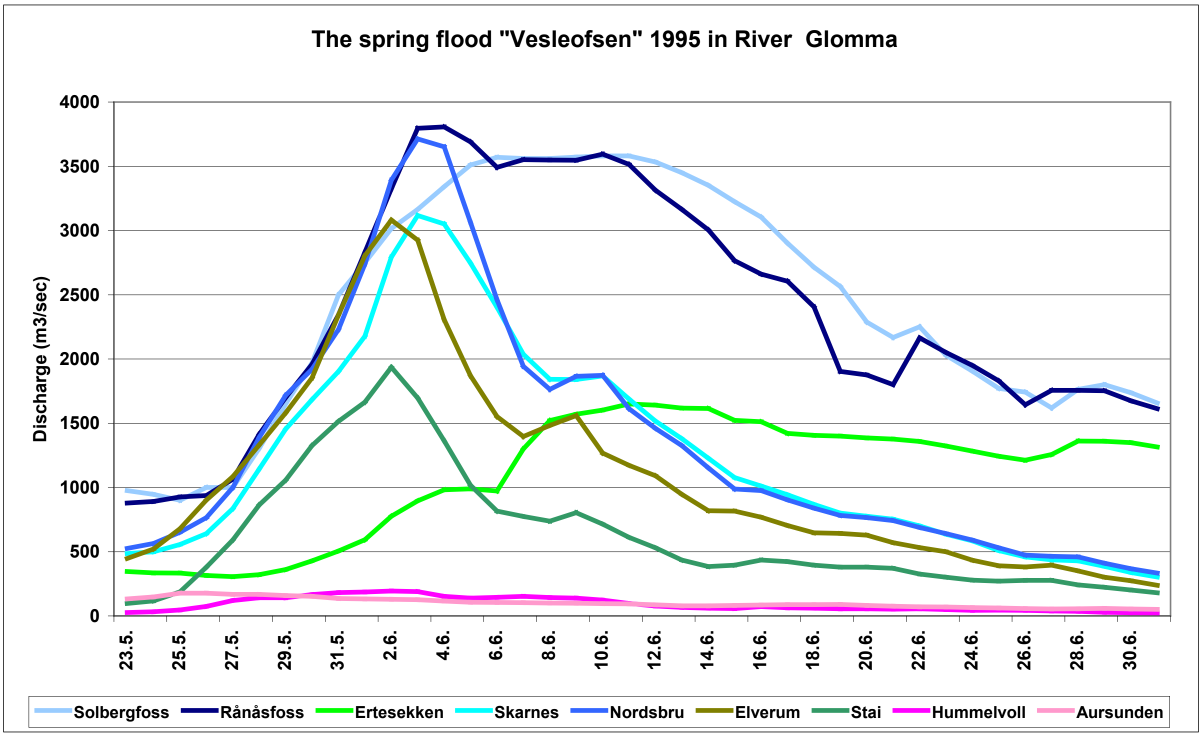


Figure 3.1.42.3 Observed discharge at gauging stations on the main branch of River Glomma from Aursunden to Solbergfoss below Øyeren in 1995.

The discharge at stations along the main tributary Vorma/Mjøsa/Gudbrandsdalslågen is shown in Figure 3.1.41.4. The discharge at Ertesekken in Vorma close to the junction with the main river is located downstream Lake Mjøsa. The graph illustrates how the large lake delays the flood wave. The release out of Lake Mjøsa was temporarily delayed in order to allow the flood wave from the main river to pass before the flood from the western branch.

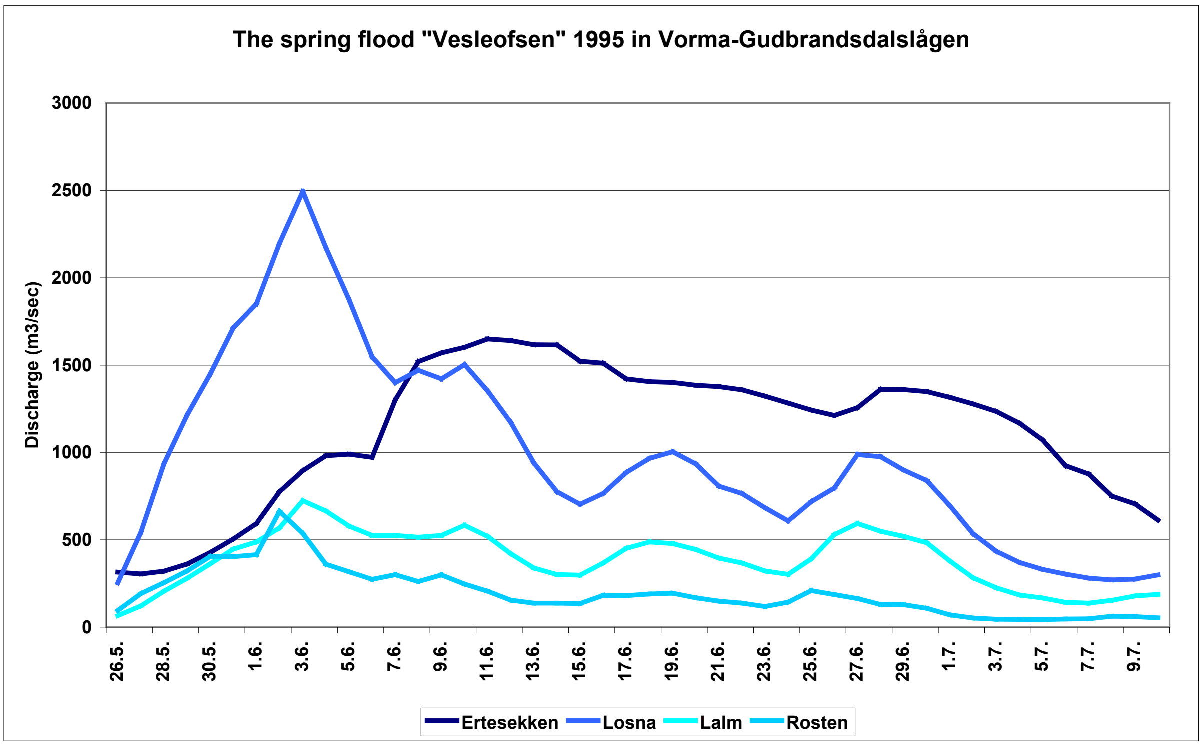


Figure 3.1.41.4 Observed discharge at gauging stations on the main branch of River Glomma from Aursunden to Solbergfoss below Øyeren in 1995.

The flood ranks as the second largest at 2.145 Losna (1896-2014) and at 2.614 Skjenna/Lårgård/Rosten (1879-2014). The flood did not rank among the largest further upstream at 2.346 Lesjaverk or in the main tributaries Otta or Sjoa. Later in the summer the levels noted 2 June were exceeded.

The flood was severe from rivers in the mountain plateau between Østerdalen and Gudbrandsdalen with severe damages caused by River Moksa at Tretten in Gudbrandsdalen. Figure 3.1.41.5 show observed specific discharge and precipitations observed at stations west of Østerdalen. The discharge started to rise 26 May and peaked 1-3 June at most stations.

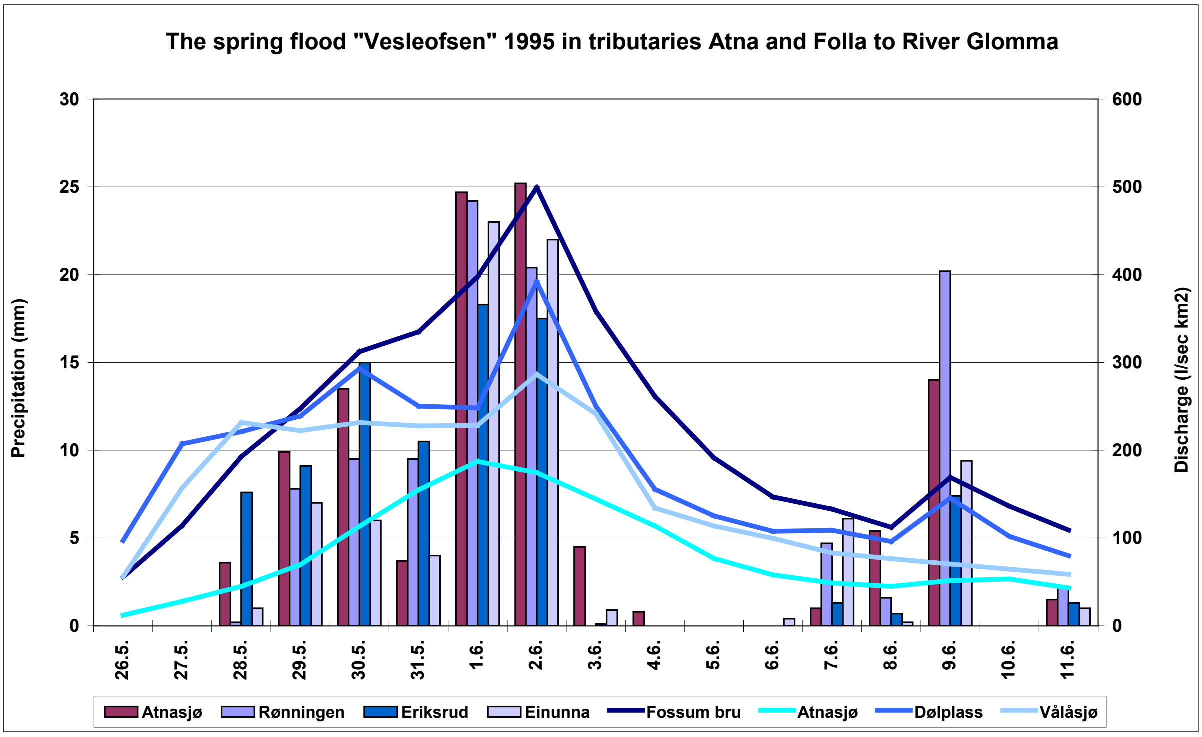


Figure 3.1.41.5 Observed precipitation and specific discharge at stations in River Atna and Folla in 1995.

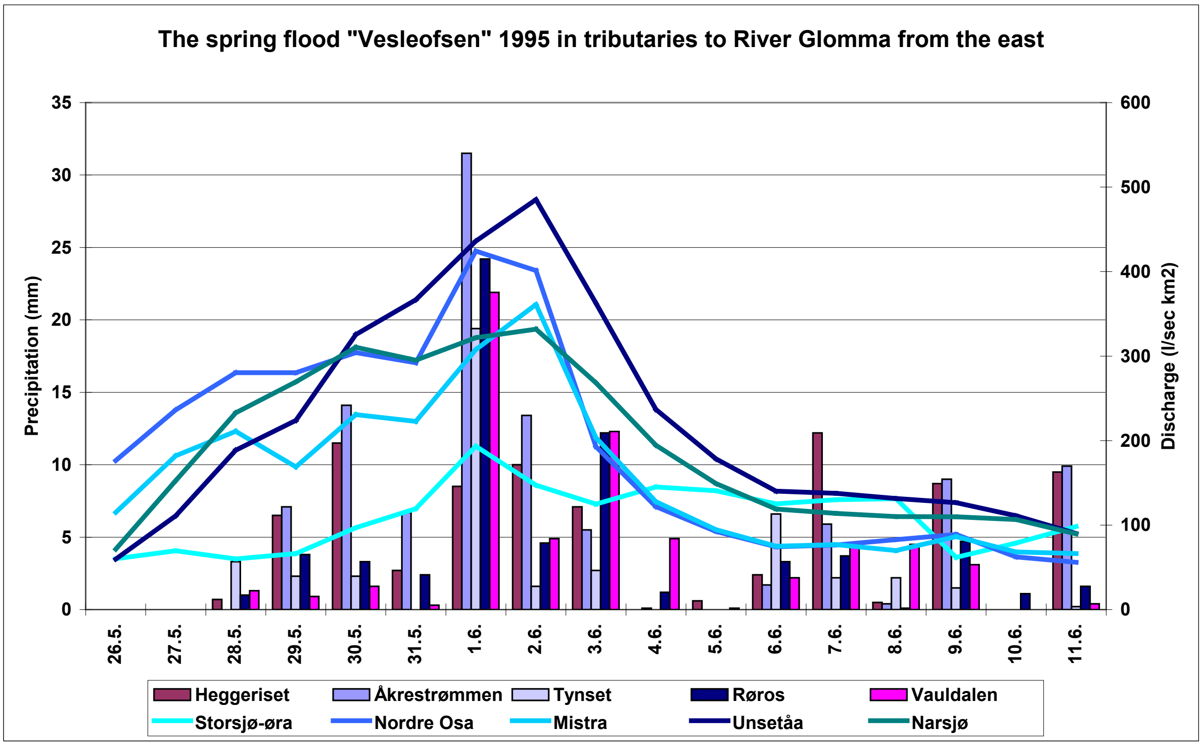


Figure 3.1.41.6 Observed precipitation and specific discharge at stations in River Rena, Nøra and upper Glomma in 1995.

Figure 3.1.41.9 show discharge and precipitation in the Otta basin draining Jotunheimen further west.

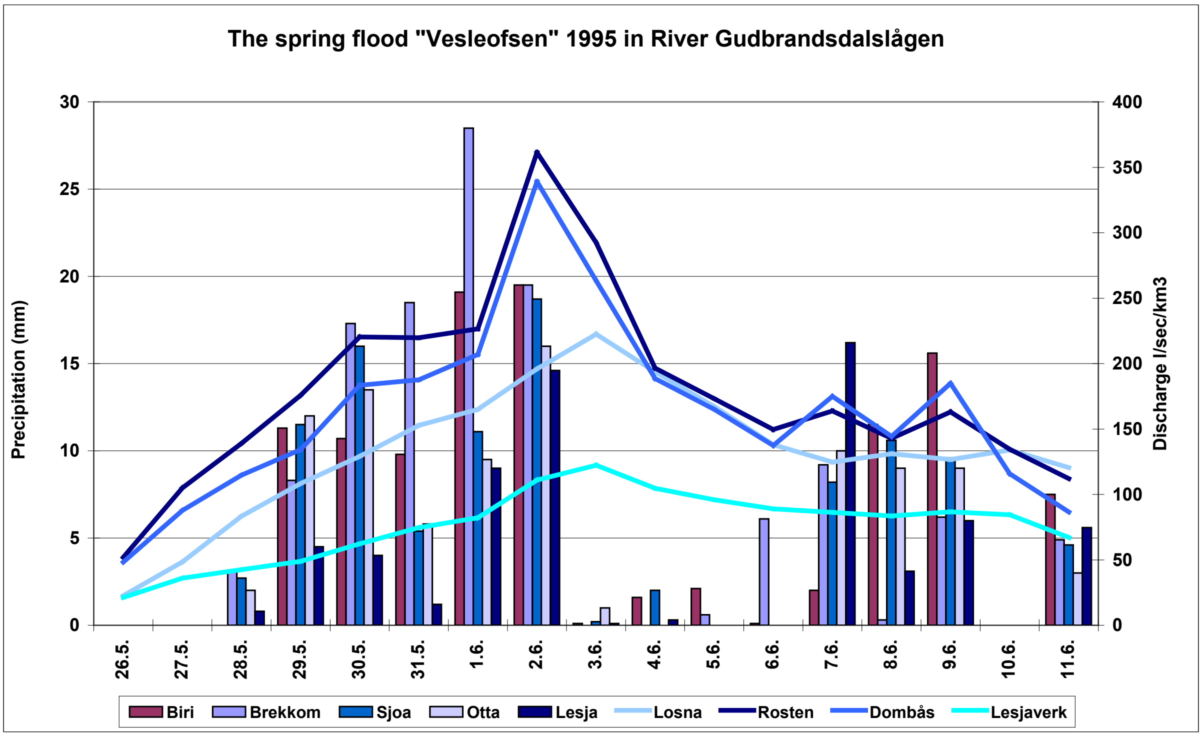


Figure 3.1.41.7 Observed precipitation and specific discharge at stations in River Gudbrandsdalslågen in 1995.

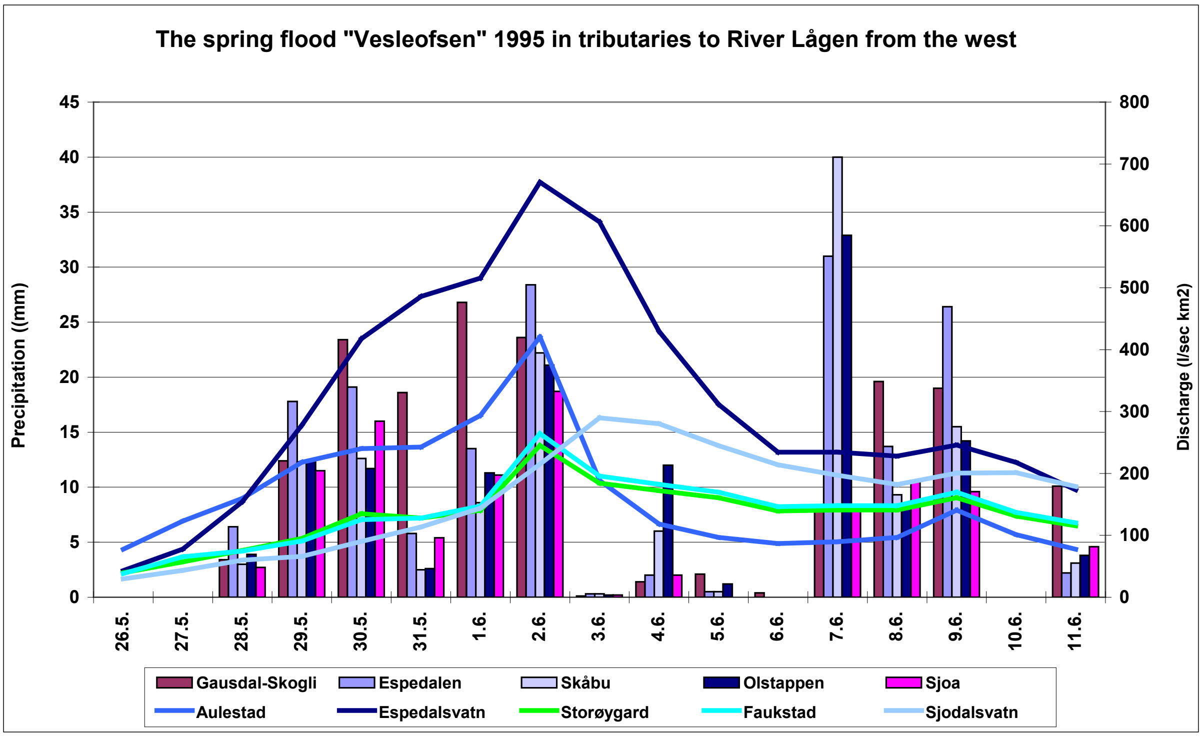


Figure 3.1.41.8 Observed precipitation and specific discharge at stations in River Gausa, Vinstra and Sjoa in 1995.

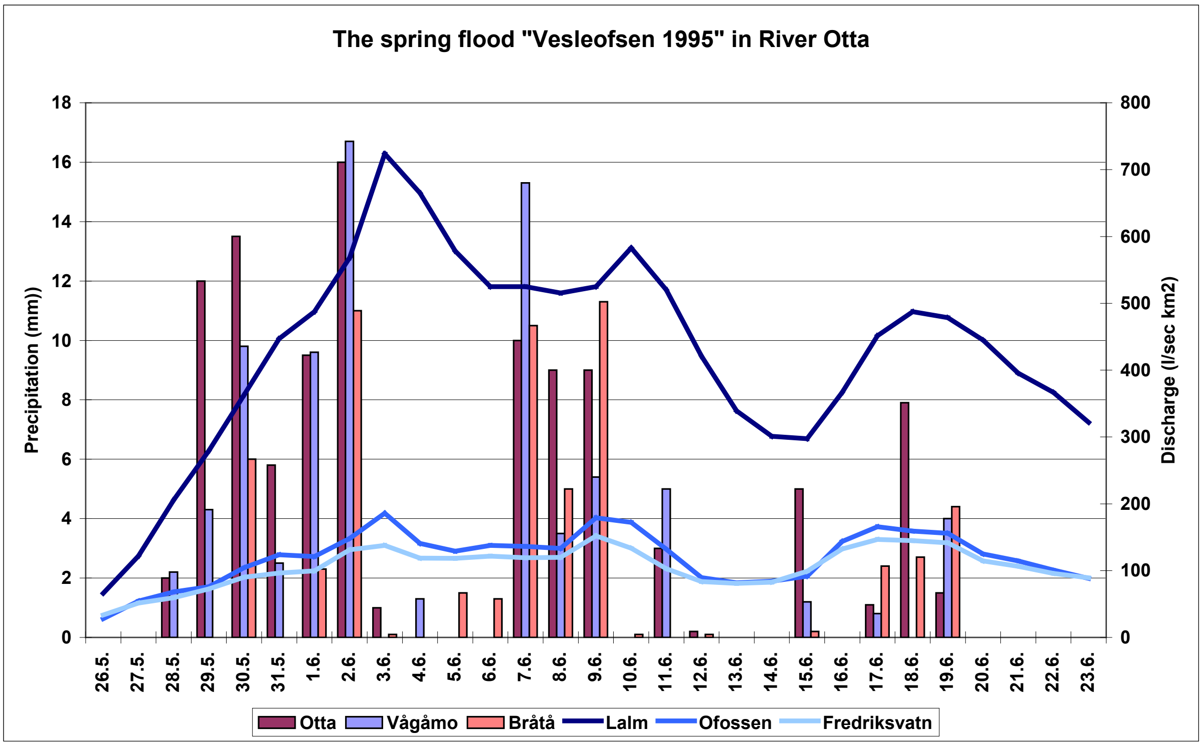


Figure 3.9.41.9 Observed precipitation and specific discharge at stations in River Otta in 1995.

River Trysilelv

The flood was also large in River Trysilelv.

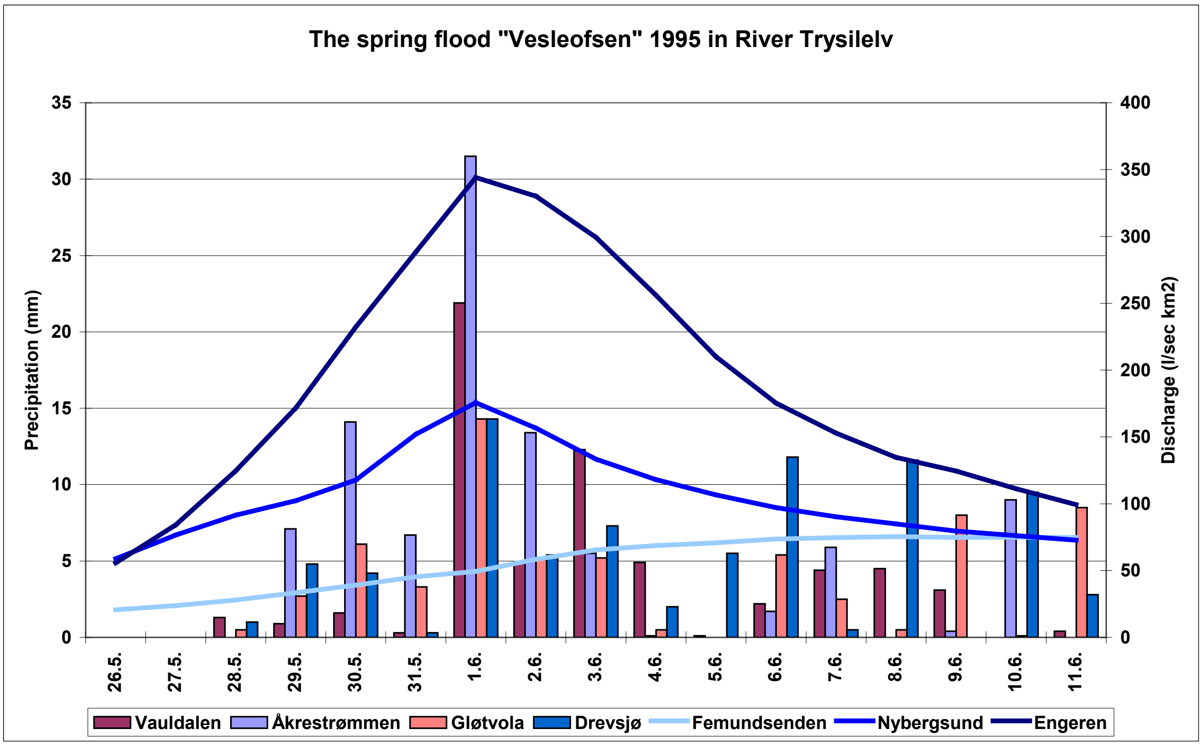


Figure 3.1.41.10 Specific discharge and precipitations at stations in River Trysilelv.

River Drammenselv

The water course is heavily regulated, and the 1995 flood is not among the largest annual floods in the main branches affected by the operation of the power schemes. The flood is, however among the largest in natural catchments in the different branches of the water course as shown in Figure 3.1.42.11.The flood was 10th largest in River Simoa 1972-2014, fifth largest 1962-2014 in River Rukkedalselv at Lake Buvatn, largest in River Vindeelv 1920-2014 and largest in River Etna 1919-2014. The flood did not cause severe problems in the lower part of this water course because of the large reservoir capacity.

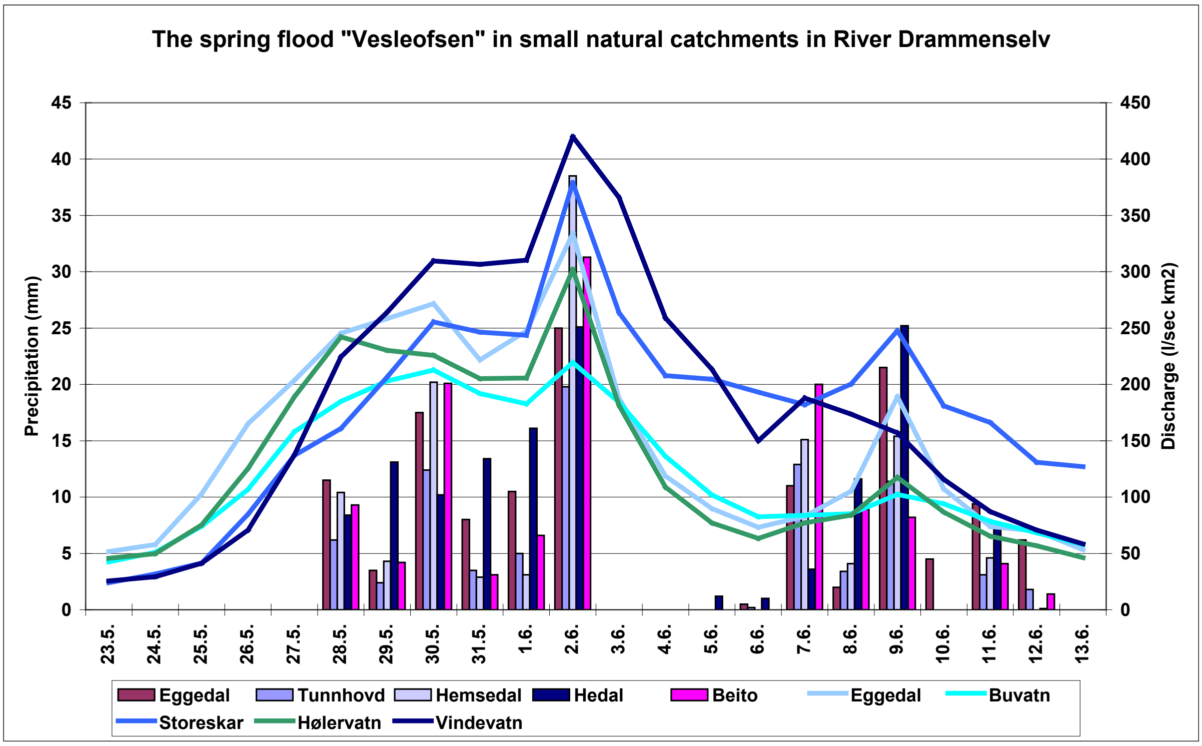


Figure 3.1.41.11 Specific discharge and precipitation during Vesleofsen in natural catchments in River Drammenselv.

Other rivers

Large flood occurred also in rivers in Trøndelag. The flood ranks as the fourth larges in River Driva 1908-2014 and the fifth largest in River Gaula 1908-2014. Further north the flood was large in some rivers at the border to Sweden. The flood was the largest in River Huddingelv 1944-2014 and second largest in River Muruelv 1926-2014.

Flood, damages

The flood caused severe damages in River Glomma. One elderly man drowned as he drove into River Gudbrandsdalslågen. The damages are summarised in Table 1
3.1.41.12.

An area of 167 622 daa farmland was inundated in Hedmark, Oppland Akershus and Østfold counties by the flood in Rivers Glomma and Trysilelv. Additional 3000 daa farmland was inundated in counties Buskerud and Sør-Trløndelag.

NOU(1996)

Direct damages

Natural Perils Pool	800
Natural Perils Fund	204
Damages to crops	35
Damages to main roads and railways	94
Damages to important buildings, ie museer, schools etc	31
Damages at municipal and county installations	65
Other insurances	20
Egenandeler	100
Sum, direct damages	1349

Indirect Damages

Interruption insurance etc.	100
Loss of income NSB etc.	54
Sum, indirect damages	154

Preparedness, clearing up, flood preventing: Governmental organisations

Defence, Civil defence, Police, NVE	248
Muncipalities Counties	65
Sum expences for preparedness etc.	313

Totalt estimate of the damages caused by *Vesleofsen* is approx. 1,8 bill. NOK.
Compensations from insurance companies accounts for 1 bill., while compensations from the State for non insurable properioes accounts for 800 mill. NOK.

Consequences of the flood

The flood forecasting developed significantly as a result of the experiences of the flood. NVE started publishing data and warnings on the internet. A commission did examine the causes and consequences of the flood. The findings were published in NOU 1996 19..
A large research programme, HYDRA, was afterwards established (Eikenes et al, 2000).

The flood was most severe in the mountainous region between Østerdalen and Gudbrandsdalen. When the flood culminated, there was still a lot of snow surviving in the most alpine areas west of Gudbrandsdalen. This was also the case during other severe floods in the Glomma basin, such as the severe flood in 1967. Fortunately ,the rivers flowing out of Jotunheimen tend to produce less intensive floods at the time of the large floods in the rest of the Glomma catchment. Typically, later floods occur in these years, fed by melting of the remaining snow in the highest parts of the catchment.

3.1.42 The combined snowmelt and rainfall flood 6-7 May 2004.

The spring in 2004 was mild from April to early May. The snowmelt started therefore early, causing a moderate flood in rivers at Østlandet. The snow had disappeared in the lowland in the first days of May, but some snow remained in the mountain slopes in the valleys at Østlandet. Rainfall in combination with snowmelt started a flood which peaked 6-8 May at Tinn in Telemark, Hallingdal in Buskerud, Bøverdalen, Leirdalen and Dovre in Oppland, Drivdalen in Sør-Trøndelag and Fjærland in Sogn. Observed daily rainfall and discharge in Ottadalen is shown in Figure 3.1.42.1, in River Begna and River Etna in Figure 3.1.42.2, in River Hallingdalselv and River Simoa in Figure 3.1.42.3, in River Numedalslågen in Figure 3.1.42.4 and in Telemark in Figure 3.1.42.5.

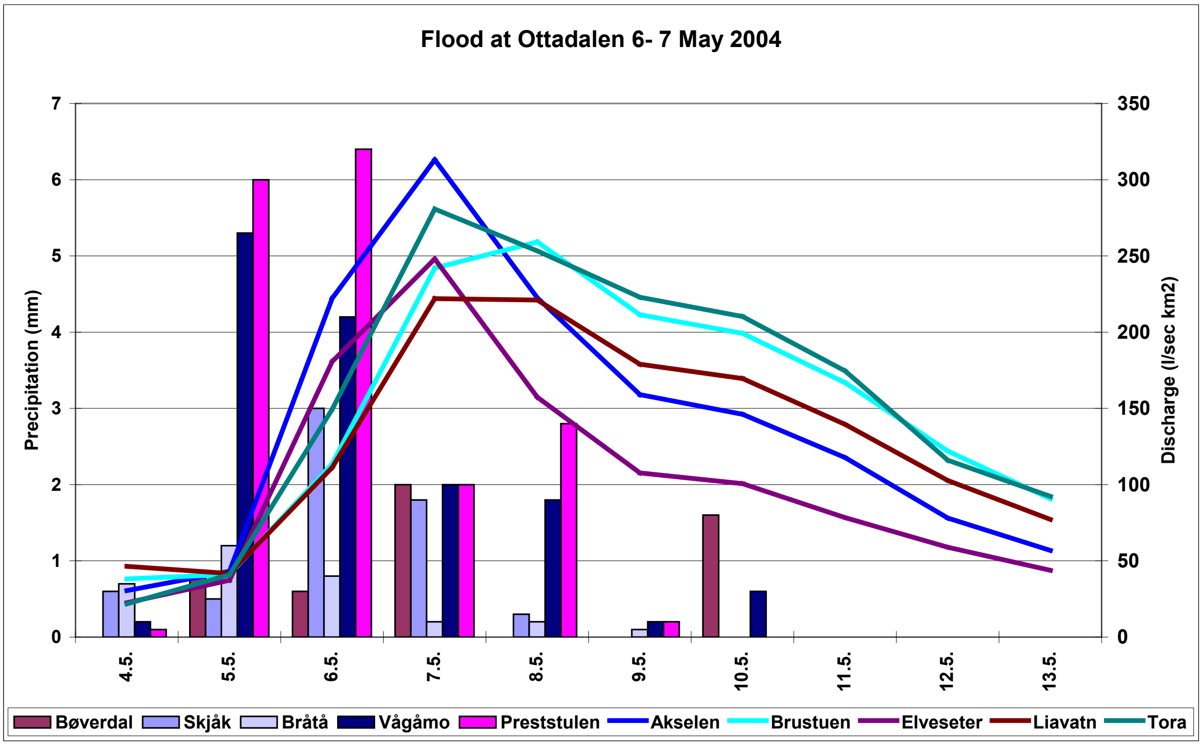


Figure 3.1.42.1 Observed precipitation and daily discharge during the spring flood in Ottadalen in May 2004.

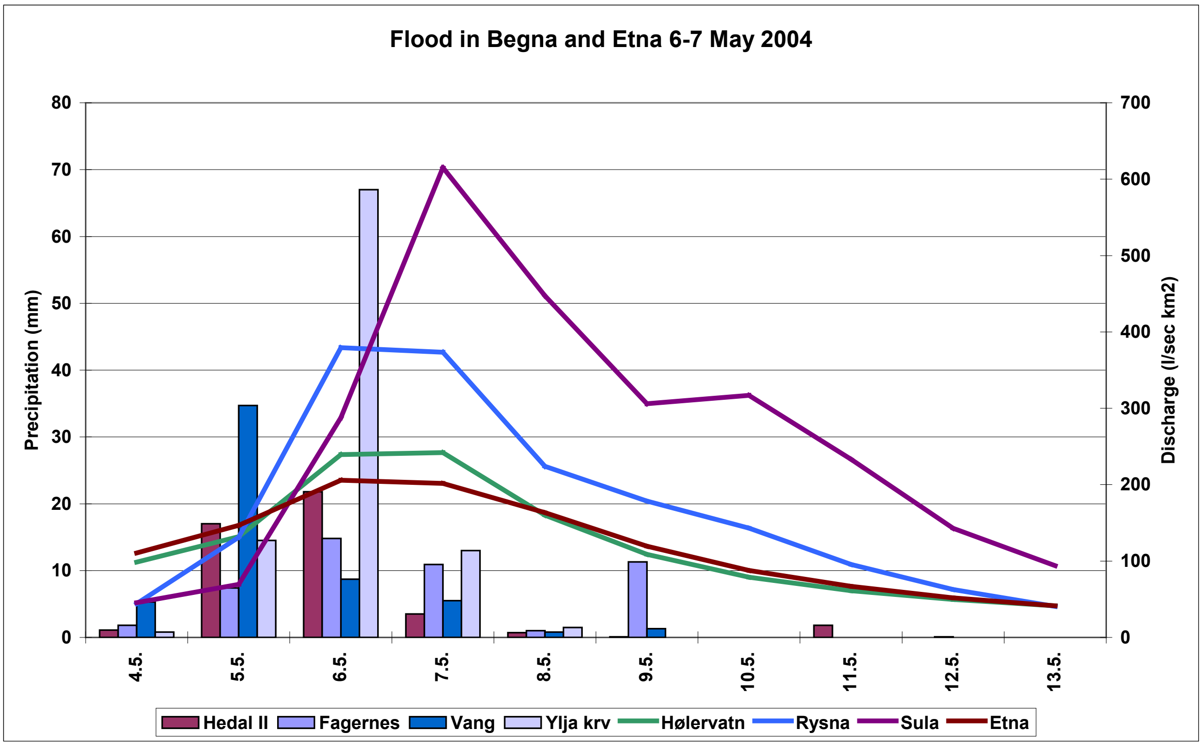


Figure 3.1.42.2 Observed precipitation and daily discharge during the spring flood in River Begna and Etna in May 2004.

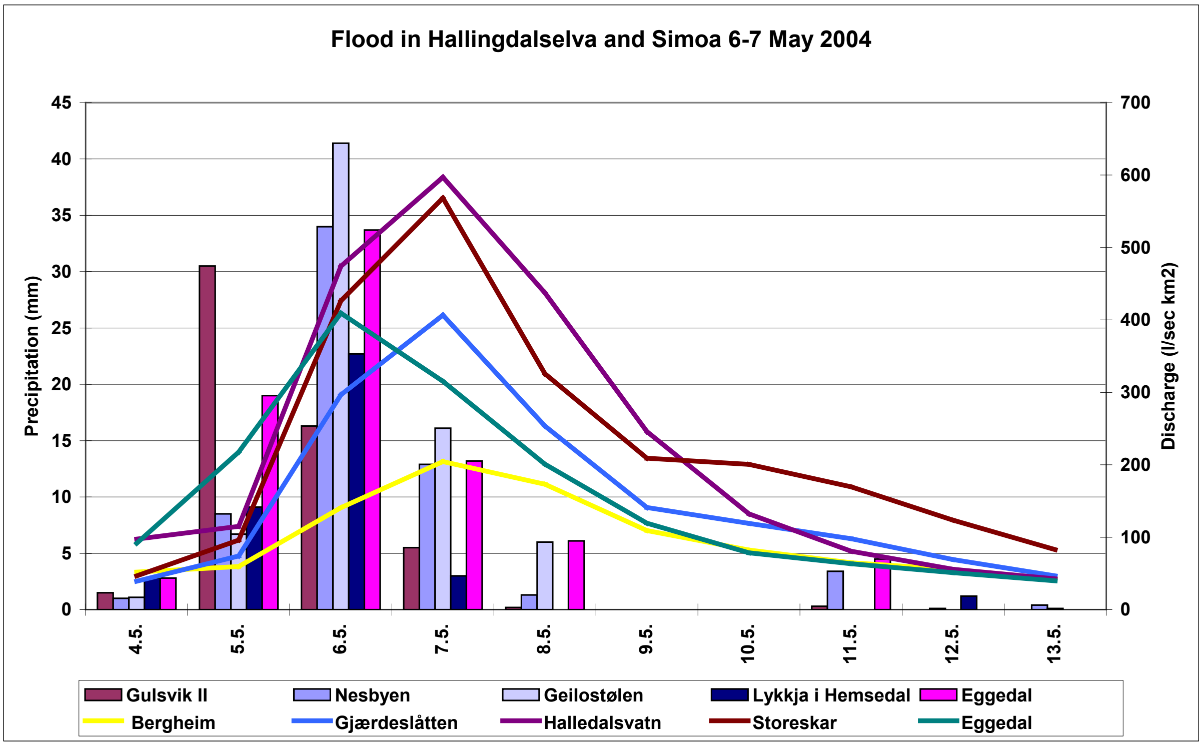


Figure 3.1.42.3 Observed precipitation and daily discharge during the spring flood in Hallingdal and Sigdal in May 2004.

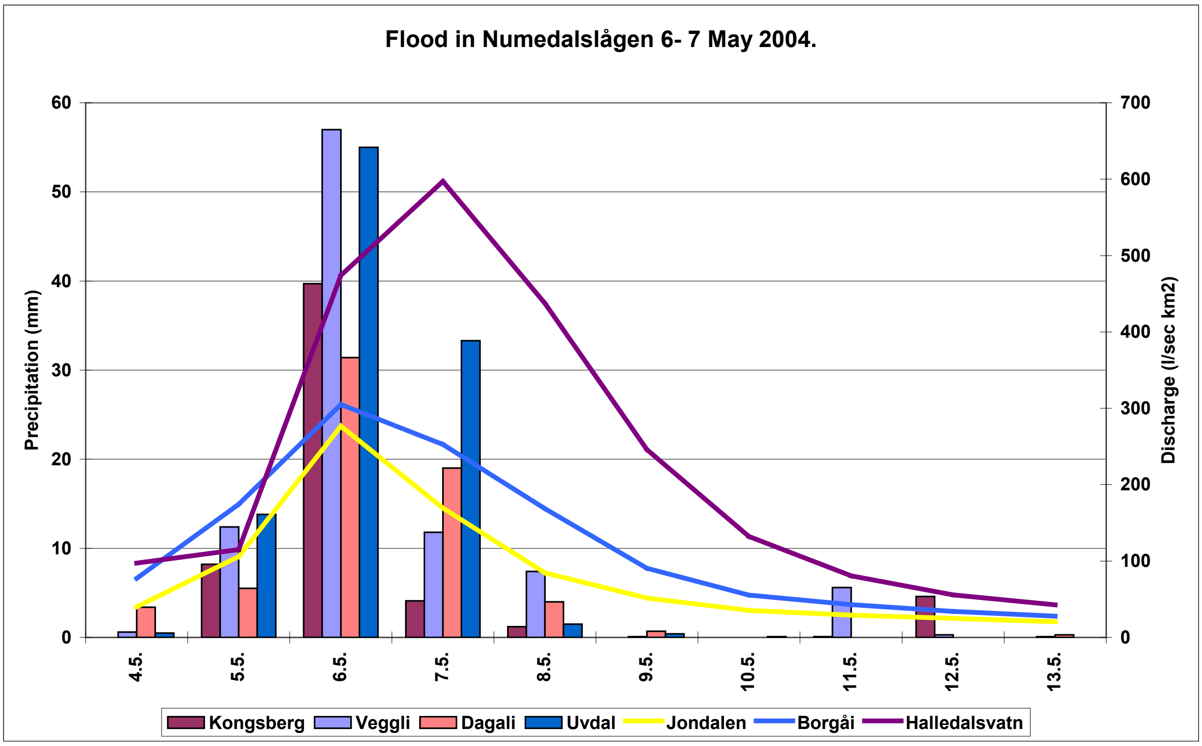


Figure 3.1.42.4 Observed precipitation and daily discharge during the spring flood in River Numedalslågen in May 2004.

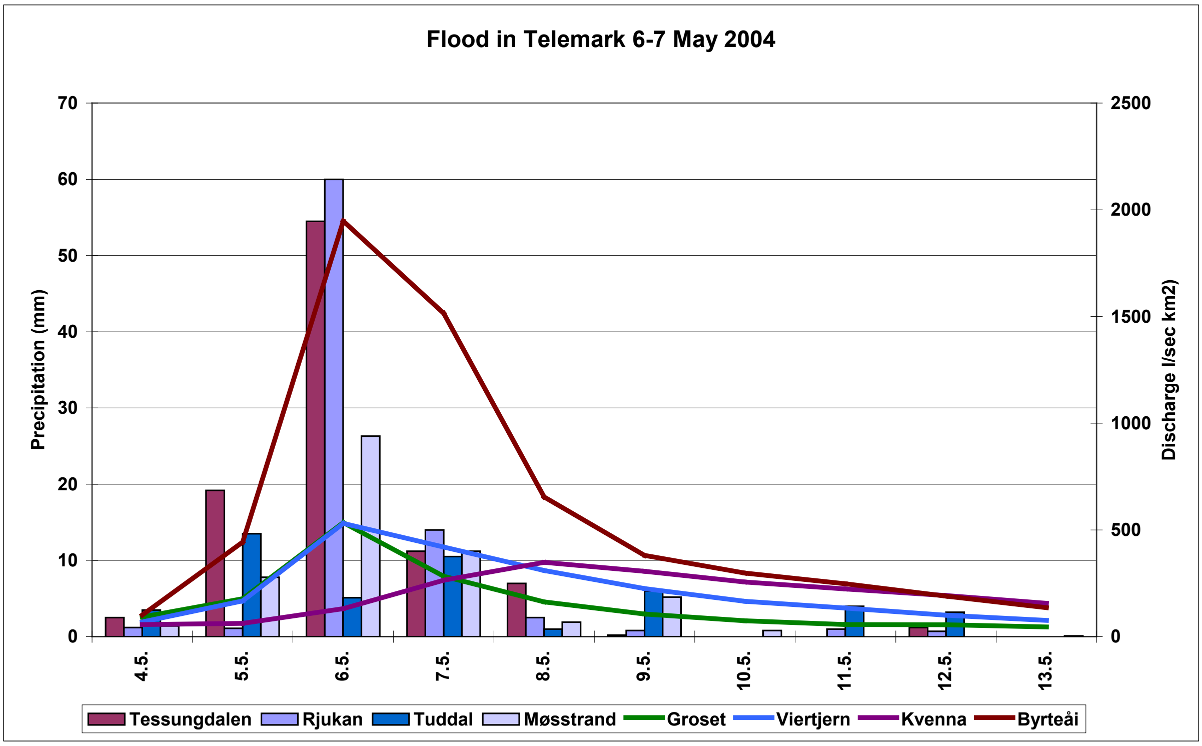


Figure 3.1.42.5 Observed precipitation and daily discharge during the spring flood. in Telemark in May 2004.

The flood was not among the largest in the main rivers except in River Hallingdalselv at 12.97 Bergheim, where the flood was the fifth largest 1921-2013. The flood in River Simoa at Eggedal was also the fifth largest 1971-2013. The discharge was the largest in this river since

the regulation in 1940. The discharge in 16.66 Grosetvatn was the largest since the observations started in 1949. The return period was estimated to 100-200 years.
The flood in Gudbrandsdalslågen at Rosten was eight largest 1879-2013. The return period was estimated to 20 år. River Jora at Dombås had an estimated return period of nearly 50 years. The flood was large in small tributaries to the larger rivers.

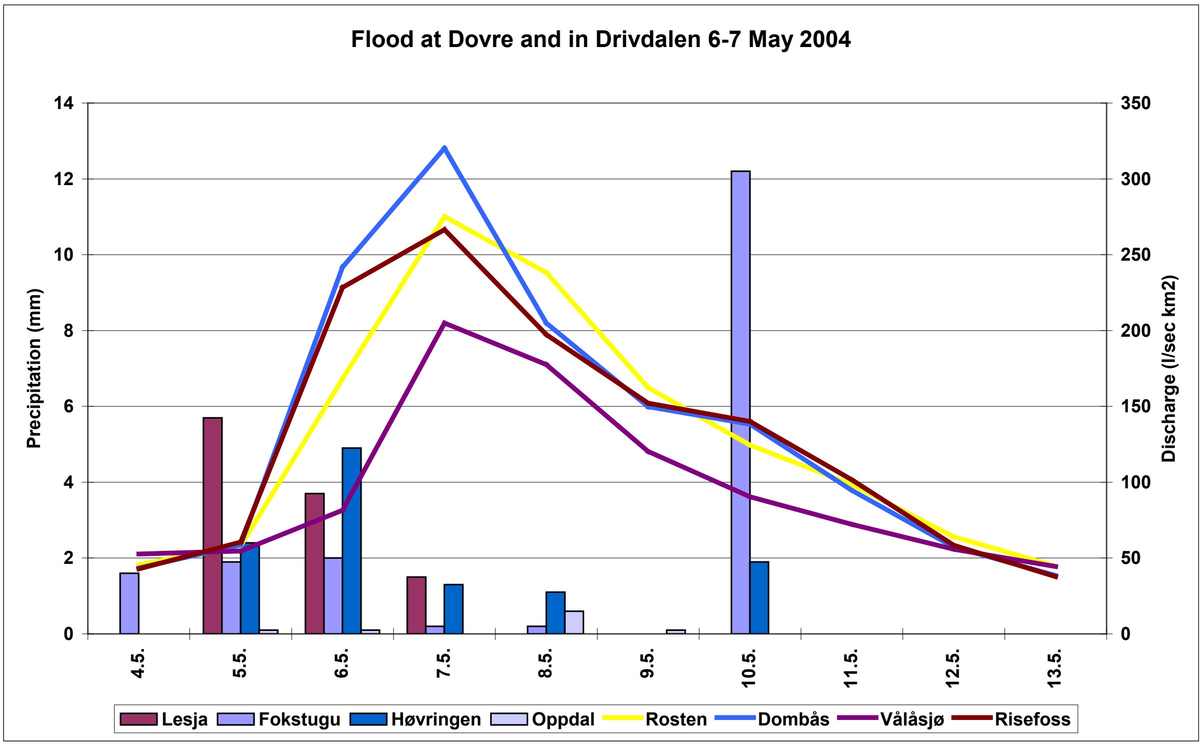
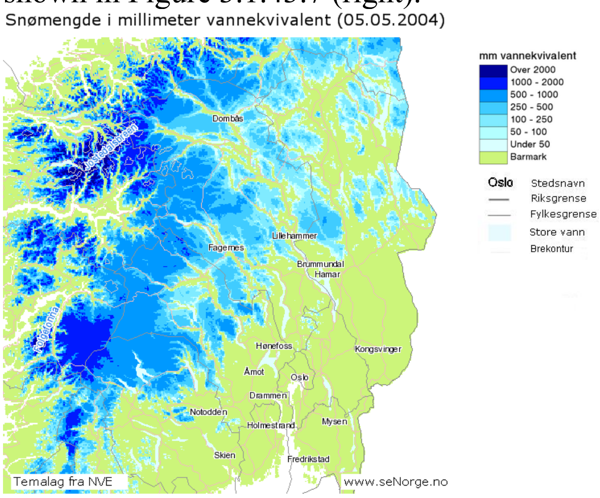


Figure 3.1.42.6 Observed precipitation and daily discharge during the spring flood at Dovre and in Drivdalen in May 2004.

Cause of the flood:

Initial conditions

The snow had disappeared in the lowlands and in the bottom of the valleys prior to the start of the rainfall 5 May as shown in Figure 3.1.43.7 (left) and the groundwater levels were high as shown in Figure 3.1.43.7 (right).



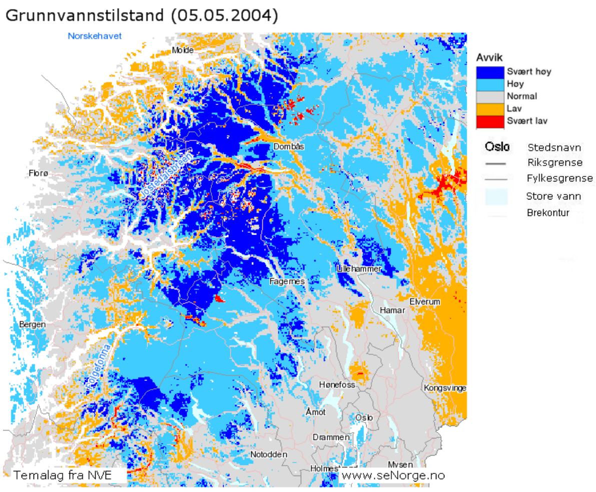


Figure 3.1.42.7 The distribution of the snow cover (left) and the groundwater conditions prior to the start of the flood 5 May 2004 (right).

The weather causing the flood was of the southeasterly Vb-type. A blocking high was located at the Atlantic with a weak ridge located to the north extending from Greenland across the Norwegian Sea across Norway towards southeastern Europe. A trough was extended from the Norwegian Sea across Iceland to a depression across Great Britaina and the North Sea. This depression was linked through a low across Northern Italy. Warm and humd air was streaming from southeast along the frontal zone between the warm air to the east and the cold air over the North Sea over southern Norway. The sequence of weather types 6- 9 May were: **TRW**, **TM**, **TM**, **TM** (Grosswetterlagen) and **C**, **CN**, **N**, **CN** (Lamb-Jenkinsson)

The air temperature, snowmelt and precipitation during the flood

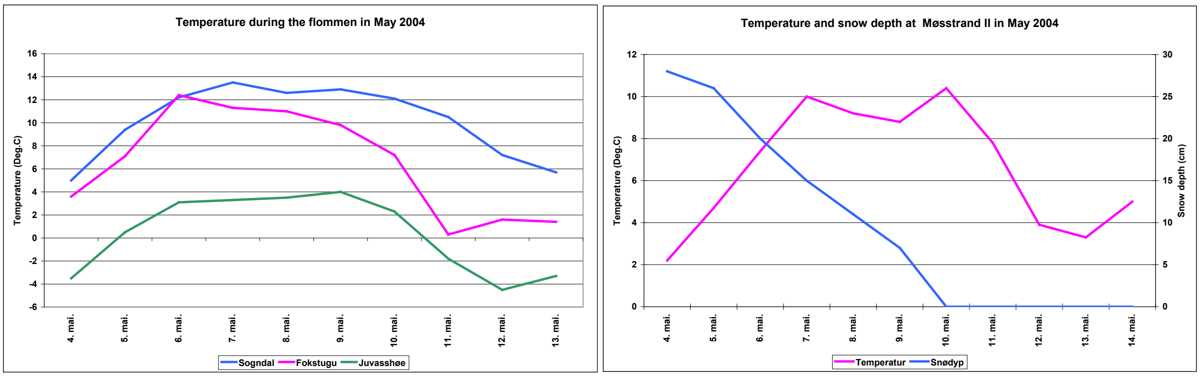


Figure 3.1.42.8 Observed temperatures at Sogndal (moh), Fokstua (moh) and at Juvasshytta (moh) in early May 2004 (left) and observed air temperature and snow depth at Møsvatn II (moh) (right).

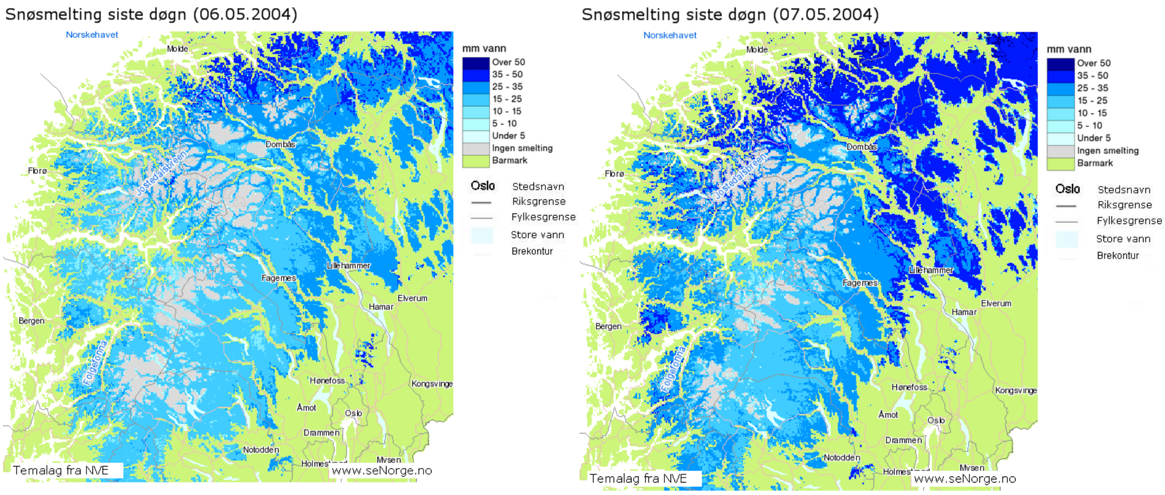


Figure 3.1.42.9 Snowmelt 6 May (left) and 7 May (right)

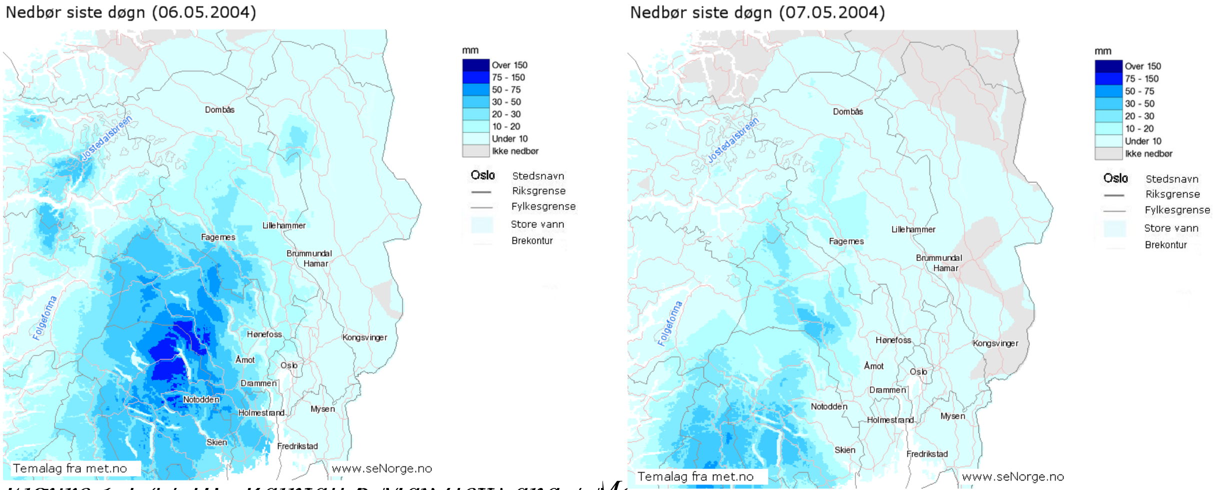


Figure 3.1.42.10 Rainfall 6 May (left) and 7 May 2004 (right).

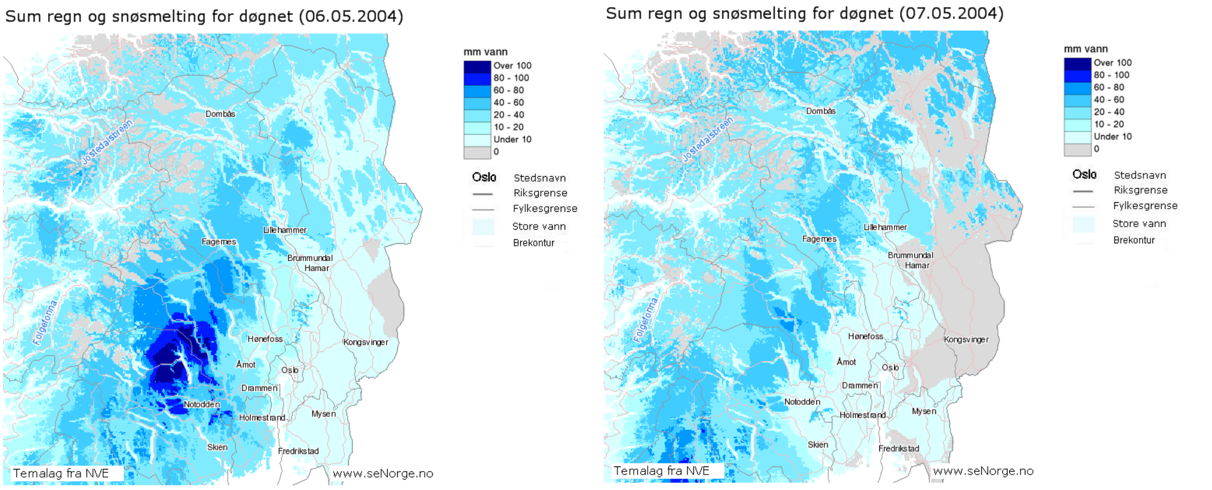


Figure 3.1.42.11 Sum of rainfall and melting 6 May (left) and 7 May (right).

Flood damages:

Gudbrandsdalen

River Radåa flowed across E-6 at Dovre. The road was closed until the debris could be cleared away. Large areas were inundated at Otta.

An ice plug caused a dam in River Vesle Juvå in Jotunheimen 6 May. The subsequent dam failure caused a wave of water, snow and ice to flow towards Bøverdalen, where a bridge on the main road RV 55 just escaped been moved away. The local population compared the slides as it came pouring down the mountain side to the mushroom cloud of a nuclear explosion. There has been no similar events since the end of the 19th Century according to the newspaper Gudbrandsdølen. The road to Leirvassbu was cut when a bridge was taken by the glacial stream Illå.

Hallingdal

The mild weather caused heavy snowmelt in the mountain slopes. The inflow from these slopes caused a large flood in the main rivers Hallingdalselv and Hemsil. Large areas in Hallingdal and Hemsedal were inundated. The railway to Bergen and the main road RV-7 in

Hallingdal were blocked by the flood. Somebuildings, including the stave church from 1200 were in danger of being flooded.

The flood caused the municipal sewer net to flood at Nesbyen causing damages to a number of properties. The flooding was aggravated by backwater from River Hallingdalselv. The damages was compensated with 14 mill. NOK at Nesbyen.

Tinn

The town Rjukan suffered badly from the extreme flood in 1927. When the rainfall started 6 May, people was reminded abut the previous disaster. There was a construction in the steep mountain side, aimed at preventing the town from future landslides. There was a culvert through this wall for draining flood water. Gravel and sand were blocking this culvert, causing the wall to serve as a dam instead. The local authorities feared that the wall would fail, releasing large amounts of water and rubble into the town. A total of 22 families, living in houses exposed to this slide was evacuated. Fortunately, the water could be drained without releasing the slide. The total expenses for Tinn muncipality was 715.317 NOK.

3.1.43 The summer floods at Østlandet in June - July 2007.

Great Britain suffered from extreme floods in 2007 (Pitt, 2007; Marsh & Hannaford, 2007; Environment Agency, 2007). The rivers most severly affected was River Severn and the western part of River Thames. The flood was caused by a string of rainstorms following in an atmospheric river. The trajectory of the rainstorms was defined by the stability of the jetstream over Britain.

Most of the precipitation fell out over England, but some of the rainstorms moved further east across the North Sea and into Norway. A local rainstorm caused flooding in the Hovin area in eastern Oslo 24 June. The rainfall lasted two hours with a total rainfall 14,9 mm the first and 39,6 mm in the second hour. Another rainfall event occurred in western part of Oslo and in Bærum with a similar duration and amouth of preciptation 28-29 June.

A more prolonged rainfall event occurred 2-11 July when rivers in Telemark and Buskerud suffered from rainfall floods. Figure 3.1.43.1 show observed daily rainfall and discharge at selected stations. The weather types 2-9 July were: **WZ**, **WZ**, **WZ**, **WZ**, **TRM**, **TRM**, **TRM**, **WZ** (Grosswetterlagen) and **C**, **C**, **C**, **W**, **C**, **NW**, **W**, **C** (Lamb- Jenkinsson).

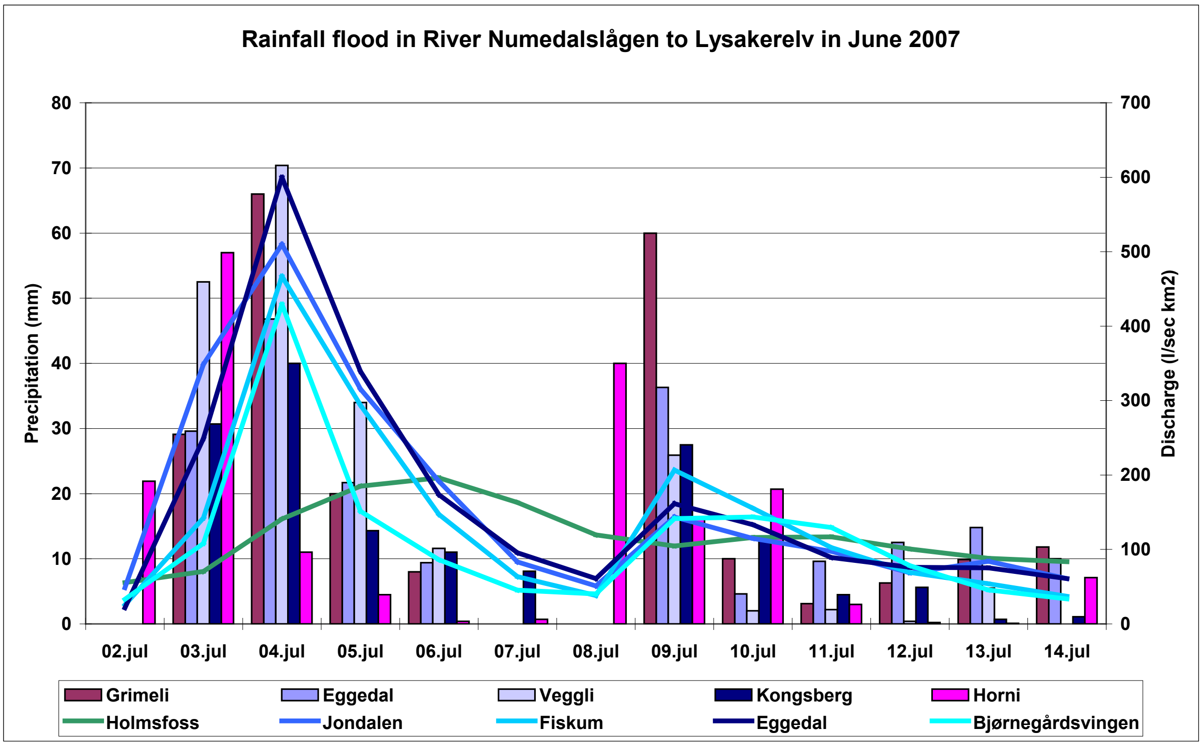


Figure 3.1.43.1 Observed daily rainfall and discharge in early July 2007.

The weather types were **WZ** (Grosswetterlagen) and **C** (Lamb-Jenkinsson) 2- 4 July.

Flood damages:

Oslo, Akershus and Vestfold

Date: 23.June
Number of damages: 700
Compensations: 50 Mill. NOK

Buskerud and northern Vestfold:

Date: 3-11. July
Number of damages: 600 + near 600 urban flooding
Compensations: 81 Mill. NOK + 35 mill NOK urban flood
River Numedalslågen flooded the scene of a pop concert in Kongsberg.

The damages in Britain:

Insurances: 3 Bill. GBP
Infrastructure: 1 Bill. GBP

3.1.44 The spring flood in Glomma 10-12 June 2011 (*Pinseflommen 2011*)

High temperatures and heavy rainfall caused a major flood in parts of Østerdalen and Gudbrandsdalen from 9 – 11 June 2011. The flood affected also the upper part of River Begna, River Lærdøla and River Driva. Inundations and landslides caused many roads and railway lines to be closed, and for a few days most of the communications between Oslo and Trondheim were closed.

Initial conditions

The snow reservoir:

Most of the snow had melted prior to the flood except in the alpine areas west and North of Gudbrandsdalen. High air temperatures caused most of the remaining snow during the flood. The snow reservoir was less than prior to most of the large spring floods in the Glomma basin. The remaining snow depth at 7 June is shown in Figure 1.

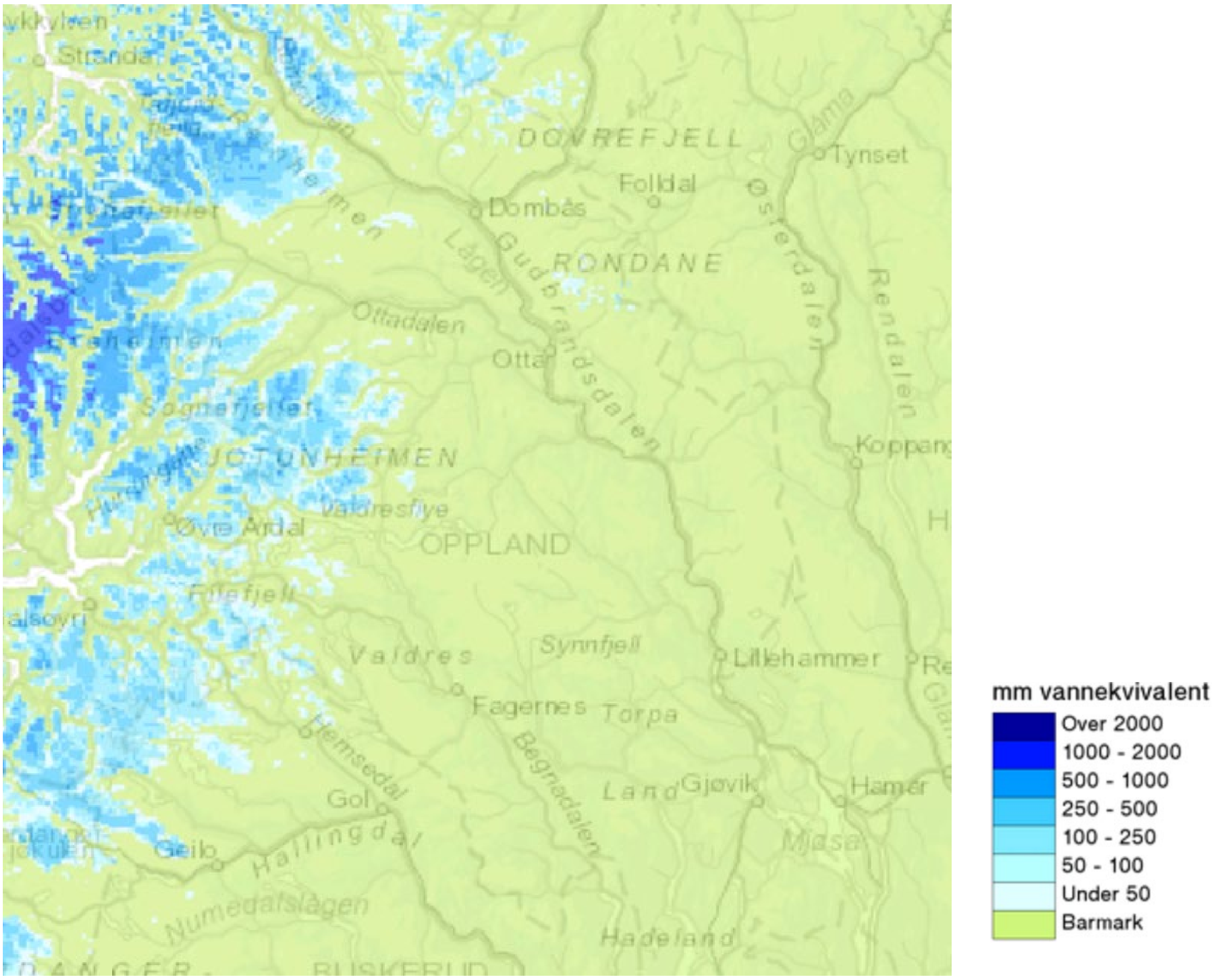


Figure 3.1.44.1 The water equivalent of the snow in the mountain districts of Southern Norway 7 June 2011.

The soil and ground water reservoirs:

The soil water deficit and the groudwater reservoir prior to and at the peak of the flood is shown in Figure 3.1.44.2 and 3.1.44.3. Prior to the flood the soil water deficit was normal to large, but the flood caused the soil in in the slopes and the flood plain of Gudbrandsdalen to be saturated when the flood peaked 11 June. The groundwater levels were low to normal prior to the flood, but rose to high levels when the flood culminates as shown in Figure 3. The flood caused more landslides than *Vesleofsen* in 1995, but far less than *Storofsen* in 1789. In 1789 there was layers of frozen soil in the steep hills of Gudbrandsdalen which caused lauers of saturated soil caused by intense snow melting and extreme rainfall to cause several hundred landslides. In June 2011 there were hardly any remaining layers of frozen soil causing similar disasters.

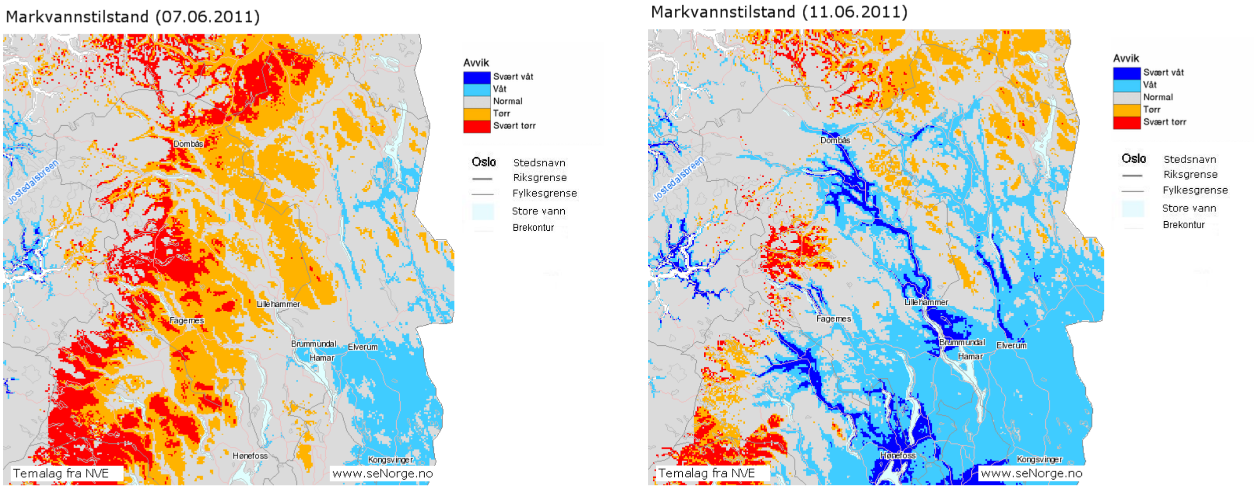
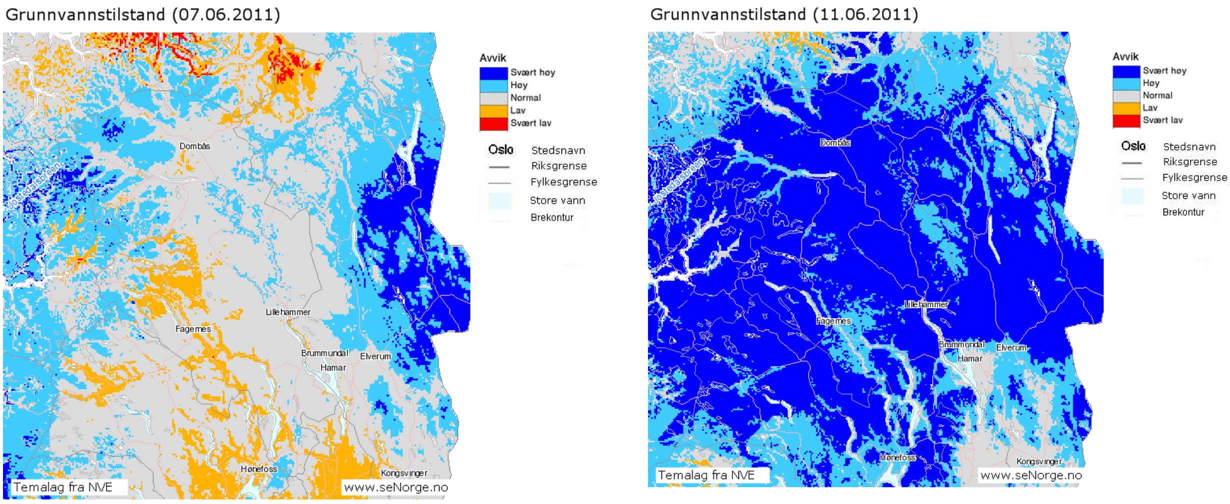


Figure 3.1.44.2 The soil water deficit prior to the flood and at the peak north of Lake Mjøsa.



Figur 3.1.44.3 The ground water reservoir prior to the flood and at the peak north of Lake Mjøsa.

Cause of the flood:

The weather type:

The daily weather types causing the flood 7-12 June were: **SZ**, **SZ**, **HNZ**, **HNZ**, **HNZ**, **HNZ** (Grosswetterlagen) and **C**, **C**, **CW**, **CSW**, **U**, **CSE** (Lamb-Jenkinsson).

The flood event was generally caused by a Vb-low (Van Bebber 1891), se Figure 3.1.44.4. This weather type is characterised by blocking anti-cycloness in the Atlantic and over East Europe with depressions over the Mediterranian moving northwestward around the eastern flank of the Alps toward the Central and occasionally towards the North Europe. East of the depression is very warm air masses, whereas to the west cool air masses from the Norwegian Sea causes a sharp front to produce thunderstorms and heavy rainfall lasting several days.

These Vb-lows has caused some of the most disastrous floods in Europa such as the flood in River Elbe in August 2002 causing damages of 24 mrd Euro. *Storofsen* i Norge was caused by the same weather type in July 1789 as well as the severe floods in 1927, 1938 and recently 2011 and 2013. The worst floods occur in July/August at the warmest time of the year. The distribution of the rainfall in June 2011 is similar to that of *Storofsen*, but affected a smaller region. The rainfall intensities were also much smaller than in 1789. Other large floods caused by this weather type was the flood in the northern part of Østerdalen, Gaula and Orkla in 1940, the flood in Gudbrandsdalen and in Telemark in August/September 1938 and the mountain flood in Gudbrandsdalen in June/July 1958. Rain floods caused by Vb-lows are more common in southern Sverige and in Finland (Vedin and Eriksson, 1988).

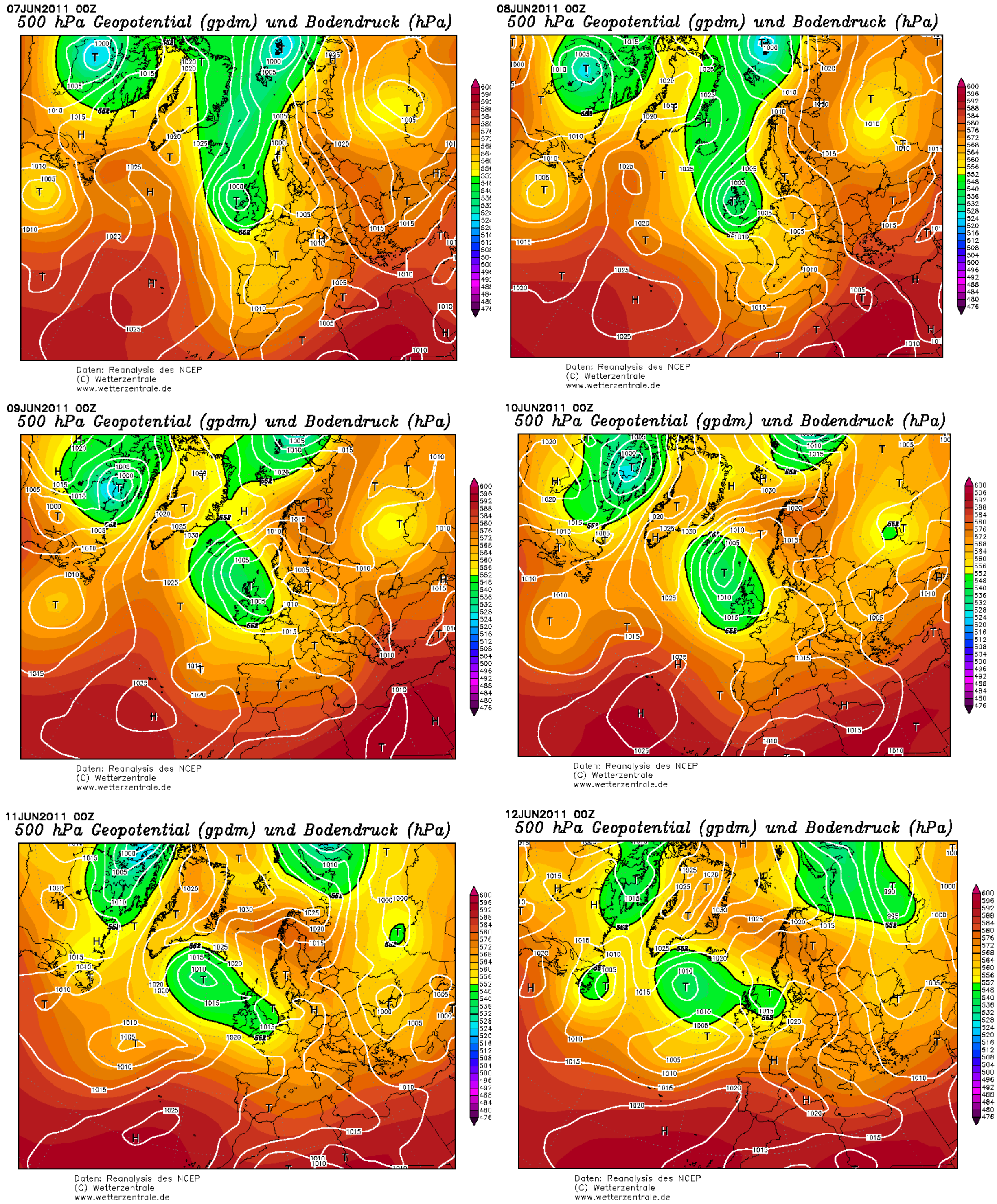


Figure 3.1.44.4 Daily weather maps 7 – 12 June 2011. Source: www.wetterzentrale.de

The distribution of the rainfall:

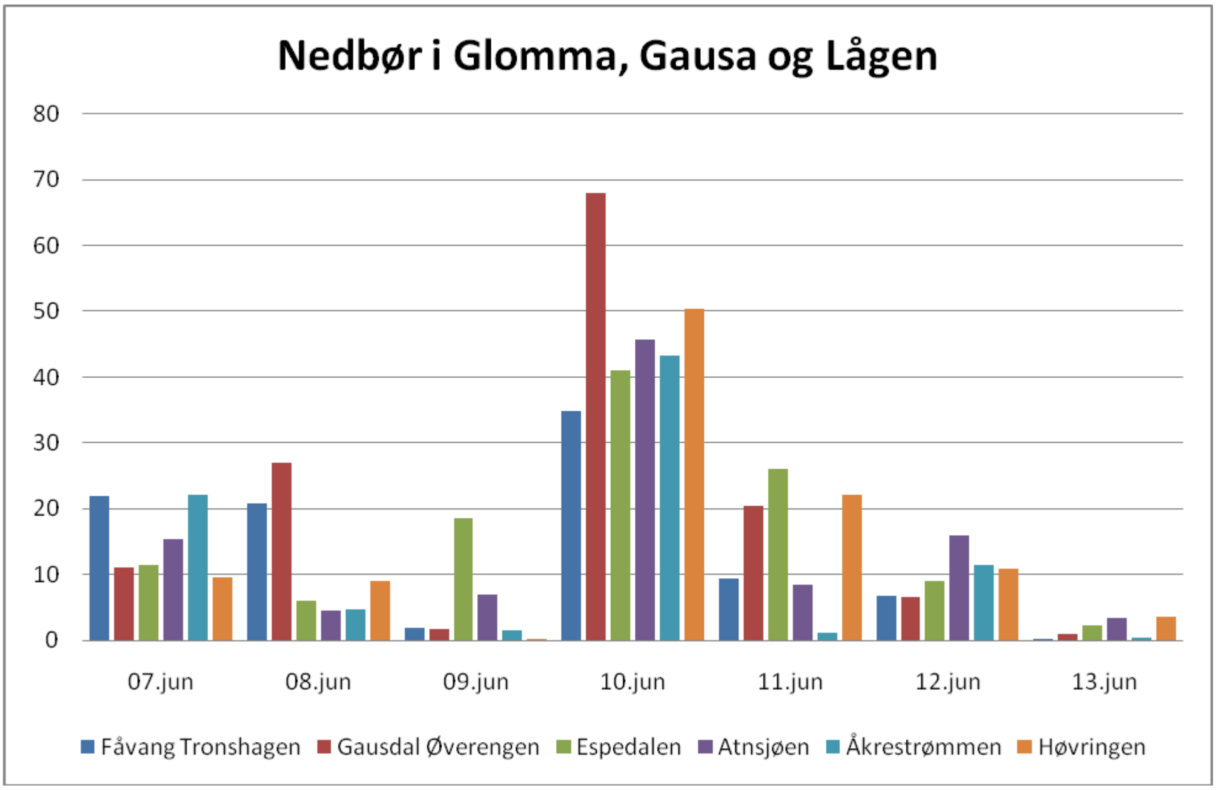


Figure 3.1.44.5 Observed rainfall at stations in Østerdalen, Gudbrandsdalen og Gausdal. Up to 136 mm fell from 7-12 June, mostly the 10 June at Gausdal. The rainfall distribution is has some similarity to the distribution during Storofsen 21.-23.juli 1789, but were less extendet than the 1789 event.

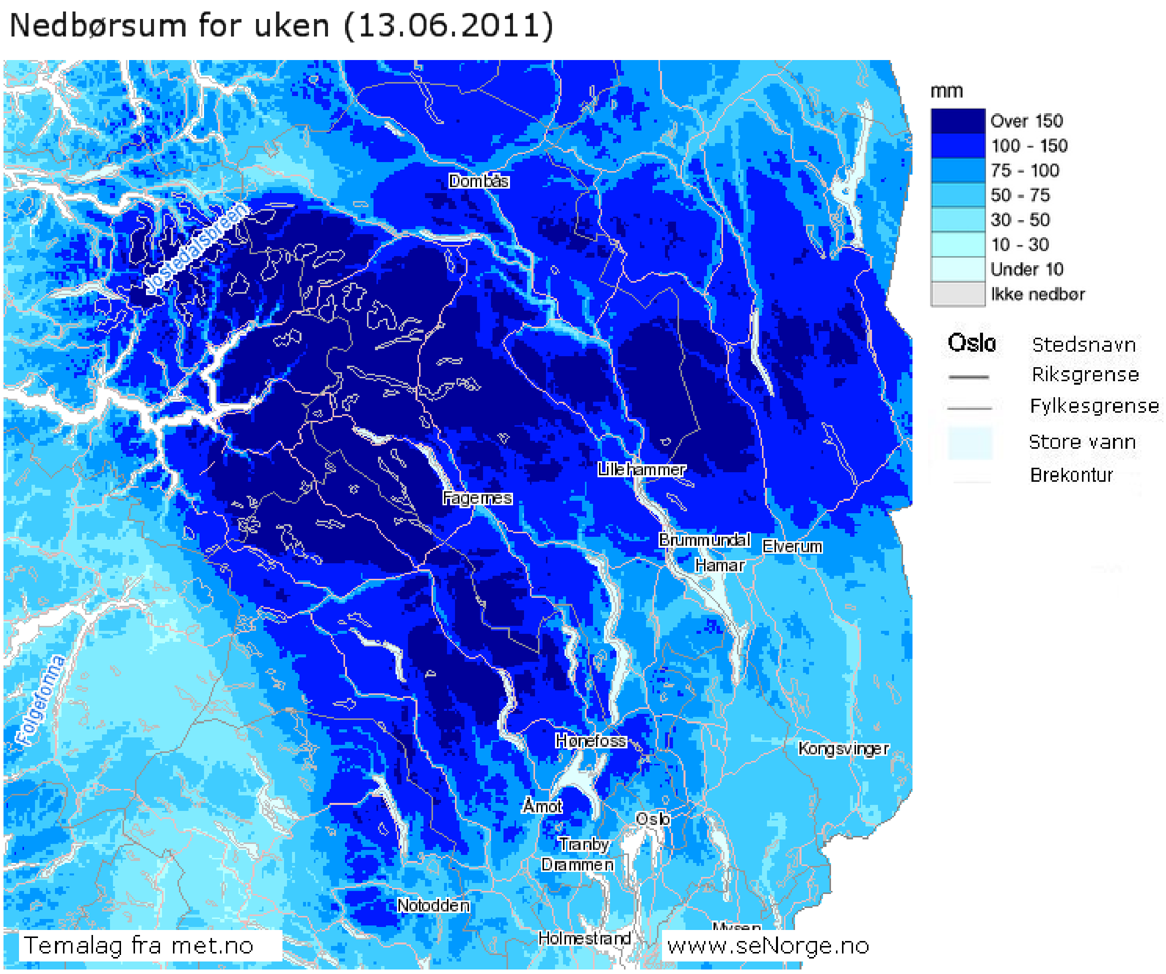


Figure 3.1.44.6 Hovedtyngden av nedbøren falt vest for Gudbrandsdalen, men det var også mye nedbør i fjellet på østsiden fra Lillehammer til Ringebu i Gudbrandsdalen og Østerdalen til Storelvdal.

Add map

Figure 3.1.44.7 Daily precipitation and discharge in rivers east of Østerdalen in June 2011.

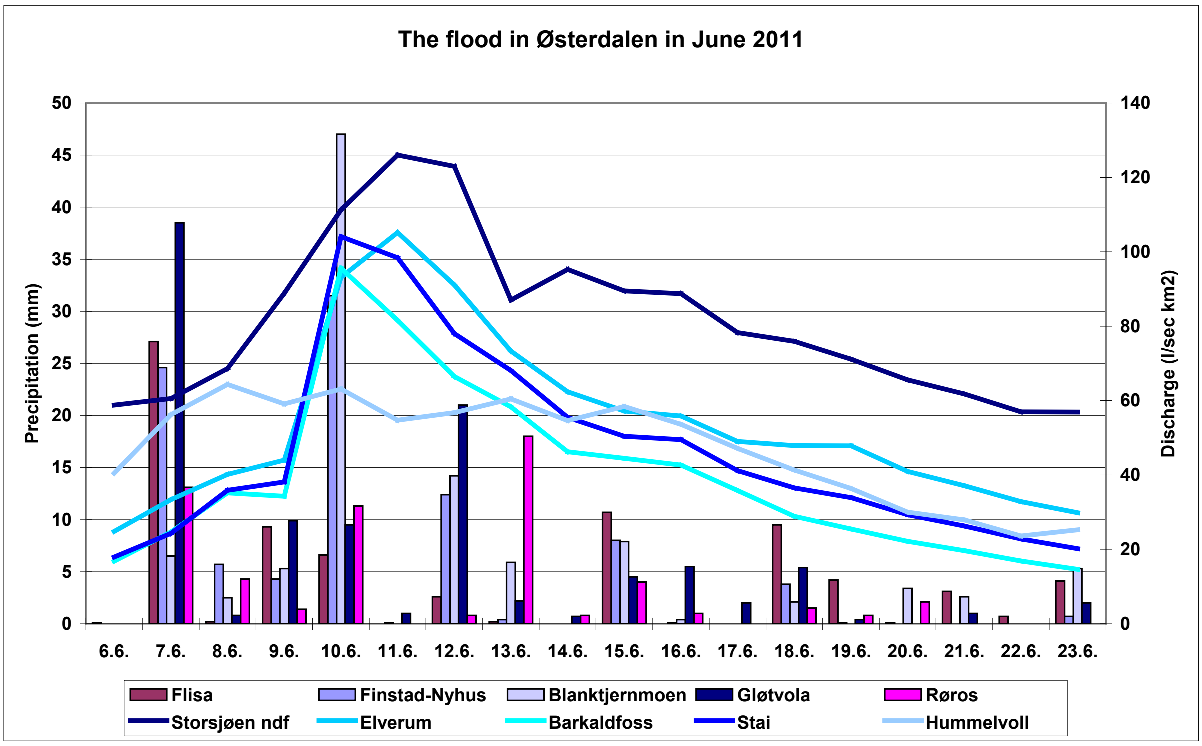


Figure 3.1.44.8 Daily precipitation and discharge at stations in Østerdalen in June 2011.

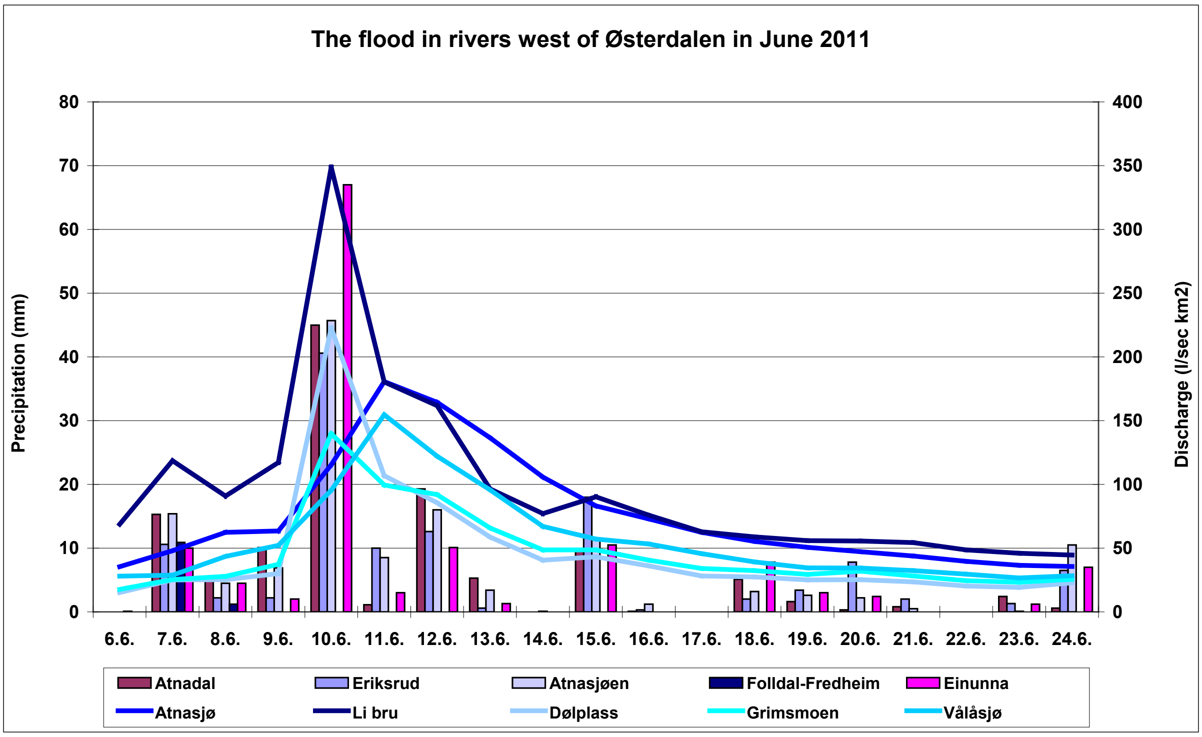


Figure 3.1.44.9 Daily precipitation and discharge in rivers west of Østerdalen in June 2011.

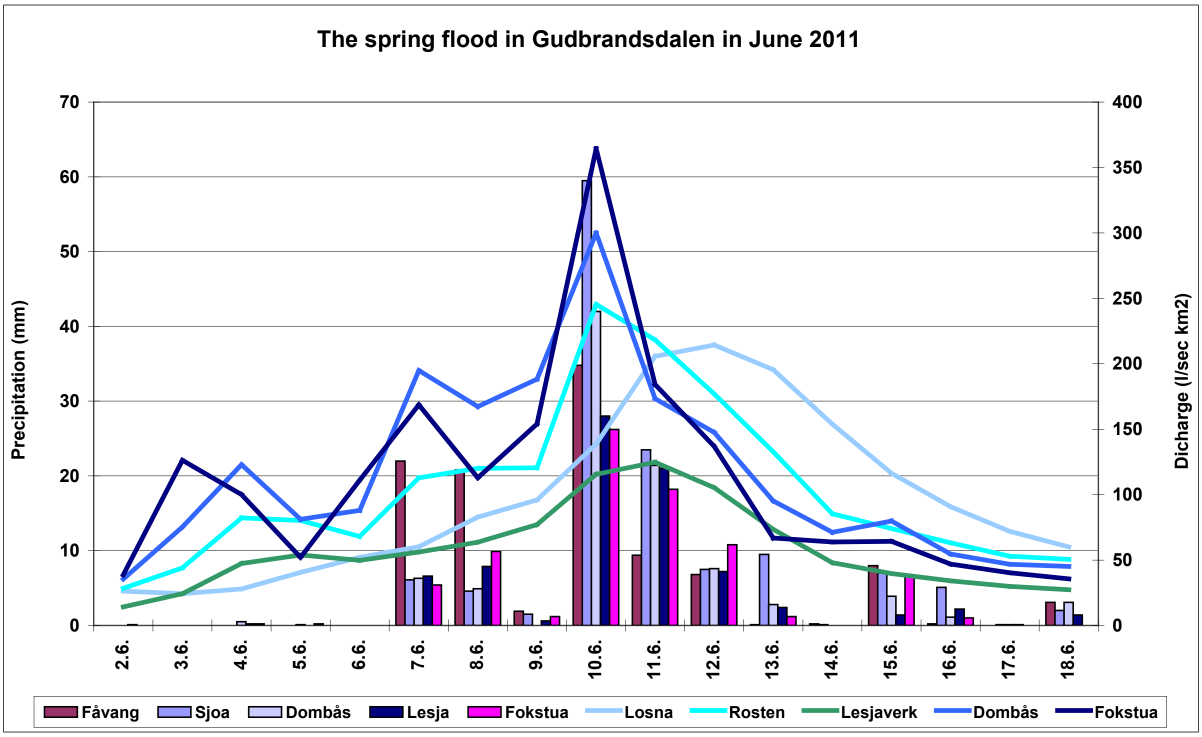


Figure 3.1.44.10 Daily precipitation and discharge at stations in Gudbrandsdalen in June 2011.

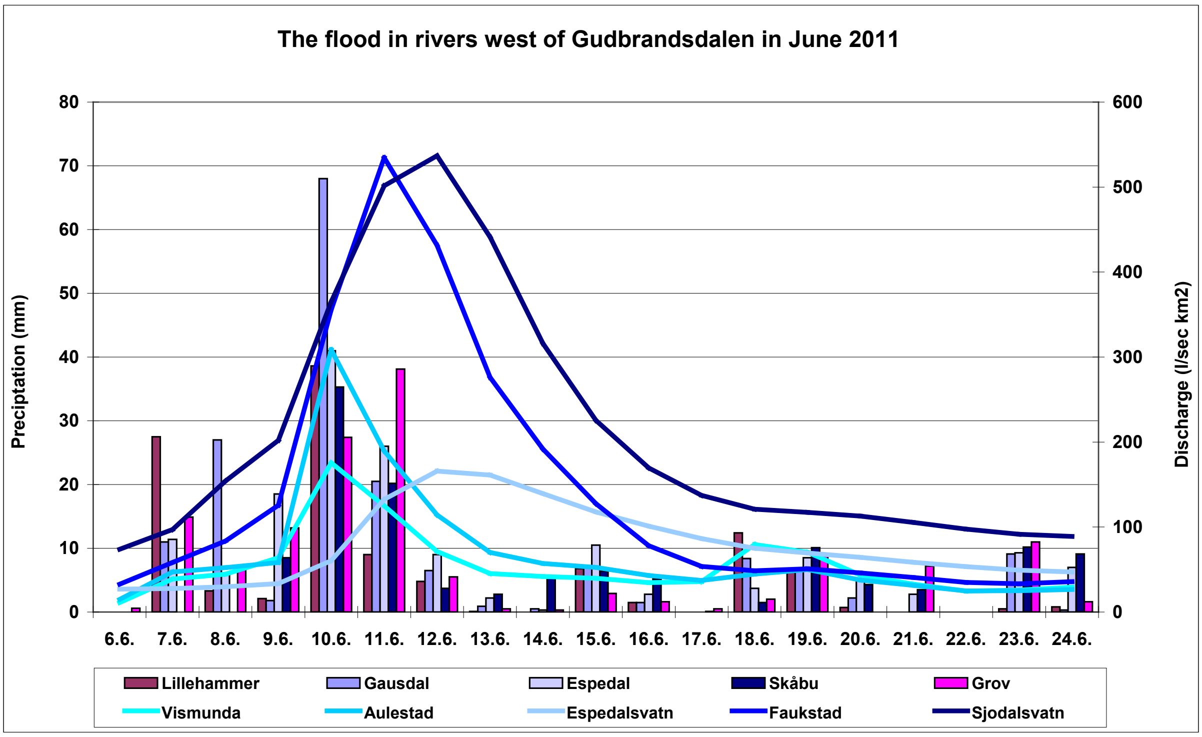


Figure 3.1.44.11 Daily precipitation and discharge in rivers west of Gudbransdalen in June 2011.

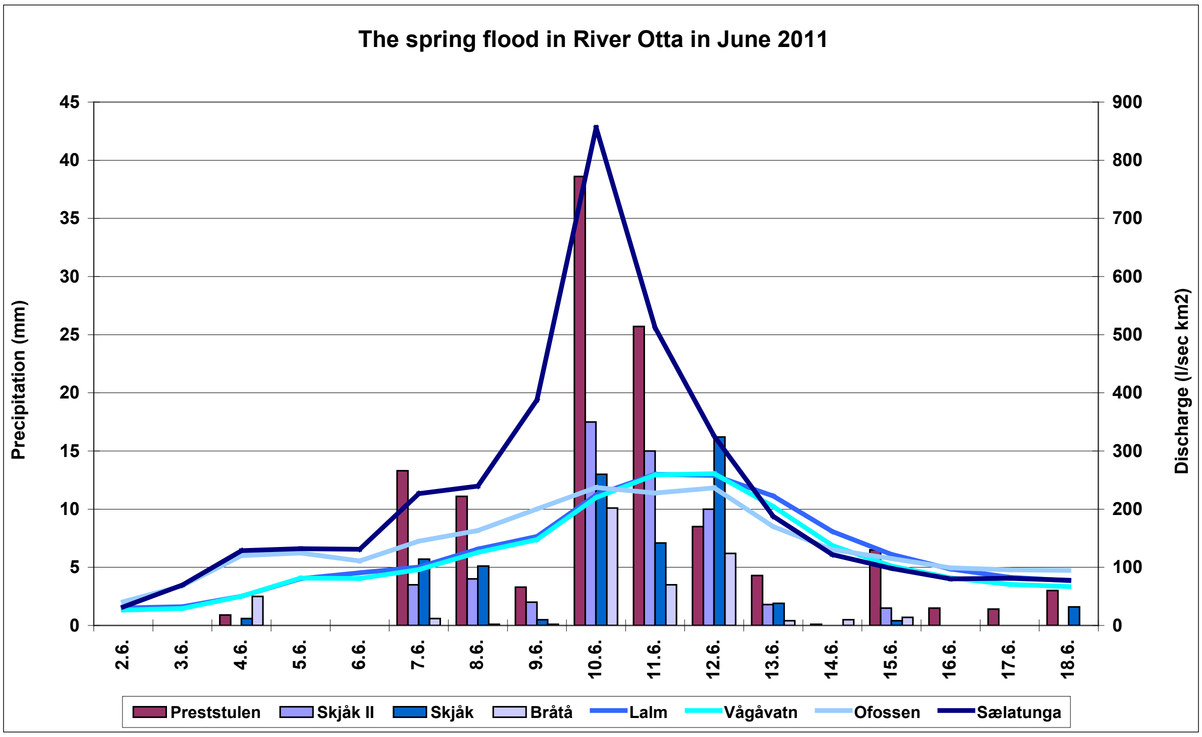


Figure 3.1.44.12 Daily precipitation and discharge in rivers in Ottadalen in June 2011.

Flood damages:

Fatalities:

An 82-year old man was killed at Svingvoll in River Gausa.

Closed roads:

E6 was closed at Fron and at Sel at Rosten.

E16 was closed in Begnadalen because of flood and at Maristuen in Lærdal because of landslide.

RV 3 was closed because of the flood between Rena and Koppang in Østerdalen.

RV 51 was closed at Maurvangen, where the road crosses over River Sjoa east of Lake Gjende.

RV 7 was closed because of a rockfall at Eidfjord.

Closed railway lines:

Dovrebanen: Damages on the railway superstructure at 35 locations between Lillehammer and Dombås. The line was closed from 10 to 16 June
Raumabanen: The line was closed from 10 to 14 June

Damages at buildings:

Damages for 30 mill. at Fåvang sawmill. Many planks were taken by River Lågen.

Extrensive damages from landslides and erosion in Veikledalen in Nord-Fron. A full evacuation of the part of the valley exposed to further slides was considered (Aftenposten 23 June 2011). This village suffered severe damages during Storofsen i 1789 (Sommerfelt, 1943), in May 1934, and again in May 2013.
Camping sites along River Gudbrandsdalslågen and River Driva were inundated.
200 people were evacuated - 50 in Fron.
The damages to insured properties were estimated to 260 mill. NOK.

3.1.45 The rainfall flood in Notodden 24 July 2011

Varm and unstable airmasses from southeast caused several rainstorms in South Norway in the summer 2011. Intense rainfall caused urban flooding in Oslo and Akershus 24 June. Another rainstorm occurred at Sangefjell southwest of Ål. The railway line between Ål and Geilo was undermined, causing the traffic to stop until 11 July.

Convective rainfall caused several rivers to flood 22-26 July especially in Buskerud and Telemark. The highest return periods were observed at Holmsfoss in River Numedalslågen and at Begna in River Begna. An intense rainstorm occurred at Notodden in Telemark 24 July causing extensive flooding in the district and severe damages.

Initial conditions:

The soil water was the groundwater storage were filled up at the time of the rainstorm as shown in Figure 3.1.45.1.

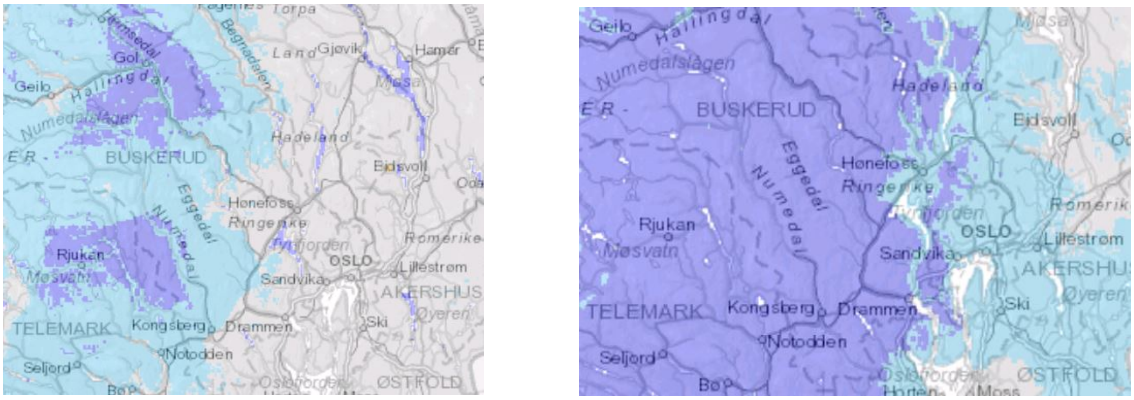


Figure 3.1.45.1 The storage capacity of the soil water storage (left) and the groundwater condition (right) 24 July 2011.

The rainfall and flood:

Intense concetive rainfall occurred in Drammen, Kongsberg and around Notodden and at locations east and west of Oslo as shown in Figure 3.1.45.2 (left). The weather types 22 26 July were: **TRM**, **TRM**, **TRM**, **TRM, TRM** (Grosswetterlagen) and **A**, **N**, **N**, **CN**, **AN** (Lamb-Jenkinsson). The floods occurred mostly in small rivers without direct observations of the discharge. The discharge mostly based on the larger rivers is shown in Figure 3.1.45.2 (right),

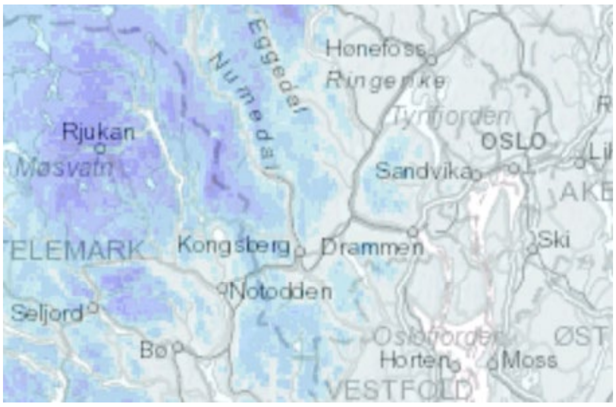


Figure 3.1.45.2 Distribution of the rainfall (left) and the runoff (right) 24 July 2011 in East Norway.

Flood damages:

Roads:

E134 was closed east of Notodden. Several county roads were closed in Buskerud and Telemark.

Railway:

The railway line at Notodden station was completely undermined.

Damages to properties:

Many houses had the basement inundated in eastern Telemark and Western Buskerud. Camping sites were inundated at Meløstranda camping in Vestfold and at Seljord in Telemark.

Economical losses:

3.1.46 Rainstorms in August and September in East Norway in 2011.

The warm and unstable weather continued through the summer in East Norway. Oslo suffered from an intense rain- and hailstorm 10 August, caused by **TRM** (Grosswetterlagen) and **SW** (Lamb-Jenkinsson). More widespread rainfall 15 August occurred at Valdres in Oppland where landslides blocked E16 at Aurdal. The railway line as well as E6 was blocked at Stange in Hedmark and Eidsvoll in Akershus suffered from inundation. The weather types causing this event was **WZ**, **WA** (Grosswetterlagen) and **W**, **CW** (Lamb-Jenkinson). These floods were caused by a weak front moving northwards causing the severe flood in River Gaula 16 August.

Another rainstorm caused damages at Makrellbekken station of the Oslo metro 28 August. The weather types causing this event was **WA** (Grosswetterlagen) and **NW** (Lamb-Jenkinson). River Mesna in Hedmark suffered from flooding 31 August, caused by **HNA** (Grosswetterlagen) and **A** (Lamb-Jenkinson). Rainfall from the remnants of *Hurricane Irene* caused the railway line to close between Strandlykkja and Espa at Hedmark 5 September caused by **SZ** (Grosswetterlagen) and **CW** (Lamb-Jenkinson). The railway line through Østerdalen was also damaged between Koppang and Rena. The rainstorm flooded many basements at Løten and Brummunddal from smaller brooks and rivers. Some privately owned bridges were taken and many basements were filled with flood water.

New rainstorms occurred 7, 11 and 19 September caused local flooding in Aust-Agder, Telemark, Buskerud, Vestfold, Akershus and Hedmark, inundating roads and the railway line at Gullhella in Asker. The weather types causing these three events were **SWZ**, **WZ**, **WA** (Grosswetterlagen) and **NW**, **C**, **ANW** (Lamb-Jenkinson).

3.1.47 The extreme rainstorm in Eiker and Modum 6-7 August 2012 (*Frida*)

Intense rainfall during the extreme weather Frida caused local floods with return period in excess of 50 years in parts of Buskerud and Vestfold. The rainfall caused local floods in Telemark, Aust- and Vest-Agder with local inundations.

Cause of the flood:

Initial conditions

July 2012 was wet at Østlandet with 150-250 percent of the normal rainfall. Parts of Agder had a deficit, the July rainfall was from 50 to 100 percent.

A frontal system with intense showers moved northwards from Denmark in the morning 6 August 2012. Intense showers occurred in Agder, causing local floods. The depression was first located east of Aust-Agder with the front rotating around the center, before moving slowly northwards. The centre of the depression was located over the outer Oslofjord in the evening, with the front and rainfall moving over the southern part of Østlandet. Behind the front an intense squall-line formed causing intense showers in a narrow zone through Vestfold and Buskerud. Around 70-100 mm rain fell locally in a few hours. The weather types 6.-7. August were **SWZ** and **NWA** (Grosswetterlagen) and **C** and **AW** (Lamb- Jenkinsson).

The forecasts prior to the rainstorm were uncertain as to the development of the depression, the amount of rainfall and where the most intense rainfall would occur. The early forecasts indicated that most rain would fell in Agder, but when the depression moved further north, warnings were issued of heavy rainfall in Telemark and in southern districts of Østlandet.

A Phase B extreme warning of heavy rainfall was issued 6 August 9:05. The extreme weather was named Frida. Phase C warning was issued 6 August 10:42, still with focus on Agder and 15:56 and Phase D warning was issued 6 August 20:40.

Flood damages:

<u>Nedre Eiker</u>

<u>Modum</u>

The flood caused some small landslides.

1 person suffered from a broken leg.

The Enger waste handling facilty was flooded. Untreated sewage water leaked into the river and penetrated into the basements of some buildings.

Roads damaged by undermining and inundation. RV 35 flooded at two locations, some county and local road collapsed.

The railway line to Bergen was undermined at two locations.

Water penetrated into basements of many buildings, damaging gardens and access roads in domestic areas especially at Åmot.

The new power station under construction at Embretsfoss was partly flooded.

The access road to Blaafarveværkets mines was destroyed. Erosion and deposition of sand and gravel damaged farmland.

3.1.48 The large flood in Gudbrandsdalen 22-23 May 2013 (Pinseflommen 2013)

Another severe flood occured in the middle part of Gudbrandsdalen, Gausdal and in lesser degree in Østerdalen in May 2013, causing even more severe damages at Kvam than during the severe flood on Whitsunday 2011.

Initial conditions:

The winter 2012/2013 had a temperature deficit in January and March, a surplus in February, close to normal in April and a large surplus in May, which was even higher in North Norway which caused the snowmelt flood there, se below. The precipitation showed a deficit from January to April, but a surplus of 200- 500 % of the normal in May. The surplus was largest in the western districts of East Norway. Near the border to Sweden, the surplus was lower.

Snow

The snow reservoir was less than normal in most districts in East Norway prior to the flood. The snow reservoir in the catchment of Lake Mjøsa was estimated to 80 percent of the normal by Glommen and Laagens Brukseierforening (GLB). The distribution of the water equivalent of the snow reservoir 16 and 23 May is shown in Figure 3.1.48.1. Some snow was remaining above 700 m.a.s.l. as shown in Figure 3.1.48.2 observed at the snowpillow at Kvarstadsætra and in Figure 3.1.48.3 observed at Heimdalsvatnet in East Jotunheimen. Further west some mountain catchments had more snow than normal, especially Hallingdal where the observations are shown in Figure 3.1.48.4 for the snow pillow of Bakko at Hol. Figure 3.1.48.5 show the snowmelt in mm water equivalent in the week 16-23 May.

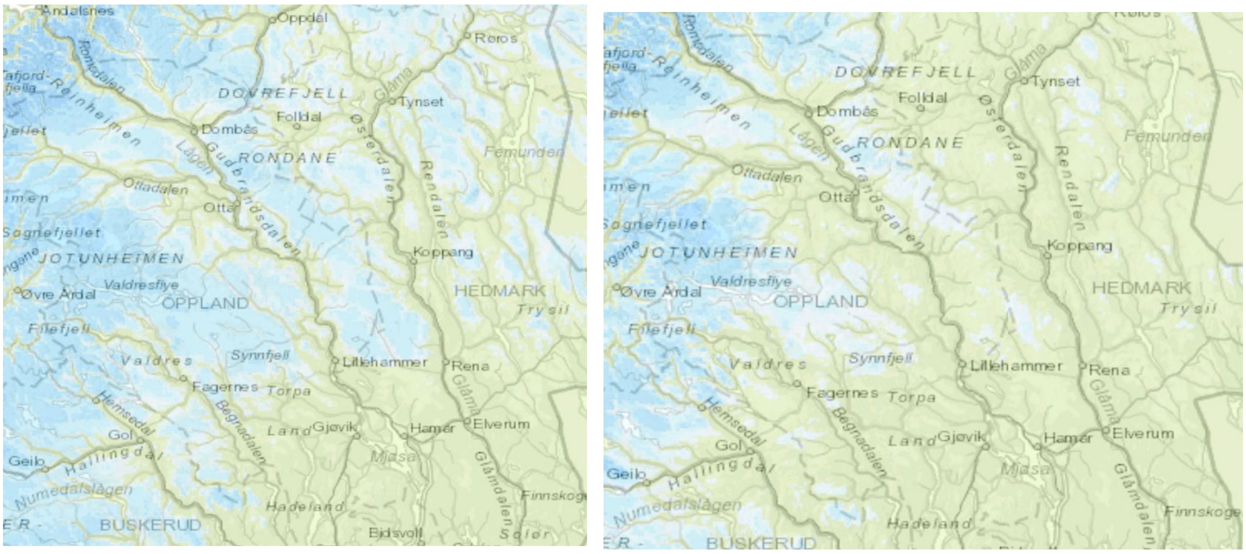


Figure 3.2.48.1 The water equivalent of the snow storage 16 and 23 May 2013.

Ground water and soil moisture deficit

The groundwater storage was very high and the spoil moisture deficit very low at the time of the flood as shown in Figure 3.1.48.2

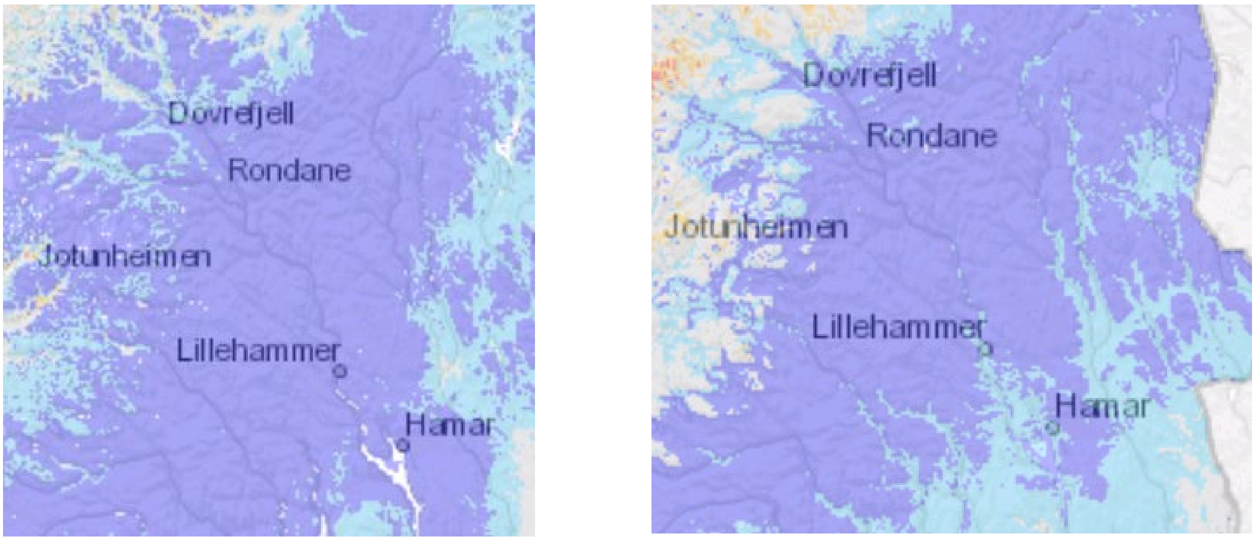


Figure 3.1.48.2 The ground water storage and the soil mosture deficit 23 May 2013.

Weather

The cold weather this winter was caused by transport of cool air masses from the north. The spring was late, but warm air from south- southeast were pushing towards the cold air over East Norway until i finally broke through causing the snowmelt to start. As in 2011 heavy showers fell from the frontal zone between the warm and humid air in the east and the cooler maritime air masses in the west, mostly over Gudbrandsdalen. Weather types 22- 23 May were: **TRM** (Grosswetterlagen) and **ANW** and **N** (Lamb-Jenkinsson).

- ***Preciptation and snowmelt***

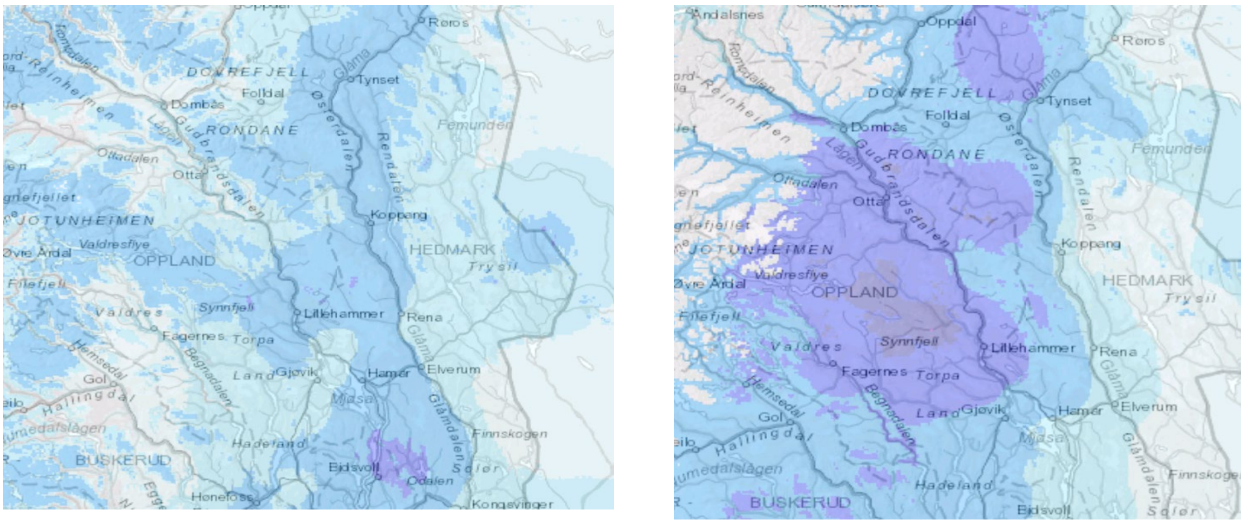


Figure 3.1.48.3 The distribution of the snowmelt and the precipitation 22 (left) and 23 May (right 2013.

Discharge

The flood peaked in Østerdalen and in Gudbrandsdalen 22 or 23 May. At Øyeren the flood peaked at the level 102,79 m 26 May. This level exceeds the level of the 2011 flood by 41 cm, which is the highest since Vesleofsen in 1995. There was a secondary flood 31/ May to 1 June in River Otta and the tributaries from the alpine areas in Jotunheimen and Reinheimen.The spatial distribution of the discharge 23 May is shown in Figure 3.1.48.4.

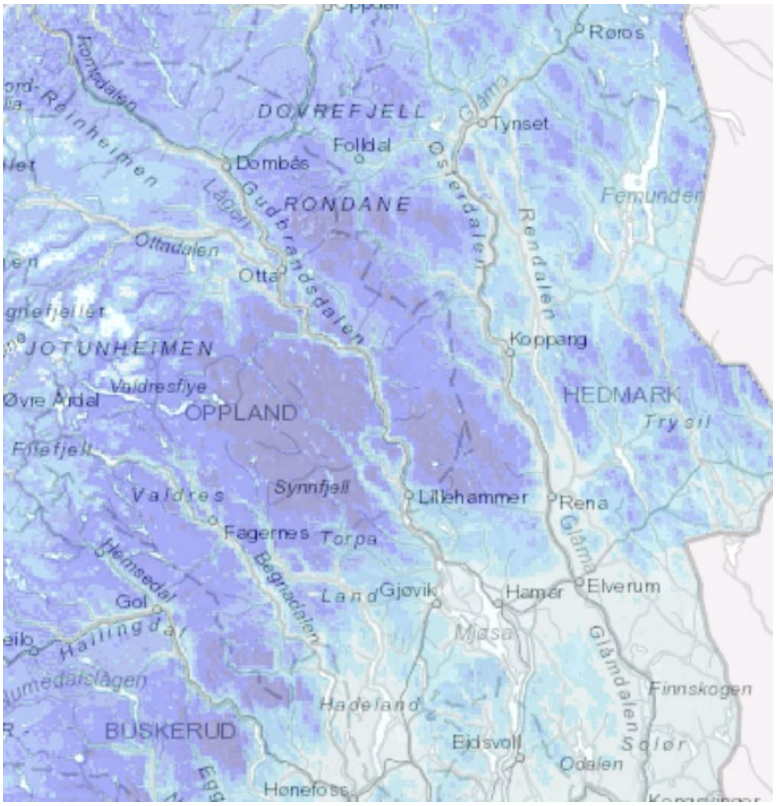


Figure 3.1.48.4 The spatial distribution of the discharge 23 May 2013.

Observed preciptation and discharge in River Glomma in Østerdalen is shown in Figure 3.1.48.5, in tributaries west of Glomma in Figure 3.1.48.6, in River Gudbrandsdalslågen in Figure 3.1.48.7, in tributaries west of Gudbrandsdalslågen in Figure 3.1.48.8 and in River Otta in Figure 3.1.48.9.

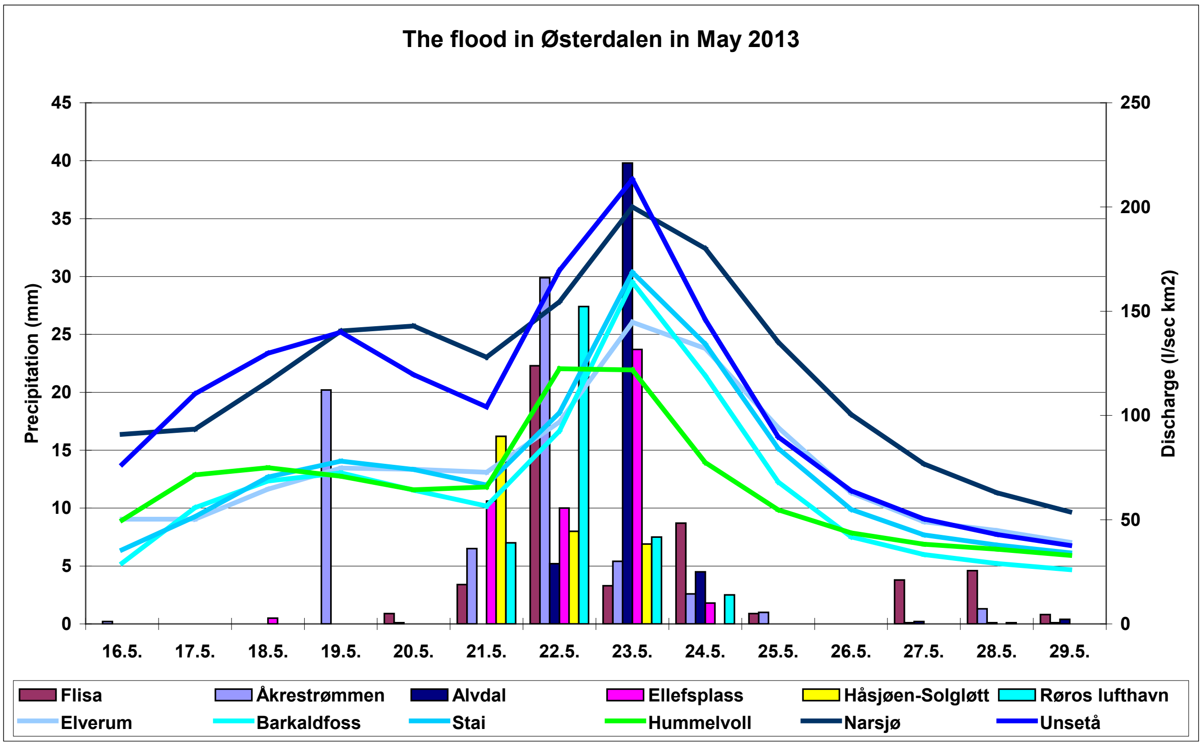


Figure 3.1.48.5 Daily precipitation and dicharge at stations in Østerdalen in May 2013.

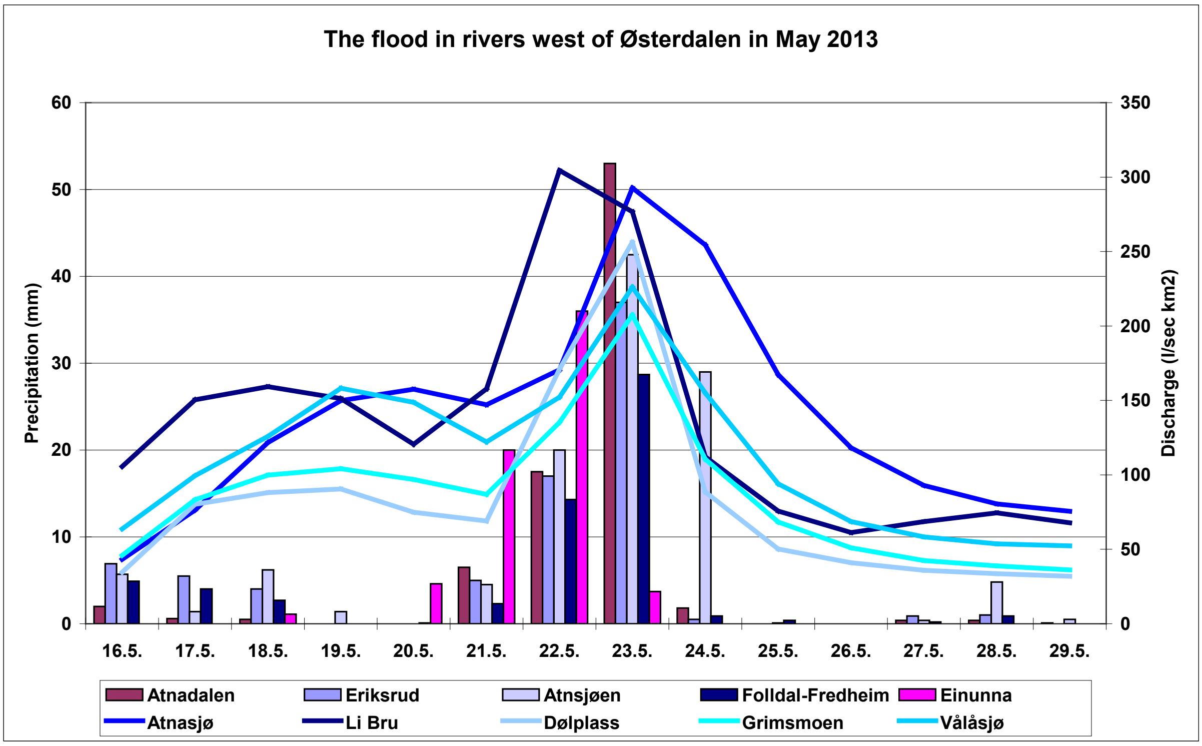


Figure 3.1.48.6 Daily precipitation and discharge in rivers west of Østerdalen in May 2013.

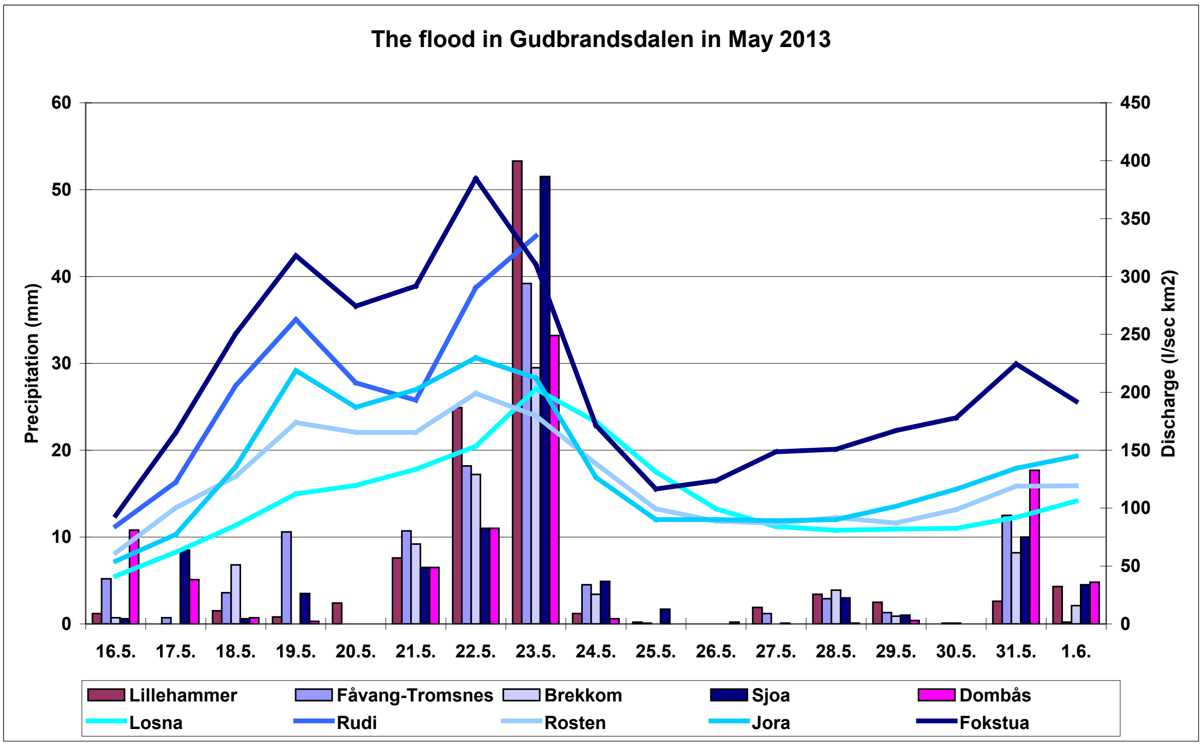


Figure 3.1.48.7 Daily precipitation and dicharge at stations in Gudbrandsdalen in May 2013.

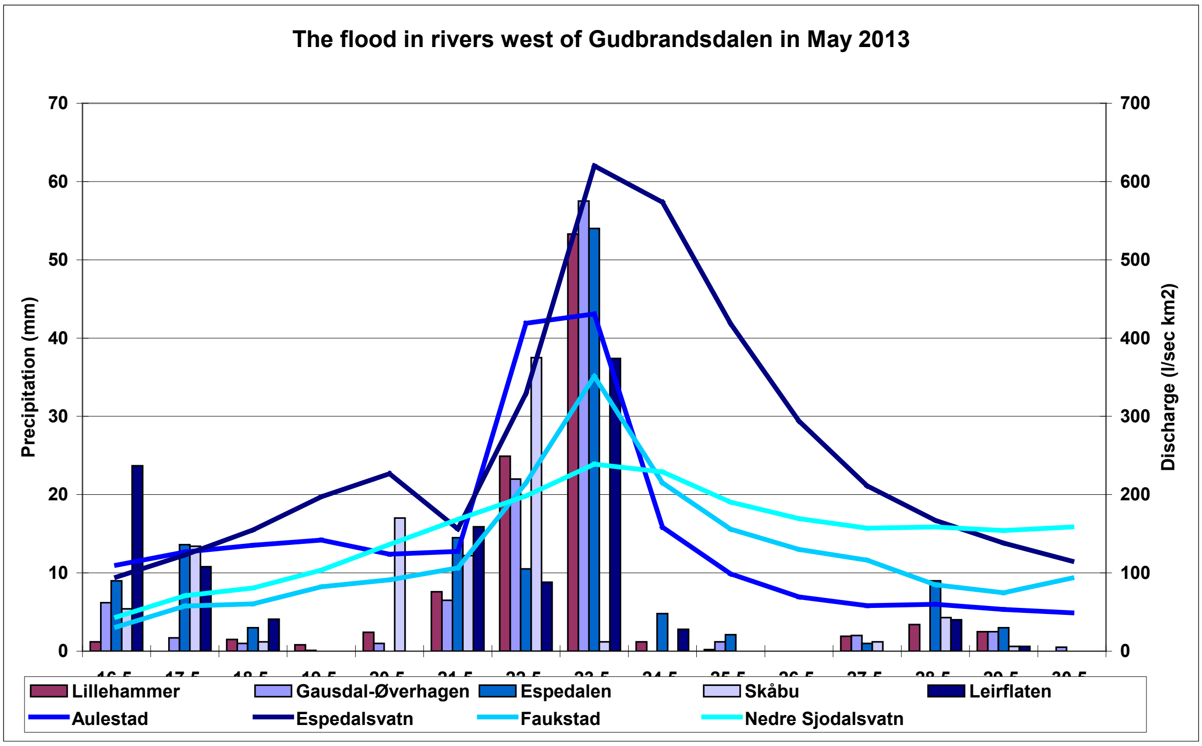


Figure 3.1.48.8 Daily precipitation and dicharge in rivers west of Gudbrandsdalen in May 2013.

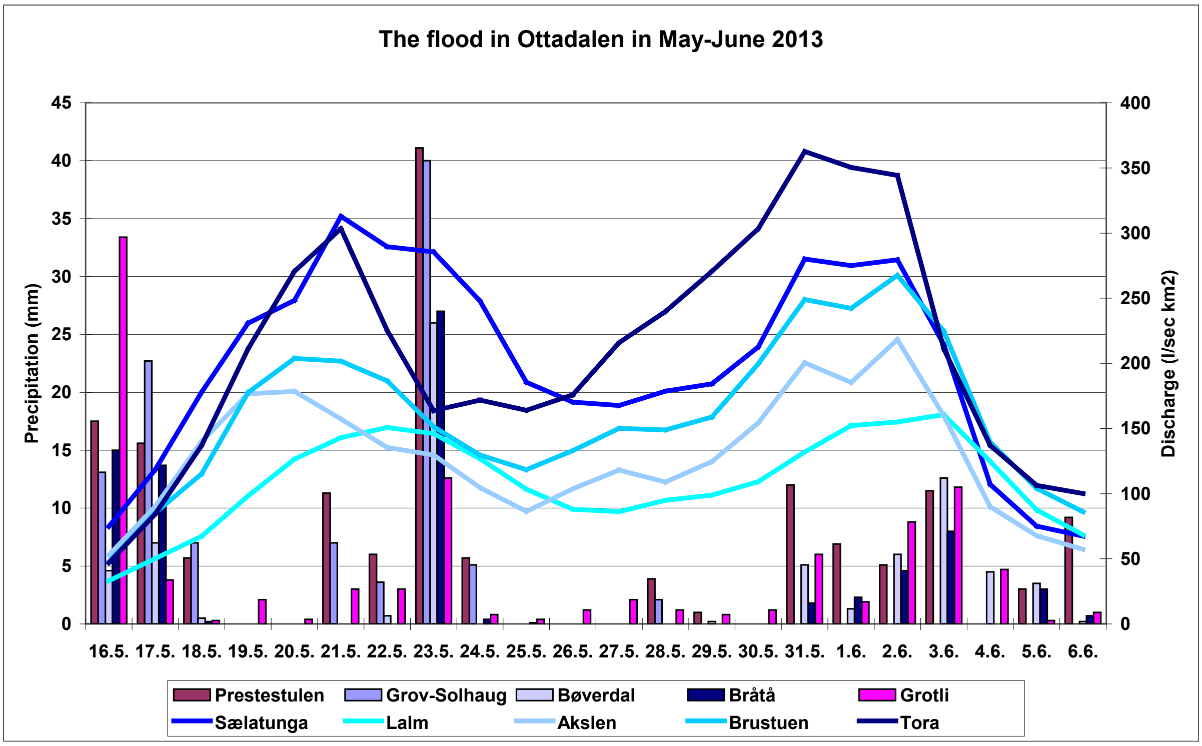


Figure 3.1.48.9 Daily precipitation and discharge at stations in Ottadalen in May 2013.

Flood damages:

RV 3 was taken by the flood between Atna and Hanestad in Østerdalen.

The traffic on the main railway line between Hamar and Eidsvoll was temporary halted because of the flood. 35 inhabitants were evacuated at Eidsvoll, as a dam in River Holta could fail.

A landslide occurred near Fåvang railway station in Gudbrandsdalen.
The flood caused the main railwayline through Gudbrandsdalen, as well as the line trough Østerdalen and the railway line to Kongsvinger to close, because of erosion and landslides. The damages on the roads and railway was estimated to 400 Mill. NOK and damages covered by insurances 240 mill.

The flood damages in Gudbrandsdalen was estimated to 1 Bill NOK. around four times the cost of the Whitsunday-flood in 2011.

The damages at Kvam was as large as the damages two years earlier and 113 people was evacuated because of the ravages of Storåa and Veikleåa.

The flood caused also damages at Holtålen in Gauldalen where some bridges were damaged. These bridges had been damaged during the flood 16/8 2011.

3.1.49 The large spring flood in River Trysilelv 26 - 30 May 2014.

There was a risk of a large spring flood at Østlandet in May 2014. The weather during the snowmelt did not cause a large flood except in River Trysilelv, where the fourth largest flood since 1909 occurred at Nybergsund. Observed rainfall and discharge is shown in Figure 3.1.49.1.

Cause of the flood

The flood was primarily caused by snowmelt, but moderate rainfall 24-26 May contributed to the peak. The weather types 25-26 May 2014 were: **TM** (Grosswetterlagen) and **SE** and **C** (Lamb-Jenkinsson).

Figure 3.1.49.2 show the spatial distribution of the snow water equivalent 16 May when the discharge started to rise because of the increasing snow melt (left). The increasing flood was caused by snowmelt until 24 May when some rain fell until 26 May when the flood peaked. The spatial distribution of the rainfall observed in the morning 26 May is shown in Figure 3.1.49.1 (right).

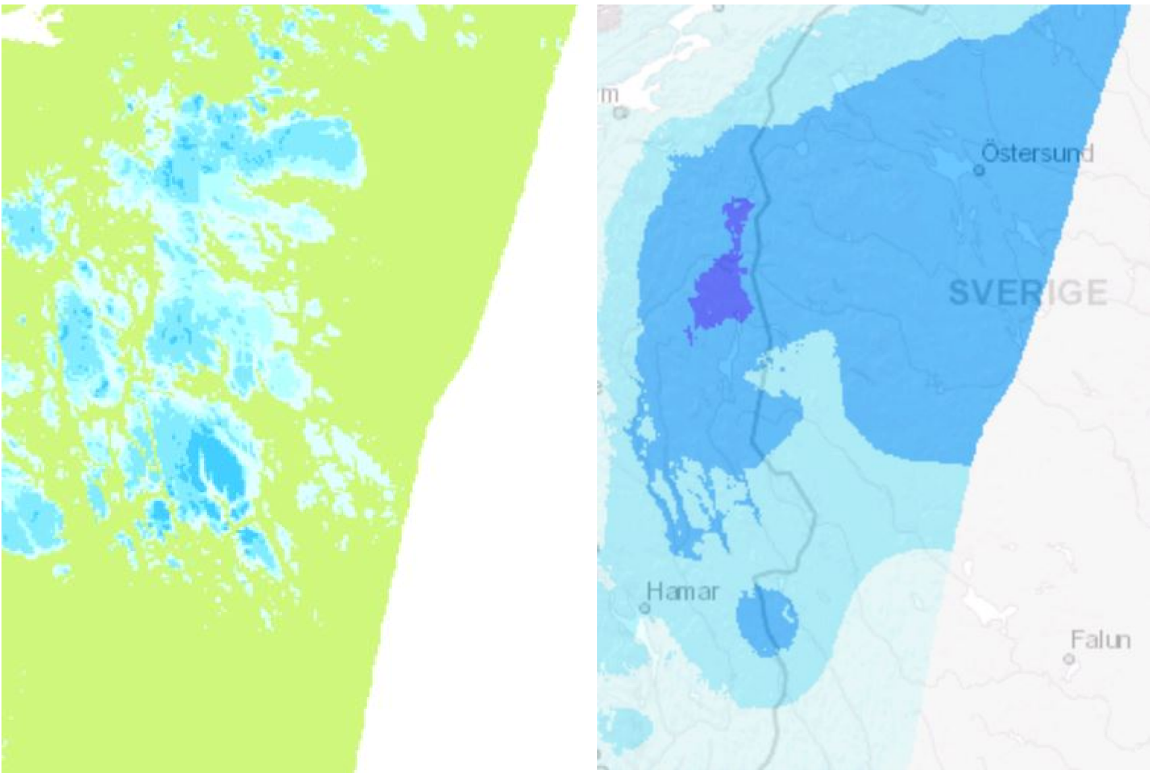


Figure 3.1.49.1 The spatial distribution of the snow water equivalent at the start of the snowmelt 16 May 2014 (left) and of the rainfall 26 May (right).

3.1.50 Rainstorm in Oslo 26 June 2014

The late spring and summer were very warm in Oslo, and several events of thunderstorms occurred causing local flooding in parts of Oslo. The most intensive event occurred 26 June 2014, setting new records both for 1 hourly and 24 hourly rainfall. The heaviest rainfall fell near the Metorological institute at Blindern. There are unfortunately no gauging stations in the brooks nearby the institute, and therefore no discharge data are available from the location with the heaviest rainfall. The weather types 24-28/June were: **HNZ**, **HNZ**, **HNZ**, **HNZ**, **TM** (Grosswetterlagen) and **A**, **ASE, SE, C, N** (Lamb-Jenkinsson).

3.2 Large floods near the south and southwest coast

3.2.1 Floods and land slides at Sørlandet 12 -15 September 1837.

A severe flood occurred at Buskerud, Telemark and Sørlandet in September 1837.

Initial conditions:

The winter 1836/1837 was cold and the snow reservoar was unusually large in the spring. The spring melting was late. The levels of the lakes and reservoirs were high through the summer. Long term rainfall caused the largest flood for the last 60 years in the major rivers at Sørlandet.

The flood:

A heavy rainfall during a severe thunderstorm caused small brooks as well as the larger rivers to inundate farmland and roads.

Flood damages:

Otra: The timber boom "Stray-lensen" failed, releasing several thousand logs into the river. The timber destroyed the nearby bridge.

Nidelva: The water level at Struebroen was 30 feet - the highest in at least 60 years. The bridge at Refnes was taken by the flood. The local populating feared that the timber booms would fail, but the water started to fall before rhe booms failed.

Drangedals- or Kammerfosselva: The river went bankfull, either in 1837 or in 1839. During one of these two floods the Kammerfoss bridge failed.

Telemark: The priest farm at Mo was damaged by large landslides 14 September after 2 days of torrential rainfall. The family was rescued from the farm which was abanoned. The damage was estimated to 1/6 of the original value for 12 years.

Buskerud/Numedalslågen: A part of the bridge over Numedalslågen at Stuberø was taken.

3.2.2 Long duration rain flood at Nidelva 24 September 1839.

A large flood occurred at Nidelva after abouth a month and incessant rainfall. The level of rivers and brooks grew, causing inundation.

Flood damages:

The farmers suffered damages to the grain and potato crops, because the inundation made harvesting impossible. The timber boom at Asdal failed night to 24 September, releasing 9600 logs. The greater part of the log went into the western channel of the river to the sea, causing large losses to the owners. The water inundated the post road at Refnæsbroen and Struebroen.

3.2.3 Extreme rainstorm from the Kragerø water course to Lyngdalselv 17-18 September 1864.

An intense rainstorm caused severe floods in several smaller rivers at Sørlandet in September 1864. The extreme weather occurred prior to re-analysed weather maps are available from www.wetterzentrale.de. Grosswetter indices are therefore not available for the event. Weather indices for the Lamb classification are available. The indices indicate a westerly wearher type over Britain, but a depression moved in from west. The depression was situated 15-16 September over Britain, before the circulation shifted into a westerly weather type again. The most intensive rainfall has affected rivers from Vegårdselv to Nidelva.

Daily water level observations are available at Lake Hoseidvatn, and Øvre and Nedre Tokevatn in the Kragerø water course, at Lake Lundevatn, Lundestrømmen and Songevatn at Vegårdselv, at Rossøy, Buodden and Kjellerfoss at Nidelva and at Storstrømmen at Otra as shown in Figure 1.

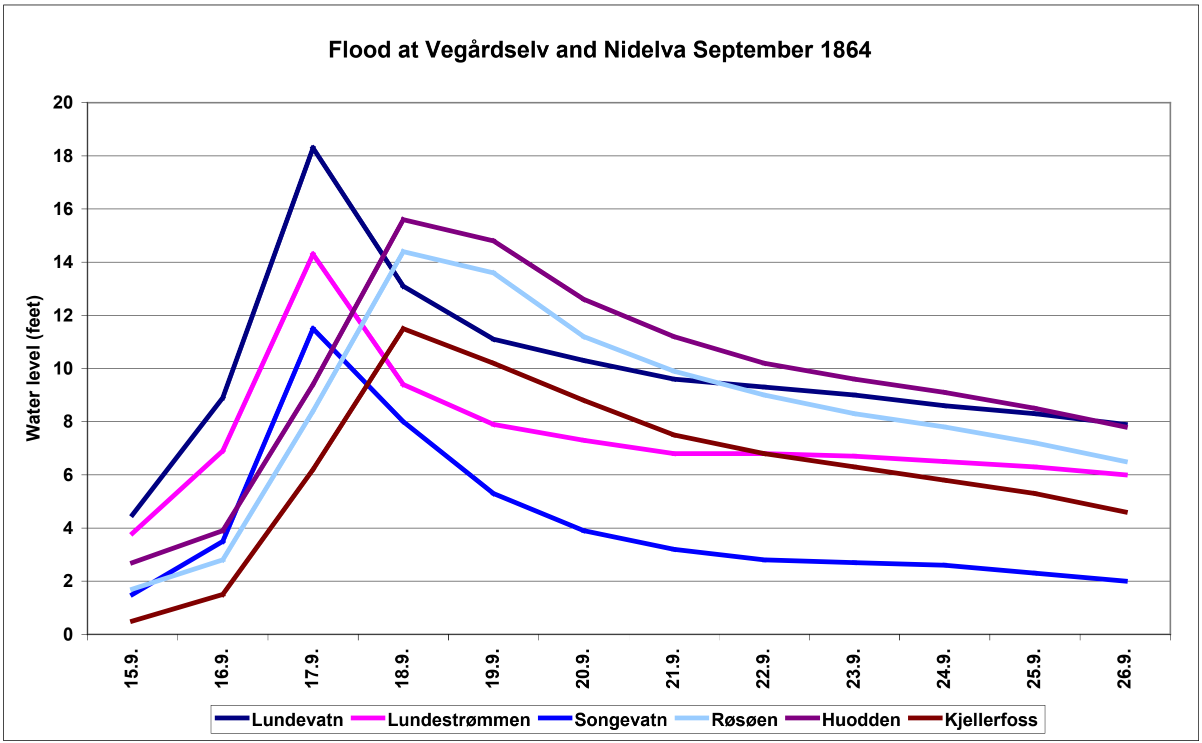


Figure 3.2.3.1 Observed water levels at Sørlandet during the rainstorm in 1864.

Estimates of the discharge at culmination are known at Vegård, Skjerka dam and Molandselv at River Vegårdselv. The discharge was estimated to 270 m^3/s or 728 l/s km^2, 92 m^3/s or 2396 l/s km^2 and 64,6 m^3/s or 2460 l/s km^2 respective (Kanalvæsnets historie). The flood level is known at a location 1 km downstreams Øyslebø church near River Mandalselv from 1864.

Flood damages:

River Lyngdalselv shifted to a new channel.

3.2.4 Flood and slide in Otra in November 1864

Snowfall in November 1864 succeeded by mild weather and rain from southwest 3.-4 December caused the level of River Otra to rise fast. A landslide at Saga in Vennsla killed five people (Furseth, 2006).

3.2.5 The rainfall flood at Sørlandet and western part of East Norway in October 1892.

Long term rainfall in September and October 1892 caused a large flood in the southernmost districts of South Norway to the Drammenselv basin in East Norway. Figure 3.2.5.1 show observed daily rainfall and discharge at some stations which were operating as early as in 1892.

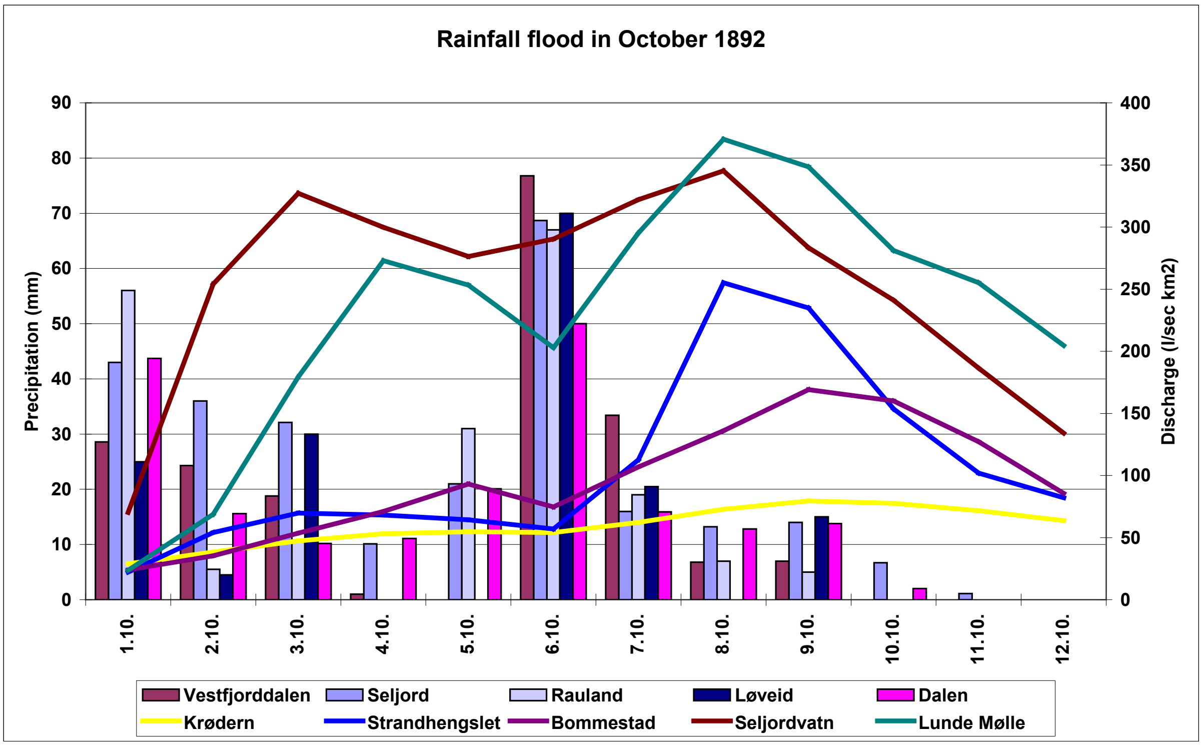


Figure 3.2.5.1 Observed daily rainfall and discharge during the flood in October 1892.

Rating curves had been established at a few stations in River Drammenselv, River Numedalslågen, River Skienselv and River Nidelv, but not in River Otra or River Mandalselv where only the stage is known at a couple of stations. A large flood occurred in River Simoa at Strandhengslet and in River Numedalslågen at Bommestad where the flood was second largest (1879 -1927). The flood in 1927 was marginally larger than the flood in 1992.

The flood was fifth largest inflow flood in River Skienselv at Lake Seljordvatn (1884-1970). The water levels in Lake Norsjø and in Lake Hjellevatn are known from 1851. The flood ranks as fourth største in Lake Norsjø; only exceeded by the floods in 1927, 1860, 1888 og 1879. The discharge was estimated to 2140 m^3/sec or 214 l/sec km^2 against 2330 or 233 in 1879. In Lake Hjellevann the flood was fifth largest; only exceeded by the floods in 1860, 1927, 1879 and 1872. The dicharge was estimated to 2260 m^3/sec in Lake Hjellevatn i 1892. In Lake Totak the flood was less than the autumn flood in 1891 and was exceeded by three larger spring floods in (1885-1907). The largest occurred in 1897 of 265 m^3/sec or 322 l/sec km^2. Upstream Vrangfoss the discharge was estimated to 873 m^3/sec or 243 l/sec km^2. In Lake Tinnsjø the flood was second largest (1885- 1907) with a discharge of 570 m^3/sec or 160 l/sec km^2, but eceeded by the spring flood in 1897 of 720 m^3/sec eller 202 l/sec km^2.

The flood was severe in River Toke and in River Nidelv. The flood level is known in Lake Tokevatn, together with flood marks from 1934 and 1949. At Lunde Mølle at River Nidelv the flood was probably the largest (1874- 2002), and is considered as one of the largest autumn floods which has occurred in the district. The flood level is known at Lindtveit near Bøylefoss.

The flood was also large in rivers further west such as River Tovdalselv and River Otra. The heaviest rainfall was observed at Mandal where 448 mm rain fell in October 1892. The second largest rainfall fell in Bjelland (385 mm) and at Oksøy (383 mm). The floods in River Mandalselv and River Lygna must also have been severe. There is a flood mark at a location 1 km downstream Øyslebø church near Mandalselva where another floodmark exists from the flood in 1864.

The cause of the flood:

The flood was caused by long duration rainfall. A depressiom was located over the North Sea between Scotland and Norway with several frontal passages from west. Weather type: **TB** 1.-4 Oct **TRW** 5-7 Oct (Grosswetterlagen) and **C** (Lamb/Jenkinsson).

Flood damages:

The flood penetrated into basements and houses at Blegebakken in Skien. The total damages was assessed 27.525 NOK in the town.

The Asdal timber boom failed because of the flood. The timber tore away the Vippa bridge. Farmland was inundated at Froland (Aamlid, 1986).

"Vestlandske Tidende" wrote that by 4 October: River Nidelv had risen 13 feet, or 4 meters. Two days later logs were piling up at the Asdal timber boom.Iron chains were used to secure the boom, but the pressure from the accumulated logs caused the boom to fail at 18:30 yesterday releasing between 2000 and 3000 dozens of logs. About 1000 dozens were grounded where the river split into two channels, but the rest smashed into the iron bridge which disappeared into the river. A new bidge was built two years later and was in use for the subsequent fifty years.

3.2.6 Extreme rainstorm at Gjerstadelv and Vegårdselv in August 1896.

A Vb-event caused extreme rainfall at Gjerstad and Vegårdselv 13-14 August 1896. A blocking anti-cyclone in the Atlantic in combination with a warm low over Greece and Turkey set up transport of warm air masses towards northwest. Another colder low was situated in the North Sea. The heavy rainfall occurred in the front between the warm and the cold air masses over Sørlandet. The daily rainfall, shown in Figure 1, are among the highest observed anywhere at Sørlandet. The weather types 13- 14 August were classified as **NWA** and **TRM** (Grosswetterlagen) and NW and **CNW** (Lamb-Jenkinsson).

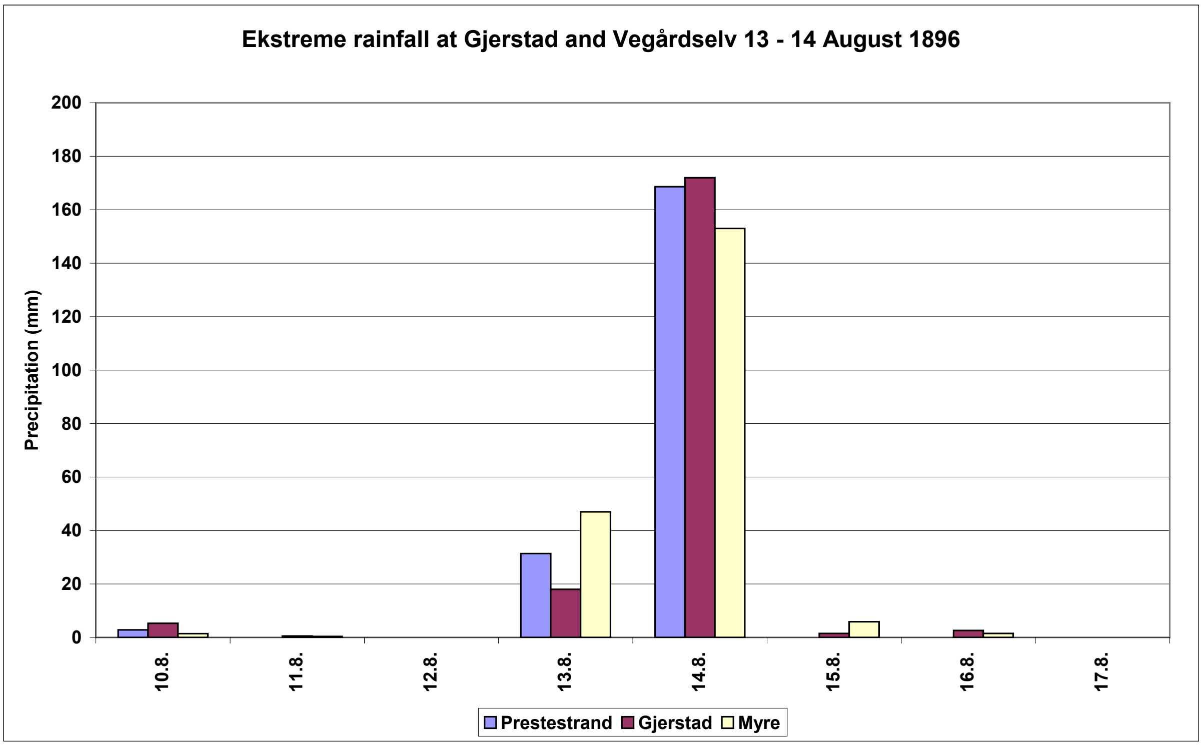


Figure 3.2.6.1 Observed precipitation at stations in Vegårdselv and Gjerstadelv during the extreme rainfall in August 1896.

The resulting flood was not among the most extreme in the larger rivers where som data are available. No data were observed in the smaller rivers where the extreme precipitaion must have caused local floods.

3.2.7 Flood from Agder to Hordaland "Storflodi" in November 1898.

Long duration rainfall in October to early November resulted in a severe flood in rivers at Vest-Agder and Rogaland 3 November 1898. The flood is known as *Storflodi.*

The flood:

Between a strong polar front cyclone over Iceland and the Azores high west of the Iberian penninsula mild air masses was streaming toward northwest Europe from 22 October to 5 November, when the wind direction shifted to northwest, succeeded by colder air masses from east. The depression moved closer to the coast of West Norway as the associated front moved over southwest Norway 2-3 November. The maximum oneday rainfall was observed at Bakke (135,5 mm) and at Suldal (135,5 mm). The weather type was classified as **WZ** (Grosswetterlagen) and **W** (Lamb-Jenkinsson).

Observed precipitation and daily rainfall is shown in Figure 3.2.7.1.

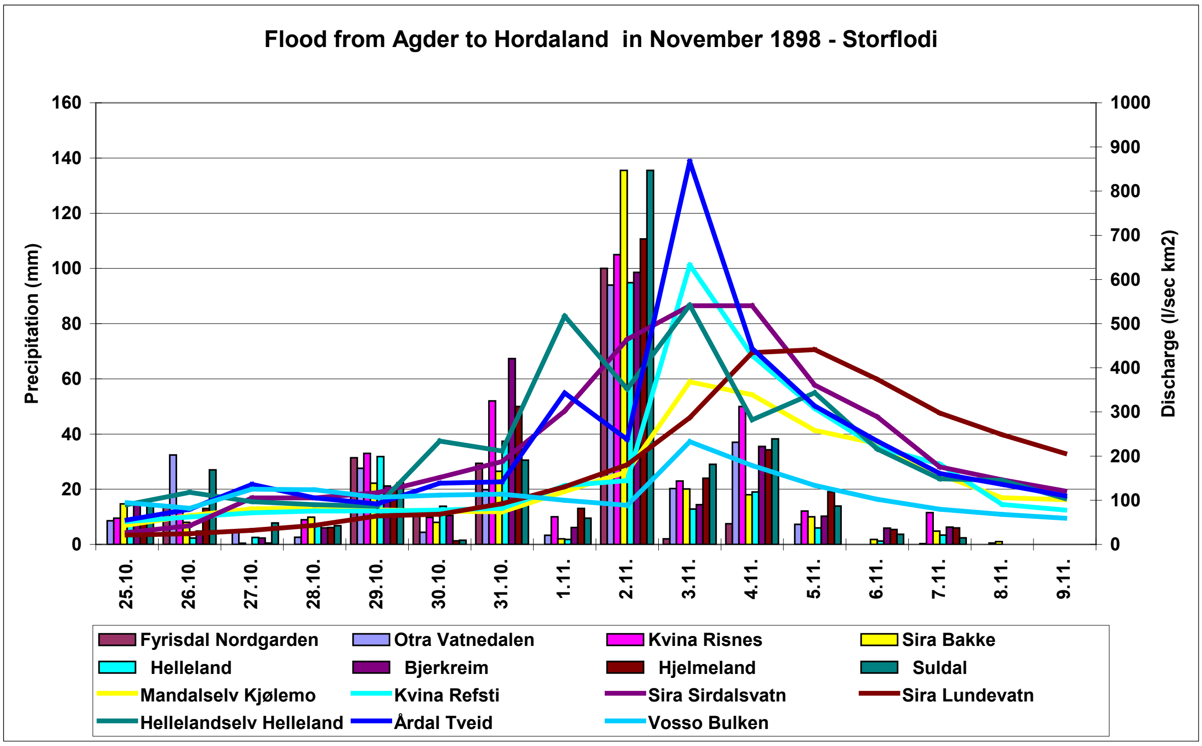


Figure 3.2.7.1 Observed rainfall and daily discharge during Storflodi - a large flood caused by long-term rainfall in November 1898.

The flood ranks as the largest observed in River Sira (1894-1968). It may have been exceeded by later floods, but a comparison is not feasible because of extensive regulation, including both storage in a large reservoir and diversion from the neighbour River Kvina. The flood was the third largest observed at River Kvina at Refsti (1897-2007) and the sixth largest observed at Tveid in River Årdalselv in Ryfylke since 1896.

3.2.8 The rainstorm at Drangedal in August 1912

There are two articles in Drangdal published by Drangedal historielag describing a large flood caused by torrential thunder and rainfall at Drangedal. There are unfortunately no hydrological data available from the event which is typical for simular events in southwest Telemark and in Aust-Agder. According to Grova (1984) the event occured during the night of 12 August in upper Drangedal. Rainfall data show however that heavy rainfall fell in the district on 8 August this year (Met.no, 1912). The oneday rainfall exceeded 100 mm at three locations. Some rain fell also on the 12 August, but the total amounts to only 40 mm twoday rainfall, and the flood did most likely occur on the 8 August, rather than the 12.

The rainfall was linked to a Vb-type event with warm air masses moving in from southeast with source in the Mediterrainan. Weather type: **WZ** (Grosswetterlagen) and **N** (Lamb-Jenkinsson). The fields of the farms at Bergane and Grova were inundated. Bridges were taken, the bridge at Bergan drifted into the forest at Strånd, and bridge at Austad ended at Samkom. The river did not shift to a new bed.

Sydtveit (1983) describes a similar event which she believes occurred in early September at the Lohne farms in Drangedal. She mentioned that the bridge at Bergan was taken which could indicate at the flood is the same as described in Grova (1984) in August.

She mentions that the river shifted to a new bed upstreams the bridge at Svarthøl and over the fields at Flåte farm. A polar front depression further to the west moved in 5 September. A cold front passed eastward forcing the warm air from southeast away. The event she describes could be caused by the cold front passage if she is mistaken about the time the bridge at Bergan was taken.

3.2.9 The flood at Sør-Vestlandet October 1916.

A large flood occurred in October 1916 from Kvina in Vest-Agder to Åkrafjorden at Sunnhordaland. The flood had the highest return period at stations in River Kvina and Sira, and less at stations further west and northwest.

Initial conditions:

October and November were mild at Sør-Vestlandet, and hardly any snow had accumulated in the mountains. Further east snow started to acumulate from 7 October and in Nord-Norway already from 1 October, but the accumulated amounts were not large anywhere. The main cause of the flood was long term rainfall.

The flood:

Mild air masses from the Atlantic streamed towards Great Britain, Denmark the Netherlands, Germany, southern Sweden and Sørlandet in Norway. The transsport was caused by a ridge from the Azores island over the Iberian penninsula and smaller polar front lows at Iceland and towards northwest into the Norwegian Sea. Several small fronts moved towards Norway at the northern margin of this stream causing repeatedly rain at southwest Norway. The weather types 13-15 October were **WA**, **WA** and **WZ** (Grosswetterlagen) and **AN**, **CW** and **NW** (Lamb/Jenkinsson).

Figure 3.2.9.1 show observed precipitation and daily discharge is shown for stations from Kvina to Sunnhordaland. The highest daily rainfall was observed 13 October at Samnanger in Hordaland of 109 mm, the highest discharge was observed at Fjellhaugvatn in Sunnhordaland (1026 l/s km^2).

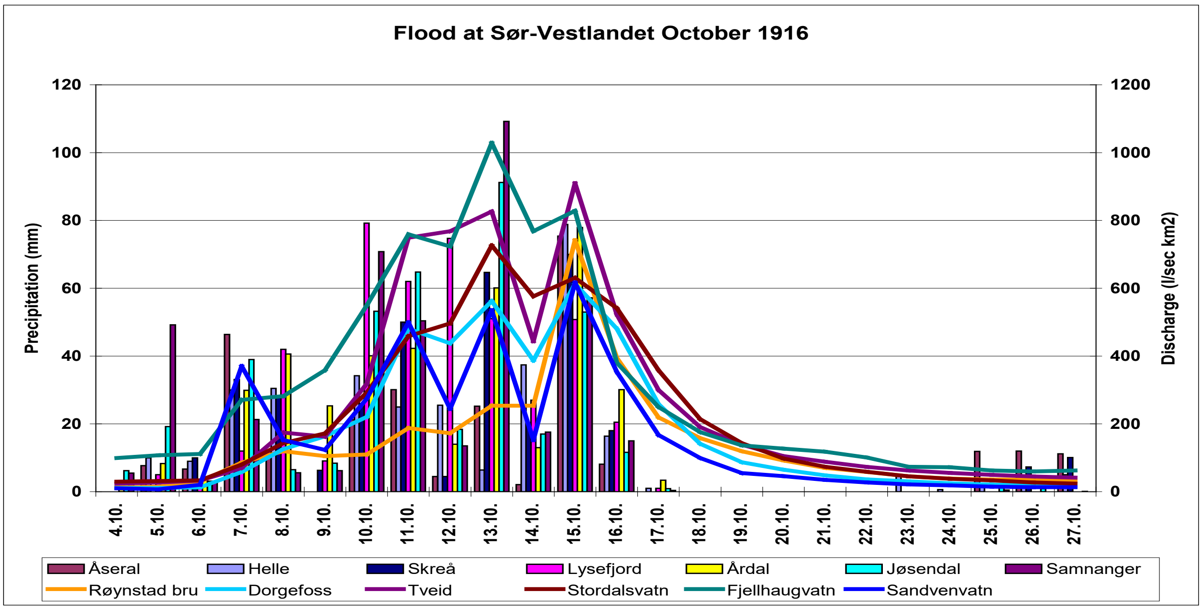


Figure 3.2.9.1 Observed precipitation and daily discharge at southwest Norway in October 1916

3.2.10 Winter flood at Rogaland to Sunnfjord January 1923.

Rainfall caused two floods in coastal rivers from Jæren to Sunnfjord in late January 1923. The first occurred 25-27 January and the second smaller 1-3 February.

Initial conditions:

January and February 1923 were mild at Sørvestlandet as shown in Figure 3.2.10.1. There were very little snow in the water courses at Jæren in January and no snow in February. A storm in the Oslofjord caused a steamship to founder at Filtvedt with seven fatalities 20 January. An avalanche damaged a farm at Meringsdal at Nesset im Møre and Romsdal 25 January.

The flood:

Between an anti-cyclone west of and later over Great Britain and a low in the Norwegian Sea mild and humid air masses were streaming from west-southwest over Vestlandet. The first flood was caused by rainfall from 24 to 27 January. The second flood was caused by rainfall 31 January to 3 February. The weather type were **NWA** (Grosswetterlagen) and **AW** (Lamb/Jenkinsson) for the first flood and **WS** (Grosswetterlagen) and **W** (Lamb/Jenkinsson) for the second. In Figure 2 observed daily presentation and discharge are shown for both floods.

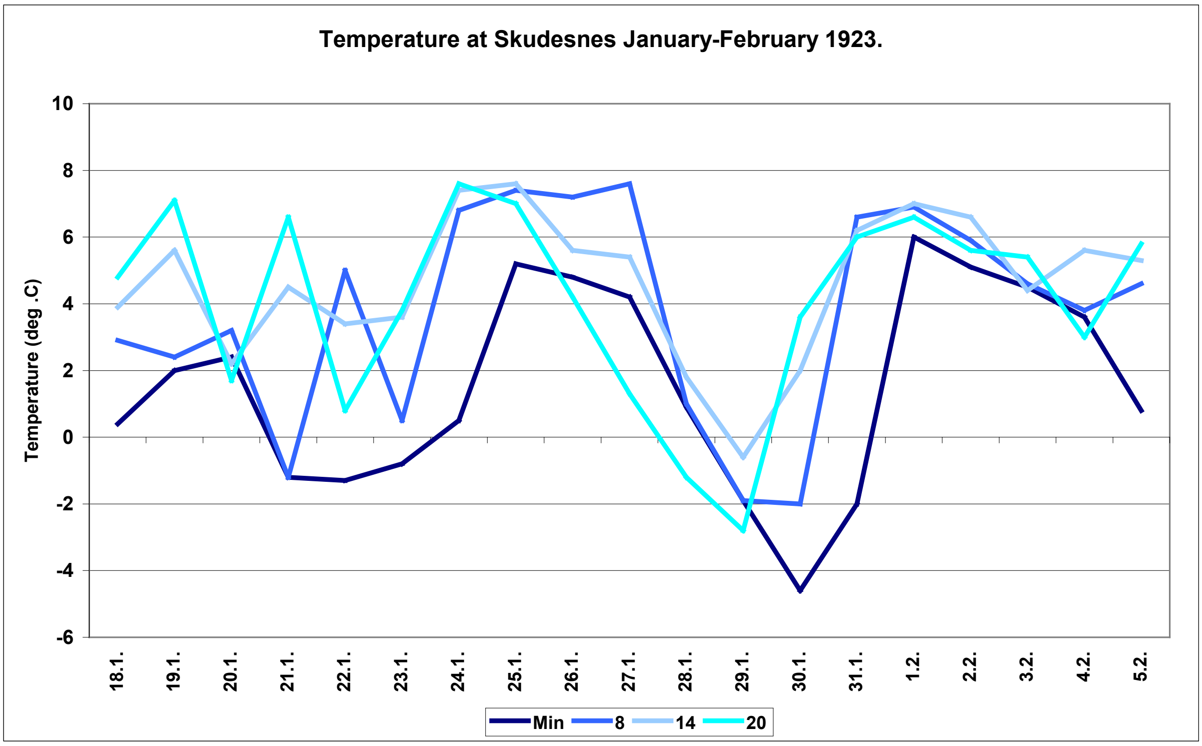


Figure 3.2.10.1 Observed temperatures at Skudenes in Rogaland in late January and early February 1923.

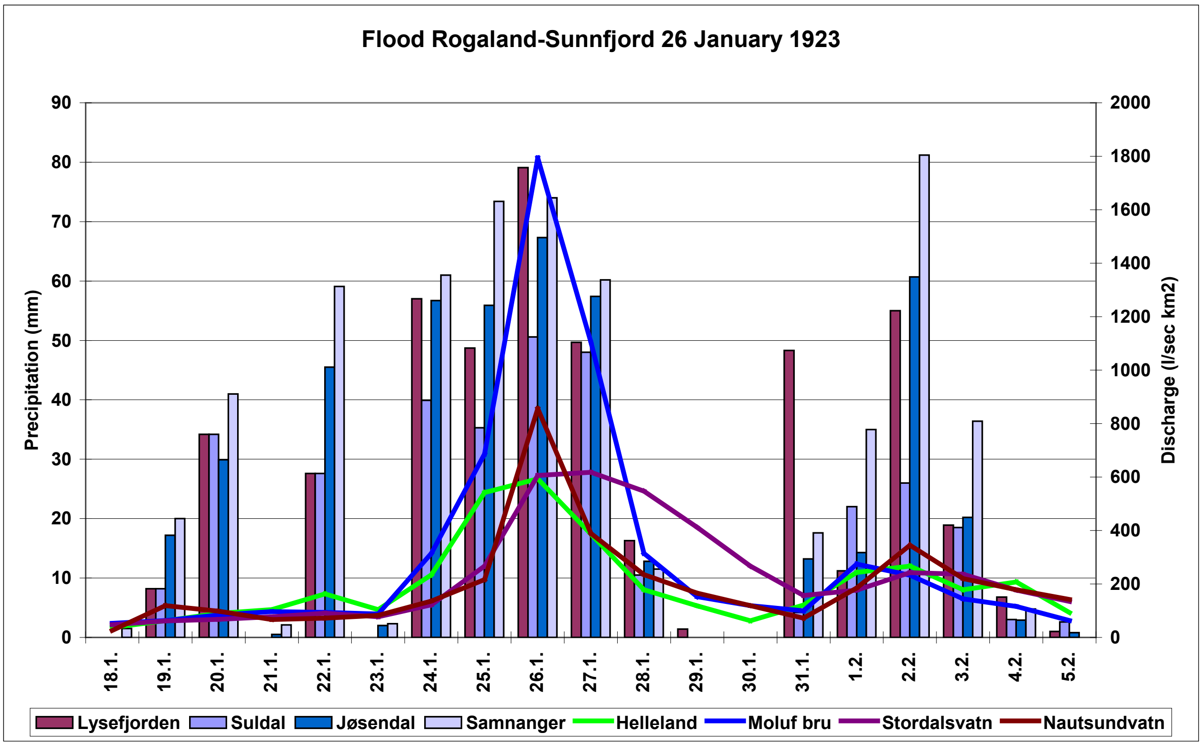


Figure 3.2.10.2 Observed precipitation and daily discharge from Rogaland to Sunnfjord January-February 1923.

The flood was the seventh largest in 112 år in River Bjerkreimselv and in River Sira at Lindeland bru the fifth largest 1913-1971.

3.2.11 The rainfall flood from Ryfylke to Sunnfjord 12 September 1923.

Heavy rainfall caused floods in Rogaland, Hardanger and ytre Sunnfjord 12 September 1923.

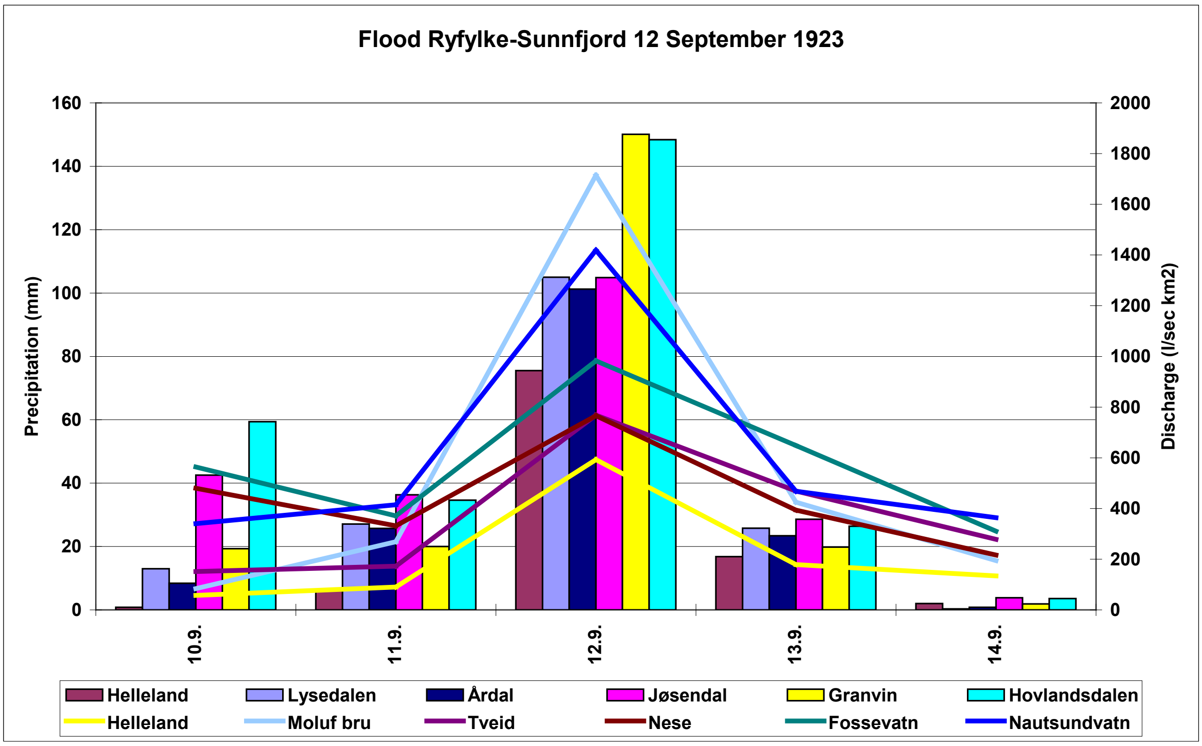


Figure 3.2.11.1 Observed precipitation and discharge (daily values) during the flood in September 1923.

The flood does not rank among the largest at active stastions in 1923 in spite of heavy rainfall up to 150 mm in one day. The flood was probably largest at Granvin in Hardanger, where no discharge station exists.

Cause of the flood:

An intense low east of Island moved towards northeastwards to Norway 12. September. The front moved across the coastal region of Vest-Agder, Rogaland, Hordaland and Sunnfjord. Weather type: **BM/WZ** (Grosswetterlagen) and **W/NW** (Lamb/Jenkinsson)

3.2.12 Flood from Vest-Agder to Ryfylke 12 November 1923.

After a dry period, intense rainfall 11.November 1923 caused large floods in rivers from Kvina to Årdalselv in Ryfylke the next day. Figure 3.2.12.1 show observed daily precipitation and discharge.

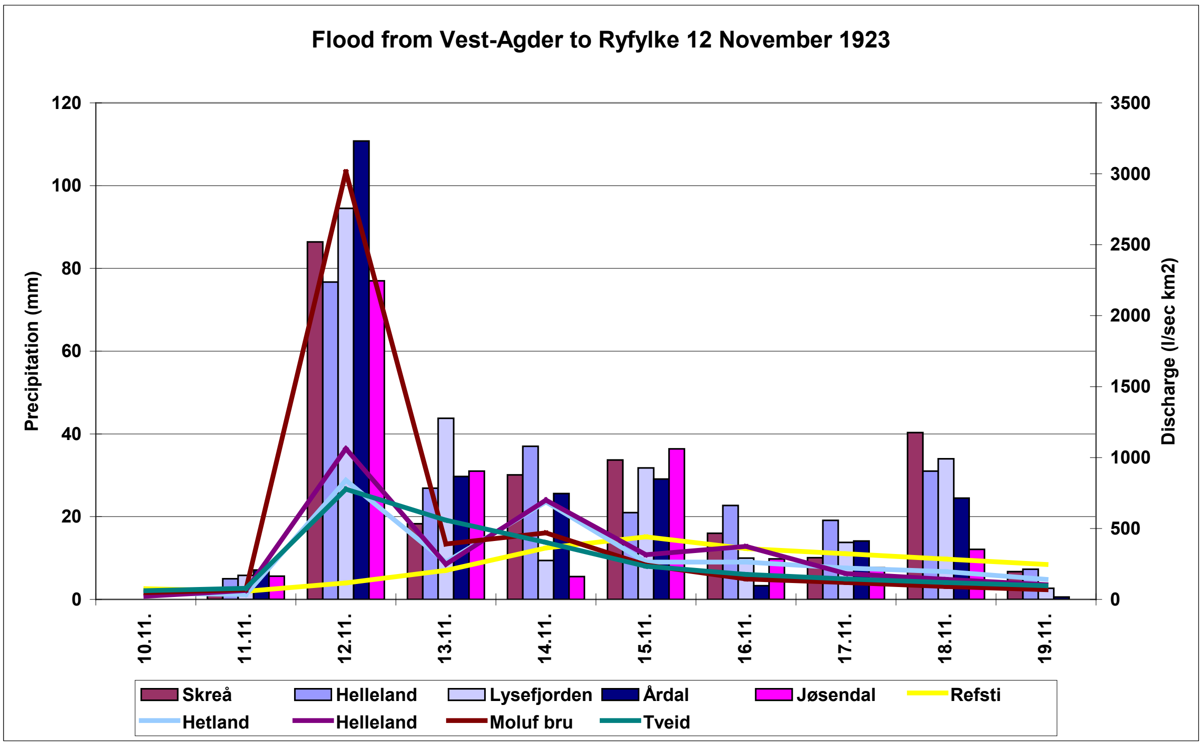


Figure 3.2.12.1 Observed precipitation and daily discharge during the flood in Vest-Agder and Rogaland in November 1923.

The flood was the third largest in River Hellelandselva 1996-2013, the largest in River Frafjordelv at Moluf bru 1914-1950, the largest naturalised flood in River Jørpelandselv 1914-2004 and the eight largest floods in River Årdalselv at Tveid 1896-1957.

Cause of the flood:

A depression near Iceland moved eastwards towards Lofoten 12 November. An anti-cyclone was located at the Atlantic from Portugal to the Azores. A front moved in from southwest over Sørlandet and Vestlandet causing to the flood 12 November. The weather types were: **BM** (Grosswetterlagen) and **A/W** (Lamb/Jenkinsson).

3.2.13 Flood in Rogaland 2-3 October 1927.

Heavy rainfall caused a flood in rivers at Vest-Agder and Rogaland 1927. The flood is not among the most extreme in the district. The event is included as an example of floods linked to atmospheric rivers.

Initial conditions:

Several precipitation areas moved towards southwest Norway from the southwest Atlantic Ocean from mid-September. The groundwater reservoir filled up, and new rainfall would easily cause larger floods.

Figure 3.2.13.1 show the trajectories of tropical cyclones in the North Atlantic in the autumn 1927. This year is not among the years with high frequence of tropical cyclones, but four cyclones moved towards Europe. The fourth hurricane of this year appeared near the Cape Verde islands. The maximum wind velocity was 105 knots. The cyclone moved towards the west coast of Ireland, forming a kernel of warm and humid air above the occluded front on the surface.

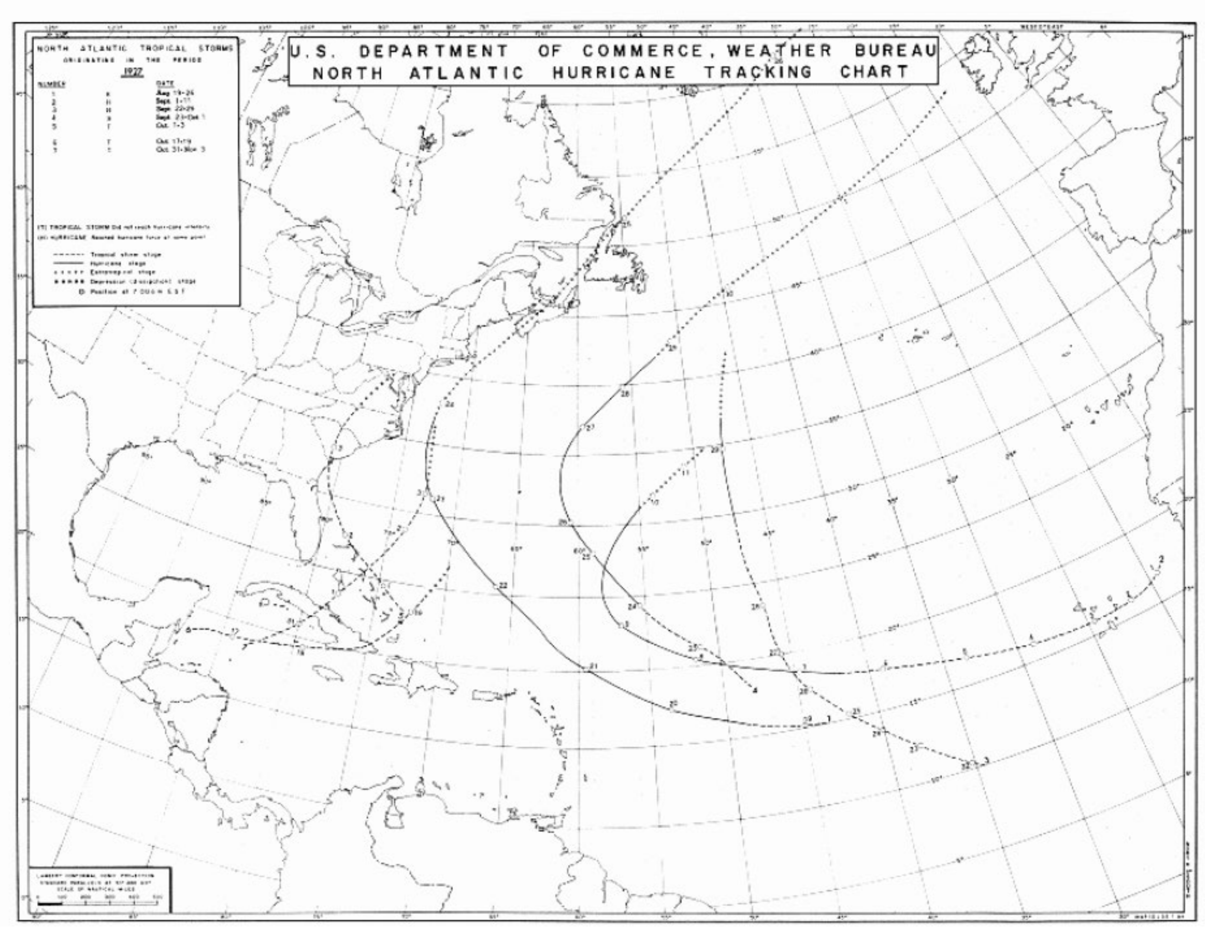


Figure 3.2.13.1 The trajectories of tropical cyclones in the north Atlantic in 1927 (Source: National Hurricane Center)

The flood:

The extratropical depression moved across the North Sea along the coast from southwest Norway, producing rainfall in coastal rivers. Observed rainfall and daily discharge at stations in Vest-Agder and Rogaland is shown in Figure 3.2.13.2. The maximum rainfall 68 mm observed in the morning 2 October fell at Hjelmeland at Ryfylke. The weather type 2 - 3 October were **BM** and **HB** (Grosswetterlagen) and **C** and **A** (Lamb Jenkinson).

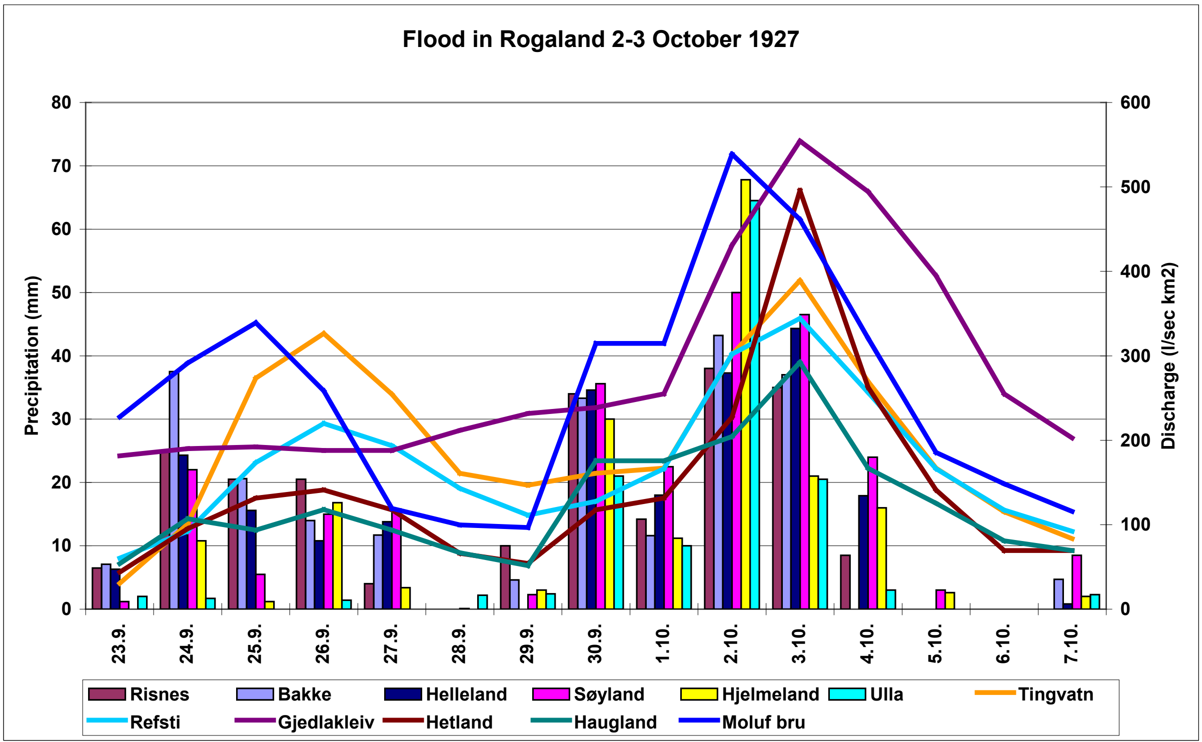


Figure 3.2.13.2 Observed precipitation and daily discharge at stations in Vest-Agder and Rogaland in September-October 1927.

3.2.14 The large autumn flood in Vest-Agder and Rogaland in October 1929.

The flood 25 October 1929 was the largest or second largest observed flood since 1896 from River Mandalselv in the east to the River Bjerkreim in the west. The cause of the flood was long term regnvær lasting until 23 October. Torrential rainfall 24 and 25 October resulted in 51 and 76 mm at Risnes at Fjotland, 45,7 and 111,4 mm at Espeland at Lygna and 55 and 82.9 mm at Bakke. The monthly rainfall was 611 mm at Espeland, 484 mm at Risnes and 534 mm at Bakke. The region with high precipitation extended from Valle at Setesdalen to Oppstryn at Nordfjord, mostly in coastal rivers. No snowmelt contributed to the flood.

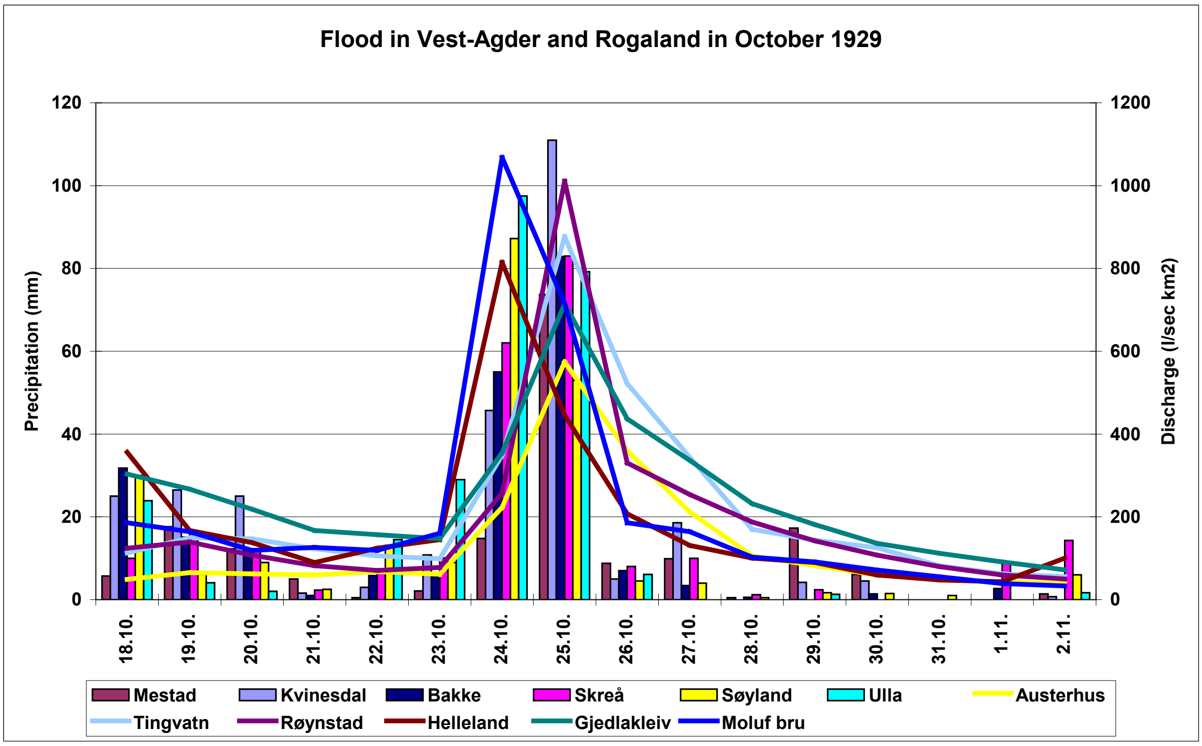


Figure 3.2.14.1 Observed rainfall and daily discharge during a large rainfall flood from Vest-Agder to Rogaland 24-25 October 1929.

Figure3.2.14.1 show observed rainfall at six precipitation and daily discharge at six discharge stations. The resulting flood was the largest observed flood in River Mandalselv since 1896, the second largest in River Lygna since 1922, the second largest in River Kvina since 1898, the second to the fourth largest at stations in River Sira and the second largest flood observed in River Bjerkreimelv since 1897. Several rivers at Vestlandet were also flooding, but none of the floods there ranks among the largest observed at these stations.

A low in the Norwegian Sea caused mild and humid air to stream from southwest towards southwest-Norway. Heavy rainfall fell in the coastal catchments from Vest-Agder to Nordfjord. The highest observed one-day rainfall was 128 mm at Bergsdal and 120 mm at Samnanger at Hordaland. The two- day rainfall at Ryfylke was 177 mm. Weather type 24-25 October were **WS** (Grosswetterlagen) and **C**/**CW** (Lamb/Jenkinsson).

3.2.15 The large flood in Vest-Agder and Rogaland in November 1931.

This flood is ranked at the second or third largest flood in a region extending from Otra to Jæren. The flood was caused by intense precipitation as rain in coastal rivers from Otra to Nordhordaland. A moderate amount of snow was initially present at high altitudes 1 November, but it melted fast as the temperature rose. The contribution of meltwater to the flood was quite insignificant. Figure 3.2.15.1 show observed precipitation at six precipitation and six discharge stations.

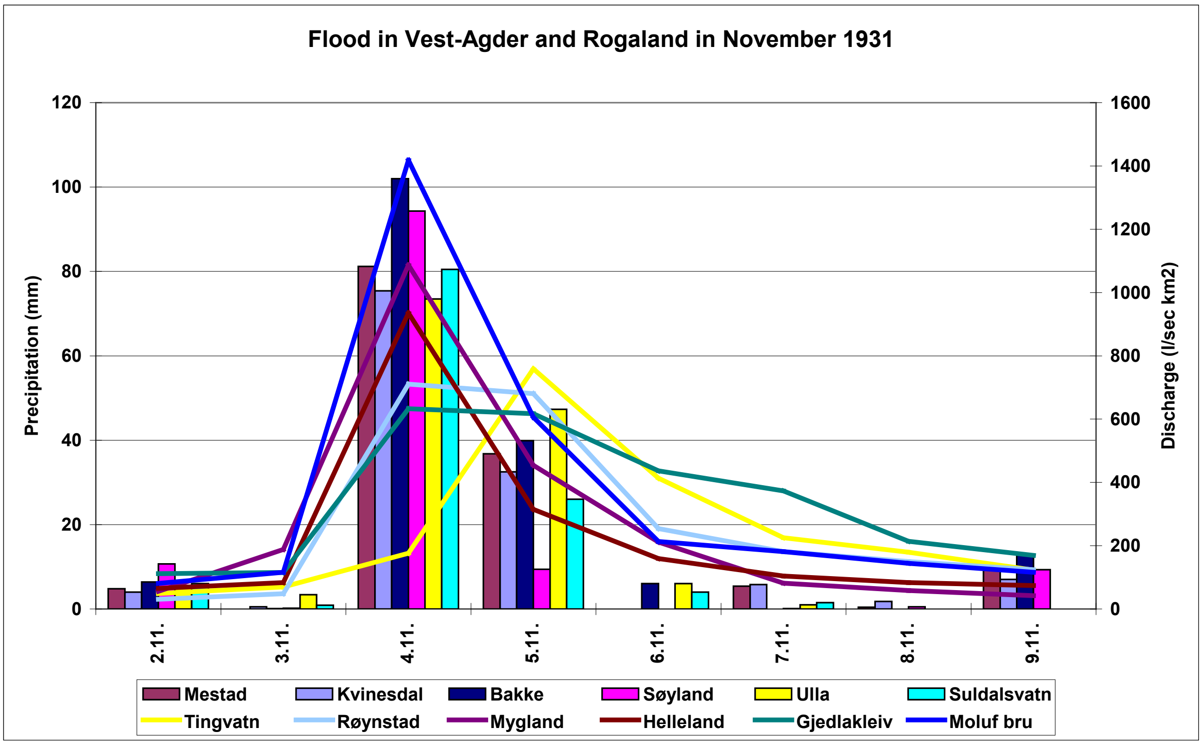


Figure 3.2.15.1 Observed rainfall and daily discharge from Kvina to Suldal during a flood 4 November 1931.

The flood was the second largest since 1896 in River Mandalselv at 22.4 Kjølemo, the third largest since 1922 at 24.9 Tingvatn in River Lygna, the seventh largest since 1898 at 25.7 Refsti in River Fedaelv, the sixth largest since 1920 at 26.4 Fidjelandsvatn in River Sira, the second largest since 1897 in River Bjerkreimselv and the seventh largest since 1903 in River Suldalslågen. There were also floods in Rivers in Sunnhordaland.

Cause of the flood:

The flood was caused by a low from the Atlantic moving towards northeast from south of Iceland and into the Norwegian Sea. This set up a strong and mild air stream from south-southwest towards
southern Norway. This resulted in a two-day rainfall of 90 to 142 mm in coastal catchments from Mestad to Eksingedal. Largest one day rainfall was observed at Bakke (102 mm) 4 November. Weather type: **SWA** (Grosswetterlagen) and **CW** (Lamb/Jenkinsson).

3.2.16 A large rainfall flood at Sørlandet, Telemark and Oslo 18-21 June 1933.

Widespread rainfall 18-21 June 1933 caused a flood in Rivers Manndalselv and Otra. The floods in Tovdalselv, Nidelv, in Telemark and in the Oslo district were moderate. Figure 3.2.16.1 show observed daily rainfall and discharge at gauging stations in River Mandalselv and Otra.

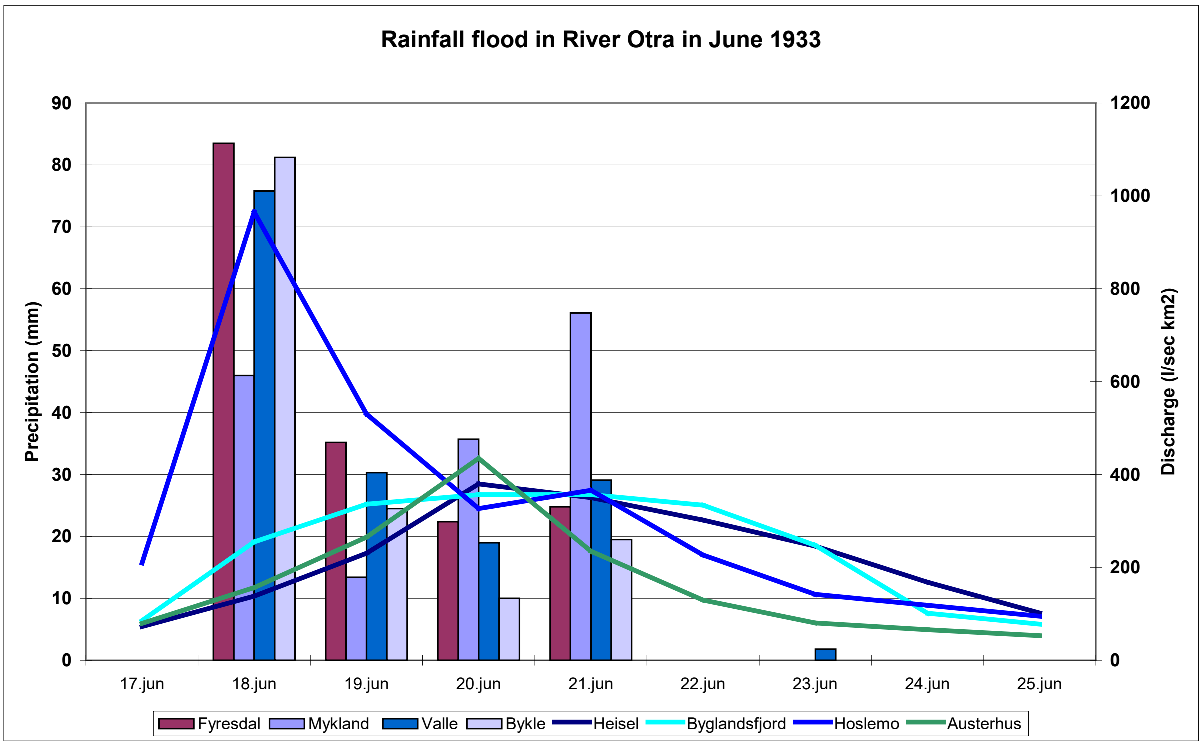


Figure 3.2.16.1 Observed rainfall and discharge during the flood in River Mandalselv and Otra in June 1933.

The flood was the largest observed flood at 21.11 Heisel 1930-2014, at 21.24 Byglandsvatn 1913-2014 and at 21.21 Hoslemo further upstreams 1919-1981. The flood was the 11th largest observed in River Nidelv at 19.127 Rygene 1900-1914 and the largest at 19.39 Bøylefoss 1915-1944.

Cause of the flood:

June 1933 was was warm in Southeast Norway. The snow disappeared by 20 April at the meteorological stations. Snowmelt did therefore not contribute to the flood. A depression moved in from the north Atlantic towards the North Sea with the core located over Britain 17 June. The depression was located between anticyclones north of the Azores in the Atlantic and another extending from Spitsbergen to northern Russia. The distribution of the low and the anticyclones were similar to the Vb-pattern, but the rainfall did not origin in the Mediterranian. The weather types were: **NWZ** (Grosswetterlagen) and **C** (Lamb-Jenkinson)

3.2.17 Rainfall floods at Sørvestlandet in September 1936.

Rainfall 5 -8 September 1936 caused minor floods in coastal rivers from Vestfold to Vest-Agder as shown in Figure 3.2.17.1. Another rainstorm caused another moderate flood at Sør-Vestlandet 25 September as shown in Figure 3.2.17.2.

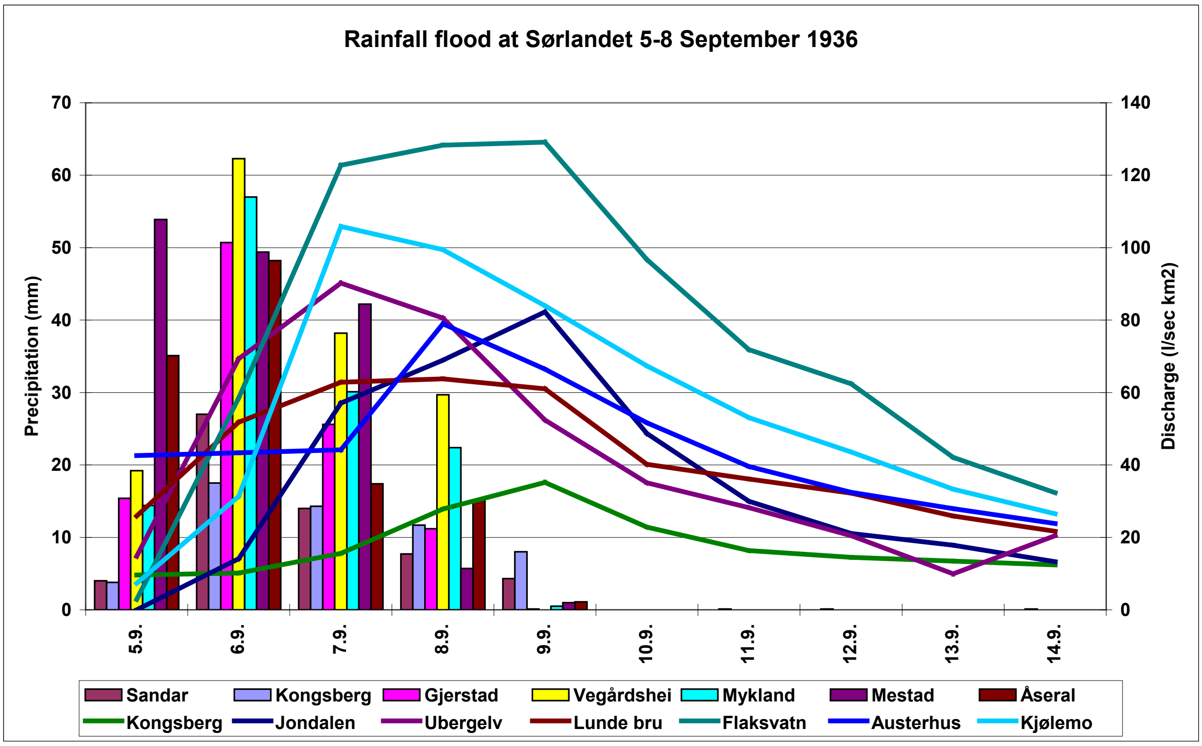


Figure 3.2.17.1 Observed precipitation and daily discharge at Sørlandet in early September 1936.

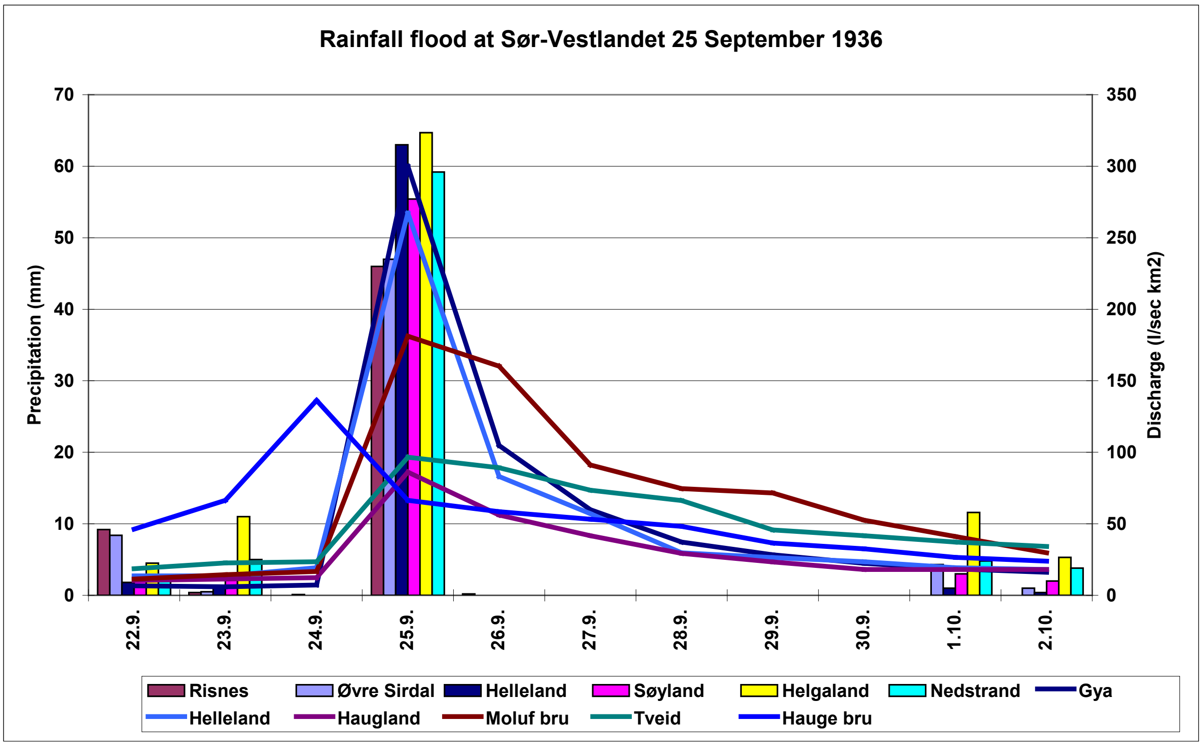


Figure 3.2.17.2 Observed rainfall and daily discharge at Vest-Agder and Jæren during the rainfall flood 25 September 1936

The activity of the hurricane season in the North-Atlantic was high in summer and autum 1936 and some hurricanes took a trajectory towards northwest Europe as shown in Figure x. The hurricane 1936-11 became extratropical 6 September southwest of Ireland and moved in over Britain and Sørlandet 6-8 September causing the rainfall which caused the flood.

One reason for the low flood discharges was that the second half of August had been dry, resulting in a low groundwater reservoir. The rainfall was higher, both in late August ane especially in the three first days of September, which may have contributed to initiationg the large mountain slide at Loen 13 September. Weather type **WZ** (Grosswetterlangen) and **C** (Lamb-Jenkinsson).

The next hurricane, 1936-12, followed at more westerly trajectory before turning towards northeast and becoming extratropical. This rainstorm reached Rogaland 25 September causing up to 64 mm rainfall which caused larger floods than the previous hurricane remnants. Weather type **U** (Grosswetterlagen) and **NE** (Lamb-Jenkinsson).

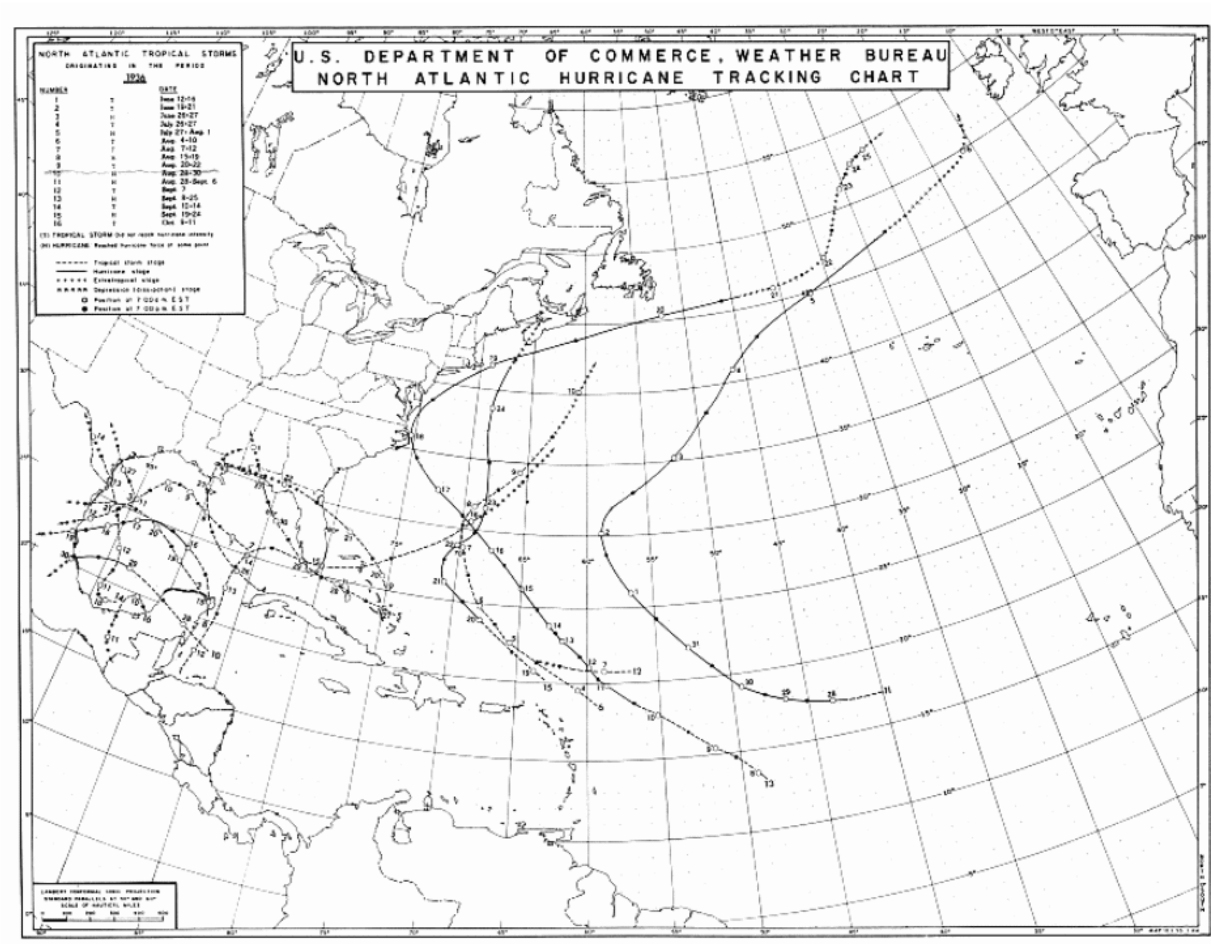


Figure 3.2.17.3. Tropical hurricanes in the North Atlantic summer and autumn 1936. (Source: National Hurricane Center)

3.2.18 Winter flood in coastal rivers at Vest-Agder and Rogaland in December 1936.

Intense rainfall caused a flood in coastal rivers in Rogaland and Hordaland 14-15 December 1936. Less intensive rainfall caused new floods 20-23 December as shown in Figure 3.2.18.1.

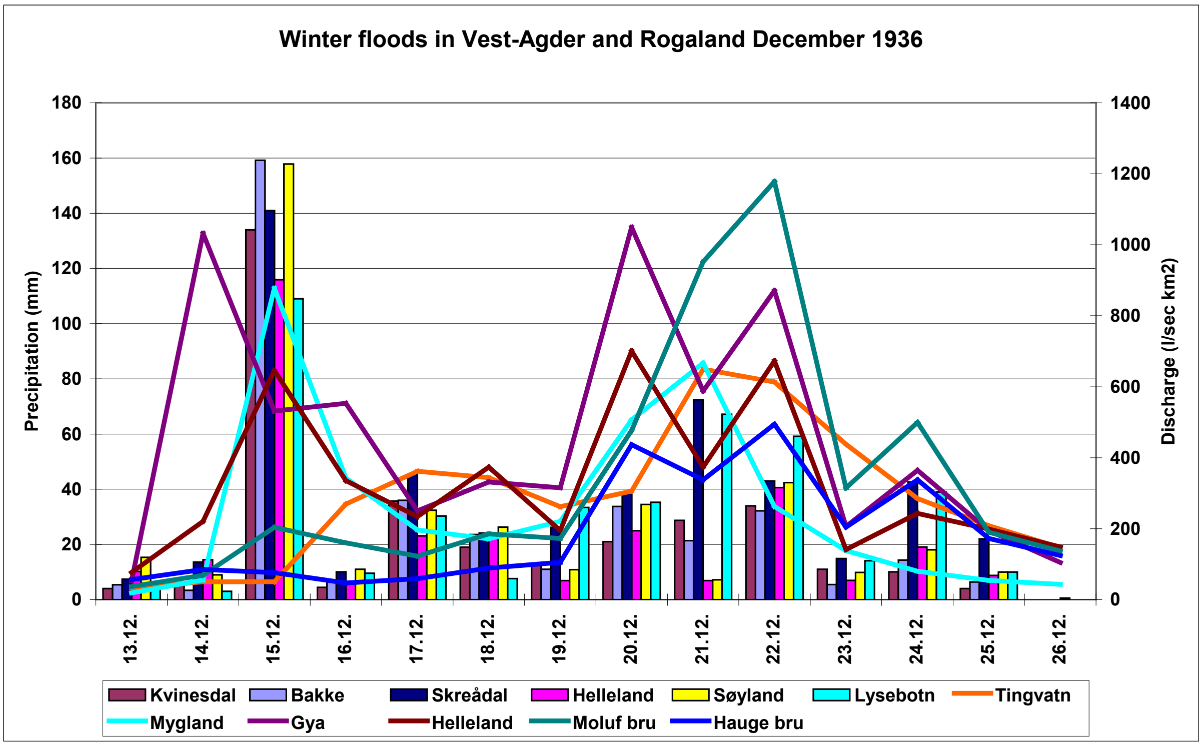


Figure 3.2.18.1 Observed precipitation and daily discharge in Vest-Agder and Rogaland in December 1936.

Although the precipitation intensities were extremely high as observed in the morning 15 December the resulting floods does not rank among the largest in the rivers which went into flood. The flood was the sixth largest in 112 years at Refsti in River Kvina, at River Håelv at Haugland the seventh in 90 years and at River Lygna at Tingvatn the eight largest in 85 years. The flood observed 20-23 December ranks only as the largest in 1936, but larger annual floods have been observed several times in other years.

Mild and humid air masses moved in from southwest 13-22 December south of the polar front which caused the long-term rainfall. The intense rainfall 15 December moved in from south over Sør-Vestlandet. 173 mm rainfall was observed at Ørsdalen at Bjerkreim 15 December. More than 150 mm was observed at three stations from Kvinesdal to Bergsdalen in Hordaland and more than 100 mm at 16 stations. The weather types were **SWA** (Grosswetterlagen) and **SW** (Lamb- Jenkinsson) 15 December and **HM** (Grosswetterlagen) and **SW/W** (Lamb-Jenkinsson) 20-22 December.

Snowmelt may have contributed a little to the flood, but the contribution was probaly more significant in Hardanger.

3.2.19 An exceptional rainstorm at Mykland in Aust-Agder in August 1939.

An extreme rainstorm occurred at Mykland at River Tovdalselv 28 August 1939. The rainfall caused floods in smaller streams in the district and caused local landslides. Discharge observation are not available in the smaller rivers where the flood was most severe. Figure 3.2.19.1 show observed daily rainfall and discharge. The discharge was observed at station in larger rivers in the district where the flood magnitudes probably was smaller.

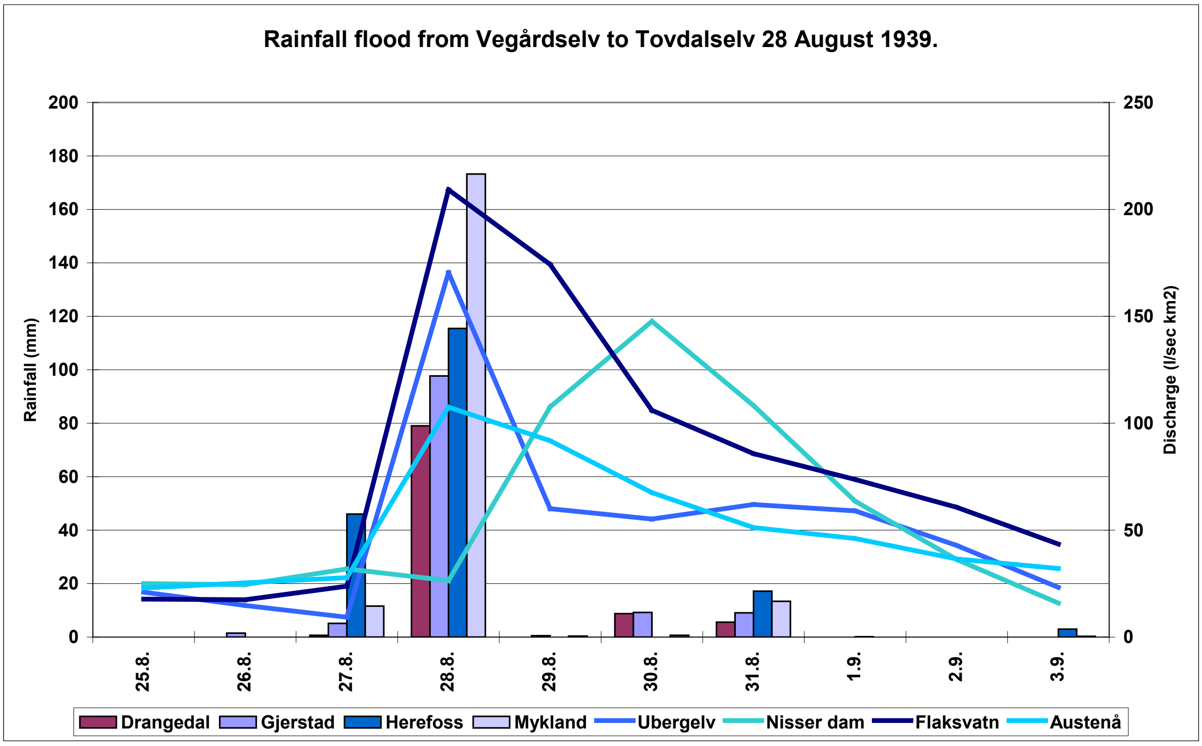


Figure 3.2.19.1 Observed rainfall and daily discharge during an exceptional rainstorm at Mykland in Aust-Agder 28 August 1939.

An anti-cyclone with a varm kernel was located across northern Russia with extrension to the west towards Scandinavia 27-28 August 1939. South of the ridge weak depressions in the varm air caused locally violent thunderstorms in Telemark and Aust-Agder. The weather types were: **HFA** (Grosswetterlagen) and **SE/A** (Lamb/Jenkinsson).

The rainfall observed at Mykland is among the largest oneday rainfall observed at Sørlandet and in western Telemark. The district is vulnerable to local floods caused by extreme summer or early autumn rainstorms, such as 14 October 1799 in River Hisâ, 12-20 September 1737 from River Otra to River Drangedalselv, 28 July 1855 at Fyrisdal, 17-18 July at Nisserdal and Fyrisdal, 17-18 September 1864 from River Otra to Tokeelv, 13-14 August 1896 in River Gjerstadelv and Vegårdselv and 8 August 1912 at Drangedal.

Flood damages:

The flood caused extensive damages at the local roads. Some roads were so damaged that several weeks was requred to repair the damages. Two bridges were taken at the road to Lauvrak. The damages to the roads in Aust-Agder was assessed to more than 50.000 NOK. at At Mykland the damages amounted to at least 20.000 NOK. Farmland had been washed away and barns were taken. Three dams were torn down by the flood, and timber was lost (Lauvrak, 1991).

3.2.20 Flood in Vest-Agder and Rogaland in October 1943.

Long duration rainfall from the second part of September to 7 October caused a rainflood in the rivers of western Vest-Agder and Rogaland 6 September. The rainfall was also heavy in West-Norway to Hølonda at Sør-Trøndelag. Most rainfall fell at Samnanger with 70 and 63 mm rain and at Hovlandsdal at Sunnfjord with 73,6 and 70,5 mm respective on the 6 and 7 October. Higher rainfall had already been observed 20 September when 118,6 mm at Samnanger and 112,3 mm was observed. Observed rainfall and daily discharge in Vest-Agder and Rogaland is shown in Figure 3.2.20.1.

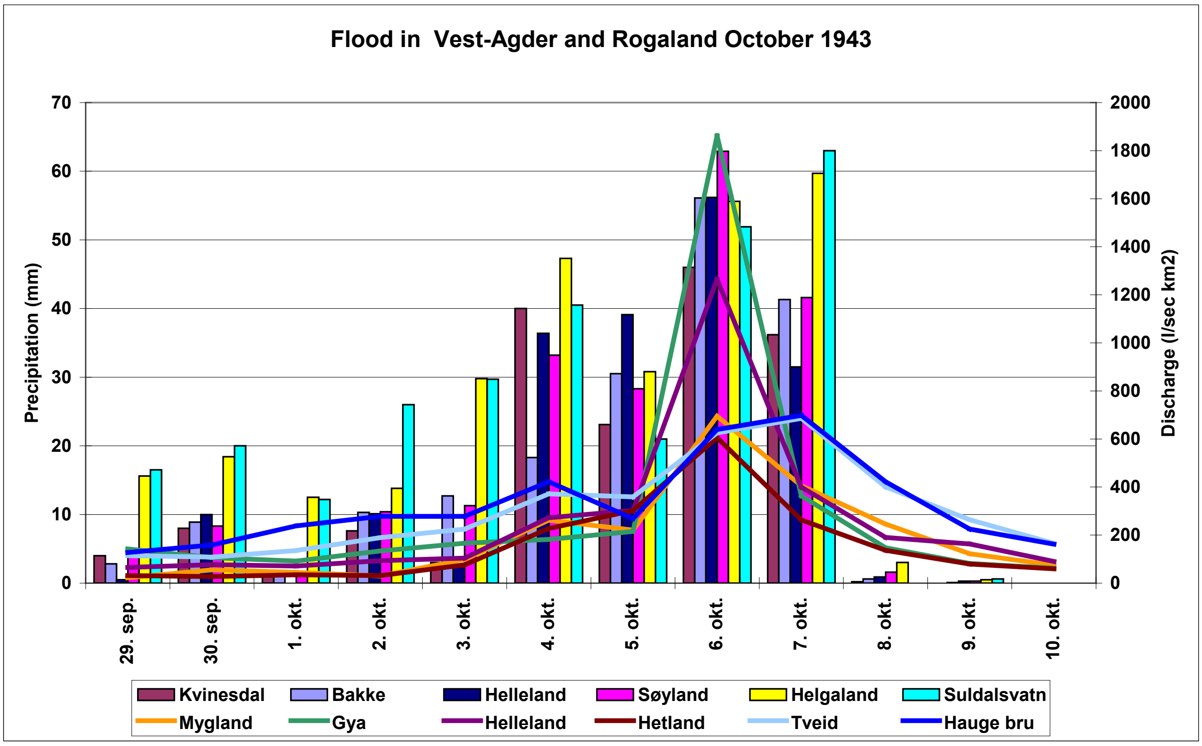


Figure 3.2.20.1 Observed rainfall and daily discharge in Vest-Agder and Rogaland in October 1943.

A low was situated west of Vestlandet, and mild and humid airmasses moved in from southwest at Sørlandet and Vestlandet. The weather type was **WA** (Grosswetterlagen) and **W** (Lamb-Jenkinsson). The flood was caused by long duration rainfall, gradually increasing thrrough the week before the flood. No snow was present in the upper part of the basins. The rainfall intensities were not particulary high compared to other floods in the region. The groundwater reservoir was filled up at the start of the flood causing the relative high discharges in some of the rivers.

3.2.21 A rainfall flood at Jæren 13. September 1957.

A large flood occurred at Jæren 13 September 1957 after a week of moderate rainfall. Figure 3.2.21.1 show daily rainfall and discharge during the flood.

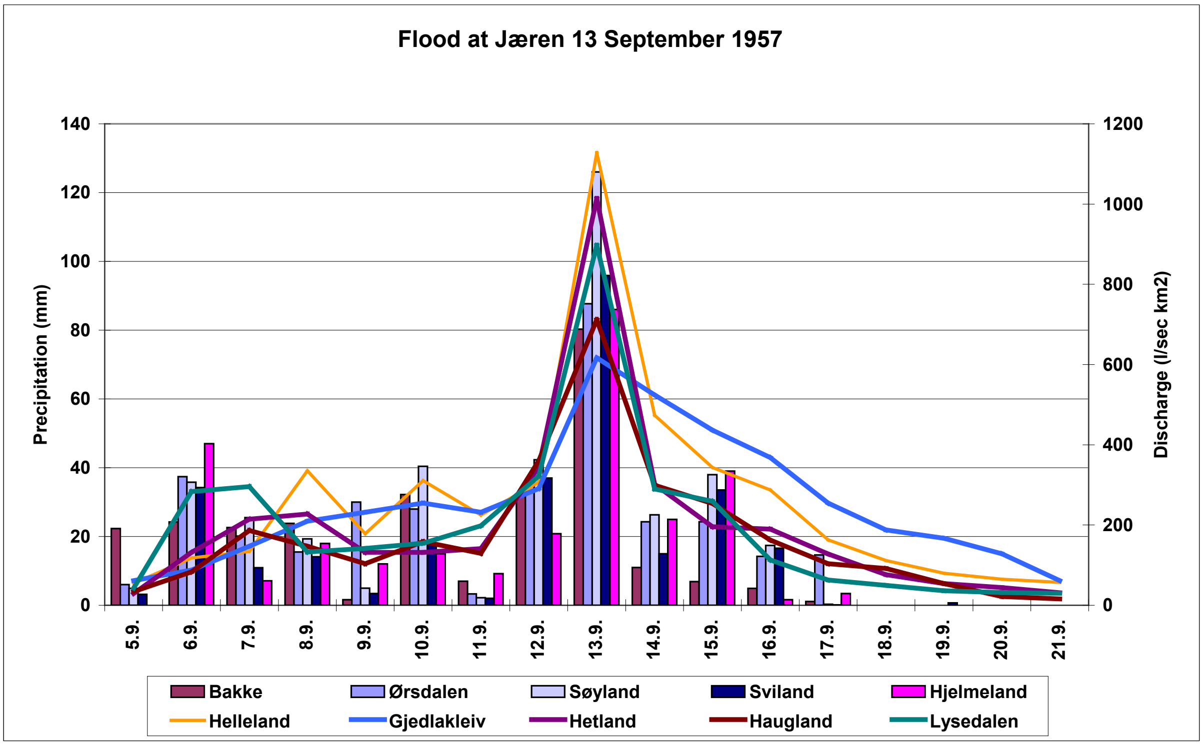


Figure 3.2.21.1 Observed rainfall and daily discharge during a rainstorm at Jæren 13 September 1957.

The flood was second largest in River Hellelandselv (1896- 2008), seventh largest in River Bjerkreimselv in 112 years, third largest in River Ogna at Hetland 1915- 2001 and second largest in River Håelv at Haugland 1918-2008.

A strong low over Sørlandet 12 September moved westwards and was located over Rogaland next day. The weather types were: **TRM** (Grosswetterlagen) and **NW** (Lamb/Jenkinsson).

3.2.22 Floods at Sørlandet in August and November 1959.

Two rainfall floods occurred at Sørlandet in August and November 1959. The first occurred 15-16 August and the second 15-16 November. The first flood took place in rivers from Tovdalselv to Sira. The second flood occurred mostly in coastal rivers both in Aust-Agder and Vest-Agder.

The flood in August:

Warm air masses came streaming from southeast towards Sørlandet caused by a strong low northwest of Great Britain and an anticyclone over Finland. The weather type on 15-16 August were **WW/NEA** (Grosswetterlagen) and **SW/A** (Lamb/Jenkinsson).
Observer rainfall and daily discharge is shown in Figure 3.2.22.1. The highest one-day rainfall was 120,9 mm observed at Mykland. The highest one day discharge was observed at River Mandalselv at Forgård bru on 15 August (445 l/s km^2) and at Austenå (372 l/s km^2). The floods does not rank among the larger floods at Sørlandet in spite of a high daily rainfall.

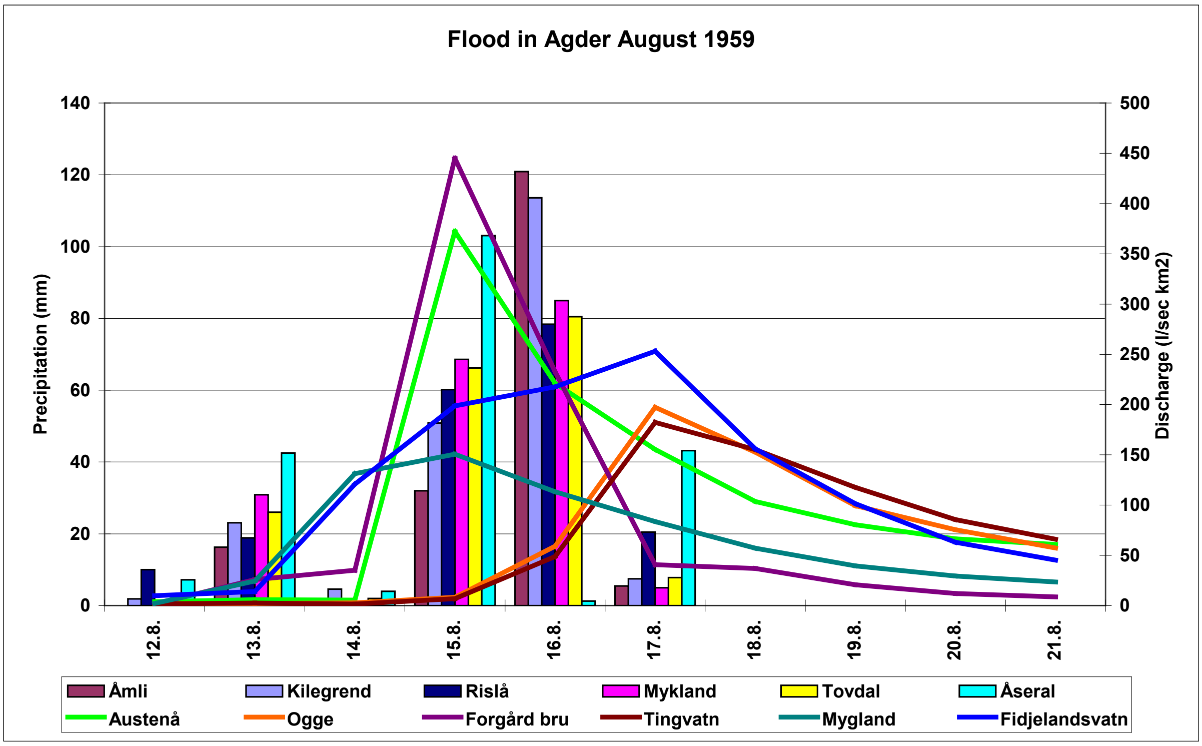


Figure 3.2.22.1 Observed rainfall and daily discharge in Agder in August 1959.

The flood in November:

Mild air masses came streaming from southeast from Central-Europe caused by a strong low over Great Britain and an anticyclone over the Kola penisula. The polar front was located over Sørlandet with cooler air masses to southwest causing the heavy rainfall at the coast. The weather type were **HM** (Grosswetterlagen) and **AS/S** (Lamb-Jenkinsson).

Observed rainfall and daily discharge is shown in Figure 3.2.22.2. The highest one-day rainfall of 109 mm occurred at Tovdal 15 Nov. The highest discharge was observed at River Kvina at Mygland 762 l/s km^2).

The flood ranks as the highest at River Ubergelv 1924-1971, as fourth at Nideelva at Lunde Mølle 1900-2004, as the second largest at River Tovdalselv at Flaksvatn since 1899 and as the largest at Ogge 1950-1993.

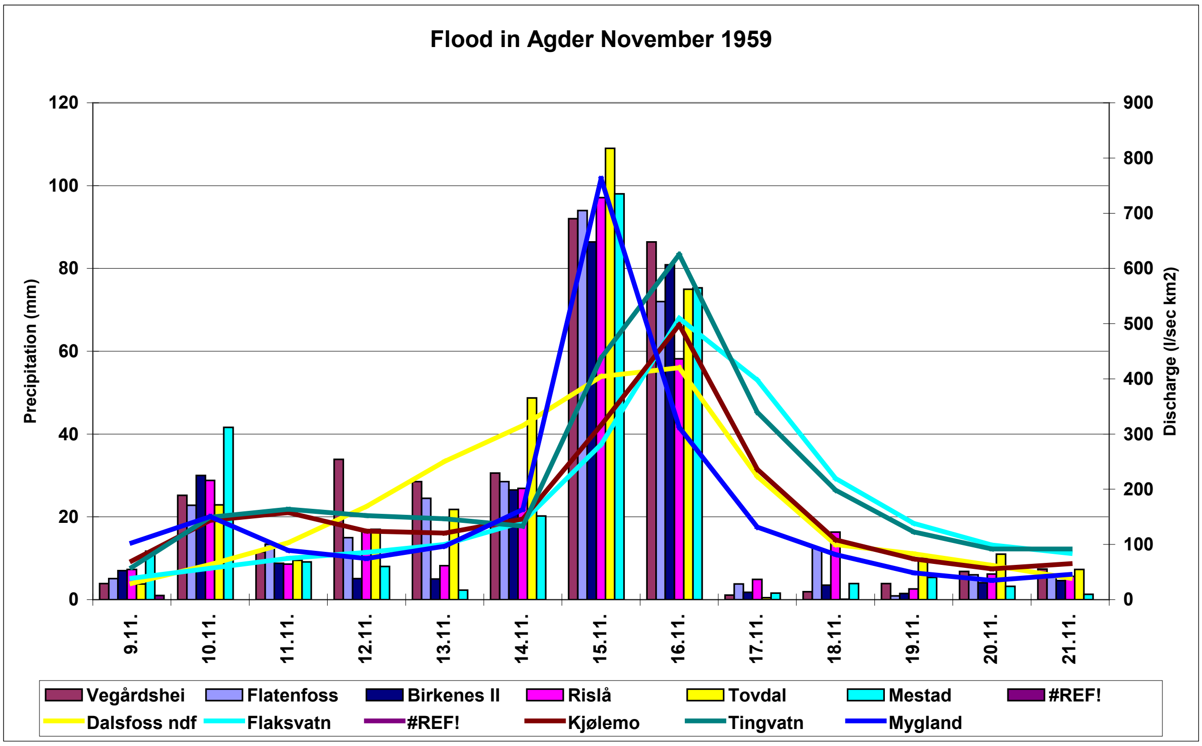


Figure 3.2.22.2 Observed rainfall and daily discharge at Agder during the flood in November 1959.

3.2.23 Flood from Buskerud to Sørlandet 13-15 October 1976.

Heavy rainfall caused a flood in smaller rivers in the southwest part of Østlandet and at Sørlandet. The flood was large in coastal basins, but less at higher altitudes whwere the rainfall gradually turned into wet snow.

The flood:

Warm air masses from southeast moved towards the coast of Sørlandet following a Vb-type trajectory. Cooler airmasses to southwest caused the rainfall to turn into wet snow in the hills. The weather type was **WS/WW** (Grosswetterlagen) and **W/C** (Lamb-Jenkinsson).

The observed precipitation and daily discharge is shown in Figure 3.2.23.1. The highest one-day rainfall 131,6 mm was observed at Rislå 13 October. The distribution of precipitation is shown in Figures 3.2.23.2.

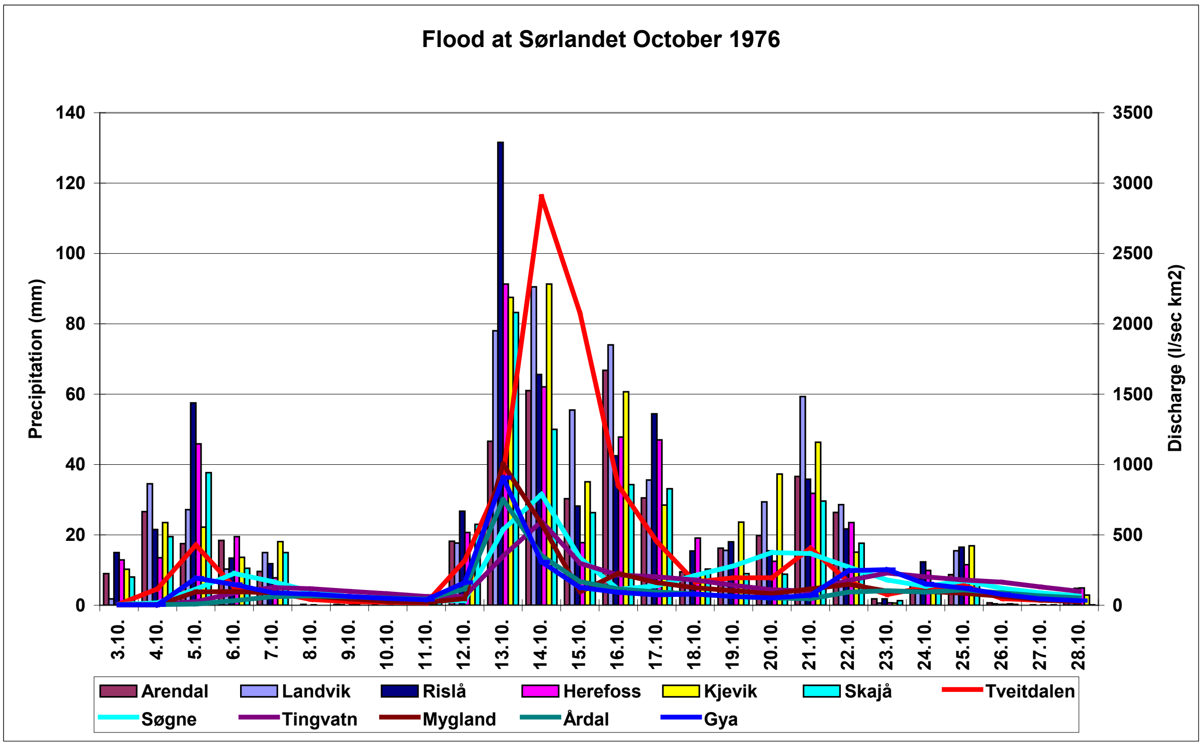


Figure 3.2.23.1 The observed precipitation and daily discharge during the flood in coastal rivers at Sørlandet in 1976.

The research catchment Tveitdalen in Tovdalselv had the largest daily discharge since the start of the observations in 1972 (2903 l /s km^2). The peak value of the tiny catchment was 3372 km^2). The daily flood ranks as the fourth largest at Ogge 1922-1993, but only as the 23 largest at Flaksvatn. The flood was the largest at Søgneelv since the start of the observations in 1973. The flood was the sixth and the eight largest at Årdal and Sandvatn in the Sira basin.

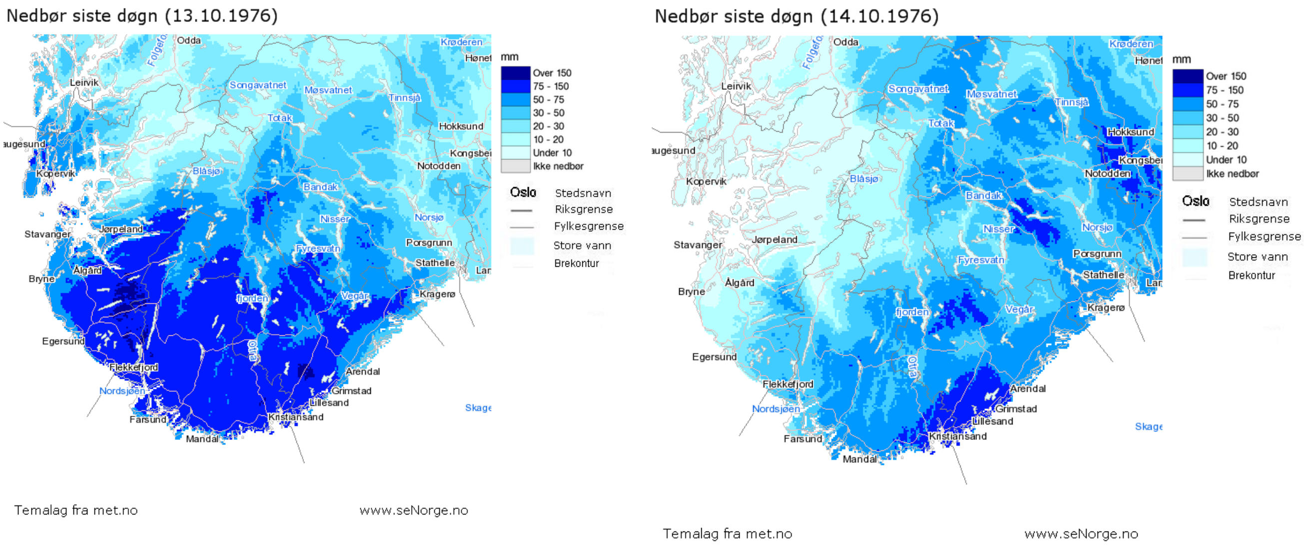


Figure 3.2.23.2 The distribution of precipitation 13 and 14 October 1976.

3.2.24 Flood at Sørlandet 1986 caused by remnants of *Hurricane Charlie*.

A flood in coastal rivers in Austagder was caused by a rainstorm 27-29 August 1986. In the morning 28 August 115 mm rain was observed at the met.station Landvik. Figure 3.2.24.1 show observed daily rainfall and discharge at the gauging stations Gjerstad and Tjellingtjernbekk in River Gjerstadelv, Tveitdalen in River Tovdalselv and Søgne in River Søgneelva. The three first catchments are squite small. The instantaneous discharge was therefore much higher at culmination. The peak discharge was 538 l/s km^2 at Gjerstad, 1160 l/s km^2 at Tjellingtjernbekk, 2202 l/s km^2 at Tveitdalen and 388 l/s km^2 at Søgne. Several other smaller streams in the Nidelva catchment were in flood.

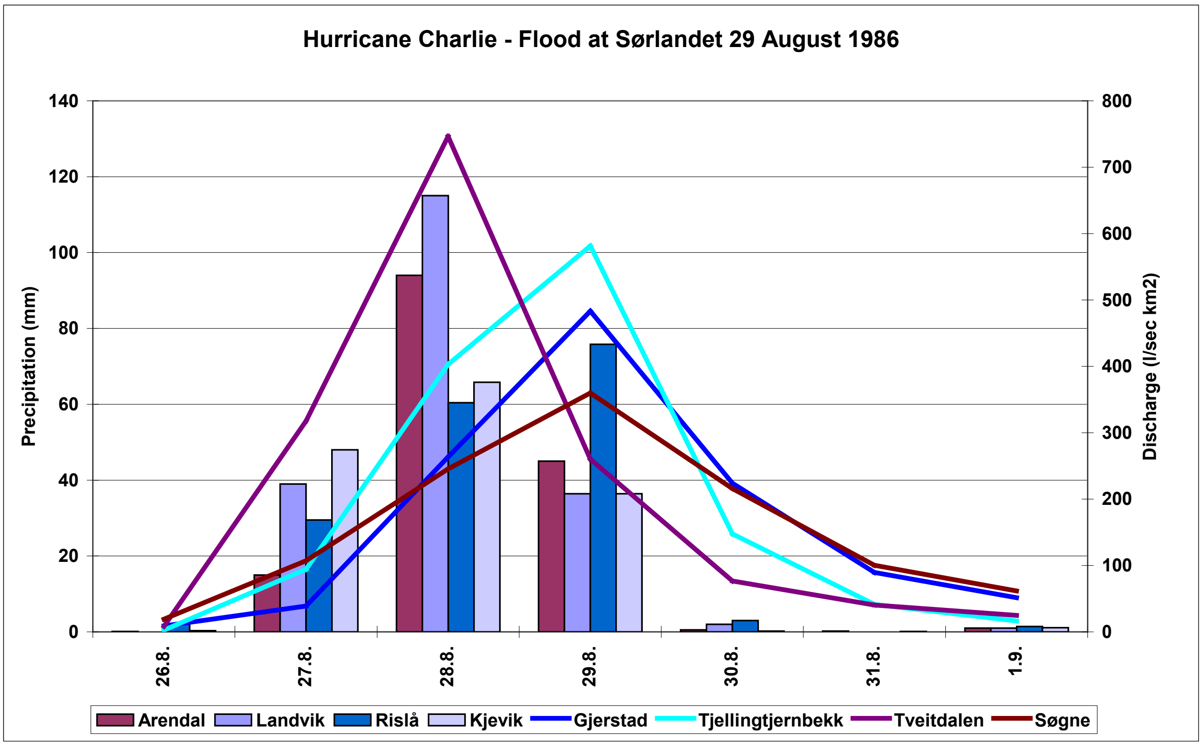


Figure 3.2.24.1 Observed precipitation and daily discharge caused by remnants of Hurricane Charlie on the coast of Aust-Agder in August 1986.

The distribution of the rainfall observed 28 August is shown in Figure 3.2.24.2. The most intense rainfall occurred in a narrow zone along the coast from Mandal to Skiensfjorden. This is typical for many floods in towns at Sørlandet. The rainfall extended also into Vestfold and two secondary rainfall maxima was present; one in western Telemark south of Lake Bandak and one in from Drammensmarka to Tyristrand in Buskerud.

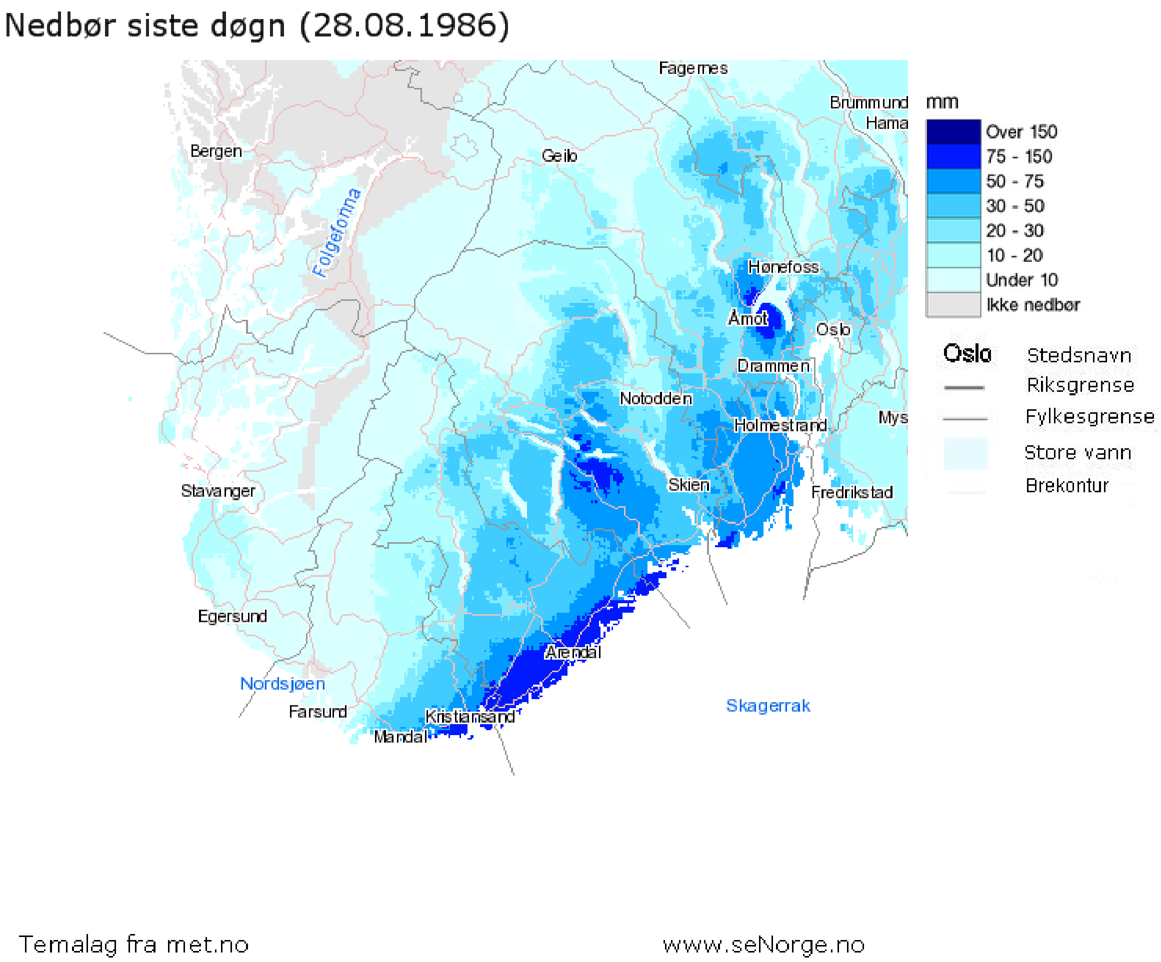


Figure 3.2.24.2 The distribution of the rainfall 28 August 1986.

A tropical depression appeared over Florida 11 August with intense thunder mowing westward into the Mexican Gulf 12 August. The depression moved northwards across western Florida and Georgia. It moved out into the Atlantic at South Carolina 15 August. The depression drifted slowly towards northeast while it increased in strength to tropical storm 15 August and to a Safir-Simpson category 1 hurricane 17-18 August named Charley. As the cyclone moved east-northeast over colder water it was downgraded to a tropical storm. Den 21 Charley joined a strong extratropical low moving towards Ireland and England causing extensive damages in Ireland. The low filled in the North Sea south of Arendal, but a new low formed southeast southeast for origical storm center and moving northeastwards. The weather type were: **TRM** (Grosswetterlagen) and **CN** (Lamb/Jenkinsson). The trajectory of Charley is shown in Figure 3.2.24.3.

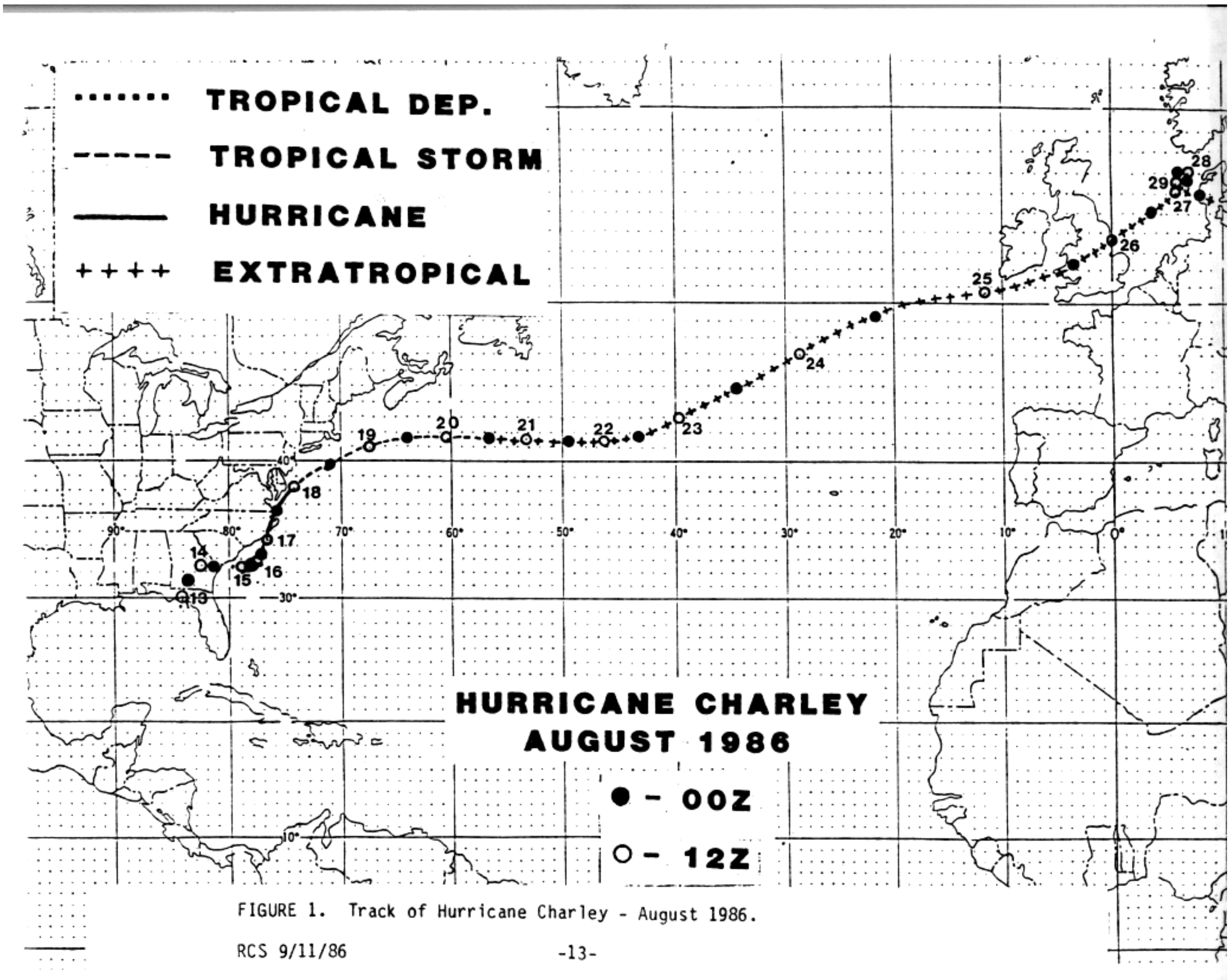


Figure 3.2.24.3 The trajectory of Hurricane Charley. (Source: National Hurricane Center).

3.2.25 The severe flood in Southeast Norway 16 October 1987.

The severe weather 16 October 1987, caused most damage further east along the Oslofjord, although most rainfall occurred at Sørlandet, where also the resulting flood had the highest return period.

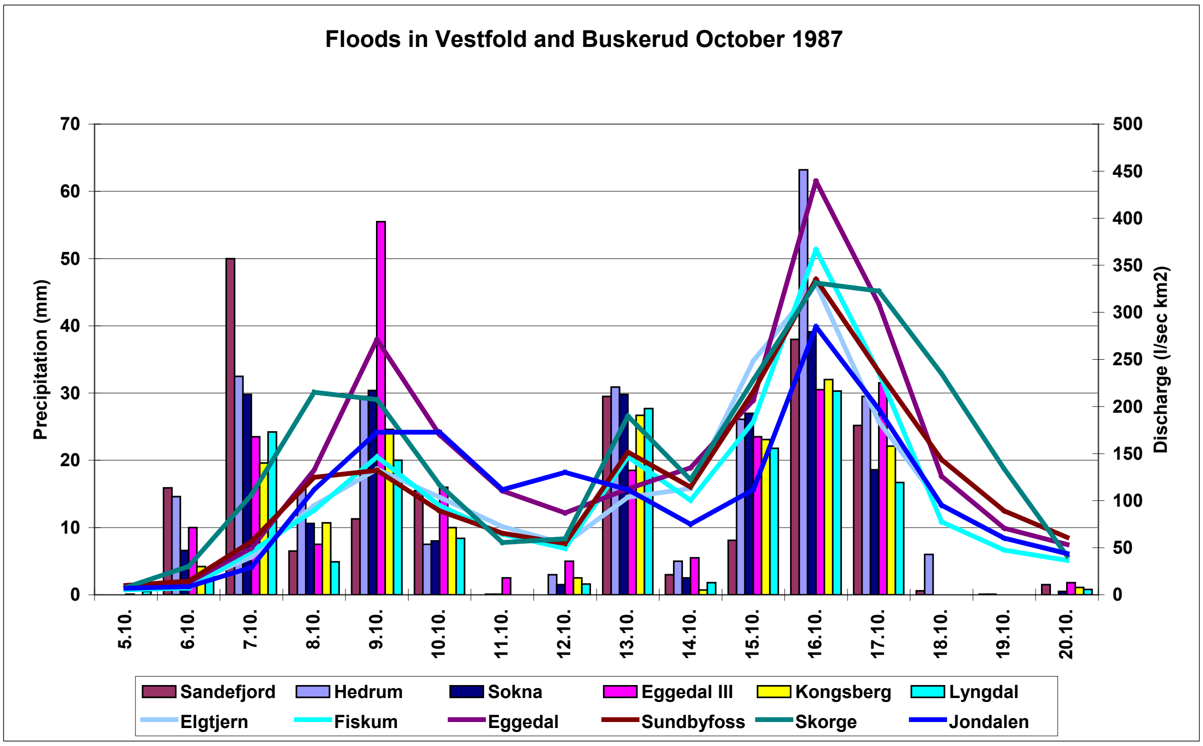


Figure 3.2.25.1 Observed precipitation and daily discharge in Agder during the rain flood in October 1987.

The flood was the largest observed in River Nidelv at Lunde Mølle 1900-2004, in River Gjøv at Lake Tovsliøytjønn 1969-2002 and in River Tovdalselv at Lake Flaksvatn 1899-2000. It was the second largest in River Tovdalselv al Austenå 1924-2000, in River Raudåna and in River Stigvasså 1972-2003. Further west the return period was lower. The flood extended into River Bjerkreimselv in Rogaland.

3.2.26 Winter flood at Jæren in January 1989.

A polarfront hurricane struck the coast from Møre and Romsdal to Nord-Trøndelag 15 January 1989. At the same time heavy rainfall caused a local flood at Jæren, largest in River Bjerkreimselv. Figure 3.2.26.1 show observed daily precipitation and discharge at Jæren.

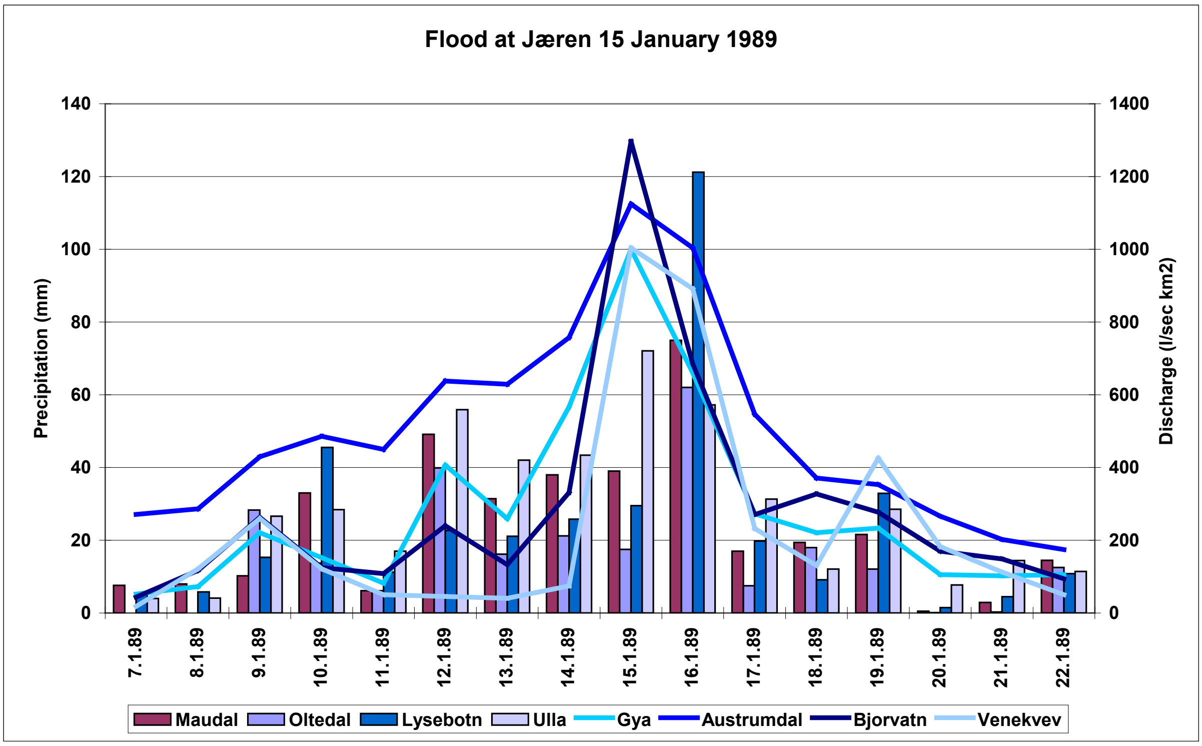


Figure 3.2.26.1 Observed precipitation and daily discharge at Jæren during the winter flood in January 1989.

3.2.27 The large flood in December 1992 in Vest-Agder and Rogaland.

A major flood occurred in Vest-Agder and Rogaland in December 1992. Coastal rivers further east had also floods. The flood in River Sandvikselv in Bærum was the fifth largest since 1968. The flood extended northward at Vestlandet to coastal rivers in Hordaland south of Bergen.

Initial conditions

Most of the district was covered by snow, with exception of the outer coast from Mandal and westwards to Låg-Jæren 23 November. Most of the snow melted in the days prior to the flood at lowlying altitudes, but the snow cover increased in the mountains. Figure 3.2.27.1 show the extention of the snow cover 23 November and 1 December. The ground water level was relatively high 23 November in a wide zone from the coast to the inland in Vest-Agder and Rogaland. There was initially a deficit in groundwater and soil moisture at the higher altitudes in the region, but the groundwater level increased significant and the soil moisture content was very high during the flood. Figure 3.2.27.2 show the groundwater conditions 23 November and 1 December. Figure 3.2.27.3 show the soil moisture conditions on the same dates.

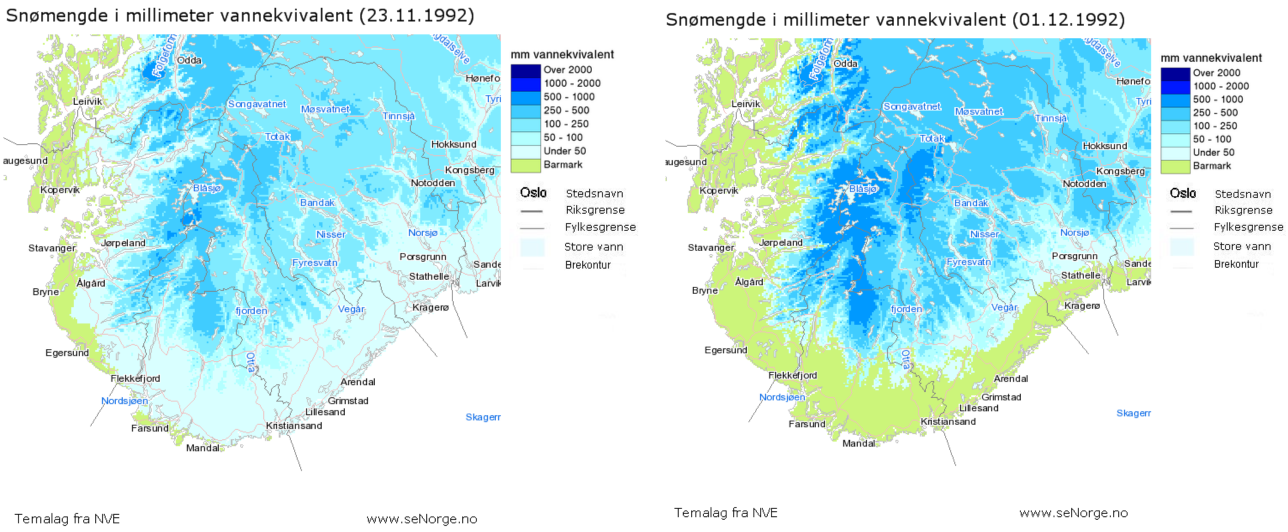


Figure 3.2.27.1 The snow cover at Sørlandet and Rogaland 23 November and 1 December.

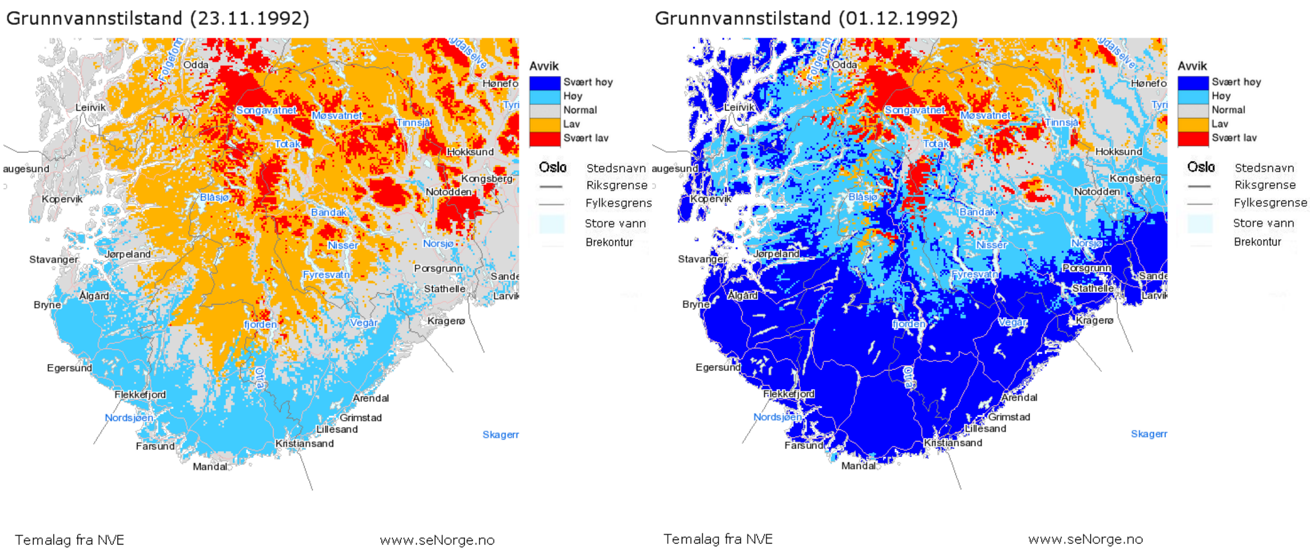


Figure 3.2.27.2 The groundwater conditions at Sørlandet and Rogaland 23 November and December.

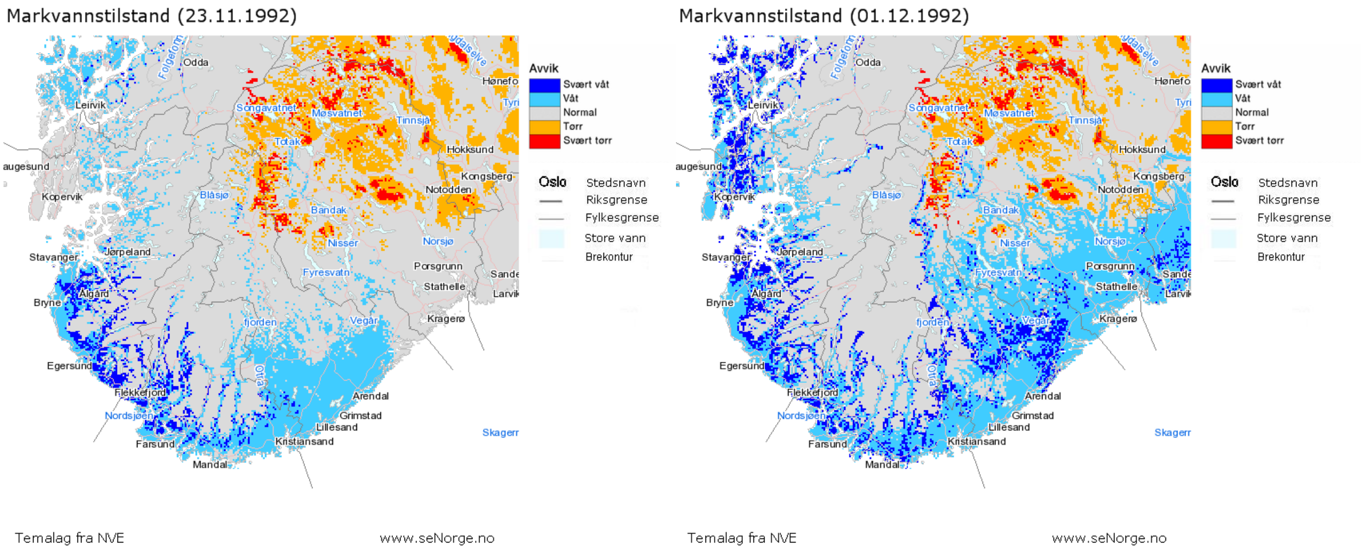


Figure 3.2.27.3 The soil moisture conditions during 23 November and 1 December,

The flood:

The weather:

A strong depression was initially situated south of Iceland 30 November - 3 December. The depression set up a mild and humid air stream from south-southwest towards Southwest Norway. The depression filled gradually as it moved in northeast direction south of Iceland. A secondary low was located outside the coast of Rogaland and Hordaland 1 December. The subsequent two days a southwesterly weather type ie **SWZ** (Grosswetterlagen) and **W/SW** (Lamb/Jenkinsson) caused heavy precipitation.

This weather type has caused several of the largest autumn and winter floods in Rogaland and Vest-Agder such as *Storflodi* in November 1898 and the severe floods in October 1929 and November 1931.

Figure 3.6.27.4 show observed precipitation and discharge at five precipitation and five gauging stations.

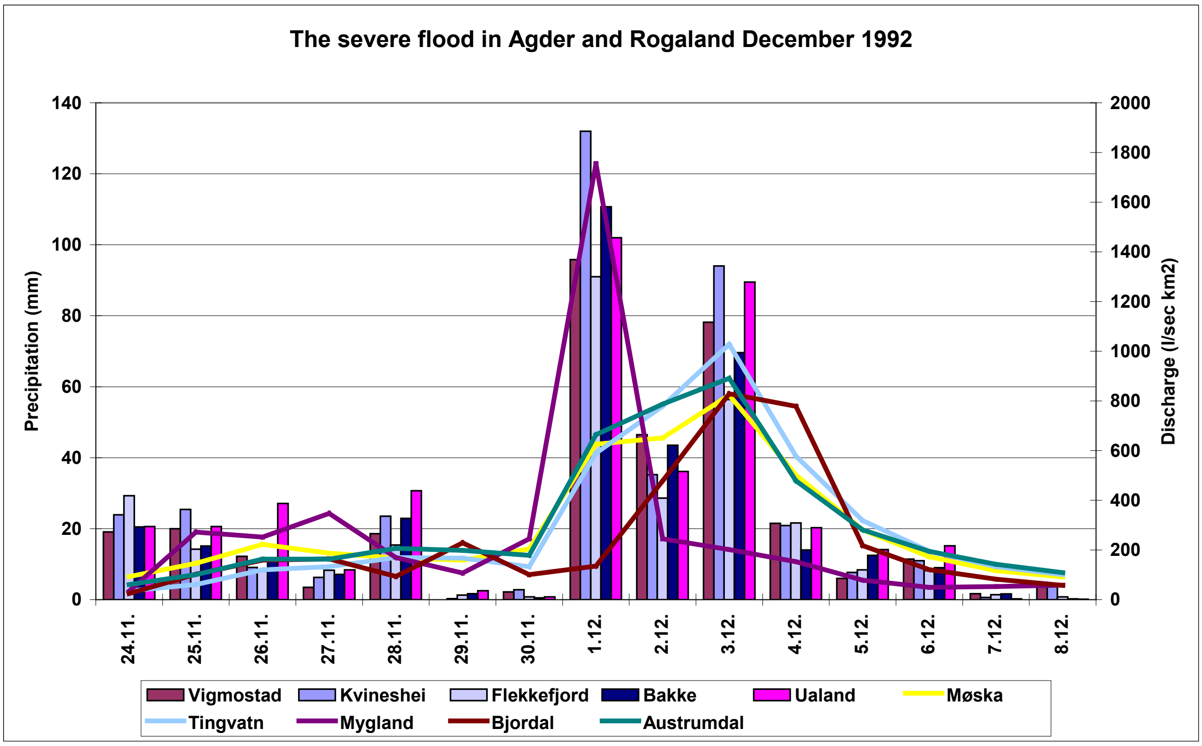


Figure 3.2.27.4 Observed daily precipitation at five precipitation and five gauging stations at Sørlandet and Rogaland.

The flood was second largest at Rettå in River Tovdalselv since 1950 and in River Mandalselv since 1978. It was the largest flood in River Lygna since 1922, in River Kvina since 1898 and in River Bjerkreimselv since 1897. In River Hellelandselv the flood was fifth largest since 1896.

3.2.28 Flood at Sørlandet caused by remnants of tropical storm Lisa 5 October 2004.

The remnant of the tropical storm Lisa crossed over the southern part of England and moved towards the coast of Sørlandet in Norway. Prior to the passage some rainfall occurred in Vestagder 3 and 4 October. The remnant of Lisa reached the coast of Norway 5 November, resulting in 40 to 122 mm rainfall. Figure 3.2.28.1 show observed rainfall and discharge caused by the remnant of tropical storm Lisa.

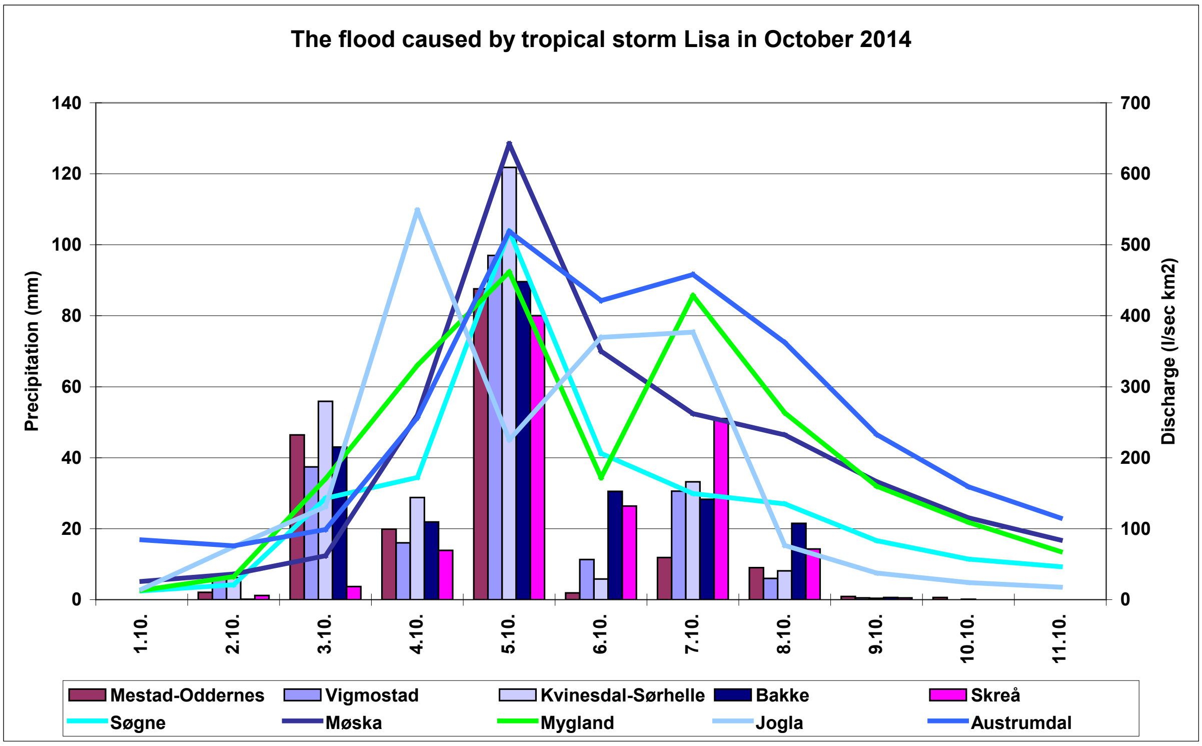


Figure 3.2.28.1 Observed daily precipitation at five precipitation and five gauging stations caused by tropical storm Lisa.

The weather type 5 October 2004 was: **SWA** (Grosswetterlagen) and **CSW** (Lamb-Jenkinsson).

Lars Andreas Roald

Floods in Norway

Appendix C

West Norway (Vestlandet)

1Table of contents

Introduction to Appendix C.

Appendix C comprises tree parts. The first part summarises the hydrological structure of West Norway. The second part describes historical floods in each river within the area and the third part describes historical floods known from historical sources and later observed floods at gauging stations in the rivers from Rogaland to Sogn og Fjordane counties in Norway. The rivers are ordered from Jæren to Nordfjord. The region described in the report includes most of the larger watercourses in West Norway where data or information about historical floods prior to the observations are available.

1. Part 1 – Overview by districts

Appendix C covers the counties Rogaland, Hordaland and Sogn and Fjordane. Rogaland comprises of two districts: Jæren and Dalane to the south and Ryfylke to the north. Several floods have occurred further east at Sørlandet (see Appendix B) as well as at Jæren and Dalane. Description of floods occurring in both districts has been included in one of thr Appendixes, but are referred to in the other Appendixes as well.

Hordaland is divided into three districs: Sunnhordaland, Hardanger and Nordhordaland and Voss. Sogn og Fjordane has been divided into three districts: Sogn, Sunnfjord and Nordfjord.

Many floods have occurred at the district Sunnmøre (see Appendix 4) as well as in Nordfjord. Description of floods occurring in both districts has been included in one of the Appendixes but are referred to in the other district as well.

Figure 1 Locations of 19 gauging stations at Vestlandet utilised in the book: "Det regne så de søyde og Tora slo - Flom i Norge" Another 43 stations within the region were utilised in the current study.

The current study is based on 138 stations in addition to the 34 stations used in the previous book in Norwegian. The Region Vestlandet comprises mostly middle sized or small watercourses with a few or one station within each river. stations in each river. Some data from the 19thCentury prior to the data available on the NVE databases have also been used.

The region Vestlandet comprises 10 districts. Table 1 list the number of stations used in the study per region.

Table 1 Overview of the number of gauging stations used in the districs in West Norway.

Catchment	Number of stations	Number shown in Figure 1	Additional shorter series
Dalane Jæren	7	2	5
Ryfylke	6	1	5
Sunnhordaland	6	1	5
Sørfjord/Hardanger	7	3	4
Bergenshalvøya	2	1	1
Vosso	2	1	1
Nordhordaland	6	1	5
Sogn	24	4	17
Sunnfjord	11	2	9
Nordfjord	11	5	6

The flood data included also many stations with shorter series in the upper part of the larger catchments, especially at Østlandet.The number of stations used at Østlandet in the study is 104 stations and at Sørlandet 30 stations. This appendix describes large floods at Vestlandet. This appendix comprises three parts. The first part gives an overview of the number of stations utilized in the study for each major water cource in the region. The location of long-term stations is shown in Figure 1. The study utilized also additional shorter series. For selected rivers are historical floods listed where past floods are known prior to direct observations of the water levels. lists the largest annual floods known from historical sources and later observed floods at shorter gauging stations in the rivers of southeastern Norway. The rivers are ordered from the border to Sweden to River Sira, the watercourse near the border to the southern part of Vestlandet. The region described in the report includes most the largest watercourses in Norway. The descriptions of Glomma, Drammenselv and Skienselv comprise a number of large subcatchments. The report is structured according to the hierarchy of these rivers, following the various subcatchments to the top of each river. The number of stations in each major water course are shown in Table 1.

The second part describes individual stations. The text includes the catchment characteristics for each station and gives in tabular form the date and rank of the ten largest floods observed at each station. Most of the longterm series has been affected by hydropower regulations. The effect of regulations is that the flood magnitudes is reduced from the start of the operation of the hydropower scheme. The rank given in the tables refer to the observed data. The floods have not been corrected to naturalized floods from the start of the regulation. This is the reason why fewer large floods occur in recent years in many flood series. The flood series are also shown as graphs for a number of longterm series. Actual discharges are not listed in the tables, but the discharge is given for the largest flood in each series in the unit m^3/sec, l/sec km^2 and mm/day. These values may change when the rating curve is updated.

The third part describes of historical floods at Vestlandet. Most large floods extend over more than one river and can also extend across the boundary between the regions described in each volume. Some old floods prior to the start of observations are given, based on other historical sources. Most of the descriptions cover floods based on observations. The description of each flood includes graphs of observed specific discharge and daily rainfall from a number of stations. The cause of the floods is given with a description of the initial conditions and the weather type causing the flood. Some information of flood damages is also given where this information is available.

2.1 Jæren and Dalane

Rogaland comprises Jæren and Dalane in the south and Ryfylke north of the Boknfjord. Ryfylke comprises low-lying rivers on the coast and rivers further inland with mountainous rivers with extensive hydropower regulations. The district is exposed to heavy rainfall from the North Sea. The largest floods occur most frequently from September to December. There are also many floods in rivers near the coast in the south in January. Among the long-term daily precipitation series, which has been digitised are 43450 Helleland, 44480 Søyland and 44800 Sviland. There are two urban research stations at Sandnes.

2.1.1 RIVER SOKNO

River Sokno is a small coastal basin flowing towards the Norwegian Sea between the larger Sira and Bjerkreim rivers. The river flows through the village Sokndal, which has recently suffered from floods several times. The discharge has beeb observed at the gauging station 26.29 Refsvatn. This station has been active 1978-2017. Catchment characteristics and the date and ranks of the ten largest floods observed at Refvatn is given in Table 2.1.1. The dominant flood season is from November to December. The date and the discharge of the largest flood at Refvatn is shown in Table 2.1.2.

Table 2.1.1 Catchment characteristics of the gauging station Refvatn and the dates and the ranks of the ten largest floods observed at the station.

Station	26.29 Refsvatn	The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	52,95	1979	4/11	3
Station altitude (m.a.s.l.)	35	1984	25/12	8
Mean altitude (m.a.s.l)	297	1992	3/12	6
Top altitude (m.a.s.l.)	545	2000	19/10	4
Lake (%)	9,3	2006	11/12	5
Bog (%)	1,08	2008	24/10	9
Forest (%)	22,7	2009	20/11	1
Mountain (%)	58,68	2010	7/10	7
Glacier (%)	0	2012	21/11	10
		2017	2/10	2

Table 2.1.2 Date and discharge of the largest flood observed in River Sokno at 26.2 Refvatn.

Station	26.29 Refsvatn
Year	2009
Date	20/11
q (m3/sec)	52,68
qsp (l/sec km2)	995
qsp (mm/day)	86

2.1.2 RIVER BJERKREIMSELV

River Bjerkreimselv is located at the district Dalane east of Jæren in Rogaland and has a catchment area of 697,5 square kilometers. The river flows into the North Sea at Egersund. The discharge has been observed at several stations. The river was regulated in 1930.

Observations started in 1896 at 27.2 Bjerkreim bru. The observations were later moved downstream to the station 27.25 Gjedlakleiv, and joint discharge series have been established at both stations.

The tributary River Gya has a gauging station 27.20 Gya, which has been operating 1933-2014. The rating curve is uncertain at high water levels.

River Hellelandselv is a tributary to River Bjerkreimselv from the east and has a catchment area of 241 square kilometres. The gauging station 27.24 Helleland has a longterm data series. The annual flood occurs most frequently in September (12 percent), October (16 percent), November (24 percent) and in December (20 percent), but also in January (10 percent). Catchment characteristics for three gauging stations in River Bjerkreimselv are shown in Table 2.1.3. The date and ranks of the ten largest floods (daily values) are given im Table 2.1.4. Table 2.2.3 gives the date and discharge of the largest daily flood at each of the three gauging stations in River Bjerkreimselv. The data series of annual floods are shown in Figure 2.1.1 for Gjedlakleiv and in Figure 2.1.2 for Helleland.

Table 2.1.3 Catchment characteristics of three gauging stations in River Bjerkreimselv.

Station	27.24 Helleland	27.20 Gya	27.25 Gjedlakleiv
	Basin characteristics		
Catchment area (km^2)	184,72	60,49	635,15
Station altitude (m.a.s.l.)	86	203	49
Mean altitude (m.a.s.l)	489	597	527
Top altitude (m.a.s.l.)	904	900	1011
Lake (%)	8,35	7,62	12,3
Bog (%)	1,12	2,66	0,87
Forest (%)	22,62	19,65	17,48
Mountain (%)	48,35	55,83	52,34
Glacier (%)	0	0	0

Table 2.1.4 The year, dates and ranks of the ten largest annual floods observed at the three gauging stations in River Bjerkreimselv.

27.24 Helleland			27.20 Gya			27.25 Gjedlakleiv		
1896-2014			1933-2014			1897-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1917	6/11	8	1943	6/10	3	1911	6/11	4
1923	12/11	3	1957	20/12	1	1923	26/1	8
1931	4/11	9	1963	11/10	1	1929	25/10	2
1932	17/1	6	1979	14/8	9	1931	4/11	4
1940	26/11	6	1992	2/1	5	1932	19/12	7
1943	6/10	1	1997	2/3	8	1935	22/9	3
1957	13/9	2	2006	11/12	7	1957	13/9	8
1968	29/10	4	2009	20/11	4	1992	3/12	1
1992	1/12	10	2010	6/10	6	2005	15/11	10
2009	20/11	5	2011	13/9	10	2009	20/1	6

Table 2.1.5 The date and discharge of the largest flood (daily values) observed at the three gauging stations in River Bjerkreimselv.

Station	27.24 Helleland	27.20 Gya	27.25 Gjedlakleiv
Year	1943	1957,1963	1992
Date	6/10	20/12,11/10	3/12
q (m^3/sec)	233,99	128,38	519,74
qsp (l/sec km^2)	1267	2122	818
qsp (mm/day)	109,4	183,4	70,7

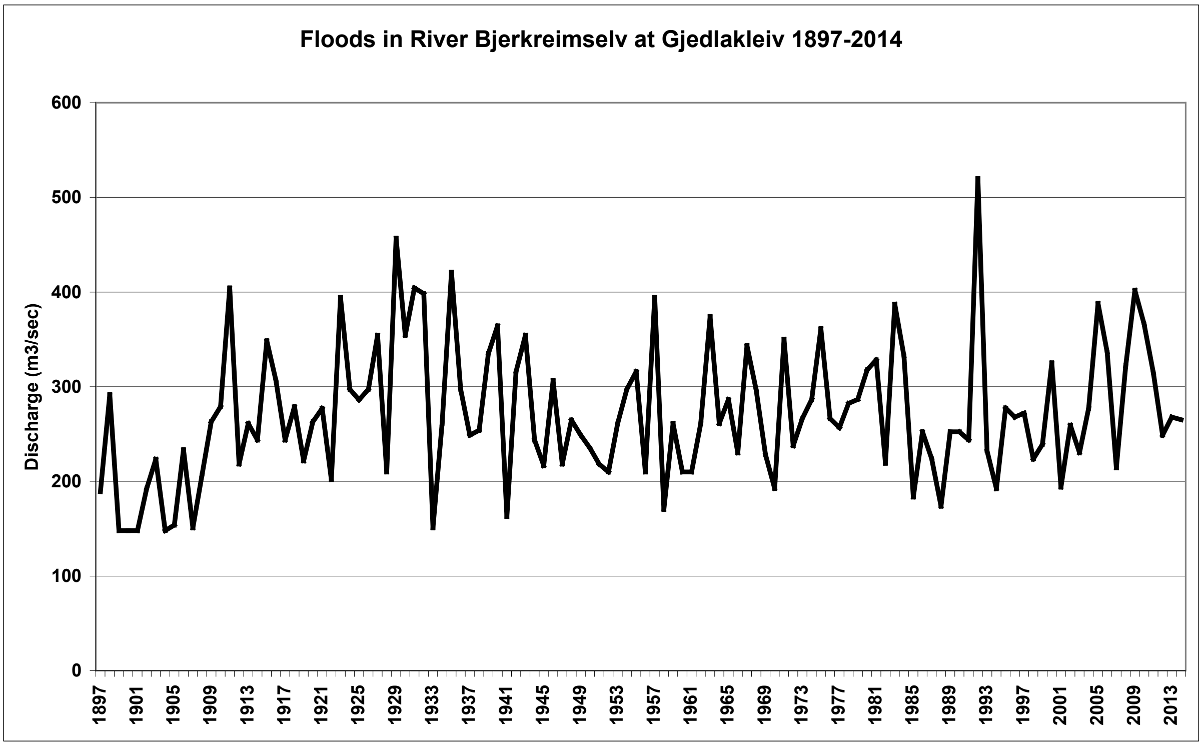


Figure 2.1.1 The annual flood (daily values) in River Bjerkreimselv at Gjedlakleiv.

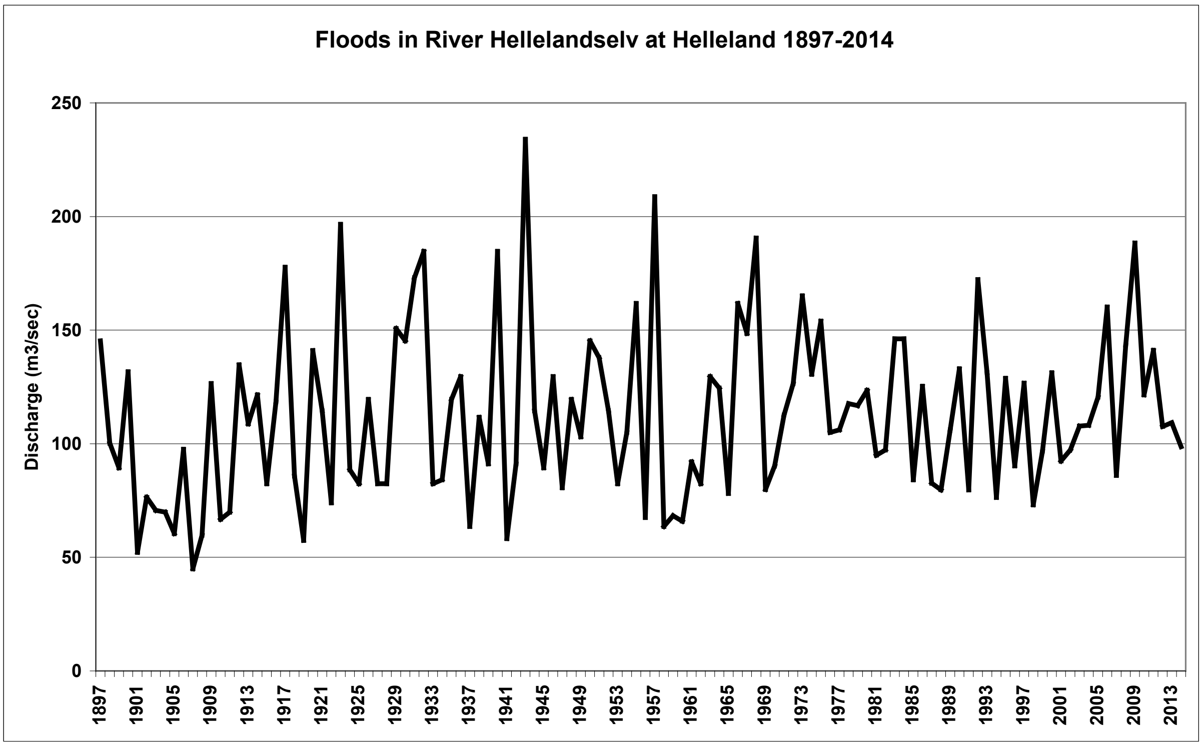


Figure 2.1.2 Observed floods (daily values) in River Hellelandselv at Helleland 1897-2014.

2.1.3 RIVER OGNA

River Ogna is a small watercourse at Jæren flowing westwards from Lakssvelefjellet to the sea at Ognebukta west of the River Bjerkreimselv. The catchment area of River Ogna is 102 square kilometers. The gauging station 27.3/26 Hetland has a catchment area of 70,70 square kilometers. The data series of annual floods is shown in Figure 2.1.3 for Hetland. The catchment characteristics are shown in Table 2.1.6, the date and the rank of the ten largest annual floods (daily values) in Table 2.1.7 and the date and discharge of the largest observed flood (daily values) in Table 2.1.8. The lower part of the catchment is regulated with two power stations Hetland and Svanedal.

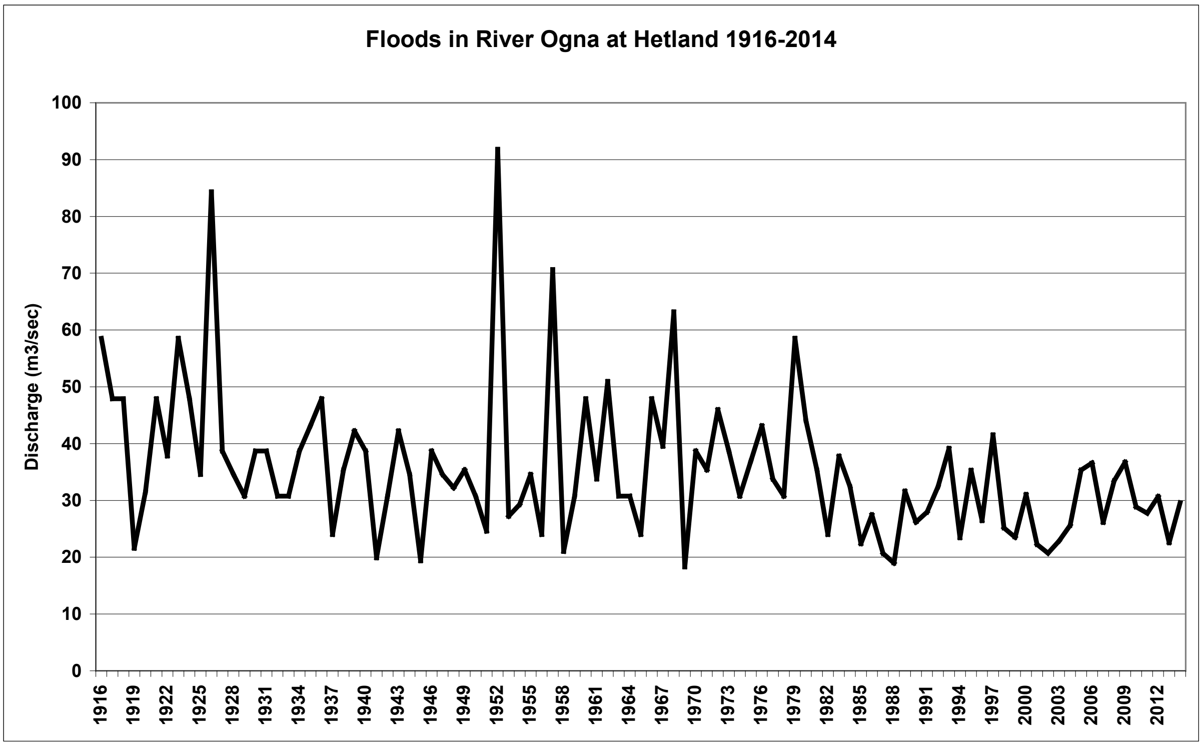


Figure 2.1.3 Observed floods (daily values) in River Ogna at Hetland 1897-2014.

2.1.4 RIVER HÅELV

River Håelv is a lowland watercourse located at Jæren west of River Ogna and southeast of Stavanger. The catchment area is 162 square kilometres. The discharge has been observed at the gauging station 28.1/7 Haugland since 1918. The largest annual floods occur from September to January, most frequently in December (24 percent). The data quality is somewhat affected by growing vegetation in the river channel.

The data series of annual floods is shown in Figure 2.1.4 for Haugland. The catchment characteristics are shown in Table 2.1.6, the date and the rank of the ten largest annual floods (daily values) in Table 2.1.7 and the date and discharge of the largest observed flood (daily values) in Table 2.1.8.

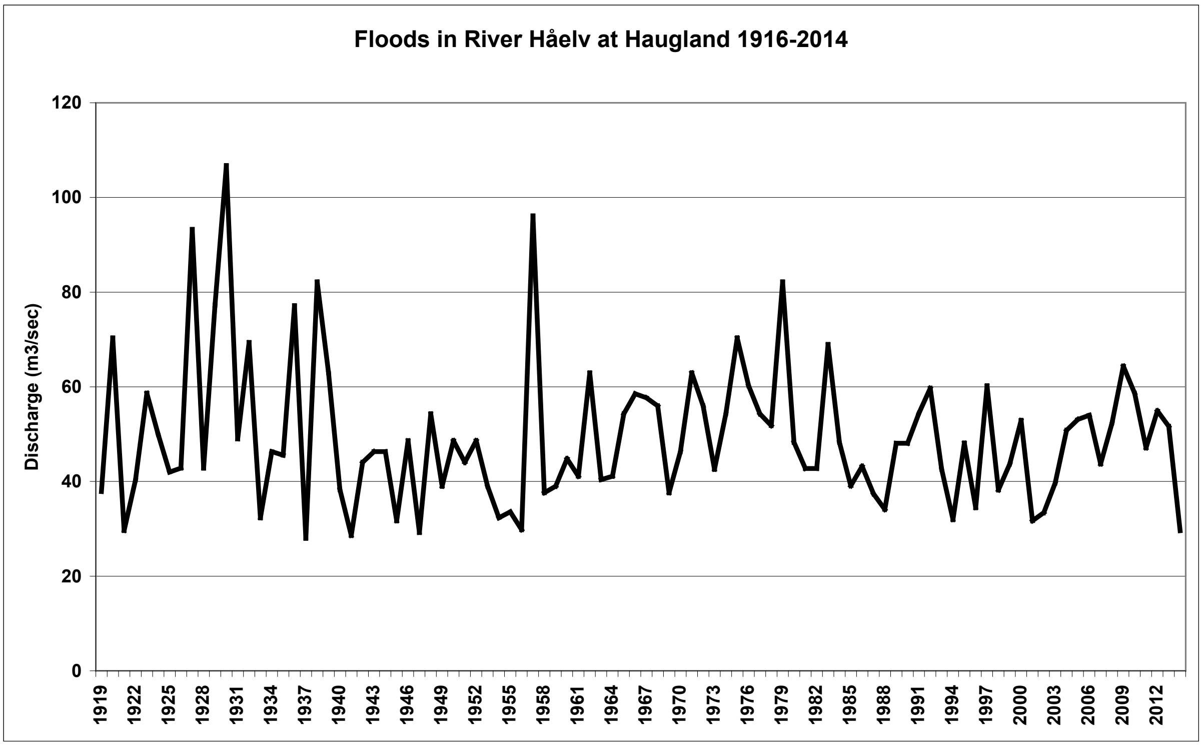


Figure 2.1.4 Observed floods (daily values) in River Håelv at Haugland 1919-2014.

2.1.5 RIVER FRAFJORDELV

River Frafjordelv is located further north on Jæren. The river flows from the east and north to the bottom of Frafjorden, the inner part of Høgsfjorden, the southeasternmost branch of Boknafjord. The gauging station 30.1 Moluf bru has been operating from 1914 to 1983. Catchment characteristis are listed in Table 2.1.6, the date and rank of the ten largest annual floods (daily values) in Table 2.1.7 and the date and discharge of the largest flood (daily value) in Table 2.1.8.

Table 2.1.6 Catchment characteristics for gauging stations at Hetland, Håland and Moluf bru.

Station	27.26 Hetland	28.7 Haugland	30.1 Moluf bru
	Basin characteristics		
Catchment area (km^2)	70,29	139,35	130,43
Station altitude (m.a.s.l.)	21	16	32
Mean altitude (m.a.s.l)	188	178	863
Top altitude (m.a.s.l.)	555	432	1159
Lake (%)	6,07	6,11	7,01
Bog (%)	3,33	1,35	0,41
Forest (%)	12,53	7,15	6,72
Mountain (%)	60,09	61,2	80,41
Glacier (%)	0	0	0

Table 2.1.7 The year, dates and ranks of the ten largest annual floods observed at the gauging stations at Hetland, Håland and Moluf bru.

27.26 Hetland			28.7 Haugland			30.1 Moluf bru		
1915-2014			1918-2014			1914-1983		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1916	2/1	5	1920	17/11	8	1921	22/1	9
1917	6/11	8	1927	2/8	3	1923	12/11	1
1918	4/10	8	1929	8/11	6	1925	28/5	6
1923	12/11	5	1930	11/1	1	1926	23/8	10
1926	12/3	2	1932	11/1	10	1930	13/11	3
1936	15/12	8	1936	15/12	7	1931	4/11	6
1952	25/9	1	1938	4/10	4	1940	26/11	2
1957	13/9	3	1957	13/9	2	1943	6/10	8
1968	29/10	4	1975	21/1	9	1947	22/11	5
1979	4/11	5	1979	28/2 2/3	4	1948	21/10	4

Table 2.1.8 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Hetland, Håland and Moluf bru.

Station	27.26 Hetland	28.7 Haugland	30.1 Moluf bru
Year	1952	1930	1923
Date	25/9	11/1	12/11
q (m^3/sec)	91,80	106,75	374,03
qsp (l/sec km^2)	1306	766	2868
qsp (mm/day)	112,8	66,2	248

2.2 Ryfylke

The district is exposed to heavy rainfall from the North Sea from west/southwest. Several fjords are branching off the large Boknafjord and are running eastwards. The branch Høgsfjord is running to southeast with the larger Lysefjord branching toward northeast. The village Jørpeland is located on the northern side of Høgsfjord, northeast of Stavanger. The river Jørpelandsåni runs through the village. The river was regulated in 1935. The extreme weather Loke caused severe damages to the village in November 2005. West of Jørpeland is the village Tau with the precipitation station Bjørheim. The village Hjelmeland is located on the coast northwest of Jørpeland. An extreme rainstorm caused by an atmospheric river 24- 27 November 1940 caused wide-spread damages in west Norway. The worst day, 26 November, fell 190 mm rain at Jørpeland II and 179 mm at Hjelmeland. This day 223,9 mm was observed at Indre Matre further north. Unfortunatrly, there were no gauging station s operating in either village in 1940.

The island Ombo is located west of Hjelmeland. Farms on this island suffered badly from floods and landslides in the late summer1763. Some similar events are known. They are possibly the result of the remains of a tropical cyclone.

River Lyseelv at the bottom of Lysefjorden was regulated in 1985. The catchment is exposed to heavy rainfall events as observed at 45200 Lysefjorden and 45350 Lysebotn. Further north Årdalsfjorden, Jøsenfjorden, Sandsfjorden, Hylsfjorden and Saudafjorden is running northeastwards. Vindafjorden runs northwards further west to Vikedal and Sandeid.

Most of the smaller rivers flowing towards the Boknafjord are regulated, mostly as a part of the huge Ulla-Førre development. Flood data is given below from three main rivers in the district, River Årdalselv, River Ulla and River Suldalslågen.

2.2.1 RIVER ÅRDALSELV

River Årdalselv is located at Ryfylke north of Jørpeland and flows westwards from the mountains west of the Blåsjø reservoir to the Fognafjord. The station 33.2 Tveid has been operating siden 1896. The catchment area was 512 square kilometres until the river was regulated in 1957. A sub-catchment of 266 square kilometres was diverted to River Lyse. The flood regime is maritime and dominated by autumn floods. The largest annual flood occurs most frequently in September (17 percent), October (21 percent), November (16 percent) and December (12 percent). The spring flood are occasionally the largest flood in the year, in May 2,9 percent, July and August 9 percent and 5 percent in July of the years.

The catchment suffered severe damages from the disastrous flood in December 1743 resulting in tax deductions at 34 farms in Årdal (Eikeland, 1969). The data series of annual floods is shown in Figure 2.2.1 for Tveid. The catchment characteristics are shown in Table 2.2.1, the date and the rank of the ten largest annual floods (daily values) in Table 2.2.2 and the date and discharge of the largest observed flood (daily values) in Table 2.2.3.

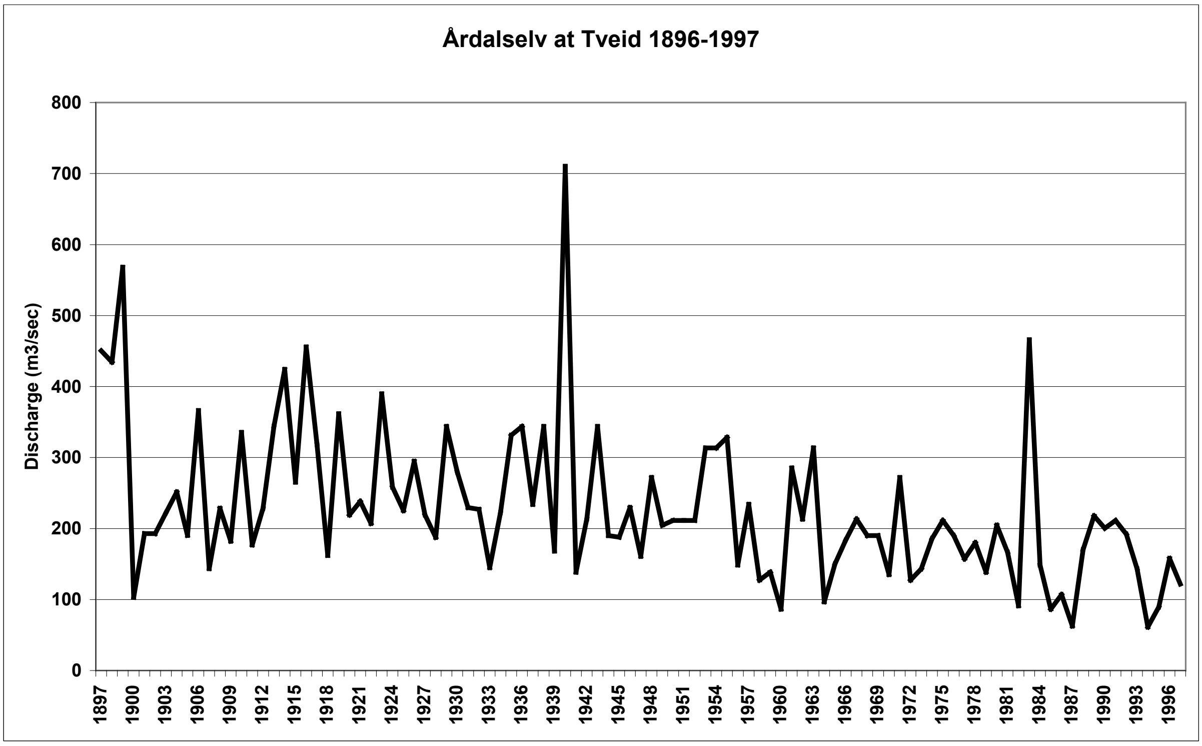


Figure 2.2.1 Annual floods (daily values) in River Årdalselv at Tveid 1897-1996.

2.2.2 RIVER ULLA

River Ulla or Ullalandsåni flows from the huge reservoir Blåsjø southwards to the Jøsenfjord. River Førre flows from Blåsjø to the bottom of the fjord further east. The two rivers were separate before the regulation.

The gauging station 35.2 Hauge bru in River Ulla was active 1905-1983. In River Førre the gauging station 35.17 Førre limningraf was active 1961-1981.The station 35.2 Hauge bru provided key data for the planning of the large hydropower development of Ulla-

Førre. River Ulla was regulated in 1981 as a part of the Ulla-Førre power scheme. The long-term flood series observed at Hauge bru was used for the dam safety assessment of the dams in the large reservoir Blåsjø. The possibility of establishing a good rating curve during large floods was almost impossible because of the hazardous condition at the station. The rating curve was therefore only measured up to the level of the mean annual flood. Observations at the station was resumed in 2002. A long-term precipitation series is available at 46050 Ulla.

The data series of annual floods is shown in Figure 2.2.2 for Hauge bru. The catchment characteristics are shown in Table 2.2.1, the date and the rank of the ten largest annual floods (daily values) in Table 2.2.2 and the date and discharge of the largest observed flood (daily values) in Table 2.2.3. Hydropower regulation has led to reduced floods at Tveid. Flood information has therefore been added for a smaller natural catchment at 35.9 Osali. Catchment characteristics, the date and ranks of the ten largest floods and the date and discharge of the largest floods are given in Table 2.2.4, 2.2.5 and 2.2.6.

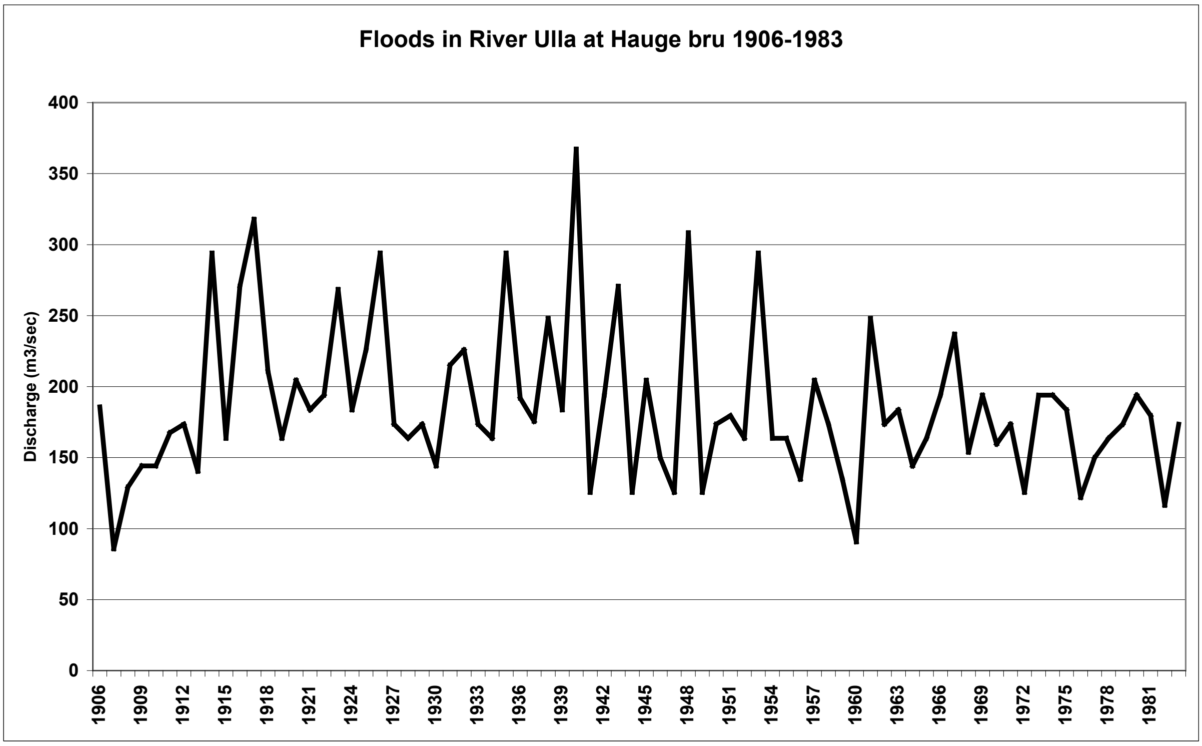


Figure 2.2.2 Annual floods (daily values) in River Ulla at Hauge bru 1906-1983.

2.2.3 RIVER SULDALSLÅGEN

River Suldalslågen is the largest river in Ryfylke and has a catchment area of 1310 square kilometres. The river drains into Sandsfjorden at Sand. The station 36.1 Suldalsvatn has been operating since 1904. The catchment was regulated in 1965. An upstream gauging station 41.2 Røldalsvatn has been operating from 1913 to 1965 and has a catchment area of 131 square kilometres. Long-term series of precipitation data are available from 46150 Sand, 46300 Suldalsvatn and 46450 Røldal.

An intense thunderstorm 21-22 August 1763 caused severe damages at 18 farms near Lake Røldalsvatn (Dalen & Dalen, 1960). The upper part of the catchment is known for heavy snowfall in most winters. Avalanches occur frequently, and have often caused fatalities (Furseth, 2002).

The catchment characteristics for the station 36.1 Suldalsvatn is shown in Table 2.2.1, the date and the rank of the ten largest annual floods (daily values) in Table 2.2.2 and the date and discharge of the largest observed flood (daily values) in Table 2.2.3. Flood data are given for the two shorter natural series at 36.13 Grimsvatn and 36.20 Djupetjørn in Table 2.2.4, 2.2.5 and 2.2.6.

Table 2.2.1 Catchment characteristics for gauging stations at Tveid, Hauge bru and Suldalsvatn.

Station	33.2 Tveid	35.2 Hauge bru	36.1 Suldalsvatn
	Basin characteristics		
Catchment area (km^2)	512	394	1304
Station altitude (m.a.s.l.)	46	23	69
Mean altitude (m.a.s.l)	877	1055	1065
Top altitude (m.a.s.l.)	1269	1597	1686
Lake (%)	13,75	17,66	8,88
Bog (%)	0,62	0,58	0,44
Forest (%)	9,37	10,12	16,34
Mountain (%)	70,72	70,28	70,01
Glacier (%)	0	0	0,58

Table 2.2.2. Dates and ranks of the ten largest annual floods observed at the gauging stations at Tveid, Hauge bru and Suldalsvatn.

33.2 Tveid			35.2 Hauge bru			36.1 Suldalsvatn		
1896-1997			1906-1983			1904-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1897	23/11	5	1914	3/2	3	1905	20/6	7
1898	3/11	6	1916	12/10	7	1910	15/6	8
1899	28/11	2	1917	29/9	2	1914	7/7	3
1906	21/7	9	1923	12/9	9	1917	29/9	3
1914	3/2	7	1926	22/8	3	1920	19/7	10
1916	15/10	4	1935	15/10	3	1938	15/11	5
1919	27/9	10	1938	18/9	10	1940	27/11	5
1923	12/11	8	1940	27/11	1	1943	7/10	1
1940	26/11	1	1943	7/10	7	1953	4/12	2
1983	27/10	3	1953	3/12	3	1967	21/7	9

Table 2.2.3 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Tveid, Hauge bru and Suldalsvatn.

Station	33.2 Tveid	35.1 Hauge bru	36.1 Suldalsvatn
Year	1940	1940	1943
Date	26/11	27/10	7/10
q (m^3/sec)	710	367	684
qsp (l/sec km^2)	1386	932	524
qsp (mm/day)	119,8	81	45,3

Table 2.2.4 Catchment characteristics for gauging stations at Osali, Grimsvatn and Djupetjønn.

Station	35.9 Osali	36.13 Grimsvatn	36.20 Djupetjønn
	Basin characteristics		
Catchment area (km^2)	22,46	34,54	6,02
Station altitude (m.a.s.l.)	643	563	1160
Mean altitude (m.a.s.l)	871	833	1264
Top altitude (m.a.s.l.)	1345	1535	1560
Lake (%)	12,3	3,16	12,33
Bog (%)	1,33	0,69	0
Forest (%)	5,88	5,56	0
Mountain (%)	80,44	87,61	87,67
Glacier (%)	0	0	0

Table 2.2.5 The year, dates and ranks of the ten largest annual floods observed at the gauging stations at Osali, Grimsvatn and Djupetjønn.

35.9 Osali			36.13 Grimsvatn			36.20 Djupetjørn		
1983-2014			1974-2014			1975-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1986	3/10	10	1983	25/10	4	1981	27/9	6
1989	7/2	5	1992	15/12	9	1982	26/9	9
1992	3/1	9	1996	3/11	10	1987	16/10	2
1999	28/11	2	1998	23/10	6	1998	28/6	3
2000	30/4	4	2005	14/9	3	2002	11/7	8
2005	15/11	8	2006	6/11	8	2003	10/9	10
2006	6/11	6	2009	20/11	2	2004	6/5	1
2009	20/11	7	2011	27/11	5	2009	30/7	5
2011	27/11	3	2013	18/5	7	2013	18/5	7
2014	28/10	1	2014	28/10	1	2014	7/7	4

Table 2.2.6 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Osali, Grimsvatn and Djupetjønn.

Station	35.9 Osali	36.13 Grimsvatn	36.20 Djupetjørn
Year	2014	2014	2004
Date	28/10	28/10	6/5
q (m^3/sec)	31,67	62,21	6,48
qsp (l/sec km^2)	1410	1801	1077,03
qsp (mm/day)	121,8	155,6	93,1
q topp		76,06	11,08
qsp topp	1823	2002	1841

2.2.4 RIVER SAUDAELV

River Saudaelv flows southwards from a mountain ridge to the north to the bottom of the Saudafjord. The river is regulated, and long-term data series are not available from the catchment. The December flood in 1743 caused the river to shift to a new permanent riverbed (Lillehammer, 1991). The rainfall flood 28 October 2014 blocked the main road through the village. Rainfall data are available at 46610 Sauda and 47600 Litledal, which is located North of the water divide to Etneelv. Further west a shorter flood series is available from the gauging station 38.1 Holmen. There is a longterm precipitation station at 46850 Hundseid in Vikedal.

2.3 Sunnhordaland

Sunnhordaland includes the districts on both sides of Åkrafjord and the catchments on the western side of the Folgefonna glacier. The flood regime is highly maritime. The catchment includes mostly lowlying catchments such as River Etneelv, as well as steep glacier streams. The district is exposed to heavy rainfall from the North Sea. A one-day rainfall of 229,6 mm was observed at the old rainfall station 47900 Indre Matre in November 1940. The accumulated rainfall over four consecutive days was 480 mm. The station was later closed, but new stations at 47820 Eikemo and 47890 Opstveit have also observed almost as high one-day rainfall. These stations are located north of Åkrafjord and south of the Folgefonna glacier. The daily rainfall series at 47500 Etne within the Etneelv catchment was digitised back to 1895.

2.3.1 RIVER ETNEELV

River Etneelv is a coastal watercourse, flowing westwards to the sea at Etne in Sunnhordaland. The river flows south of the Åkrafjord. The catchment area is 246 square kilometres. The long-term gauging station 41.1 Stordalsvatn has been operating since 1916. Catchment characteristics are listed in Table 2.3.1. The dates and ranks of the ten largest floods are given in Table 2.3.2 and the date and discharge of the largest daily flood is given in Table 2.3,3. The annual flood occurs most frequently in September (17 percent), October (26 percent) and November (15 percent). Winter floods occurs, especially in December (9 percent) and February (9 percent). The annual floods (daily values) 1913-2014 are shown in Figure 2.3.1. There is a long-term precipitation station within the catchment: 47500 Etne, which has been active since 1895. The precipitation station 47610 Kritle is located at the southern part of the catchment.

Three severe historical floods are known in River Etneelv (Dyrvik, 1972). The flood in December 1743 caused severe damages, another flood occurred in the autumn 1755 and a third flood in the winter 1769/70.

Year	Date	Remarks
1665	Whit Sunday	Farms at Kvinnherad damages from floods and slides
1686		Byrkeland farm at Jondal damaged by flood and slides
1739	15-21/9	Deductions for flood damages at 6 farms
1743	4-5/12	Extreme flood in River Etneelv and other rivers in Kvinnherad and Etne
1743		River Etneelv moved the church to the fiord and caused damages at 8 farms in the district
1753		River Sandvikselvo at Skånevik in Etne moved the sawmill to the sea
1755	Autumn	Long duration rainfall caused flood in River Etneelv
1762	30/8	Deductions granted for 27 farms in South and North Hordaland for flood damages.
1769/70	Vinter	Severe flood in Lake Stordalsvatn
1790	16/6	Deductions granted to farms at Skånevik for flood damages
1853		Flood at Lake Stordalsvatn in River Etneelv.

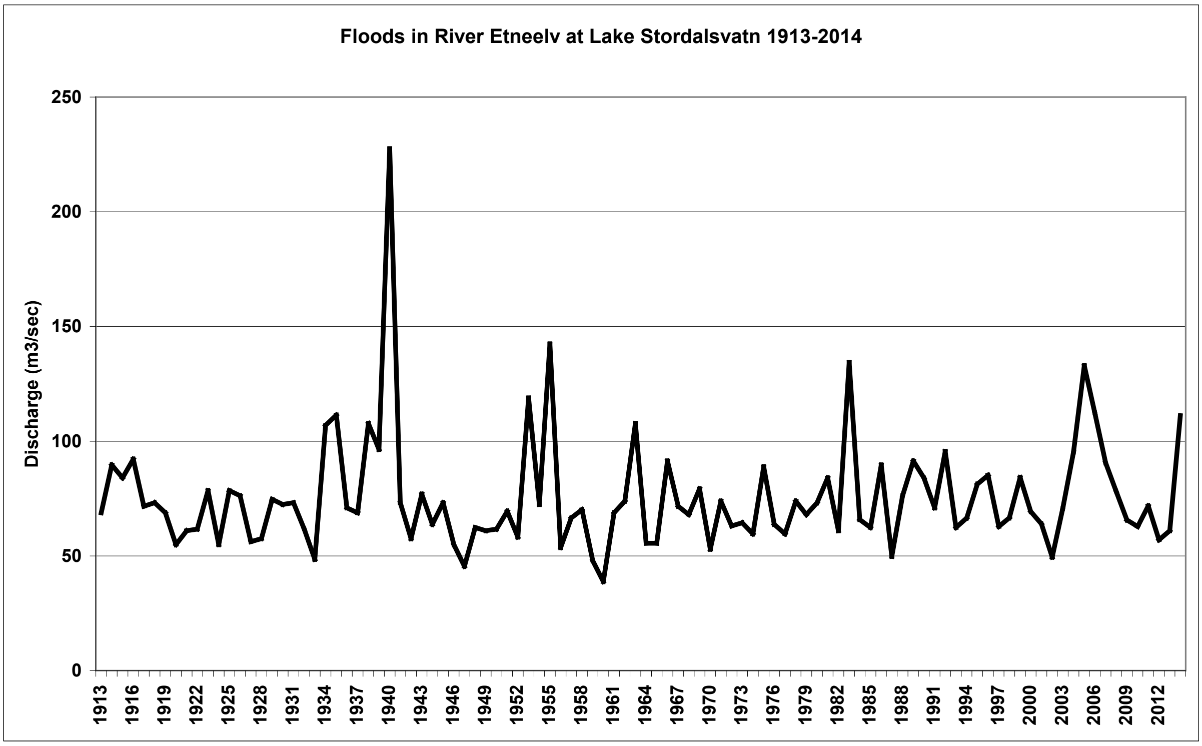


Figure 2.3.1 Annual floods (daily values) in River Etneelv at Lake Stordalsvatn 1913- 2014.

2.3.2 RIVER HANDALANDSELV

River Handalandselv is located at Kvinnherad northeast of Matrefjord, a branch of the Skånevikfjord/Åkrefjord. The gauging station 42.2 Djupevad has been active since 1963. The catchment is located within the coastal maximum precipitation zone southwest of Folgefonni. Catchment characteristics are given in Table 2.3.1. The river is not regulated. The year, date and rank of the ten largest floods are shown in Table 2.3.2. The discharge of the largest daily flood is shown in Table 2.3.3. The gauging station 42.6 Bakkelihøl is located at River Blåelvi further east on the northern side of the Åkrafjord. The station was active 1965-1984, and floods with very high specific discharges have been observed at the station. The data quality is however quite bad, but rainfall data from Indre Matre, Opstveit and Eikemo indicates that the discharge must have been extreme during some of these events. The record oneday rainfall of 229,6 mm was observed at Indre Matre 24 November 1940.

2.3.3 RIVERS DRAINING TO THE MAURANGERFJORD

A number of smaller rivers are flowing northwestwards from the Folgefonna glacier to the Maurangerfjord. River Uskedalselv flows to the fjord at Uskedal, River Hattebergsvassdraget at Rosendal, River Bondhuselv at Bondhus, River Austrepollelv at Austrepollen and River Øyreselv at the bottom of the Maurangerfjord.

There are no flood data from Rosendal, but some past events have been documented in the farm diary of the local vicarage. The village has suffered from floods, rockfalls and avalanches.

The discharge in River Bondhuselv has been observed at the gauging station 46.4 since 1964 near the fjord. A tributary to the upstream Lake Bondhusvatn is monitored at the gauging station 46.9 Fønnerdalsvatn. The river is regulated with an intake under the

Bondhusbre glacier, an outlet of Folgefonna. River Austrepollelv is regulated. The power station Mauranger kraftverk is located close to the fjord.

The discharge in River Øyreselv was observed at the gauging station 46.3 Øyreselv 1922-1981. The river was regulated in 1964.

Catchment characteristics of are given in Table 2.3.4 for the three stations Øyreselv, Bondhuselv and Fønnerdalsvatn. The year, date and rank of the ten largest floods are shown in Table 2.3.5. The discharge of the largest daily flood is shown in Table 2.3.6.

2.3.4 RIVER JONDALSELV

River Jondalselv flows from the water divide to Sørfjorden westwards towards the main Hardangerfjord. The catchment comprises one long-term gauging station 47.1 Eidevatn, which was closed in 1998. A part of the northern part of Folgefonna glacier is included in the catchment. The river was regulated in 1935. Precipitation data are available at 49050 Jondal. Catchment characteristics of Eidevatn is given in Table 2.3.1, the date and rank of the ten largest annual floods (daily values) in Table 2.3.2 and the date and discharge of the largest flood in Table 2.3.3.

Table 2.3.1 Catchment characteristics for the gauging stations at Stordalsvatn, Djupevad and Eidevatn.

Station	41.1 Stordalsvatn	42.2 Djupevad	47.1 Eidevatn
	Basin characteristics		
Catchment area (km^2)	130,6	31,9	79,2
Station altitude (m.a.s.l.)	51	88	67
Mean altitude (m.a.s.l)	681	526	959
Top altitude (m.a.s.l.)	1294	1152	1642
Lake (%)	10,6	2,79	6,7
Bog (%)	1,05	1,41	1,22
Forest (%)	24,81	42,56	27,07
Mountain (%)	57,5	50,39	52,53
Glacier (%)	0	0	8,88

Table 2.3.2 Dates and ranks of the ten largest annual floods observed at the gauging stations at Stordalsvatn, Djupevad and Eidevatn.

41.1 Stordalsvatn			42.2 Djupevad			47.1 Eidevatn		
1913-2014			1964-2014			1908-1998		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1935	15/10	8	1964	24/8	10	1914	2/2	9
1938	15/10	9	1981	23/11	6	1918	11/10	9
1940	27/11	1	1983	5/10	4	1921	26/7	4
1953	3/12	5	1990	16/3	9	1940	26/11	3
1955	6/12	2	1992	11/1	2	1953	10/10	7
1963	12/10	9	1999	4/2	7	1986	3/12	2
1983	27/10	3	2004	5/12	8	1990	17/3	6
2005	15/11	4	2005	14/11	1	1992	15/12	1
2006	6/11	7	2009	20/10	3	1993	4/2	5
2014	29/10	6	2014	28/10	5	1995	19/10	8

Table 2.3.3 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Stordalsvatn, Djupevad and Eidevatn.

Station	41.1 Stordalsvatn	42.2 Djupevad	47.1 Eidevatn
Year	1940	2005	1992
Date	27/11	14/11	15/12
q (m^3/sec)	227,5	66,2	147,2
qsp (l/sec km^2)	1742	2074	1858
qsp (mm/day)	150,5	179,2	160,5

Remarks

The largest one-day flood occurred 14 November 2005 at 42.2 Djupevad with a discharge of 66,16 m^3/sec corresponding to 2074 l/sec km^2 or to a runoff of 179,20 mm/d caused by the extreme weather *Loke*. The peak at 12:00 was at 111,45 m^3/sec corresponding to 3494 l/sec km^2. The second largest one-day flood occurred 14 September at Djupevad with a discharge of 64,95 m^3/sec corresponding to 2036 l/sec km^2 or to a runoff of 176 mm/d caused by extreme weather *Kristin*. The peak was, however, higher than the peak during Loke at 129,59 m^3/sec corresponding to 4062 l/sec km^2.

Table 2.3.4 Catchment characteristics for the three gauging stations in rivers draining the western side of Folgefonni at Kvinnherad.

Station	46.3 Øyreselv	46.4 Bondhus	46.9 Fønnerdalsvatn
	Basin characteristics		
Catchment area (km^2)	87,74	60,50	7,010
Station altitude (m.a.s.l.)	113	23	590
Mean altitude (m.a.s.l)	1151	1236	1371
Top altitude (m.a.s.l.)	1644	1649	1621
Lake (%)	9,6	3,24	3,99
Bog (%)	0,02	0,12	0
Forest (%)	3,3	11,48	2
Mountain (%)	59,48	42,02	46,65
Glacier (%)	25,26	40,08	47,31

Table 2.3.5 The year, dates and ranks of the ten largest annual floods observed at the three gauging stations in rivers draining the western side of Folgefonni at Kvinnherad.

46.3 Øyreselv			46.4 Bondhus			46.9 Fønnerdalsvatn		
1922-1981			1964-2014			1980-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1933	29/7	8	1966	7/9	1	1983	5/10	6
1935	11/8	7	1969	12/9	5	1984	31/8	7
1937	7/9	10	1973	9/9	5	1985	1/10	8
1940	26/11	2	1975	25/9	8	1988	20/9	8
1948	18/9	9	1983	26/10	3	1989	21/8	5
1953	10/10	3	1985	1/10	8	2005	14/9	1
1958	25/10	6	1986	3/12	10	2007	15/8	10
1959	25/8	9	1989	29/1	2	2010	6/10	3
1966	7/9	1	2005	14/9	7	2011	29/6	4
1971	2/10	5	2014	28/10	4	2014	28/10	2

Table 2.3.6 The date and discharge of the largest flood (daily values) observed at the three gauging stations in rivers draining the western side of Folgefonni at Kvinnherad.

Station	46.3 Øyreselv	46.4 Bondhus	46.9 Fønnerdalsvatn
Year	1966	1966	2005
Date	7/9	7/9	14/9
q (m^3/sec)	146,79	84,13	17,19
qsp (l/sec km^2)	2047	1391	2553
qsp (mm/day)	153,3	120,2	220,6

2.4 Hardanger

The south-west part of Hardangervidda is drained by River Suldalslågen and River Røldalselv. River Opo flows towards Sørfjorden at Odda, River Tysso, River Vendo and Opo at Ullensvang, River Kinso towards Sørfjorden further north and River Eio towards Eidfjord. The Hardangervidda is a mountain plateau. The annual flood occurs typical in the spring from May to July in Kinso and Eio with most of the catchments in the central parts of the plateau. More of the catchments in Suldalslågen and Opo are located at lower levels. Mild weather and rainfall occur frequently in the late summer and autumn, extending the dominant flood season from May to November. Some of the floods in Eio and Kinso are identical with floods east of the water divide in Skiensvassdraget, Numedalslågen and Drammenselva.

Farms on both sides of Sørfjorden has suffered damages from floods in small rivers and brooks without any gauging stations. A local rainstorm affecting River Tokheimelv on the west side of Odda and some small brooks caused severe damages to the town 12 October 1962 without causing a large flood in the main river Opo. Other rainstorms have caused many slides on the western side of the fjord.

Historical floods and slides in Hardanger have been extensive documented in Olafsen, (1907, 1917), Kolltveit (1963,1977) and Riksen (1969). Rivers Tysso is regulated in Tyssedal, and and River Eio are regulated in the Sima regulation.

T*able 2.4.1 Large floods known from historical sources in Hardanger.*

Year	Date	Remarks
1650		Severe flood in Hardanger
1667	September	Flood damages to farms om the western side of Sørfjorden
1670	11/7	Deductions granted for flood damages at Eidfjord
1672	24/7	Deduction granted at Hereid for flood damages
1677		Flood damages at Buar in Odda
1682	Summer	Flood and slides damaged two farms at Eidfjord deduction granted 23/9
1699		Flood damages and deductions at Vintertun in Odda
1716	20/1	Deductions for riverbank failures at farms in Odda
1723	Autumn	Damages at 18 farms in Ullensvang, 6 in Odda, 2 in Eidfjord and 2 in Granvin for floods, avalanches and slides.
1724	July-august	Deductions for damages at 13 farms for damages in autumn 1723
1725	July-august	Deductions at additional 6 farms
1742	December	Floods at Opedal and Århus in Ullensvang
1743	3-11/12	Extreme flood at Vestlandet
1743		Extreme flood in River Kinso almost destroyed the Church

1762	30/8	Deductions of 27 farms in Hordaland and Nordfjord
1769/70	2-4/2	Floods at two farms in Ullensvang
1790/94		Deductions at farms in Ullensvang and Kinsarvik

2.4.1 RIVER OPO IN ODDA

There are two Rivers in Hardanger both named Opo. The catchment of River Opo in Odda comprises partly of the southwest side of Hardangervidda and the partly of the southeast side of Folgefonna. The river flows northwards through Lake Sandvenvann and into Sørfjorden at Odda. The catchment includes two long-term stations, one at the outlet of Lake Sandvenvatn and one in the tributary Nordelva at Lake Reinsnosvatn. This tributary flows westwards through Låtefoss and into River Opo from the south-west part of Hardangervidda. Shorter series are available in the tributary Jordalselvi flowing from the glacier arm Buarbre at the gauging station Jordal. Some floods in this tributary has been caused by slides from the glacier into the river, damming the stream with subsequent dam failures.

The gauging station 48.1 Lake Sandvenvatn has a catchment area of 470 square kilometers. The annual flood occurs at Sandvenvatn from May to December, most frequent in October (19 percent), September (16 percent) and June (16 percent). Floods in the late autumn were caused by heavy rainfall penetrating from west through Åkrafjord.

Daily longterm precipitation data has been digitised from the precipitation station 49250 Jøsendal.

Some historical floods are known in Opo. A slide dammed River Jordalselv, and the subsequent dambreak damaged the farm Buer in 1677. The large autumn floods caused inundations and caused many slides which damaged farms from 1723 to 1725. The large flood 4-5 December 1743 caused also severe damages in the catchment.

The data series of annual floods is shown in Figure 2.4.1 for Sandvenvatn. The catchment characteristics are shown in Table 2.4.1, the date and the rank of the ten largest annual floods (daily values) in Table 2.4.2 and the date and discharge of the largest observed flood (daily values) in Table 2.4.3 below.

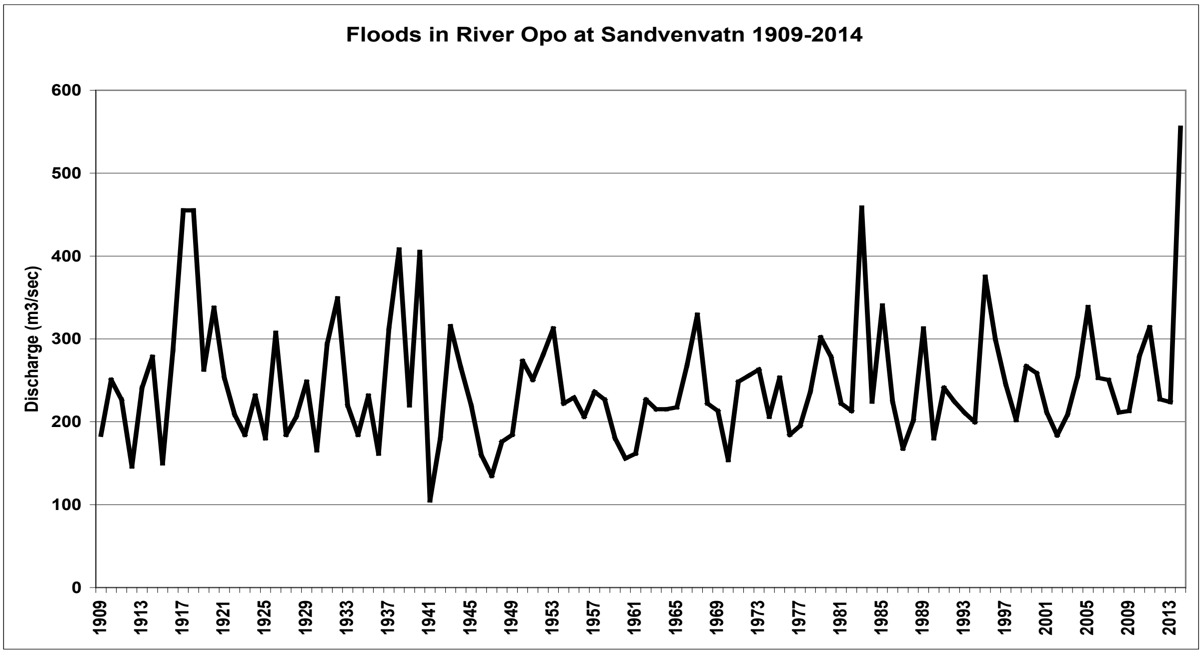


Figure 2.4.1 Annual floods (daily values) in River Opo at Lake Sandvenvatn 1909-2013.

2.4.2 RIVER OPO AT ULLENSVANG

Between River Opo at Odda and River Kinso, four rivers drain the western flank of Hardangervidda. These rivers are River Tysso, River Espeelv, River Vendo and River Opo at Ullensvang. River Tysso has a catchment of 337 square kilometres. The discharge is strongly modified because of regulation. The regulation includes also River Vendo. River Opo flows through Ullensvang. There are no data series available for floods in these rivers, but the damage reports tell about severe damages from floods, avalanches, landslides and rockfalls in Ullensvang especially in the 18thCentury.

2.4.3 RIVER KINSO

River Kinso flows from the west side of the Hardangervidda plateau to the Sørfjord at Kinsarvik. The entire catchment area is 277 square kilometres. A gauging station 50.1 Hølen is located at the catchment. The dominant flood season is in the spring. The largest annual flood occurs in May (15 percent), June (56 percent) and July (15 percent).

Historical floods are known in 1650/1651, 1682, 1723 in the autumn and 3-11 December 1743.

The data series of annual floods is shown in Figure 2.4.2 for Hølen. The catchment characteristics are shown in Table 2.4.2, the date and the rank of the ten largest annual floods (daily values) in Table 2.4.3 and the date and discharge of the largest observed flood (daily values) in Table 2.4.4 below.

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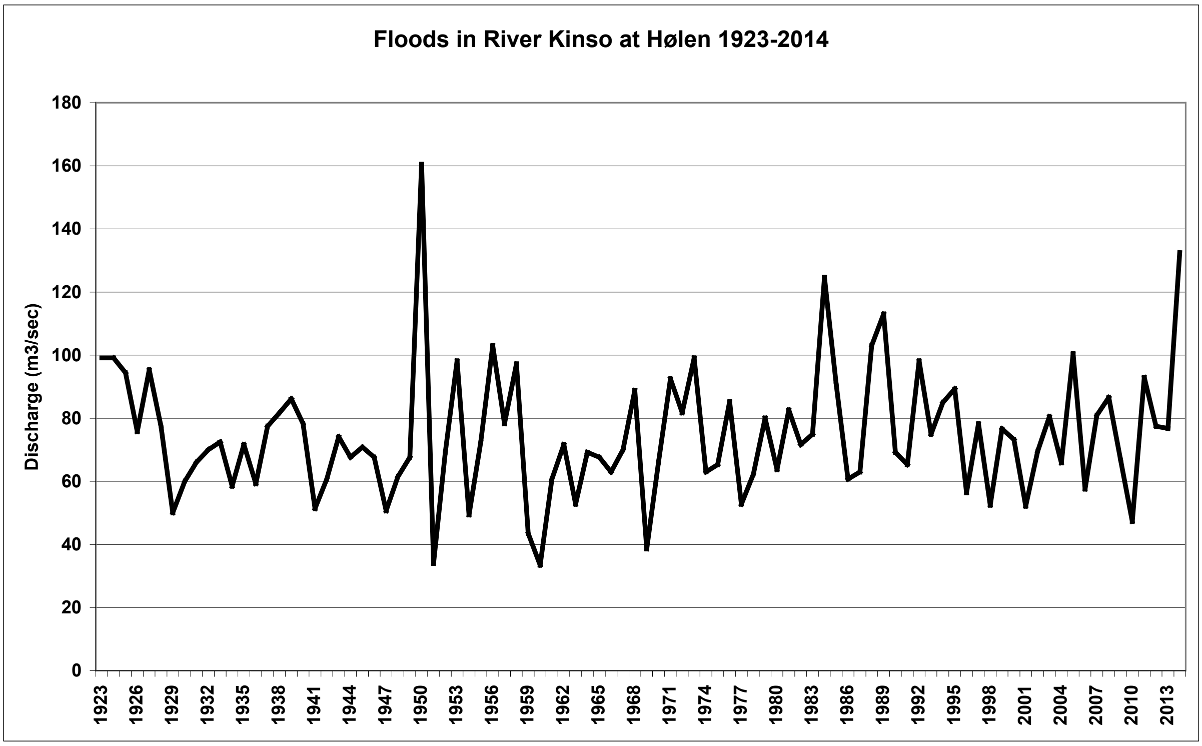


Figure 2.4.2 Annual floods (daily values) in River Kinso at Hølen 1923-2014.

Table 2.4.1 Catchment characteristics for the gauging stations at Stordalsvatn, Djupevad and Eidevatn.

Station	48.1 Sandvenvatn	48.5 Reinsnosvatn	50.1 Hølen
Basin characteristics	Basin characteristics		
Catchment area (km^2)	470,22	120,5	232,73
Station altitude (m.a.s.l.)	87	59,5	123
Mean altitude (m.a.s.l)	1090	1232	1277
Top altitude (m.a.s.l.)	1651	1635	1686
Lake (%)	6,52	9,38	8,33
Bog (%)	0,89	0,54	0,32
Forest (%)	21,44	9,53	1,84
Mountain (%)	59,63	76,37	88,15
Glacier (%)	7,39	1	0,34

Table 2.4.2 Dates and ranks of the ten largest annual floods observed at the gauging stations at Sandvenvatn, Reinsnosvatn and Hølen.

48.1 Sandvenvatn			48.5 Reinsnosvatn			50.1 Hølen		
1909-2014			1917-2014			1923-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1917	28/9	2	1938	14/11	5	1923	12/7	7
1918	11/10	2	1939	20/6	10	1924	14/7	7
1920	18/7	9	1944	20/8	4	1950	9/6	1
1932	18/12	8	1950	9/6	6	1956	2/7	5
1938	14/11	5	1958	2/7	2	1973	5/6	7
1940	27/11	6	1964	16/6	8	1984	4/6	3
1943	6/10	9	1973	8/7	3	1988	30/5	5
1983	5/10	4	1995	21/7	9	1989	29/6	4
1995	21/7	7	1996	3/11	7	1992	4/6	10
2005	14/9	10	2010	7/10	8	2005	6/7	5
2014	28/10	1	2014	28/10	1	2014	28/10	2

Table 2.4.3 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Sandvenvatn, Reinsnosvatn and Hølen.

Station	48.1 Sandvenvatn	48.5 Reinsnosvatn	50.1 Hølen
Year	2014	2014	1950
Date	28/10	28/10	9/6
q (m^3/sec)	543,6	84,07	160,46
qsp (l/sec km^2)	1154	697	684
qsp (mm/day)	99,7	60,3	59,6

2.4.4 RIVER EIO

River Eio drains the northwestern part of the Hardangervidda. The gauging station 50.3 Eidfjordvatn has been operating 1928-2013. Upstreams in the main river Bjoreio the gauging station 50. 2 Garen has been operating 1908-1975 with a break in the observations 1916-1918. Another longterm gauging station has been operating at 50. 4 Viveli in the tributary Veig

1915-2013 with a break 1981-1983. There are two large water falls in this river, the Vøringsfoss (182 m) in the main river and Valurfoss (292 m) in the tributary Veig.

The catchment characteristics of the three stations are shown in Table 2.4.4, the date and the rank of the ten largest annual floods (daily values) in Table 2.4.5 and the date and discharge of the largest observed flood (daily values) in Table 2.4.6 below.

Table 2.4.4 Catchment characteristics for the gauging stations at Eidfjordvatn, Viveli and Garen.

Station	50.3 Eidfjordvatn	50.4 Viveli	50.2 Garen
Basin characteristics	Basin characteristics		
Catchment area (km^2)	1166,92	390,54	501,23
Station altitude (m.a.s.l.)	19	874	735
Mean altitude (m.a.s.l)	1226	1268	1237
Top altitude (m.a.s.l.)	1853	1685	1857
Lake (%)	5,47	4,59	7,5
Bog (%)	4,36	3,09	4,7
Forest (%)	5,22	0,84	1,86
Mountain (%)	80,51	88,45	80,4
Glacier (%)	2,2	0	4,72

Table 2.4.5 Dates and ranks of the ten largest annual floods observed at the gauging stations at Eidfjordvatn, Viveli and Garen.

50.3 Eidfjordvatn			50.4 Viveli			50.2 Garen		
1928-2014			1915-2014			1909-1975		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1935	17/6	10	1920	26/6	8	1910	14/6	5
1938	1/9	8	1923	16/9	8	1914	6/6	3
1939	18/7	3	1938	14/6	5	1924	23/6	8
1945	25/6	6	1939	18/7	2	1927	28/6	2
1950	8/6	1	1950	8/6	1	1939	6/6	6
1956	12/6	5	1956	11/6	10	1950	9/6	9
1958	1/7	4	1958	1/7	3	1958	1/7	7
1961	2/6	7	1963	9/8	5	1961	31/5	9
1971	30/5	2	1971	30,5	7	1971	30/5	1
1973	8/7	9	1973	8/7	4	1973	8/7	4

Table 2.4.6 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Eidfjordvatn, Viveli and Garen.

Station	50.3 Eidfjordvatn	50.4 Viveli	50.2 Garen
Year	1950	1950	1971
Date	8/6	8/6	30/5
q (m^3/sec)	770,81	249,50	239,93
qsp (l/sec km^2)	661	639	479
qsp (mm/day)	57,1	55,2	41,4

Table 2.4.7 Catchment characteristics of the gauging stations at Øvre Austdalsvatn, Oselv at Røykenes and Sedal.

Station	51.2 Øvre Austdalsvatn	55.4 Røykenes	61.7 Sedal
	Basin characteristics		
Catchment area (km^2)	81,89	50,09	11,27
Station altitude (m.a.s.l.)	1040	53	179
Mean altitude (m.a.s.l)	1242	307	749
Top altitude (m.a.s.l.)	1578	960	941
Lake (%)	9,87	3,9	1,86
Bog (%)	0	0,76	0,27
Forest (%)	0	52,16	17,3
Mountain (%)	87,72	31,66	76,49
Glacier (%)	2,33	0	0

Table 2.4.8 The year, dates and ranks of the ten largest annual floods observed at the gauging stations at Øvre Austdalsvatn, Oselv at Røykenes and Sedal.

51.2 Øvre Austdalsvatn			55.4 Røykenes			61.7 Sedal		
1943-1980			1934-2014			1944-1978		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1943	20/9	2	1934	26/11	6	1946	11/8	3
1944	12/8	5	1940	26/11	2	1947	3/10	6
1950	9/6	4	1943	27/2	4	1951	27/11	6
1952	3/7	10	1946	16/2	10	1953	7/11	10
1953	10/10	3	1953	10/10	1	1965	30/10	2
1955	17/10	9	1963	9/9	8	1966	7/9	5
1958	10/7	6	1973	17/2	6	1968	26/10	9
1964	15/6	8	1982	9/3	9	1969	28/10	1
1971	3-4/11	1	1992	11/1	5	1975	21/12	4
1979	25/6	7	2005	14/9	3	1977	30/9	8

Table 2.4.9 The date and discharge of the largest flood (daily values) observed at the three gauging stations at Øvre Austdalsvatn, in river Oselv at Røykenes and Sedal.

Station	51.2 Øvre Austdalsvatn	55.4 Røykenes	61.7 Sedal
Year	1971	1953	1969
Date	3-4/11	10/10	28/10
q (m^3/sec)	78,13	144,07	49,17
qsp (l/sec km^2)	954	2816	4364
qsp (mm/day)	82,1	248,5	376,9

2.4.5 RIVER SIMA

A valley is running from north to south from Ramnberget to Luranuten. Another valley is running from west eastward under an arm of the glacier named Rembesdalskåki. This glacier arm is damming the outlet of the lake Nedre Demmevatn. When heavy glacier melting takes place, the water level rises fast (up to 100 m) in the lake. When this lake is full can it cut a canal along the south side of Luranuten causing a large flood down to Rembesdalen and Simadalen. The flood caused severe damages at farms on the bottom of Simadalen. These floods became gradually more severe as the glacier gradually decreased.

An early flood occurred in 1736. The damages were examined 24 September 1736 were examined at the fatms Øvre and Nedre Tveit, Medhus and Sæ. The two Tveit farms was granted a deduction of 2 pd 15 mk butter and Medhus 2 pd butter. Table 2.4.10 summarises some of the floods which ravaged the farms in Simadalen.

As the ice at Hardangerjøklen and Rembesdalskåki decreased, the water pressure from Lake Dimmevatn became too large, and floods became more and more frequent down into Simadalen. The conditions became so severe in the 1890's. In 1893 a flood of 35 mill m^3 caused severe damages. A tunnel was constructed in 1899 through the mountain Dyranut to protect Simadalen from further damages. The tunnel was constructed 64 m above the bottom of the lake and had a length of 380 m.

The glacier continued to decrease, and A major flood occurred 10 August 1937 and another 23 August 1938. The floods caused the valley bottom to change completely. A new tunnel was completed in 1939. This tunnel is 650 m long tunnel was constructed a a lower level of 14 m above the bottom of Nedre Demmevatn.

Table 2.4.10 Floods from glacier dammed lake Demmevatn

Year	Date	Remarks
1736		
1813		
1860	June	
1861	17/9	
1893		End of august - 35 mill m^3
1894		Tunnel through Rembesdalskåki
1897	17/8	
1937	10/8	
1938	23/8	
1969	12/9	11,5 mill. m^3 - 165.000 NOK

Table 2.4.10 lists some of these floods, which have caused severe damages in the valley below. The river is regulated from 1894.
References: Liseth (1938), Bing (1938), Liestøl (1956)

2.4.6 RIVERS AT THE BOTTOM OF THE OSAFJORD.

Two rivers flow to bottom of the Osafjord, northwest of the Simafjord. These rivers are River Austdøla and River Nordøla.

The gauging station 51.4 Øvre Austdalsvatn is located at River Austdøla with observations 1943-1980. The catchment characteristics are given in Table 2.4.8, the year, dates and ranks of the ten largest floods in Table 2.4.9 and the discharge of the largest observed flood in Table 2.4.10. Another gauging station in River Austdøla was 51.1 Lakjen. This station as active 1961-1975. The gauging station 51.3 Osseter was located at River Norddøla and was active 1961-1981. The two largest floods at Lakjen and Osseter occurred 8 July 1973 and 6 September 1966.

2.4.7 RIVER GRANVINSELV

River Granvinselv flows southward from the water divide toward Lake Granvinsvatn and the Granvinfjord. There have been some early observations at Lake Skjækervatn, but no data are available. Several of the large floods in Hardanger and in Vosso has also caused damages at Granvin. There has been a precipitation station at Granvin, where several heavy rainfall events, have been observed. Large floods, which are documented from historical sources, are listed in Table 2.4.10.

Table 2.4.10 Historical floods in River Granvinelv.

Year	Date	Remarks
1626		Flood and slides
1650		Severe flood
1667		Riverbank failure at Sævartveit
1723		Slides and flood at Røynstrand and Eide
1793	28-29/9	Severe flood. Damages at Indre and Ytre Tveito
1820	9/9	Flood in River Gauro at Lekve. Snowmelt and rainfall
1861	20/8	Rockfall at Lekve. 17 mills at the river destroyed.
1884	1/11	Severe flood - largest in the 19th Century
1888	27-29/10	Large flood in Rivers Granvinelv and Vosso
1918	11/10	Large rainfall flood - 129,7 mm observed at Granvin
1921	26/7	Flood caused by a thunderstorm
1923	12/9	Rainfall flood - 50 mm observed at Granvin
1926		A thunderstorm caused flood in River Brekkeelv
1931	4/10	Flood destroyed bridge at Klyve
1932	5/11	Flood in Rivers Granvinelv and Vosso
1938	13/11	Large flood in River Granvinelv after long duration rainfall
1939	19/7	Rainfall flood in River Granvinelv

2.4.8 RIVER TORDALSELV

River Tordalselv is a small river flowing southwards to the outer Hardangerfjord at Strandebarm. The gauging station 53.2 Fosse was active 1924-1939. An extreme flood was observed 29 November 1932. The discharge was 3062 l/sec km^2 corresponding to 264,5 mm/day. The flood occurred after some days with snowfall, which was succeeded by rising temperatures and heavy rainfall.

2.5 Nord-Hordaland, Voss and Gulen

This district comprises coastal catchments from the Bergen peninsula to the southern side of the inlet to the Sognefjord at Gulen in Sogn and the inland basin of River Vosso. The southernmost catchment, River Oselv, drains towards a branch of the Hardangerfjord. Further north and west are the city Bergen. An urban hydrological station is operating at Sandsli near the airport Flesland. Bergen has suffered repeatedly from urban flooding and slides such as the damages caused by the extreme weathers, Kristin and Loke in September and November 2005.

Most of the rivers further north has been regulated, such as the rivers at Vaksdal and Dale flowing towards the Sørfjord/Bolstadfjord/Osterfjord from the south and east. River Eksingedalselv, River Steinslandvassdraget and River Matreelv flows westwards from Stølheimen have also been regulated. The district is exposed to heavy rainfall, especially in the autumn and early winter. A daily rainfall of 100 mm occurs frequently.

2.5.1 RIVER OSELV

Oselva is a small catchment of 102 square kilometres located south on the Bergen penninsula. The river flows southwards towards Bjørnafjorden. The station 55.4 Røykenes has been operating since 1934. The annual floods (daily values) are shown in Figure 2.5.1. Catchment characteristics are listed in Table 2.4.7. The catchment is located at the coastal maximum rainfall zone and can have intense rainfall floods. The dates and ranks of the ten largest daily floods are given in Table 2.4.8, and the date and discharge of the largest annual flood (daily value) is given in Table 2.4.9.

The precipitation station 50350 Samnanger is located at the bottom of Fusafjord, northeast of the Oselv catchment. Several very heavy rainfall events has been observed at the station causing large floods in River Oselv. 156 mm rainfall was observed 10 October 1953 and 155 mm on the subsequent day causing a flood at Røykenes, which never has been exceeded even by the long duration rainstorm in 1940 or the extreme weathers Kristin and Loke in 2005.

The largest one-day flood occurred 10 October 1953 in River Oselv at Røykenes with a discharge of 144,07 m^3/sec corresponding to 2876 l/sec km^2 or to a runoff of 248,5 mm/d as a result of the extreme two-day rainfall of 311 mm at Samnanger. There are no high resolutions data from this flood. The second highest one day floods occurred in 2005 as a result of the extreme weather Kristin 14 September with the peak at 09:00 of 132,20 m^3/sec or 2639 l/sec km^2 and the extreme weather Loke 14 November at 17:30 with of 115,95 m^3/sec corresponding to 2315 l/sec km^2

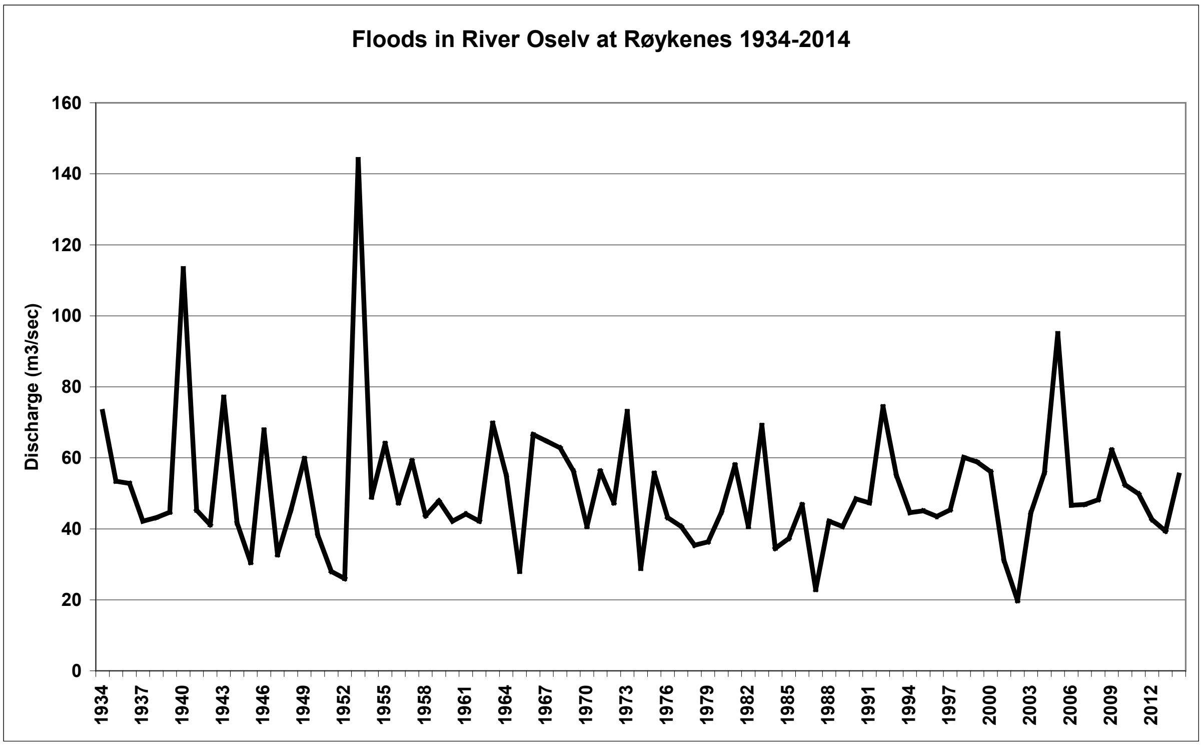


Figure 2.5.1 Annual floods (daily values) in River Oselv at Røykenes 1963-2014.

2.5.2 RIVERS IN BERGEN AND IN VAKSDAL AND DALE

The gauging station Sandsli has been active from 1984. There are some additional urban stations, which started to operate later. The precipitation has been observed at the longterm meteorological stations at Fredriksberg and at Florida. There has also been a net of precipitation stations operating for shorter periods.

River Sedalselv flows towards the Sørfjord at Vaksdal east of Bergen. There is a gauging station 61.7 Sedal, which was active 1944-1978. Catchment characteristics of this station are listed in Table 2.4.7, year, dates and rank of the ten largest floods are listed in Table 2.4.8 and the discharge of the largest flood in Table 2.4.9.

Further east the River Bergsdalselv flows towards the Bolstadfjord at Dale. The river is also regulated since 1963. The railway line and the main road E-16 runs along the fjord towards Voss. The railway line as well as the road are frequently been blocked by floods, landslides, rock falls and avalanches.

2.5.3 RIVER VOSSO

River Vosso flows into the bottom of the Bolstadfjord from southeast. The river has a catchment area of 1.489 square kilometres. The gauging station Bulken has been active since 1892. The data series is the longest at Vestlandet. The catchment is located some distance from the coast. Downstream is the village Evanger, which has suffered from large floods in River Vosso, most frequently in October 2014. There is a large lake, Vangsvatnet, extending from Bulken to Voss. There is a long-term precipitation series observed at 51470 Bulken, starting in 1895, and several other series starting later.

One tributary of Vosso runs eastwards through Raundalen from Lake Vangsvatnet along the railway line to Østlandet. This subcatchment has large floods because it is oriented towards the North Sea. Another tributary flow southward from Vikafjellet and into Vangsvatnet at Voss. The gauging station 62.5 Bulken at the outlet of Lake Vangsvatn has been operating since 1892 and has the longest continous dataseries in West Norway. The catchment area at Bulken is 1.102 square kilometres. Some earlier observations of the water levels exist from Vangsvatnet. Table 2.5.1 lists floods known from historical sources.

Table 2.5.1 Floods known from historical sources (Kanalvæsnets historie,1888; Kindem, 1933).

Year	Date	Remarks
1604		
1719	August	Extreme flood comparable with floods in 1743 and 1790
1743	4-5 December	Storflaumen
1745		Water into the church
1790		Extreme flood comparable with flood in 1743
1862		
1864		The post road was flooded
1871		
1873		The post road was flooded
1874		
1884		Water level 26 in. above the level in 1873
1888	2 November	Water levelas high as in 1873 and 5 in. above the level in 1918.

The effect of upstream regulations on the discharge is insignificant at Bulken, although changes in the outlet of Lake Vangsvatn has introduced inhomogeneities in the water level series. Catchment characteristics of the gauging station Bulken, the station Myrkdalsvatn in the tributary Strondaelva and the station Austmannshølen in the tributary from Raundalen are given in Table 2.5.2. The dates and ranks of the ten largest floods (daily values) are given in Table 2.5.3 and the date and discharge of the largest daily flood in Table 2.5.4.

Table 2.5.2 Catchment characteristics for three gauging stations in River Vosso.

Station	62.5 Bulken	62.6 Austmannshølen	62.10 Myrkdalsvatn
	Basin characteristics		
Catchment area (km^2)	1092,0	294,1	158,28
Station altitude (m.a.s.l.)	47	560	22,9
Mean altitude (m.a.s.l)	867	1129	975
Top altitude (m.a.s.l.)	1602	1602	1431
Lake (%)	3,54	4,41	3,68
Bog (%)	2,06	1,07	2,82
Forest (%)	32,42	9,02	14,39
Mountain (%)	53,98	80,9	72,3
Glacier (%)	0,39	0,62	0

The annual flood occurs most frequently from May to November. The spring flood occurs in May (12 percent) and June (22 percent). Most autumn floods occur in September (18 percent), October (15 percent) and November (12 percent).

Table 2.5.3 The year, date and the ranks of the ten largest observed floods in River Vosso.

62.5 Bulken			62.6 Austmannshølen			62.10 Myrkdalsvatn		
1892-2014			1909-1946,1963-1975			1964-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1917	3/10	4	1917	28/9	9	1967	3/8	8
1918	10/10	2	1918	10/10	1	1971	3/11	1
1950	8//6	7	1921	26/7	7	1981	23/5	4
1953	4/12	10	1928	18/9	3	1982	11/9	4
1954	14/9	9	1938	13/11	5	1985	28/5	10
1971	3/11	8	1943	6/10	4	1986	12/11	2
1989	27/6	3	1944	19/8	6	1989	26/6	7
1995	27/10	4	1965	21/9	10	1995	27/10	6
2005	14511	5	1969	12/9	8	2005	14/9	3
2014	29/10	1	1971	2/11	2	2014	28/10	9

Table 2.5.4 The date and discharge of the largest flood (daily values) observed at the three gauging stations in River Vosso.

Station	62.5 Bulken	62.6 Austmannshølen	62.10 Myrkdalsvatn
Year	2014	1918	1971
Date	28/10	10/10	3/11
q (m^3/sec)	669,57	539,57	189,84
qsp (l/sec km^2)	613	1368	1199
qsp (mm/day)	53,0	158,5	103,6

The peak discharge in 2014 occurred between 28 October 22:00 and 29 October 02:00 with 778,27 m^3/sec or 712,67 l/s km^2 at Bulken.

The annual floods (daily values) observed at Bulken 1892-2014 are shown in Figure 2.5.2.

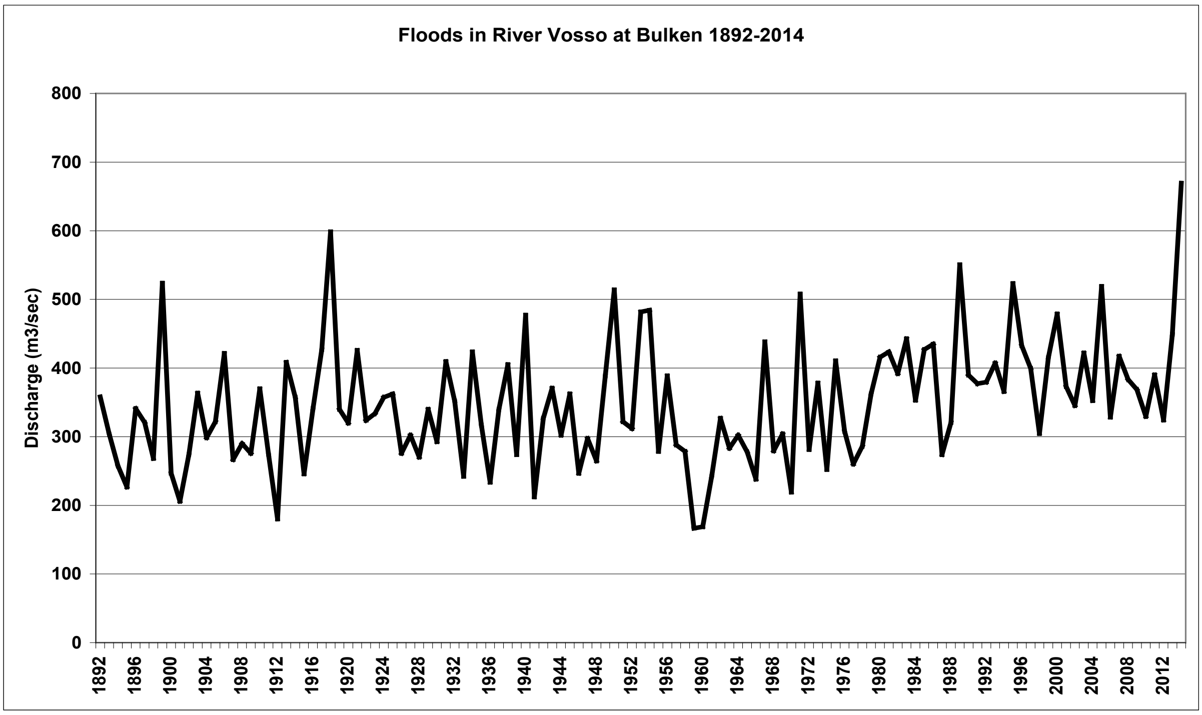


Figure 2.5.2 Annual floods (daily values) in River Vosso at Bulken (1892-2014).

2.5.4 RIVER EKSINGEDALSELV

River Eksingedalselv is located north of Vosso. The catchment area is 401 square kilometres.

The catchment comprises two gauging stations with longterm dataseries. The series at 63.1 Nese has data from 1908 to 1987. The catchment area of Nese is 345 square kilometres. The catchment was regulated in 1971. The catchment is located at the coastal rainfall maximum zone. Daily rainfall exceeding 100 mm has been observed many times at the met stations in Modalen, Haukedal, Matre and Masfjord near the coast. At further inland stations such as Eksingedal and Gullbrå the observed precipitation is lower. The annual flood occurs most frequently from June to November, peaking in September (21 percent), Octob and er (34 percent) and November (14 percent) of the years. Catchment characteristics for the three stations in River Eksingedal are shown in Table 2.5.5, the year, date and rankof the ten largest floods in Table 2.5.6 and the discharge of the largest flood in Table 2.5.7.

Table 2.5.5 Catchment characteristics of three gauging stations in River Eksingdalselv.

Station	63.1 Nese	63.2 Brakestad	63.3 Fosse
	Basin characteristics		
Catchment area (km^2)	345,53	223,66	260,45
Station altitude (m.a.s.l.)	258	496	414
Mean altitude (m.a.s.l)	914	964	945
Top altitude (m.a.s.l.)	1426	1426	1426
Lake (%)	7,11	9,21	8,55
Bog (%)	0,76	0,88	0,89
Forest (%)	9,17	2,69	5,54
Mountain (%)	79,32	85,79	82,75
Glacier (%)	0	0	0

Table 2.5.6 The year, date and the rank of the ten largest observed floods in River Eksingdalselv.

63.1 Nese			63.2 Brakestad			63.3 Fosse		
1909-1985			1935-1979			1935-1979		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1918	11/10	1	1937	7/9	10	1938	13/11	6
1925	1/10	10	1940	26/11	4	1940	26/11	2
1934	28/11	2	1942	11/9	9	1942	15/10	8
1937	7/9	7	1943	6/10	1	1943	6/10	1
1938	13/11	4	1948	4/12	3	1945	14/5	7
1940	26/11	3	1952	3/7	6	1950	8/6	9
1943	6/10	5	1953	10/10	5	1953	3/12	4
1953	10/10	8	1956	22/10	2	1956	22/10	3
1956	22/10	6	1971	10/1	7	1971	10/1	5
1980	23/1	9	1975	25/9	8	1975	23/9	9

Table 2.5.7 The date and discharge of the largest flood (daily values) observed at the three gauging stations in River Eksingedalselv.

Station	63.1 Nese	63.2 Brakestad	63.3 Fosse
Year	1918	1943	1943
Date	11/10	6/10	6/10
q (m^3/sec)	575,94	214,94	276,04
qsp (l/sec km^2)	1667	961	1060
qsp (mm/day)	144,0	83,0	91,6

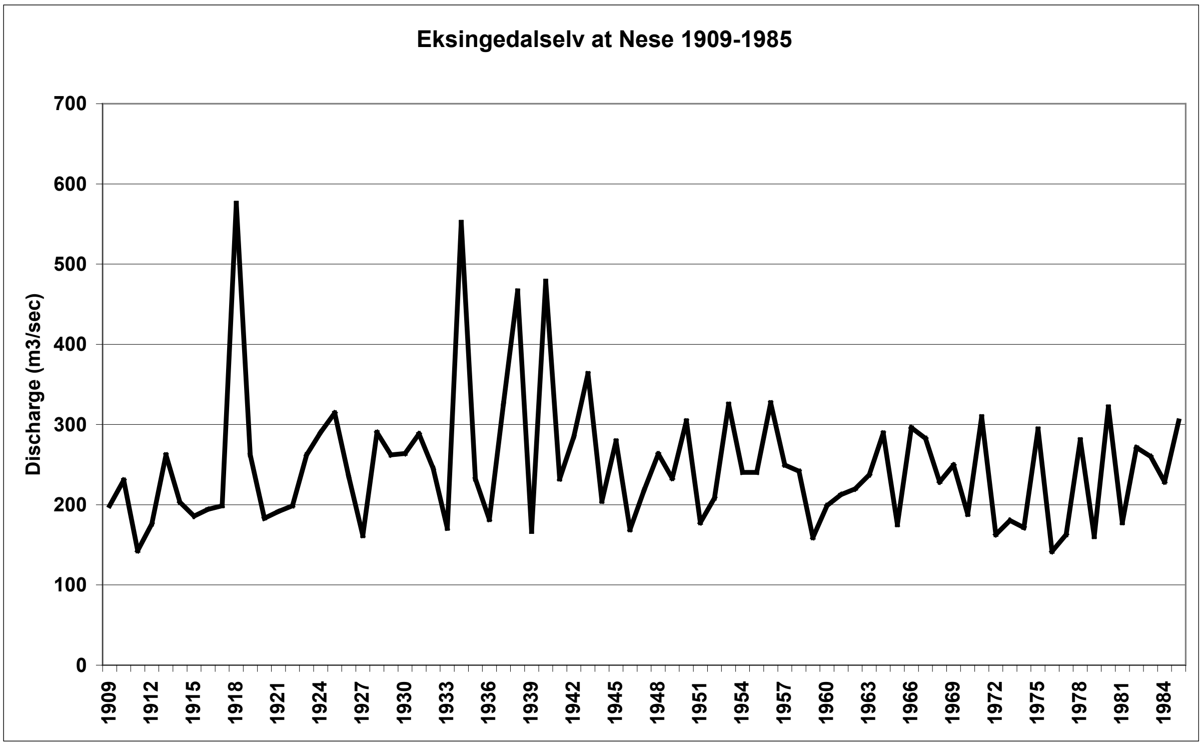


Figure 2.5.3 Annual floods (daily values) in River Eksingdalselv at Nese 1963-1985.

2.5.5 RIVER STEINSLANDSVASSDRAGET

River Steinslandsvassdraget is located at Stølsheimen and is strongly regulated. The river flows westwards to the bottom of Romarheimfjorden/Mofjorden at Modalen. The discharge was monitored at the gauging station 64.2 Steinslandsvatn 1945-1982. The precipitation station 52300 Modalen has been active since 1895, where many large rainfall events have been observed.

2.5.6 RIVER MATREELV

River Matreelv drains westwards from Stølsheimen to Masfjorden. There is a gauging station at 67.1 Fossevatn, which was active 1907-1961. Catchment characteristics are listed in Table 2.5.8, year, dates and ranks of the ten largest floods in Table 2.5.9 and the discharge of the largest daily flood in Table 2.5.10.There is a long-term precipitation station 52700 Masfjord, which has been active since 1895. Many of the large rainfall events observed at Modalen has also been observed at Masfjord.

2.5.7 RIVER HAVELANDSELV

River Havelandselv is located at Nordgulen west of Kløvtveitvatn. The gauging station 68.2 Havelandselv has been active 1964-1980 and 1998-2014. Catchment characteristics are listed in Table 2.5.8, year, dates and ranks of the ten largest floods in Table 2.5.9 and the discharge of the largest daily flood in Table 2.5.10. The catchment was regulated in 1971.

2.5.8 RIVER KLYVTVEITELV AT LAKE KLØVTVEITVATN

River Klyvtveitelv is a small watercourse located at Gulen. The river flows northward from Lake Klyvtveitvatn to the Austgulenfjord. The gauging station 68.1 Kløvtveitvatn is located at the coastal maximum precipitation zone just south of Sognefjord. Catchment characteristics are listed in Table 2.5.8, year, dates and ranks of the ten largest floods in Table 2.5.9 and the discharge of the largest daily flood in Table 2.5.10. Data observed prior to 1971 are unreliable, but the rank and dates of the larger floods seems to agree with data from other stations in the region. The catchment was regulated 23 March 2006. The station was dismantled 22 August 2006.

Three longterm precipitation stations are located within of 15 km of the station, 52700 Masfjorden, 52860 Takle and 52730 Brekke, all known for observing heavy rainfall. The largest one-day flood was observed 11 October 1953 of 3,19 m^3/sec corresponding to 714 l/sec km^2 or 61,7 m/d. The flood caused by the extreme weather *Loke* 15 November 2005 had a daily mean of 3,13 m^3/sec corresponding to 700 l/sec km^2 or 60,4 mm/d. The peak was however 3,53 m^3 /sec or 794 l/sec km^2 and may have exceeded the value in 1953. The annual floods (daily values) at Kløvtveitvatn is shown in Figure 2.5.4.

Table 2.5.8 Catchment characteristics of the three gauging stations in River Matreelv, Havelandselv and Klyvtveitelv.

Station	67.1 Fossevatn	68.2 Havelandselv	68.1 Kløvtveitvatn
	Basin characteristics		
Catchment area (km^2)	63,71	21,0	4,47
Station altitude (m.a.s.l.)	357	1	410
Mean altitude (m.a.s.l)	687	465	463
Top altitude (m.a.s.l.)	988	720	624
Lake (%)	17,2	4,33	21,48
Bog (%)	0,22	0,05	0,22
Forest (%)	20,6	20,19	23,94
Mountain (%)	58,23	50,38	53,91
Glacier (%)	0	0	0

Table 2.5.9 The year, date and the ranks of the ten largest observed floods (daily values) in River Matreelv, Havelandselv and Klyvtveitelv.

67.1 Fossevatn			68.2 Havelandselv			68.1 Kløvtveitvatn		
1917-1927,1933-1961			1964-1980,1998-2014			1922-2006		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1918	11/10	6	1966	3/6	3	1953	11/10	1
1920	13/11	8	1967	2/10	10	1975	25/9	2
1923	12/9	9	1969	16/10	9	1983	27/10	5
1934	28/11	4	1971	3/11	4	1986	11/11	6
1940	26/11	1	1972	25/1	2	1995	27/10	4
1948	18/9	10	1973	27/10	8	1997	2/3	8
1949	17/2	7	1975	16/9	7	1999	10/4	10
1953	2/12	5	1998	22/1	1	2000	8/1	9
1956	22/10	3	1999	9/4	6	2003	22/1	7
1957	9/1	2	2005	14/9	5	2005	15/11	3

Table 2.5.10 The date and discharge of the largest flood observed (daily values) at the three gauging stations in River Matreelv, Havelandselv and Klyvtveitelv.

Station	67.1 Fossevatn	68.2 Havelandselv	68.1 Kløvtveitvatn
Year	1940	1998	1953
Date	26/11	22/1	11/10
q (m^3/sec)	98,75	47,57	3,19
qsp (l/sec km^2)	1550	2265	714
qsp (mm/day)	133,1	195,7	67,7

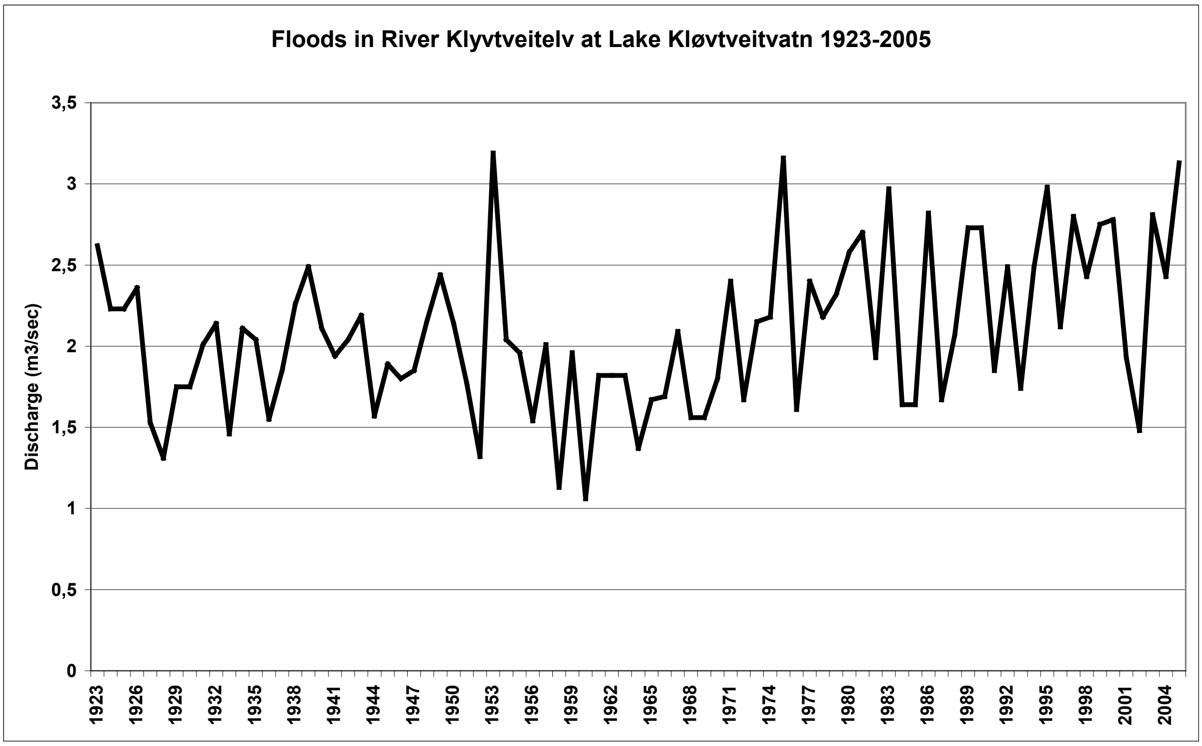


Figure 2.5.4 Annual floods (daily values) in River Kløvtveitelv at Lake Kløvtveitvatn 1922-2006.

2.6 Sogn

Sogn is the district on both sides of the Sognefjord. The outer part is exposed to heavy rainfall moving in from the North Sea and the Norwegian Sea. Many of the large events are caused by the weather type known as Atmospheric rivers. Meteorological stations such as Takle and Brekke are known for observing many large rainfall events similar to stations such as Masfjord and Modalen further south on the coast of Nordhordaland.

Several smaller rivers drain to the southern coast of the Sognefjord as described in Section 2.6.1. Further inland several large rivers such as River Flåmselv, River Aurlandselv, River Lærdøla, River Årdalselv and River Fortunelv flow to the bottom of the inner branches of Sognefjorden. These rivers flow from the water divide towards Østlandet in the mountains in Buskerud and Oppland north of the railway line to Bergen, Filefjell and Jotunheimen. The rivers are mostly regulated for hydropower production. They flow from a mountain plateau through steep and narrow valley. The mean altitude of these catchments is 1200- 1400 m.a.s.l. The catchments comprise some glaciers (3-4 percent), but mountains above the treeline comprise most of these catchments. The annual flood is therefore the spring flood and occurs most frequently in June. Some years the snow melting in the alpine districts are delayed. The annual flood occurs in July eller August in these years frequently simultaneously with floods in alpine catchments east of the water divide flowing towards the large rivers at Østlandet. These late mountain floods are usually smaller than the spring flood from the lower parts of the catchments at Østlandet. Mountain floods on both side of the water divide occurred in July 1914 and 1958. Large rainfall events har occasionally caused floods on both sides of the water divide late in the year. The annual flood occurred in these rivers in December 1743, August 1906, October 1913, 1956 and 1985.

Several longer rivers flow towards the fiord from the glaciers on the northern side of the Sognefjord, as described in Section 2.6.6-2.6.11.

2.6.1 RIVERS AT THE SOUTHERN SIDE OF THE SOGNEFJORD TO THE AURLANDSFJORD

Some small rivers are flowing northwards to the southern side of the Sognefjord from Gulen to the Aurlandfjord. These rivers origin at the northern flank of the district named Stølsheimen and are mostly regulated.

River Arnafjordvassdraget is located west of Vik versus Balestrand and Fjærlandsfjord to the north. A large rockfall caused by heavy rainfall 2 December 1811 at Nese at Arnafjord caused 45 fatalities.

River Dalselv flows from Fossfjellet northwestwards to the bottom to the Arnafjord east of Arnafjordvassdraget. A gauging station 70.8 Målset is located at the upper part of the catchment. The station has been active since 1987 and is not regulated.

River Hopra flows from Liahovden to the sea at Svoldvik west of Viksøyri. The gauging station 70.7 Tistel has been active 1969-1988. The series have several gaps.

River Feioselv flows into the fjord at Feios east of Vangsnes. This river flows northwards from the Fresvik glacier. The station 71.5 Feios was active from 1972 to October 2007, when a flood destroyed the station. The river has been regulated since 1972, when some upper parts of the catchment of Nærøydalsfjord was diverted into the Feios catchment.

Catchment characteristics of the three stations are given in Table 2.6.1, the date and rank of the ten largest annual floods (daily values) in Table 2.6.2 and the date and discharge of the largest flood in Table 6.3.

Table 2.6.1 Catchment characteristics of the gauging stations Målset, Tistel and Feios.

Station	70.8 Målset	70.7 Tistel	71.5 Feios
	Basin characteristics		
Catchment area (km^2)	7,71	15,92	74,66
Station altitude (m.a.s.l.)	870	350	55
Mean altitude (m.a.s.l)	1079	837	932
Top altitude (m.a.s.l.)	1365	1151	1635
Lake (%)	8,82	0,5	0,76
Bog (%)	24,6	0,88	0,78
Forest (%)	0	45,85	36,61
Mountain (%)	88,2	46,55	49,84
Glacier (%)	0	0	2,97

Table 2.6.2 The date and rank of the ten largest annual floods at Målset, Tistel and Feios.

70.8 Målset			70.7 Tistel			71.5 Feios		
1987-2014			1969-1988			1972-2007		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1995	26/10	3	1969	29/9	6	1978	6/11	8
1996	12/10	9	1971	2/11	2	1979	19/9	6
1997	8/6	7	1973	4/9	1	1980	23/11	3
1999	20/6	5	1974	17/9	10	1981	13/5	4
2000	18/5	10	1976	28/3	7	1982	9/9	2
2004	7/5	8	1978	24/5	5	1983	16/8	5
2005	14/11	6	1979	1/6	7	1990	19/3	10
2007	28/10	4	1980	23/11	4	1995	19/10	7
2011	28/6	2	1985	15/9	7	2003	25/9	9
2014	28/10	1	1988	30/12	3	2005	14/11	1

Table 2.6.3 The date and discharge of the largest flood at Målset, Tistel and Feios.

Station	70.8 Målset	70.7 Tistel	71.5 Feios
Year	2014	1973	2005
Date	28/10	4/9	14/11
q (m^3/sec)	8,00	10,69	66,40
qsp (l/sec km^2)	1037	671	889
qsp (mm/day)	89,6	58,0	76,8

2.6.2 RIVER AURLANDSELV AND RIVER FLÅMSELV

River Aurlandselv flows westward from the water divide towards River Drammenselv to the Aurland fjord. The catchment area is 772 square kilometres. The catchment is strongly regulated. The gauging station 72.7 Vassbygdvatn has been operating from 1900 to 1980, when the river was regulated. Precipitation data are observed at 53700 Aurland. Some historical floods were caused by slides damming River Storelva or its tributaries.

River Flåmselv flows northwards to Aurlandsfjorden. The gauging station 72.5 Brekke bru has been operating since 1908. The rating curve was established in 1939. Estimation of the discharge in earlier years based on observed water levels is therefore uncertain. The annual flood occurs from May to October, most frequently in June (35 percent) and July (21 percent). Autumn floods caused by heavy rainfall, often combined with some snowmelt, happens most frequently in September (11 percent) and October (14 percent). Data from 53410 Myrdal show that one-day precipitation events exceeding100 mm are not uncommon in the upper part of the catchment.

River Nærøydalselv flows eastwards to the bottom of Nærøyfjorden at Gudvangen. The gauging station 71.1 Skjerping has data in 1908-1938 and 1969-2012. Precipitation data is now observed at 53160 Jordalen-Nåsen. The river was regulated in 1972, when part of the catchment was diverted to the Feios watercourse. Rockfalls, landslides and avalanches occur frequently, which has dammed the river at several occasions. Catchment characteristics of the three gauging stations are listed in Table 2.6.4, the largest floods in Aurland known from historical sources in Table 2.6.5, the date and rank of the ten largest annual floods in Table 2.6.6 and the date and discharge of the largest flood in Table 2.6.7.

Table 2.6.4 Catchment characteristics of stations in Aurlandselvi, Flåmselvi and Nærøydalselvi.

Station	72.7 Vassbygdvatn	72.5 Brekke bru	71.1 Skjerping
	Basin characteristics		
Catchment area (km^2)	758,8	277,2	267,8
Station altitude (m.a.s.l.)	54	16	60
Mean altitude (m.a.s.l)	1441	1273	969
Top altitude (m.a.s.l.)	1764	1761	1602
Lake (%)	11,2	4,18	0,81
Bog (%)	0,12	0,46	2,71
Forest (%)	5,5	11,27	20
Mountain (%)	79,16	77,15	72,93
Glacier (%)	2,3	3,07	0,11

Table 2.6.5 Large floods in Aurland known from historical sources (Ohnstad, 1962)

Year	Date	Remarks
1666/67		Large flood in River Nærøyelv at Hylland
1682		Flood at Tokvam
1695		Flood at Hjøllo in Undredal
1720		Flood at Skjerping in River Nærøyelv
1739		Landslids and rockfall caused by snowmelt and rainfall dammed River Aurlandselv which shifted to a new bed.
1743		Storflaumen damaged the priests farm at Aurland
1752		River Tverrelva in Aurland dammed by slides forcing flooding of farmland.
1793		Floods and slides at Brekke in Flåm.
1799		Floods and slides at Brekke in Flåm
1826	11/7	Flood in River Aurlandselv as in Årdal and Lærdal
1879	Early summer	Snow and meltwater caused flom damages at Styvi in Nærøy as a snowdam burst.

Table 2.6.6 The year, dates and ranks of the ten largest obserloods (daily values) at gauging stations in Aurlandselvi, Flåmselvi and Nærøydalselvi.

72.7 Vassbygdvatn			72.5 Brekke bru			71.1 Skjerping		
1908-1980			1915-2014			1908-1938 1969-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1910	14/6	10	1921	26/7	2	1917	28/9	8
1914	6/7	2	1928	18/9	8	1919	26/9	1
1924	20/7	9	1950	7/6	10	1928	18/9	5
1927	3/8	8	1956	22/10	4	1929	24/10	6
1933	26/6	6	1966	7/9	7	1931	4/11	8
1939	20/6	1	1981	22/5	9	1938	13/11	1
1958	2/6	3	1984	31/8	6	1971	10/1	7
1964	15/6	7	1985	1/10	1	1974	11/9	10
1968	4/7	5	1989	28/6	5	1989	26/6	4
1973	8/7	4	2014	28/10	3	2014	28/10	2

Table 2.6.7 The date and discharge of the largest flood observed (daily values) at the three gauging stations in River Aurlandselv, Flåmselv and Nærøydalselv.

	72.7 Vassbygdvatn	72.5 Brekke bru	71.1 Skjerping
Year	1939	1985	1919
Date	20/6	1/10	26/9
q (m^3/sec)	571,43	193,37	291,35
qsp (l/sec km^2)	753	721	1088
qsp (mm/day)	65,1	62,3	94,0

20

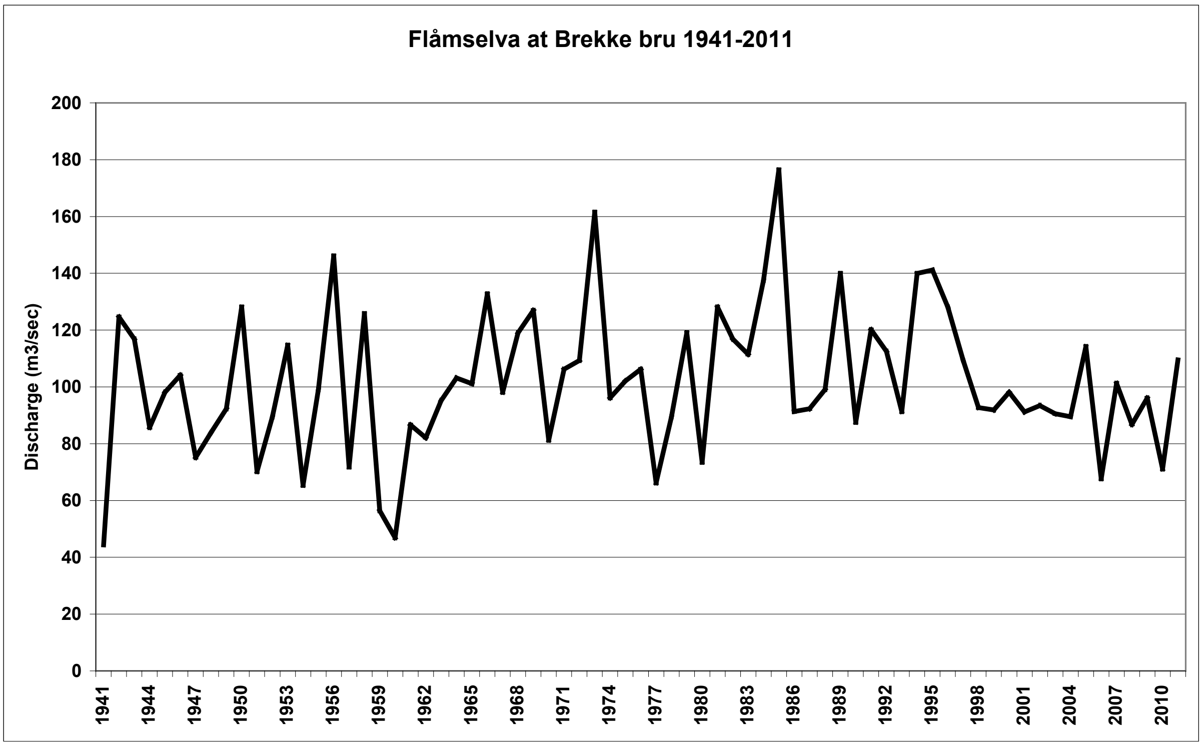


Figure 2.6.1 Annual floods (daily values) in River Flåmselv at Brekke bru 1941-2013.

2.6.3 RIVER LÆRDØLA

River Lærdalselv has a catchment area of 1.173 square kilometres. The top of the catchment extends into Valdres. Some observations of water levels exist back to the late 19th Century. The gauging station 73.4 Sælthun has been operating from 1962, but the discharge is strongly modified after the regulation in 1972.

The water level was observed at 73.39 Voll bru 1883-1916 and at 73.40 Øye bru 1884-1901. These data are not on Hydra II, but they have been published in Vannstandsobservasjoner i Norge and give some information of floods prior to the later observations at Lo bru.

The discharge has been observed at 73.1 Lo bru from 1916 to 2014. Data observed later than in 1972 is strongly modified by the hydropower regulation. The annual flood occurs most frequently in June (61,5 percent) and July (10,4 percent) of all years.

A research basin was established in the upper part of River Lærdøla at for the International Hydrological Decade in 1966. Discharge was observed at the gauging station Nedre Smedalsvatn 1966-1983 in the main river as well as in several tributaries. Presently, the discharge is monitored at the gauging station 73.27 Sula. The research basin includes a meteorological station 54750 Varden-Filefjell and snow pillows.

Large floods known from historical sources are listed in Table 2.6.8 (Laberg, 1938). Catchment characteristics of the three gauging stations Lo bru, Sælthun and Sula are given in Table 2.6.9, the date and rank of the ten largest annual floods in Table 2.6.10 and the date and discharge of the largest flood in Table 2.6.11.

Table 2.6.8 Floods in River Lærdalselv known from historical sources.

Year	Date	Remarks
1647		Damages at Moldo
1665/66		Damages at Hauge
1692	Autumn	Extreme flood
1721		Damages at Stønjum
1743	December	Damages at Stønjum
1826	11/7	Storeflaumen in River Årdalselv
1860	18-20/6	Road damaged at Galdane
1873	9/12	Damages at Tønjum and Borlaug
1879	Early June	Damages at Grøtøyane and Haugshaugen
1882		Flood damages
1889	30/5	Flood at Voll bru
1895	21/6	Flood at Voll bru
1897	27-29/5	Flood at Øye bru
1906	24/6	Flood at Voll bru and Stønjum

Table 2.6.9 Catchment characteristics of three stations in River Lærdalselv.

Station	73.1 Lo bru	73.4 Sælthun	73.27 Sula
	Basin characteristics		
Catchment area (km^2)	562,39	789,96	57,32
Station altitude (m.a.s.l.)	409	188	1006
Mean altitude (m.a.s.l)	1324	1375	1349
Top altitude (m.a.s.l.)	1917	1917	1808
Lake (%)	7,81	6,71	9,41
Bog (%)	1	0,72	0,56
Forest (%)	9,37	10,85	0,13
Mountain (%)	77,98	78,23	89,48
Glacier (%)	0,3	0,26	0,43

Table 2.6.10 The year, dates and ranks of the ten largest observed floods (daily values) at gauging stations in River Lærdalselv.

73.1 Lo bru			73.4 Sælthun			73.27 Sula		
1916-2014			1962-2014			1967-1982,1991-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1917	19/6	10	1963	29/5	7	1968	14/6	4
1920	21/6	1	1967	207	6	1971	31/5	1
1923	12/7	4	1968	3/7	5	1972	7/6	2
1924	22/6	2	1971	31/5	2	1973	8/6	9
1925	11/6	7	1972	7/6	1	1979	3/6	7
1926	10/6	8	1973	1/6	4	1997	2/6	10
1927	29/6	6	1984	28/5	10	1999	29/6	5
1938	1/9	9	1999	29/6	8	2004	7/5	3
1939	20/6	3	2004	7/5	3	2007	4/7	8
1945	26/6	5	2011	11/6	9	2011	10/6	6

Table 2.6.11 The date and discharge of the largest flood observed (daily values) at the three gauging stations in River Lærdalselv.

Station	73.1 Lo bru	73.4 Sælthun	73.27 Sula
Year	1920	1972	1971
Date	21/6	7/6	31/5
q (m^3/sec)	316,46	391,14	20,15
qsp (l/sec km^2)	563	495	665
qsp (mm/day)	48,6	42,8	57,3

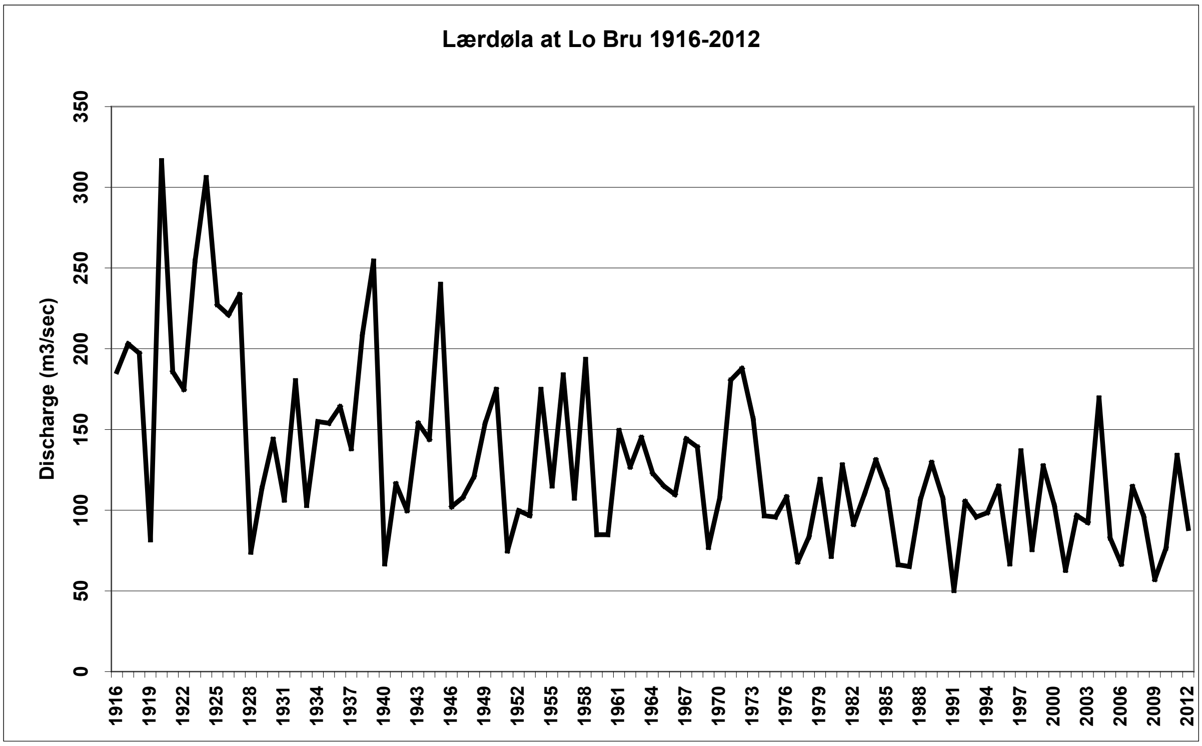


Figure 2.6.2 Annual floods in River Lærdøla at Lo bru.

2.6.4 RIVER ÅRDALSELV

The gauging station in River Årdalselv is located at Lake Årdalsvatn between lower Årdal at the bottom of the Årdalsfjord and upper Årdal where River Tya flowing westward from Lake Tyin and River Utla flowing southwards from Sognefjellet join before they flow into Lake Årdalsvatn. The observations at 74.1 Lake Årdalsvatn commenced in 1900. According to a local tradition, there is an old flood mark after a large flood near the marina at upper Årdal. It is unclear whether this mark indicates dates from the flood in 1826 or 1860. River Årdalselv is regulated with a large reservoir in Lake Tyin. Two gauging stations with shorter series exist at 74.15 Utla with data from 1972 and 74.16 Langedalen with data from 1973. The large flood Vettisfoss (m) falls into River Utla from the east. This waterfall origins in Jotunherimen and is protected against regulation. Some large floods are described in Ve (1971). These floods are listed in Table 2.6.12. Table 2.6.13 comprise catchment characteristics of these three catchments. The date and rank of the ten largest annual floods at the three stations is given in Table 2.6.14 and the date and discharge of the largest flood are given in Table 2.6.15. The annual floods (daily values) observed in Årdalsvatn is shown in Figure 2.6.3.

Table 2.6.12 Historical floods in River Årdalselv (Ve, 1971).

Year	Date	Remarks
1743	December	Storflaumen
1826	11 July	Tya, Utla and Fardøla, probably close to the flood in 1860
1854	24 June	Erosion of farmland by River Sitla
1860	June	Worst known flood especially in River Tya
1873	8-9 December	Avalanches and floods
1879	Early summer	Large floods in Rivers Tya and Utla
1906	22-24 November	Severe damages at Rivers Seimdalselv, Hæreidselv and at Breiskarjuvet

Table 2.6.13 Catchment characteristics of three gauging stations in River Årdalselva.

Station	74.1 Årdalsvatn	74.15 Utla	74.16 Langedalen
	Basin characteristics		
Catchment area (km^2)	978,69	439,54	23,8
Station altitude (m.a.s.l.)	3	48	1078
Mean altitude (m.a.s.l)	1281	1354	1328
Top altitude (m.a.s.l.)	2385	2385	1589
Lake (%)	7,44	1,76	4,2
Bog (%)	0,41	0,28	0,6
Forest (%)	11,28	11,63	0
Mountain (%)	73,8	77,89	4,2
Glacier (%)	3,84	6,44	0

Table 2.6.14 The year, date and rank of the 10 largest annual floods (daily values) at the three stations in River Årdalselv.

74.1 Årdalsvatn			74.15 Utla			74.16 Langedalen		
1901-1961,1971-2014			1972-2014			1973-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1906	16/8	2	1972	7/6	3	1973	8/7	4
1913	18/10	10	1973	8/7	3	1979	25/6	8
1914	6/7	3	1983	2/8	1	1983	2/8	10
1920	22/6	7	1985	1/10	10	1985	1/10	3
1939	20/6	1	1993	13/7	8	1986	11/6	9
1945	25/6	7	1999	29/6	7	1987	6/7	5
1956	22/10	6	2004	7/5	6	1992	23/9	6
1958	1/7	7	2005	4/7	5	2007	18/7	7
1985	1/10	4	2011	11/6	2	2013	10/5	1
2011	11/6	5	2014	28/10	9	2014	28/10	2

Table 2.6.15 The date and discharge of largest annual flood (daily values) at the three stations in River Årdalselv.

Station	74.1 Årdalsvatn	74.15 Utla	74.16 Langedalen
Year	1939	1983	2013
Date	20/6	2/8	10/5
q (m^3/sec)	569,91	254,79	43,29
qsp (l/sec km^2)	582	580	1819
qsp (mm/day)	50,3	50,1	157,1

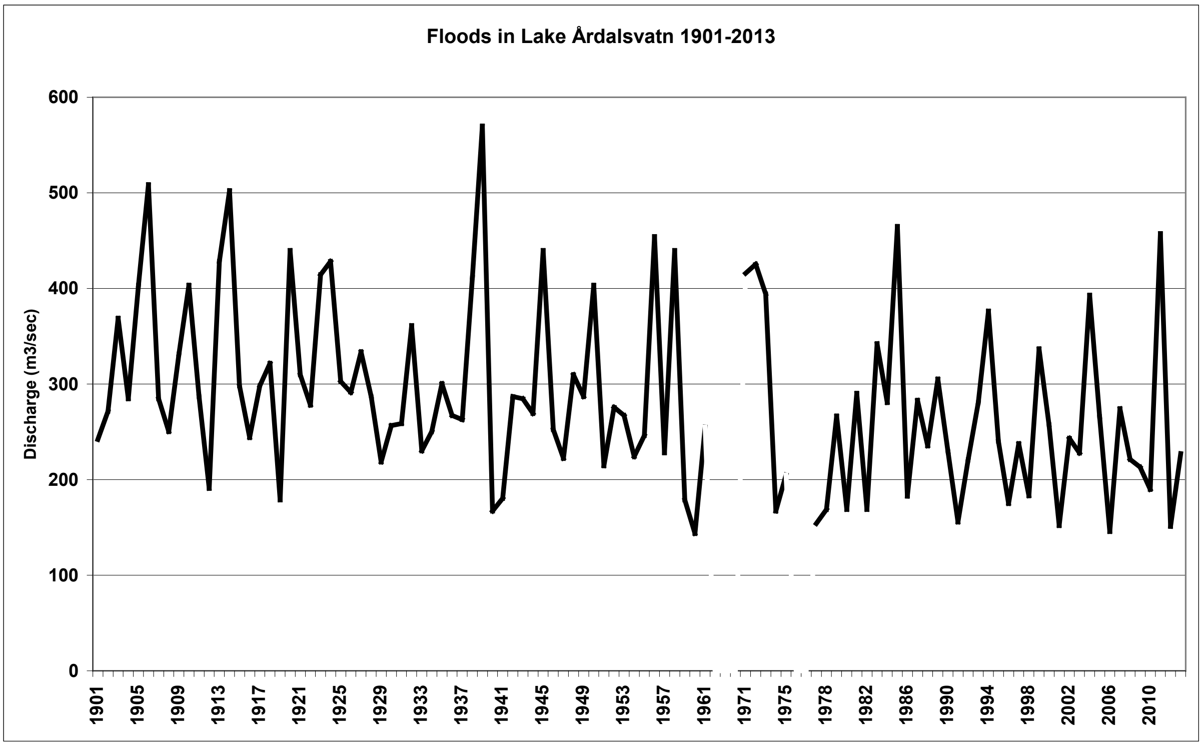


Figure 2.6.3 Annual floods (daily values) in River Årdalselv at Lake Årdalsvatn 1934-2013.

2.6.5 RIVER KROKENELV

River Krokenelv is a small catchment located on the southeastern side of Lusterfjord in Sogn. The catchment characteristics is listed in Table 2.6.16. The station has been operating since 1965 and is not affected by regulations. The annual floods are typically spring floods and has occurred in 30 percent of all years in April, 49 percent in May and 6,7 percent in July. The annual flood has occurred in 6,7 percent of all years in October and November and once in December. The date and rank of the ten largest annual floods are listed in Table 2.6.17 and the date and discharge of the largest flood in Table 2.6.18.

Table 2.6.16 Catchment characteristics of the gauging stations 75.2 Ytri bru, 75.22 Gilja and 75.23 Krokenelv.

Station	75.2 Ytri bru	75.22 Gilja	75.23 Krokenelv
	Basin characteristics		
Catchment area (km^2)	369,47	203,4	45,92
Station altitude (m.a.s.l.)	39	99	17
Mean altitude (m.a.s.l)	1383	1364	1148
Top altitude (m.a.s.l.)	2062	2012	1467
Lake (%)	8,18	3,2	0,98
Bog (%)	0,02	0,13	0,3
Forest (%)	5,96	5,51	16,2
Mountain (%)	75,28	75,96	78,22
Glacier (%)	8,48	13,78	0

Table 2.6.17 The date and rank of the 10 largest annual floods (daily values) at the three stations at 75.2 Ytri bru, 75.22 Gilja and 75.23 Krokenelv.

75.2 Ytri bru			75.22 Gilja			75.23 Krokenelv		
1918-1980			1964-2014			1965-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1920	22/6	6	1967	3/8	4	1967	30/5	4
1921	7/10	2	1968	3/7	9	1968	6/6	5
1923	17/7	4	1972	7/6	4	1969	12/9	5
1928	15/7	5	1973	8/7	2	1971	29/5	1
1932	7/7	1	1979	1/6	10	1979	1/6	5
1939	20/6	3	1985	1/10	6	1981	23/5	10
1942	18/8	8	1997	30/8	8	1985	1/10	2
1948	17/6	8	2002	10/7	7	1987	6/7	8
1950	8/6	8	2010	7/10	1	1994	24/9	3
1952	11/7	7	2014	28/10	3	2011	9/6	9

Table 2.6.18 The date and discharge of largest annual flood (daily values) at the three stations 75.2 Ytri bru, 75.22 Gilja and 75.23 Krokenelv.

Station	75.2 Ytri bru	75.22 Gilja	75.23 Krokenelv
Year	1932	2010 *	1971
Date	7/7	7/10	29/5
q (m^3/sec)	200,37	208,74	62,71
qsp (l/sec km^2)	542	1026	1366
qsp (mm/day)	48,9	88,6	118,0

* Peak value 355 m^3/sec because of glacial outburst

2.6.6 RIVER MØRKRIDSDALSELV AT GILJA

River Mørkridselv flows southwards from two large and some smaller glaciers towards Lusterfjord. East of the water divide flows River Fortunselv to Skjolden and further west the Jostedøla flows towards Gaupne and the Lustrafjord.

The gauging station 75.22 Gilja has been active since 1965. Catchment characteristics are listed in Table 2.6.16. The flood regime is alpine and affected by the Spørteggbre and Habardsbre glaciers. The dates and ranks of the ten largest annual floods are given in Table 2.6.17, the date and discharge of the largest flood in Table 2.6.18.

The annual flood has occurred in 6,4 percent of all years in April, 30 percent in May and June, 17 percent in August, 10,6 percent in September and 6,4 percent in October.

The peak 7 October 2010 was estimated to 355 m^3/s, corresponding to 1745 l/sec km^2. Two bridges and the datalogger were lost because of the flood. The largest one-day flood was estimated to 208 m^3/sec corresponding to 1026 l/sec km^2 or to a runoff of 88,6 mm/d.

2.6.7 RIVER JOSTEDØLA

Jostedalen is strongly affected by the huge Jostedalen glacier to the west. The earliest observations were done from 1949 to 1988 at the gauging station 76.1 Kroken.

The station in Lake Nigardsbrevatn is located at Jostedalen downstream the Nigardsbre glacier. River Nigardselva is a tributary to River Jostedøla. The glacier Nigardsbreen has retreated dramatically since its maximum extension during the Little Ice Age in the 1740ies. The gauging station 76.1 Kroken was established in 1949 and was active until 1988, although with some gaps in the records. The data quality was, however, very bad because of the large sediment transport and unstable controlling profile in the river. The discharge has been observed at the gauging station. The annual flood occurs in the late summer; in 35 percent of all years in July, 50 percent in August and 12,5 percent in September. The gauging station 76.5 Nigardsbrevatn was established in 1962 at the outlet of Lake Nigardsvatn. Another station 76.10 Myklemyr further downstream in the main river has been active since 1979. A tributary Vigdøla join the main river from the east near Myklemyr. The gauging station 76.11 Vigdøla has been active since 1980. The gauging station 76.4 Leirdal was also operating in Leirdalen downstream Tunsbergdalsbreen in Jostedalen, before River Leirelva was regulated. Prior to the regulation this river had a number large jøkullhlaup from Brimkjelen causing floods in Jostedøla as shown in Table 2.6.19.

Jostedalen was very badly affected during the little Ice age from advancing glaciers, floods, avalanches and rockslides. The damages in the 1740'ies were assessed several times. Deductions of the value of the farms were granted. Hoel 2012 has documented the deductions at five farms in Jostedalen in August 1742. The water level of a large flood in 1898 is known from historical sources at a location near Myklemyr.

Table 2.6.19 Jökullhlaup in Jostedalen from Brimkjelen.

Year	Date	Volume (mill m3)
1898	End of July	Unknown
1903	22.-23July	2
1926	14. August	15-30
1937	After 18. July	18
1938	23. August	10
1947	Before 28. August	Unknown
1954	Before 24. August	Unknown
1957	Before 6. August	4,2
1966	Before 28. July	5,3
1973	Before 27. July	2,5
1973	11. August	0,2

Catchment characteristics of the three stations Myklemyr, Nigardsbrevatn og Vigdøla are listed in Table 2.6.20, the dates and ranks of the ten largest annual floods (daily values) in Table 2.6.21 and the date and discharge of the largest flood in Table 2.6.22. The annual floods from Lake Nigardsvatn 1962-2014 are shown in Figure 2.6.4.

Table 2.6.20 Catchment characteristics of gauging stations in Jostedøla.

Station	76.10 Myklemyr	76.5 Nigardsbrevatn	76.11 Vigdøla
	Basin characteristics		
Catchment area (km^2)	575,82	65,29	45,45
Station altitude (m.a.s.l.)	89	285	643
Mean altitude (m.a.s.l)	1323	1546	1324
Top altitude (m.a.s.l.)	2081	1946	1740
Lake (%)	3,16	0,81	2,88
Bog (%)	0,07	0,0	1,03
Forest (%)	13,2	1,27	5,87
Mountain (%)	47,37	18,92	69,61
Glacier (%)	31,06	74,9	19,82

Table 2.6.21 The year, dates and ranks of the ten largest observed floods (daily values) at three gauging stations in Jostedalen.

76.10 Myklemyr			76.5 Nigardsbrevatn			76.11 Vigdøla		
1979-2014			1962-2014			1980-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1979	15/8	1	1969	30/7	8	1980	20/6,8/9	5
1981	1/10	10	1970	25/6	10	1981	1/10	5
1985	1/10	3	1979	15/8	2	1982	27/9	4
1989	21/9	6	1997	30/8	1	1983	2/8	9
1997	30/8	2	2003	15/8	9	1985	1/10	1
2007	15/8	8	2005	21/7	5	1986	19/6	3
2009	1/9	9	2007	15/8	6	1987	6/7	5
2010	22/7	5	2010	22/7	4	1989	26/6	2
2011	29/6	4	2011	28/8	7	1997	30/8	8
2014	28/10	7	2014	6/8	3	2007	28/10	10

Table 2.6.22 The date and discharge of largest annual flood (daily values) at the three stations in Jostedøla.

Station	76.10 Myklemyr	76.5 Nigardsbrevatn	76.11 Vigdøla
Year	1979	1997	1985
Date	15/8	30/8	1/10
q (m^3/sec)	409,09	64,02	28,61
qsp (l/sec km^2)	711	981	629
qsp (mm/day)	61,4	84,7	54,4

The largest one-day flood occurred in Lake Nigardsbrevatn 30 August 1997 with a discharge of 64,02 m^3/sec corresponding to 981 l/sec km^2 or to a runoff of 84,7 mm/day. The second largest flood was the extreme flood in August 1979 which caused severe damages inJostedalen. The flood caused by the remnants of hurricane Faith 7 September 1966 caused, however, only a minor flood, because the inner Jostedal was protected from the heavy rainfall.

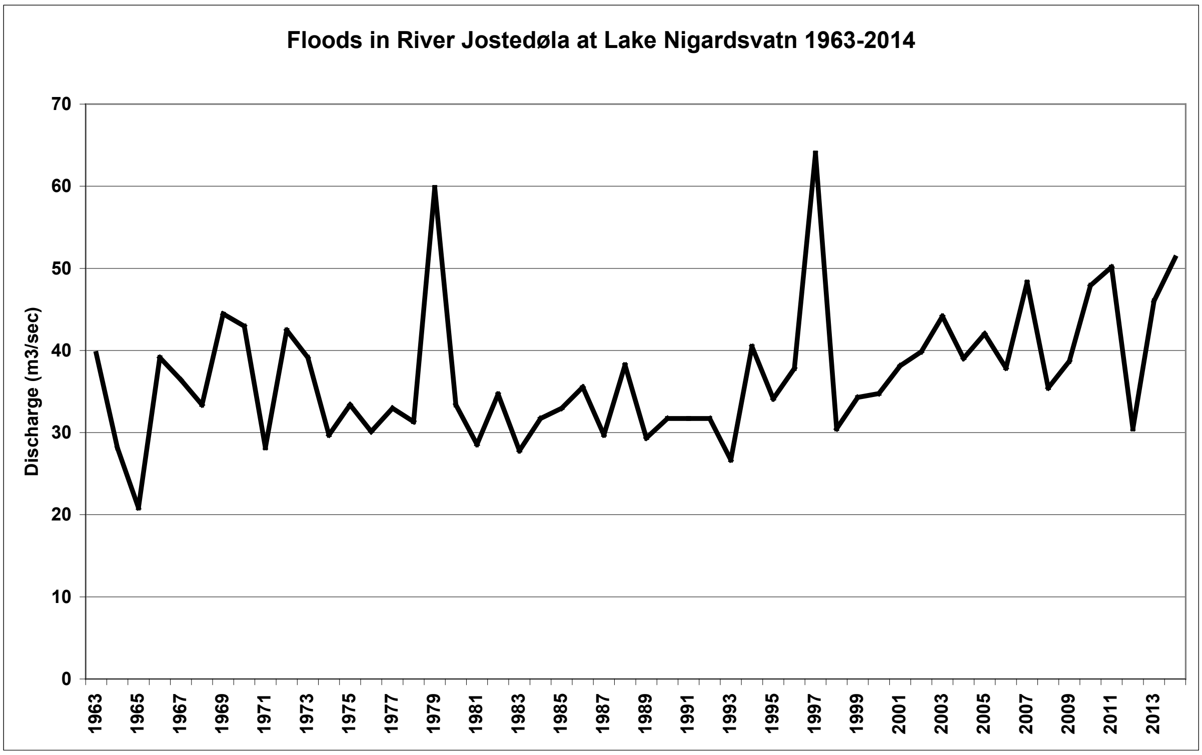


Figure 2.6.4 Annual floods (daily values) in River Jostedøla at Lake Nigardsbrevatn 1963-2014.

2.6.8 RIVER ÅRØYELV AT LAKE VEITESTRANDVATN

The gauging station 77.1 Veitestrandvatn in River Årøyelv has data from 1900 to 1982. The lake was regulated 29.10.1982. Catchment characteristics are given in Table 2.6.23, the dates and ranks of the ten largest floods in Table 2.6.24 and the discharge (daily values) of the largest observed flood in Table 2.6.25. Figure 2.6.5 show observed annual floods (daily values) observed at Veitestrandvatn 1900-1981. The annual flood occurs 17 percent of all years in June, 43 percent in July, 26 percent in August and 9 percent in September.

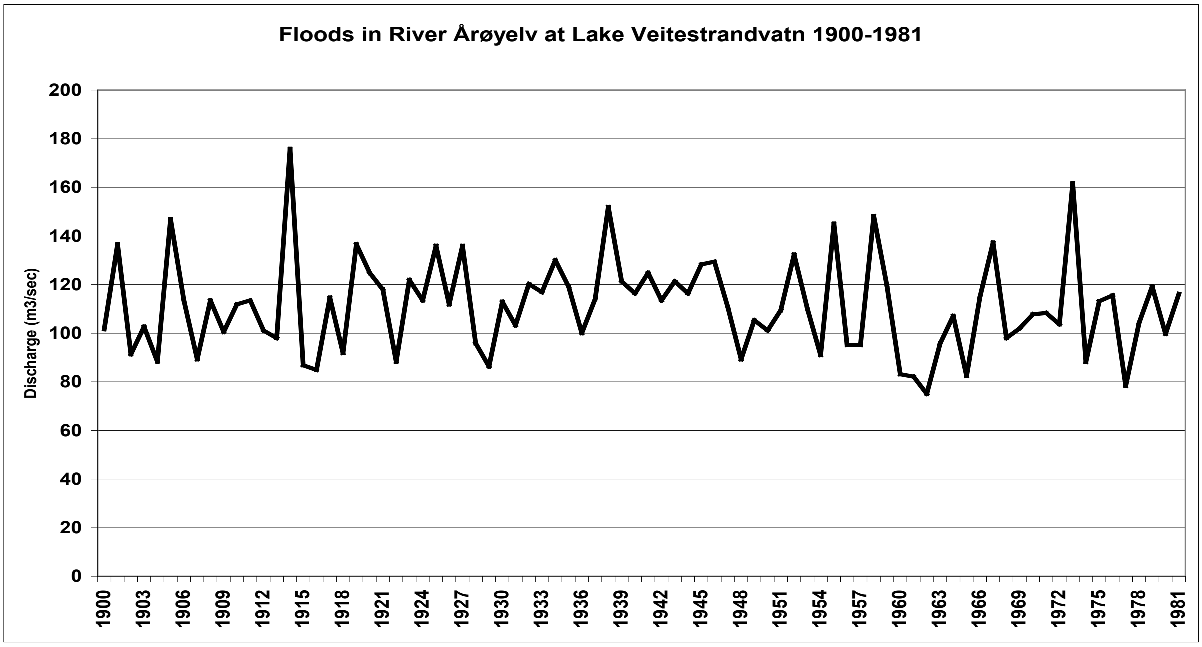


Figure 2.6.5 Annual floods (daily values) at Lake Veitestrandvatn

2.6.9 RIVER SOGNDALSELV AT LAKE SOGNDALSVATN

The gauging station 77.3 Sogndalsvatn has been operating since 1962. Catchment characteristics are given in Table 2.6.23, the dates and ranks of the ten largest floods in Table 2.6.24 and the discharge (daily values) of the largest observed flood in Table 2.6.25. Figure 2.6.6 show observed annual floods (daily values) observed at Sogndalsvatn 1963-2014.

The dominant flood season is in the summer and autumn. The annual flood has occurred in 16,3 percent of all years in May, 26,5 percent in June, 6,1 percent in July, 24,5 percent in September, 18,4 percent in October and 4,1 percent in November.

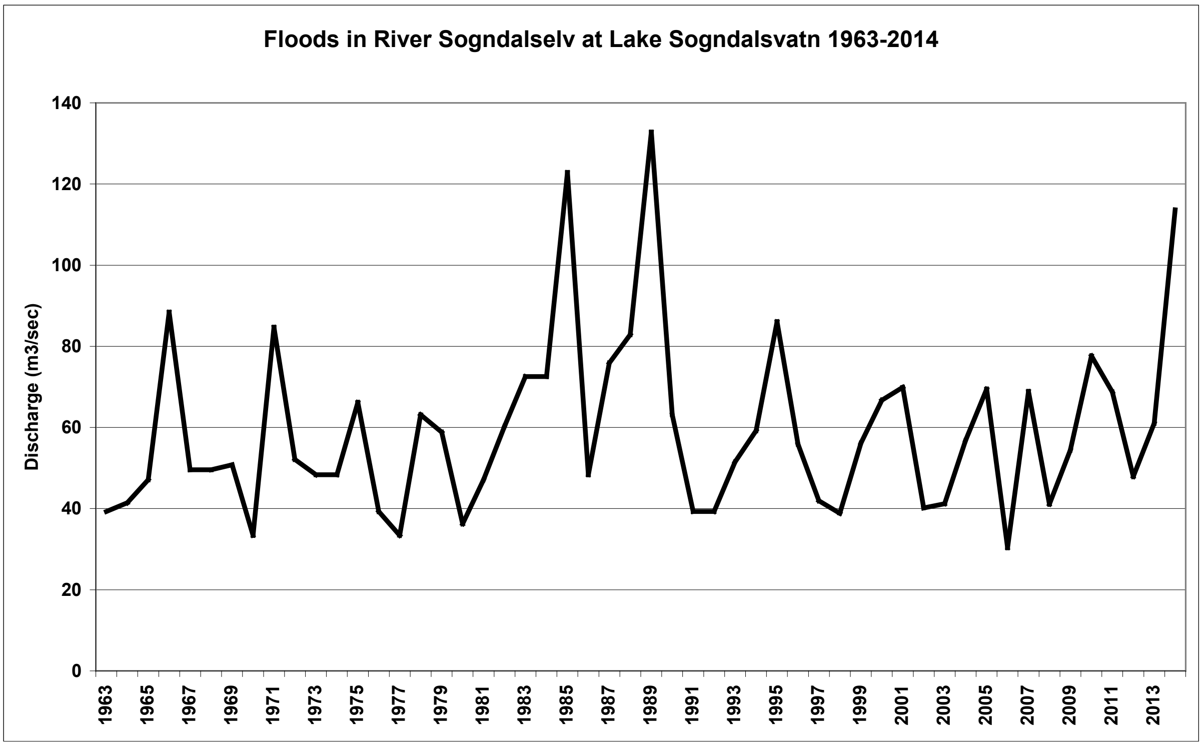


Figure *2.6.6 Annual floods (daily values) in River Sogndalselv at Lake Sogndalsvatn 1963-2014.*

2.6.10 RIVER BØYUMELV

The gauging station 78.8 Bøyumelv is located at Fjærland between Bremuseet and Bøyabreen. The observations started in 1966. Catchment characteristics are given in Table 2.6.23, the dates and ranks of the ten largest floods in Table 2.6.24 and the discharge (daily values) of the largest observed flood in Table 2.6.25.

The annual flood occurs 15,6 percent of all years in July, 26,7 percent in August, 35,6 percent in September and 20 percent in October. A gauging station in Suphellerdalen started observing at the same time, but the observations were terminated in 1980.

Table 2.6.23 Catchment characteristics of the three stations at Veitestrandsvatn, Sogndalsvatn and Bøyumelv.

Station	77.2 Veitestrandvatn	77.3 Sogndalsvatn	78.8 Bøyumelv
	Basin characteristics		
Catchment area (km^2)	386,31	110,93	40,42
Station altitude (m.a.s.l.)	171	395	40
Mean altitude (m.a.s.l)	1061	1000	1224
Top altitude (m.a.s.l.)	1914	1600	1731
Lake (%)	5,1	4,11	0,3
Bog (%)	0,85	1,33	0,35
Forest (%)	16,59	20,2	19,27
Mountain (%)	40,87	58,59	30,5
Glacier (%)	25,69	6,18	42,95

Table 2.6.24 The year, dates and ranks of the ten largest floods (daily values) at three gauging stations from Sogndal to Fjærland.

77.2 Veitestrandvatn			77.3 Sogndalsvatn			78.8 Bøyumelv		
1901-1981			1966-2014			1966-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1901	27/7	8	1966	7/9	4	1966	7/9	1
1905	4/7	5	1971	31/10	6	1968	26/10	10
1914	10/7	1	1983	26/10	10	1969	16/10	5
1919	11/9	8	1985	1/10	3	1971	7/10	8
1925	28/7	10	1987	6/7	9	1973	8/7	6
1938	1/8	3	1988	29/9	7	1976	27/7	8
1955	18/7	6	1989	26/6	1	1978	17/9	3
1958	11/7	4	1995	27/10	5	1979	14/8	2
1967	4/8	7	2010	22/7	8	2005	14/9	7
1973	9/7	2	2014	28/10	2	2014	28/10	4

Table 2.6.25 The largest discharge (daily values) at Veitestrandsvatn, Sogndalsvatn and Bøyumelv.

Station	77.2 Veitestrandvatn	77.3 Sogndalsvatn	78.8 Bøyumelv
Year	1914	1989	1966
Date	10/7	26/6	7/9
q (m3/sec)	176	116,67	78,17
qsp (l/sec km2)	455	1052	1934
qsp (mm/day)	39,3	90,9	167,1

Peak values:

77.3	Sogndalsvatn	28.10.2014 18:00	183,04 m3/sec	1650 l/sec km2
78.8	Bøyumelv	28.10.2014 14:00	105,46 m3/sec	2609 l/sec km2

2.6.11 RIVER NESSEDALSELV

River Nessadalselv flows southwards from the water divide to River Gaular to the Sognefjord east of Høyanger. A gauging station was operating at Nessadalsvatn from 1966 to 1978. The gauging station 71.1 Nessadalselv has been operating since 1983. The dominant flood season is in the autumn with occasional floods in the winter and spring. The annual flood has occurred in 11 percent of all years in February, September and December, 18,5 percent in May and 14,8 percent in October and November. Catchment characteristics are given in Table 2.6.26, the dates and ranks of the ten largest floods in Table 2.6.27 and the discharge (daily values) of the largest observed flood in Table 2.6.28.

2.6.12 RIVER ULLEBØELV

River Ullebøelv is located at west of Høyanger north of the Sognefjord and flows southwards. The station 80.4 Ullebøelv has a catchment area of 8,31 square kilometres, and the data series starts in 1927. The catchment reacts quickly to rainfall and many rainfall floods are large, since the catchment is located at the coastal maximum precipitation zone. The annual flood has occurred in 6,1 percent of all years in January, 12,2 percent in February, 12,2 percent in September, 19,5 percent in October, 14,6 percent in November and 17,1 percent in December. The annual flood has also occurred a few times in the spring and summer months. Catchment characteristics are given in Table 2.6.26, the dates and ranks of the ten largest floods in Table 2.6.27 and the discharge (daily values) of the largest observed flood in Table 2.6.28. Figure 2.6.7 show observed floods (daily values) in River Ullebøelv 1928-2014.

The most extreme flood occurred in February 1928, when a large slush avalanches devastated villages in Hordaland and Sogn, and in November 1971 when Høyanger suffered from a disastrous flood. The flood caused by Hurricane Faith is the 11th largest observed at River Ullebøelv, which may reflect the different exposure of this catchment compared to other catchments in Sogn.

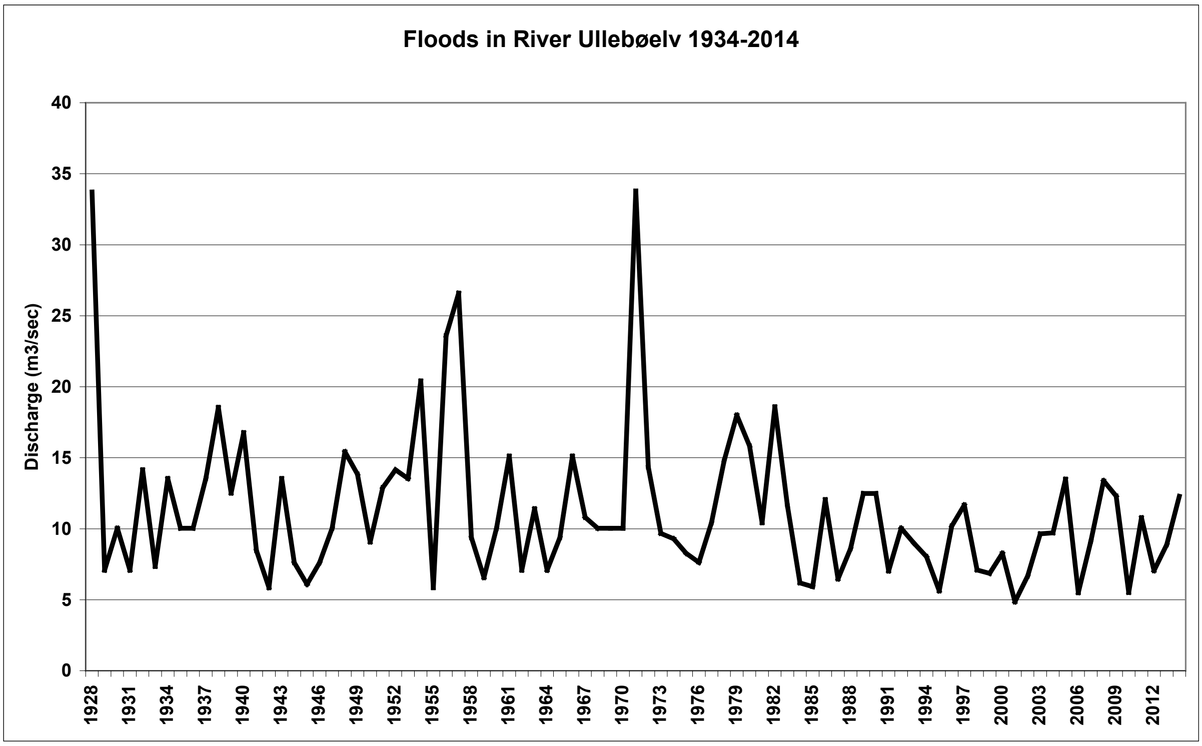


Figure 2.6.7 Annual floods (daily values) in River Ullebøelv 1934-2014.

2.6.13 RIVER HAGEELV AT LAKE HERSVIKVATN

River Hageelv is a small catchment on the coast north of the outlet of Sognefjord. The catchment is located on the island Sula in Solund. The gauging station 81.1 Hersvikvatn has been operating since 1933. Figure 2.6.8 show the annual floods observed at Hersvikvatn 1934-2014.

The flood regime is highly maritime. The annual flood has occured mostly in the autumn and early winter, but never in the late spring and summer from May to July. The most frequent months are 11,7 percent in January, 9,1 percent in February, 21,6 percent in October, 15,6 percent in November and 16,9 percent in December. Catchment characteristics are given in Table 2.6.26, the dates and ranks of the ten largest floods in Table 2.6.27 and the discharge (daily values) of the largest observed flood in Table 2.6.28.

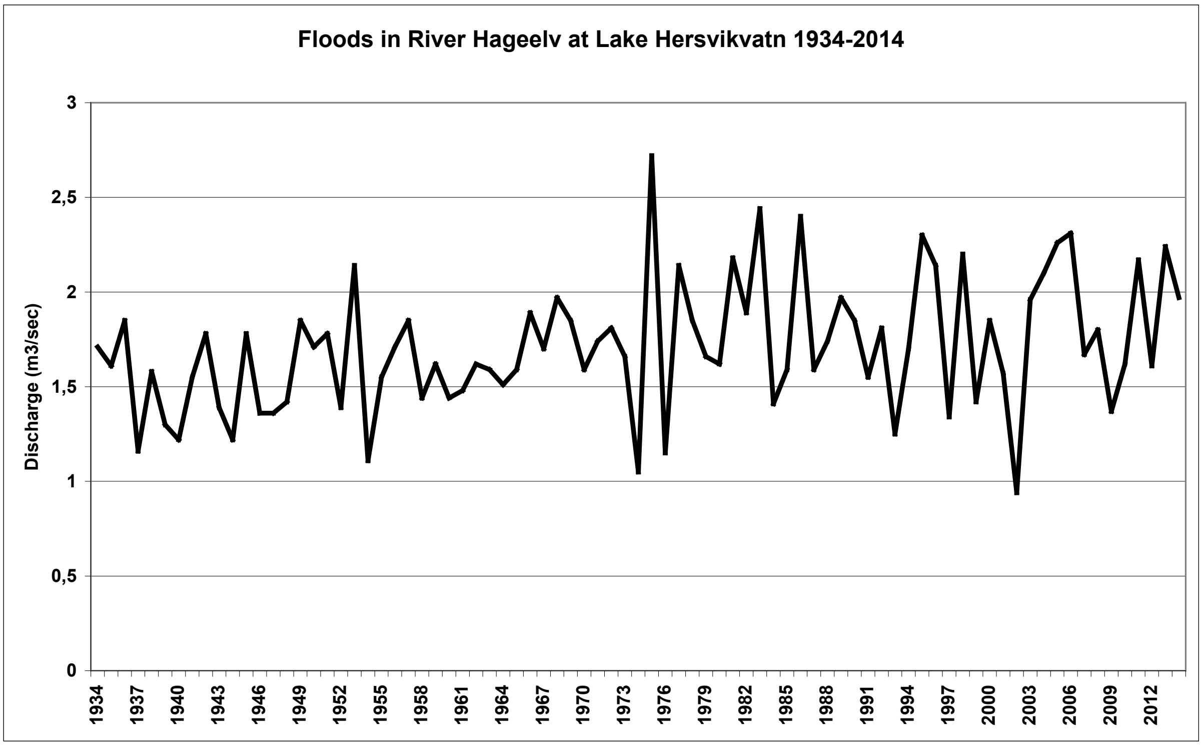


Figure 2.6.8 Annual floods (daily values) in River Hageelv at Lake Hersvikvatn 1934-2014

Table 2.6.26 Catchment characteristics of gauging stations from Balestrand to Sula in Sogn

Station	71.1/3 Nessedalselv	80.4 Ullebøelv	81.1 Hersvikvatn
	Basin characteristics		
Catchment area (km^2)	30,08	8,31	7,13
Station altitude (m.a.s.l.)	289	335	21
Mean altitude (m.a.s.l)	820	661	51
Top altitude (m.a.s.l.)	1346	886	448
Lake (%)	3,33	3,37	20,06
Bog (%)	0	0,12	1,55
Forest (%)	23,33	9,99	10,59
Mountain (%)	66,67	78,94	12,57
Glacier (%)	0	0	0

Table 2.6.27 The year, dates and ranks of the ten largest floods (daily values) at gauging stations from Balestrand to Sula in Sogn.

71.1/3 Nessedalselv			80.4 Ullebøelv			81.1 Hersvikvatn		
1965-2014			1928-2014			1934-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1966	7/9	4	1928	9/2	2	1953	12/10	2
1971	2/11	3	1938	13/11	7	1975	26/9	1
1975	27/12	6	1940	26/11	9	1983	15/12	3
1978	24/5	1	1948	27/9	10	1986	2/10	4
1981	13/5	8	1954	18/12	5	1995	27/10	5
1983	26/10	2	1956	22/10	4	1998	23/11	8
2005	14/11	5	1957	9/1	3	2004	4/12	10
2007	30/5	9	1971	2/11	1	2005	15/11	7
2011	25/7	10	1979	2/12	8	2006	11/12	5
2013	16/11	7	1982	30/8	6	2013	16/11	9

Table 2.6.28 The highest observed discharge (daily values) at Nessedalsvatn, Ullebøelv and Hersvikvatn.

Station	71.1 Nessedalselv *	80.4 Ullebøelv **	81.1 Hersvikvatn
Year	1978	1971	1975
Date	24/5	2/11	26/9
Q (m^3/sec)	30,14	33,79	2,86
qsp (l/sec km^2)	1008	4066	401
qsp (mm/day)	87,1	351,3	34,7

* 1971 2/11 a disastrous second flood occurred 27,72 m^3/sec or 927 l/sec km^2 or 80 mm/day in River Nessedalselv. This flood caused severe damages at the nearby village Høyanger. There must have been s similar extreme flood in River Nessadalselv in February 1928, simultaneous with disastrous floods in many nearby rivers, see below.

** 1971 28/2 disastrous second flood 33,71 m^3/sec or 4056 l/sec km^2 or 350,4 mm/day in River Ullebøelv.

2.7 Sunnfjord

Sunnfjord is the district between the Sognefjord to the south and Nordfjord to the north. The district is characterised by a number of small, narrow and winding fjords running eastwards from the coast. The district is exposed to heavy rainfall from the west, and many of the large floods in the district is caused by *Atmospheric rivers*.

2.7.1 RIVER GUDDALSELV

River Guddalselv is located at Fjaler in Sunnfjord. The river flows northwestwards towards Hekkefjorden, a branch of Dalsfjorden. The gauging station 82.4 Nautsundvatn has been active since 1909. River Storelv flows towards Dalsfjorden at Dale further east. The gauging station 84.3 Håland bru is located at Storelva and was active 1927-1992. Catchment characteristics of the two gaugin stations are given in Table 2.7.1, the date and rank of the ten largest annual floods in Table 2.7.2 and the largest discharge (daily values) in Table 2.7.2.

The annual floods (daily values) in River Guddalselv at Lake Nautsundvatn 1909-2014 is shown in Figure 2.7.1. River Storelv is regulated.

The two catchments are located at the coastal maximum precipitation zone. The nearby meteorological station 56520 Hovlandsdal has recorded many precipitation events, exceeding 100 mm one-day rainfall. The dominant flood season is in the winter and autumn. The annual flood occurs in 10,8 percent of all years in January, 11,8 percent in February, 21,6 percent in October, 12,7 percent in November and 17,6 percent in December.

Table 2.7.1 Catchment characteristics of Nautsundvatn and Håland bru.

Station	22.4 Nautsundvatn	22.3 Håland bru
	Basin characteristics	
Catchment area (km^2)	218,96	53,6
Station altitude (m.a.s.l.)	45	68
Mean altitude (m.a.s.l)	464	477
Top altitude (m.a.s.l.)	904	797
Lake (%)	7,53	7,46
Bog (%)	1,23	2,8
Forest (%)	39,5	41,16
Mountain (%)	40,28	28,84
Glacier (%)	0	0

Table 2.7.2 The year, dates and ranks of the ten largest annual floods (daily values) at Nautsundvatn and Håland bru.

22.4 Nautsundvatn			22.3 Håland bru		
1909-2014			1927-1992		
Year	Date	Rank	Year	Date	Rank
1913	18/10	4	1927	12/1	6
1914	3/2	9	1932	28/1	8
1932	20/1	7	1933	3/8	8
1934	26/11	5	1934	26/11	8
1940	26/11	1	1939	20/4	7
1953	11/10	10	1940	26/11	1
1955	6/12	6	1957	9/1	5
1957	9/1	2	1966	7/9	2
1967	7/9	3	1967	15/12	3
1971	10/1	7	1971	10/1	4

Table 2.7.3 The highest observed discharge (daily values) at Nautsundvatn and Håland bru.

Station	22.4 Nautsundvatn	22.3 Håland bru
Year	1940	1940
Date	26/11	26/11
q (m^3/sec)	493,19	90,58
qsp (l/sec km^2)	2252	1690
qsp (mm/day)	194,5	146,0

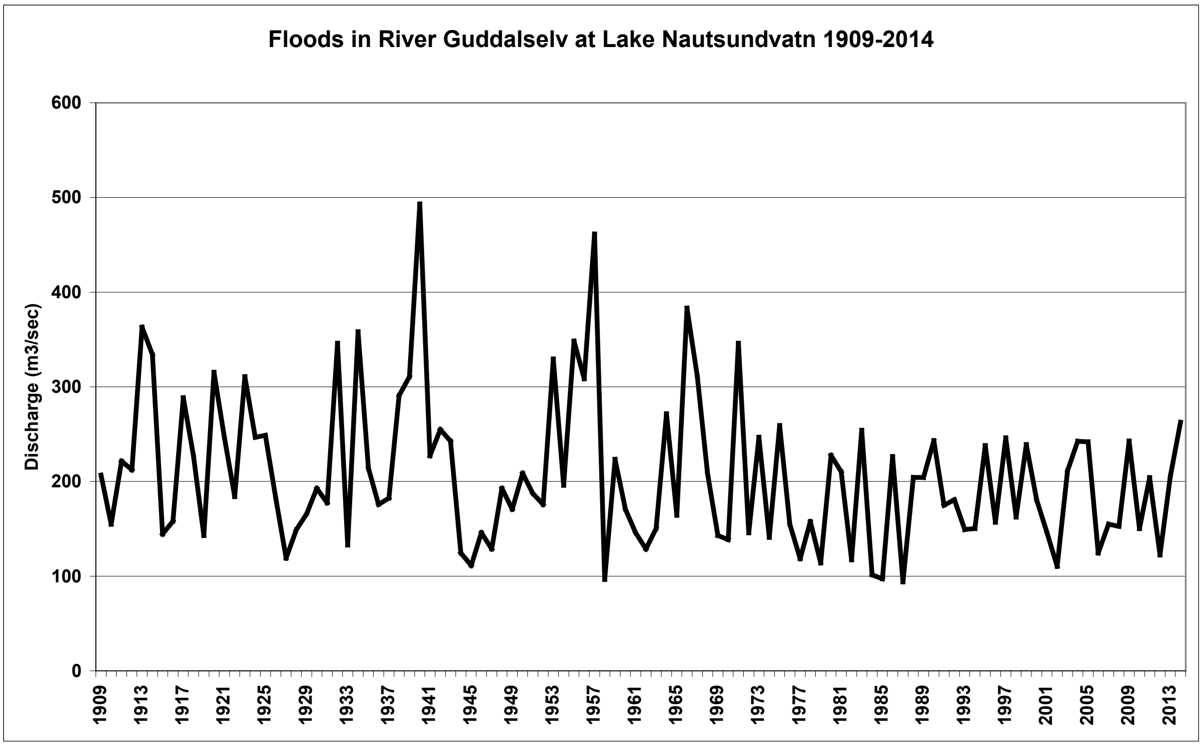


Figure 2.7.1 Annual floods (daily values) in River Guddalselv at Lake Nautsundvatn 1909-2014.

2.7.2 RIVER GAULAR AT LAKE VIKSVATN

River Gaular flows westwards from the water divide of rivers draining to the Fjærlandsfjord to the Dalsfjord in Sunnfjord. The watercourse has some glacial inflow from Grovebreen and Jostefonn in the east close to the water divide towards Fjærland.

Several slides have caused damages, both dry and slush avalanches, landslides and rock falls in the upper part of the catchment as shown in Table 2.7.4. Many of the slides were caused by excessive precipitation and have occurred simultaneously with floods. Slides have dammed River Gaular or tributaries resulting in downstream inundations.

Table 2.7.4 Floods known from historical sources in River Gaular.

Year	Date	Remarks
1748		Rockfall and flood at Indre Oppedal
1749	Late winter	Rainfall and flood at Tufte
1773		Flood in Haukedalen
1815		Landslide moved houses on the river
1816		Flood in River Grøvla
1861	15 July	Flood in River Grøvla
1906	23-24 November	Flood in Lake Viksvatn and at Haukedalen
1913	19 October	Flood in Lake Viksvatn

The gauging station 83.2 Viksvatn in Lake Hestadfjorden has been active since 1902. Several stations are located upstreams in the catchment with shorter records. The gauging station 83.7 Grønengstølvatn is located between two glaciers, Grovebreen and Jostefonn. Catchment characteristics of the three stations, Viksvatn, Haukedalsvatn and Grønengstølvatn are listed in Table 2.7.5, the date and rank of the ten largest annual floods (daily values) in Table 2.7.6 and the date and discharge of the largest flood in Table 2.7.7. The annual floods (daily values) in River Gaular at Lake Viksvatn 1909-2014 are shown in Figure 2.7.2.

There is a longterm precipitation station 56800 Gaular previously named Indre Holmedal, which was active from 1895.

Table 2.7.5 Catchment characteristics of three gauging stations in River Gaular.

Station	83.2 Viksvatn	83.12 Haukedalsvatn	83.7 Grønengstølvatn
	Basin characteristics		
Catchment area (km^2)	508,13	205,55	65,65
Station altitude (m.a.s.l.)	143	297	520
Mean altitude (m.a.s.l)	842	937	1184
Top altitude (m.a.s.l.)	1635	1635	1635
Lake (%)	9,53	9,08	4,95
Bog (%)	1,06	1,23	0,43
Forest (%)	22,52	16,27	3,21
Mountain (%)	57,3	56,52	58,78
Glacier (%)	4,93	11,34	31,23

The annual flood occurs in 26 percent of the years in June, 12 percent in July, 6,5 percent in August, 24 percent in September and 16 percent in October. There is a long-term precipitation station 56800 Gaular within the catchment.

Table 2.7.6 The year, dates and ranks of the ten largest floods (daily values) at three gauging stations in River Gaular.

83.2 Viksvatn			83.12 Haukedalsvatn			83.7 Grønengstølvatn		
1903-2014			1936-2014			1966/2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1913	19/10	3	1953	11/10	2	1966	7/9	1
1917	29/9	2	1956	22/10	10	1973	8/7	9
1942	12/9	8	1966	8/9	4	1976	28/6	5
1953	12/10	7	1973	9/9	1	1983	27/10	8
1966	9/9	8	1983	27/10	5	1985	1/10	2
1981	15/5	10	1995	27/10	9	1989	21/9	10
1983	28/10	5	2003	26/9	6	2005	14/9	3
1995	28/10	4	2005	15/9	7	2011	29/6	6
2000	15/6	6	2011	30/6	8	2013	8/10	7
2014	28/10	1	2014	28/10	3	2014	28/10	4

Table 2.7.7 The highest observed discharge (daily values) at three gaugng stations in River Gaular.

Station	83.2 Viksvatn	83.12 Haukedalsvatn	83.7 Grønengstølvatn
Year	2014	1973	1966
Date	28/10	9/9	7/9
q (m^3/sec)	293,58	182,71	98,85
qsp (l/sec km^2)	578	889	1506
qsp (mm/day)	49,9	76,8	130,1

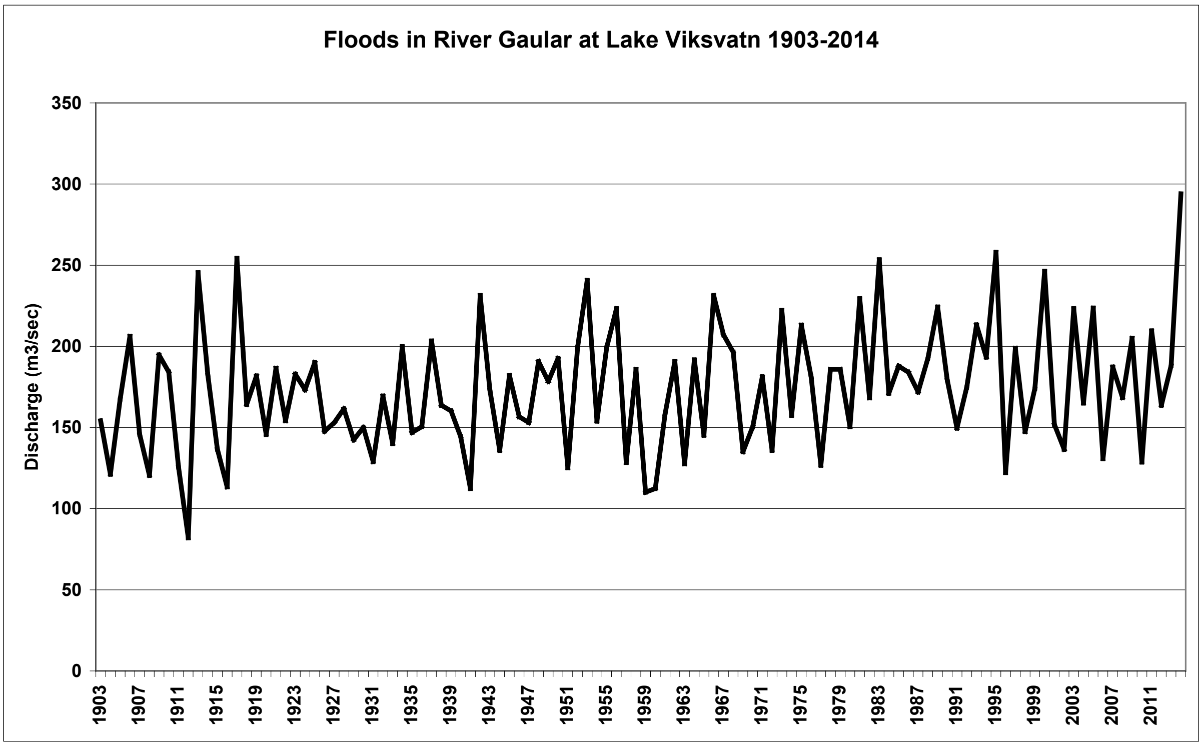


Figure 2.7.2 Annual floods (daily values) in River Gaular at Lake Viksvatn 1909-2014.

2.7.3 RIVER JØLSTRA

River Jølstra flows westward from the water divide on Jostedalsbre glacier trough the Lake Kjøsnesfjord and Lake Jølstervatn to the Førdefjord. The catchment area at the gauging station 84.1 Jølstervatn is 384,13 square kilometres. The station has been in operation 1908-1951. A new station 84.15 started operating below Lake Jølstervatn in 1951 resulting in a data series covering the period 1902-2014. A tributary join River Jølstra from Lake Holsenvatn downstream Lake Jølstervatn. The gauging station 84.20 Holsenvatn and another station 84.11 Hovefoss has both been active since 1964. The annual floods at Jøstervatn (daily values) 1902-2014 are shown in Figure 2.7.3. Catchment characteristics of the three stations are given in Table 2.7.8, the date and ranks of the ten largest floods (daily values) in Table 2.7.9 and the date and discharge of the largest flood (daily values) in Table 2-8.10.

A long-term precipitation station 57480 Botnen has been in operation since 1895. The station was equipped with a shield in 1938. Two large rainfall floods have been documented 8 September 1662 and 8 September 1668. Ice-run floods caused by slush avalanches caused damages in February 1850.

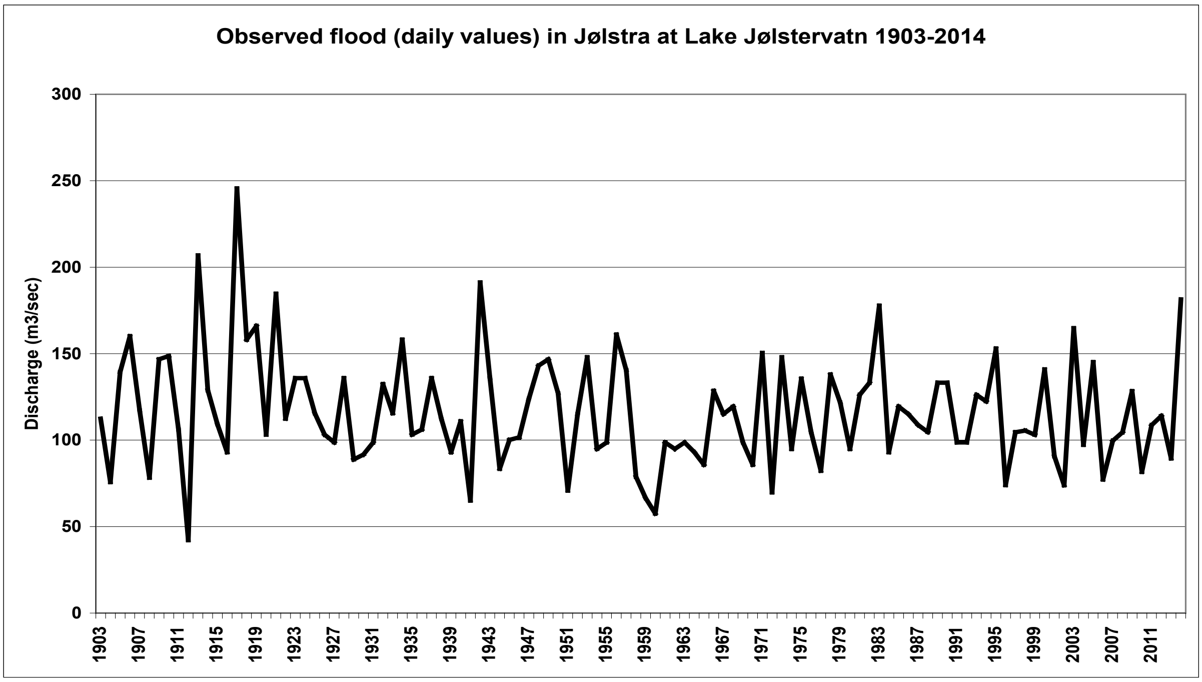


Figure 2.7.3 Annual floods (daily values) in River Jølstra at Lake Jølstervatn 1903-2014.

Table 2.7.8 Catchment characteristics of three gauging stations in River Jølstra.

Station	84.15 Jølstervatn ndf	84.20 Holsenvatn	84.11 Hovefoss
	Basin characteristics		
Catchment area (km^2)	384,13	70,48	234,13
Station altitude (m.a.s.l.)	207	131	20
Mean altitude (m.a.s.l)	748	674	627
Top altitude (m.a.s.l.)	1648	1425	1469
Lake (%)	11,5	5,96	4,52
Bog (%)	1,8	0,74	4,94
Forest (%)	21,95	32,88	26,03
Mountain (%)	46,67	51,04	55,96
Glacier (%)	6,81	0	0,03

Table 2.7.9 The year, date and rank of the ten largest floods (daily values) at three gauging stations in River Jølstra.

84.15 Jølstervatn ndf			84.20 Holsenvatn			84.11 Hovefoss		
1903-2014			1964-2014			1964-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1906	24/11	10	1966	7/9	2	1965	17/9	3
1913	19/11	2	1971	3/11	6	1971	10/1	1
1917	28/9	1	1973	9/9	7	1978	10/11	5
1919	12/9	7	1975	28/12	4	1980	23/11	9
1921	19/10	4	1981	13/5	2	1983	2610	2
1942	12/9	3	1983	27/10	1	1984	30/8	4
1956	23/10	9	1989	20/11	10	1986	3/12	9
1983	27/10	6	1995	27/10	9	1990	6/2	5
2003	26/9	8	2005	15/11	5	2004	5/12	8
2014	28/10	5	2014	28/10	8	2005	14/11	7

Table 2.7.10 The highest observed discharge (daily values) at three gauging stations in River Jølstra.

Station	84.15 Jølstervatn ndf	84.20 Holsenvatn	84.11 Hovefoss
Year	1917	1983	1971
Date	28/9	27/10	10/1
q (m^3/sec)	245,51	62,05	448,92
qsp (l/sec km^2)	639	868	1917
qsp (mm/day)	55,2	75,0	165,7

2.7.4 RIVER NORDDALSELV

River Norddalselv flows from the southern side of the Ålfotsbre towards the Norddalsfjord. The catchment area at the gauging station 85.1 Norddal is 97,64 square kilometres.
The station has been in operation 1908-1963. The catchment was regulated 17/10-1963. The precipitation station Grøndalen is located within the catchment. The large rainfall events observed on this station are comparable with the observations at Opstveit in Sunnhordaland. The neighbor river, Oselv, flows from the water divide towards Hyen and Lake Ommedalsvatn to the Høydalsfjord. The precipitation station Eikefjord and Eimhjellen has also observed many events of daily rainfall exceeding 100 mm.

River Solheimselv is a tributary to the Førdefjord flowing northwestward to the fjord west of Førde. The gauging station 85.4 Straumstad has been active since 1974. Catchment characteristics of Norddal and Straumstad are given in Table 2.7.10, the dates and ranks of the ten largest floods in Table 2.7.12 and the discharge (daily values) of the largest observed flood in Table 2.7.13.

2.7.5 RIVER RISEELV

River Riseelv is located at Svelgen west of the Ålfoten glacier. The river flows into the Nordgulen fjord. The gauging station 85.1 Risevatn has a natural catchment area of 32,57 square kilometres. Catchment characteristics are given in Table 2.7.11, the dates and ranks of the ten largest floods in Table 2.7.12 and the discharge (daily values) of the largest observed flood in Table 2.7.13. River Riseelv is regulated since 1972.

Table 2.7.11 Catchment characteristics of three gauging stations in River Norddalselv, River Solheimselv and River Riseelv.

Station	85.1 Norddal	85.4 Straumstad	86.1 Risevatn
	Basin characteristics		
Catchment area (km^2)	97,64	109,68	32,3 *
Station altitude (m.a.s.l.)	8	6	24
Mean altitude (m.a.s.l)	713	586	733
Top altitude (m.a.s.l.)	1345	1383	1350
Lake (%)	12,79	6,15	8,87
Bog (%)	0,25	1,29	0
Forest (%)	10,01	25,36	19,67
Mountain (%)	67,42	51,23	67,98
Glacier (%)	1,45	4,4	0,28

- 18,4 km2 of the catchment of 86.1 Risevatn was diverted 15.12-1972. The remaining catchment is 13,9 km^2.

Table 2.7.12
The year, dates and ranks of the ten largest floods (daily values) at three gauging stations in river Nordalselv and River Riseelv.

85.1 Norddal			85.4 Straumstad			86.1 Risevatn		
1909-1986			1974-2014			1929-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1913	18/10	4	1975	23/9	2	1931	4/11	10
1921	16-17/10	2	1986	1/10	10	1932	20/12	3
1922	27/8	7	1989	19/1	2	1938	14/11	7
1928	15/7	6	1990	6/2	5	1943	2/10	9
1932	20/9	7	1994	7/10	8	1947	12/10	6
1947	12/10	3	1995	27/10	1	1950	6/10	7
1956	22/10	10	2003	18/10	7	1962	13/8	5
1966	7/9	9	2004	5/12	6	1964	29/7	4
1971	10/1	5	2005	14/9	4	1966	7/9	1
1975	23/9	1	2013	16/11	9	1971	10/1	2

Table 2.7.13. The highest observed discharge (daily values) at three gauging stations.

Station	85.1 Norddal	85.4 Straumstad	86.1 Risevatn
Year	1975	1995	1966
Date	23/9	27/10	7/9
q (m^3/sec)	189,96	196,95	55,68
qsp (l/sec km^2)	1944	1796	1710
qsp (mm/day)	168,0	155,2	147,7

2.8 Nordfjord

Nordfjord extends from Sunnfjord to the South to Sunnmøre further north. The district extends from the coast eastwards to rivers flowing from the water divide at Jostedalsbre glacier and the water divide towards Ottadalen in east Norway. The Ålfoten and Gjegnalund glaciers are located at the southern side of the outer Nordfjord. These maritime glaciers are together with the southwest flank of Folgefonna in Sunnhordaland and the western flank of Svartisen glacier in Nordland the wettest places in Norway. Using observed discharge data in the glacier stream, precipitation data from nearby rainfall stations and mass balance data from the glacier, the annual precipitation has been estimated to 4500 mm at Ålfotbreen.

Four glacier streams drain the western flank of the Jostedalsbre glacier and Myklebustbre glacier towards Nordfjord. These rivers are Gloppenelv, Oldeelv, Loelv and Strynselv. Long- term data series exists in these rivers starting in the early 1900s, although the series from Gloppenelv was terminated in 1949. The observations in River Strynselv have a gap, but the station is now in operation again. A comparison of the long-term series in Nordfjord show that the occurrence and seasonality of large floods are similar in River Gaula, Jølstra and Breimselv. The largest floods occur frequently in the autumn. The glacial rivers Oldeelv and Loelv are characterised by summer floods because of a larger contribution from melting glaciers. They are also less exposed to rainstorms from southwest and early spring and late autumn flood are less frequent in these rivers.

2.8.1 Hyen

Hyenfjord is a branch running southwards from the main fjord east of the Ålfoten and Gjegnalund glaciers. River Skjerdalselv is a small river, which flows northeastward from the glaciers. A severe flood ravaged the farm, Skjerdal, at the outlet of the river into the fjord 28 October 2007. The gauging station 86.12 Skjerdalselv has been active since 1983. The gauging station 86.10 Åvatn or Ommedalsvatn is located near the bottom of the fjord in River Ommedalselv. Further upstream in the river was the gauging station Gjengedalsvatn located. This station was active from 1964 to 2000. Table 2.8.1 list catchment characteristics, Table 2.8.2 list the date and ranks of the ten largest floods and Table 2.8.3 list the date and discharge of the largest flood at the three stations.

Table 2.8.1 The catchment characteristics of three rivers flowing towards Hyenfjord.

Station	86.12 Skjerdalselv	86.10 Åvatn	86.4 Gjengedalsvatn
	Basin characteristics		
Catchment area (km^2)	23,76	162,13	55,94
Station altitude (m.a.s.l.)	291	27	482
Mean altitude (m.a.s.l)	1045	696	865
Top altitude (m.a.s.l.)	1465	1465	1465
Lake (%)	3,45	5,83	8,79
Bog (%)	0,29	3,77	3,95
Forest (%)	14,65	19,46	4,5
Mountain (%)	56,06	64,21	75,05
Glacier (%)	20,54	1,07	2,98

Table 2.8.2 Year, dates and ranks of the ten largest floods (daily values) at three gauging stations flowing towards Hyenfjord.

86.12 Skjerdalselv			86.10 Åvatn			86.4 Gjengedalsvatn		
1983-2014			1974-2014			1964-2000		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1999	1/11	6	1985	1/10	5	1964	29/7	5
2001	16/8	10	1988	29/12	9	1966	7/9	2
2003	26/6	5	1989	20/1	6	1971	3/11	7
2004	27/9	9	1990	6/2	4	1983	27/10	3
2005	14/9	8	1994	23/11	3	1985	1/10	1
2007	28/10	1	1995	27/10	1	1989	26/6	3
2009	9/9	4	2000	13/6	7	1990	6/2	8
2011	28/6	2	2005	14/9	8	1991	15/9	10
2012	30/6	7	2013	8/10	10	1994	7/10	9
2014	28/10	3	2014	28/10	2	1995	27/10	6

Table 2.8.3 The highest observed discharge (daily values) at three gauging stations

Station	86.12 Skjerdalselv	86.10 Åvatn	86.4 Gjengedalsvatn
Year	2007	1995	1985
Date	28/10	27/10	1/10
q (m3/sec)	45,23	152,81	61,28
qsp (l/sec km2)	1904	943	1095
qsp (mm/day)	164,5	81,4	94,57

2.8.2 RIVER GLOPPENELV

River Gloppenelv extends from Jostedalsbre and Myklebustbre glaciers to the east through River Storelva to Lake Breimsvatn. At Gloppen the river ends in the Gloppenfjord, a branch of Nordfjord. The earliest observations started at 87.1 Breimsvatn at a location downstreams the lake, where data was observed from 1900 to 1949. This series has been joined with the series 87.2 Eidsfoss to a series covering the period 1900-2016. Catchment characteristics of 87.2 Eidsfoss and the dates and ranks of the ten largest floods are given in Table 2.8.4. The annual floods observed at Eidsfoss are shown in Figure 2.8.1.

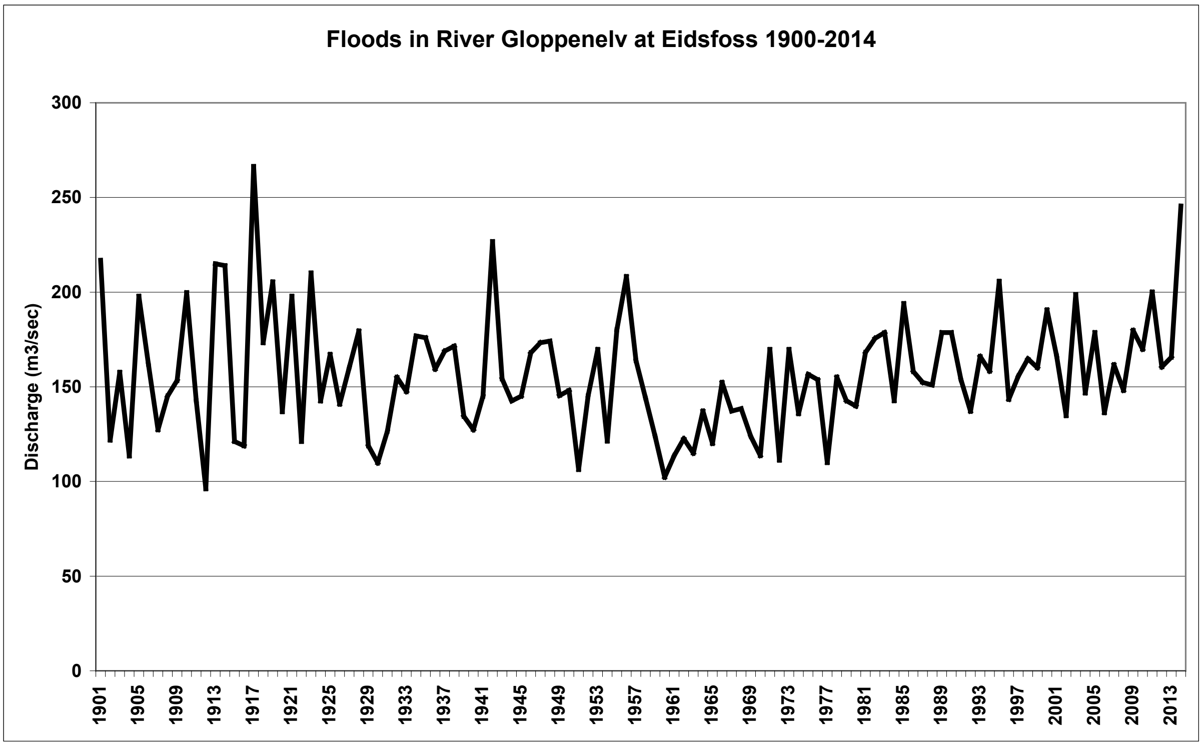


Figure 2.8.1 Anual floods observed in River Gloppenelv at Eidsfoss 1900-2014.

Table 2.8.4 Catchment characteristics and dates and rank of the ten largest floods observed at Eidsfoss in River Gloppenelv 1900-2014.

Station 87.2 Eidsfoss		The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	615,55	1901	1/10	4
Station altitude (m.a.s.l.)	14	1913	19/10	5
Mean altitude (m.a.s.l)	870	1914	8/7	6
Top altitude (m.a.s.l.)	1844	1917	28/9	1
Lake (%)	5,36	1923	13/7	7
Bog (%)	1,14	1942	12/9	3
Forest (%)	23,56	1956	23/11	8
Mountain (%)	49,79	1995	28/10	9
Glacier (%)	11,53	2011	30/6	10
		2014	29/10	2

Recently data are also collected at 87.3 Teita bru further upstreams from Lake Breimsvatn.The station was moved to a nearby location at Bergheim in 2006. The long-term precipitation station 58320 Myklebust has been active since 1895. Catchment characteristics at Teita/Bergheim are given in Table 2.8.7, the dates and ranks of the ten largest floods in Table 2.8.8 and the discharge (daily values) of the largest observed flood in Table 2.8.9.

The population living within the catchment has suffered repeatedly from floods, avalanches and slides. The December flood in 1743 caused damages at many farms. The flood in July 1789 at Myklebust was so large that the farmer had to ride on horseback into the farm buildings. This was probably a result of extreme glacial melting because of foehn winds caused by Storofsen in east Norway

2.8.3 RIVER OLDEELV

The Olden catchment is together with the nearby catchment of Loen and Stryn among the worst affected districts from all kind of natural disasters. Rockfalls, avalanches, landslides and floods have occurred frequently during the little Ice Age, causing loss of lives as well as severe damages to most of the farms as shown in Table 2.8.5.

The catchments include western outlets of the Jostedalsbre glacier and as well other smaller glaciers. There is a longterm series observed at 88.2 Nordre Oldevatn. The catchment characteristics are given in Table 2.8.7. The glacier arm Briksdalsbre is located at the catchment toghether with other arms of the Jostedalsbre and Myklebustbre glaciers. There as been many devastating floods and disasters caused by avalanches and sliding ice in the glacier rivers. The dates and ranks of the ten largest annual floods are given in Table 2.8.8. The highest daily discharge is given in Table 2.8.9. The annual floods in River Oldeelv are shown in Figure 2.8.2. The catchment has a longterm precipitation station 58480 Briksdal. The station was equipped with a shield in 1906.

Table 2.8.5 Floods known from historical sources in River Oldeelv.

Year		Date	Remarks
1649			Flood at Auflem and Muri
1685			Flood at Tungøen
1687			Flood and Rockfall at Sunde
1693			Flood at Brunnestad
1697			Rockfall and riverbank failure at Mindresunde
1702			Flood from advancing glaciers at Tungøen and Åbrekka
1706			Flood from advancing glaciers at Myklebust and Melkevoll
1710			River damages at Håhjem, Gjerde and Sunde
1715			Riverbank failure at Kvamme and Førde
1718			Severe flood in most rivers
1719			Severe flood at Kvamme and Førde, comparable to the 1743 flood.
1722			Riverbank failure at Sunde
1734			Flood bursting from glacier at Tungøen
1736			Flood at Kvamme and Førde
1738			Flood at Kvamme and Førde
1742		7 December	Landslide and flood at Tungøen
1743		5-12 December	Ice fallout, rockfall and flood at Melkevoll, Tungøen and Muri
1804		Summer	River Tverrelv caused damages at Rustøen
1805		18 September	River Tverrelv caused damages at Rustøen
1812			Riverbank failure at Gjerde and Sunde
1883			Riverbank failure at Bak-Yri
1899		End of July	Flood at Melkevoll
1906			Flood in River Sulka at Kvamme and For

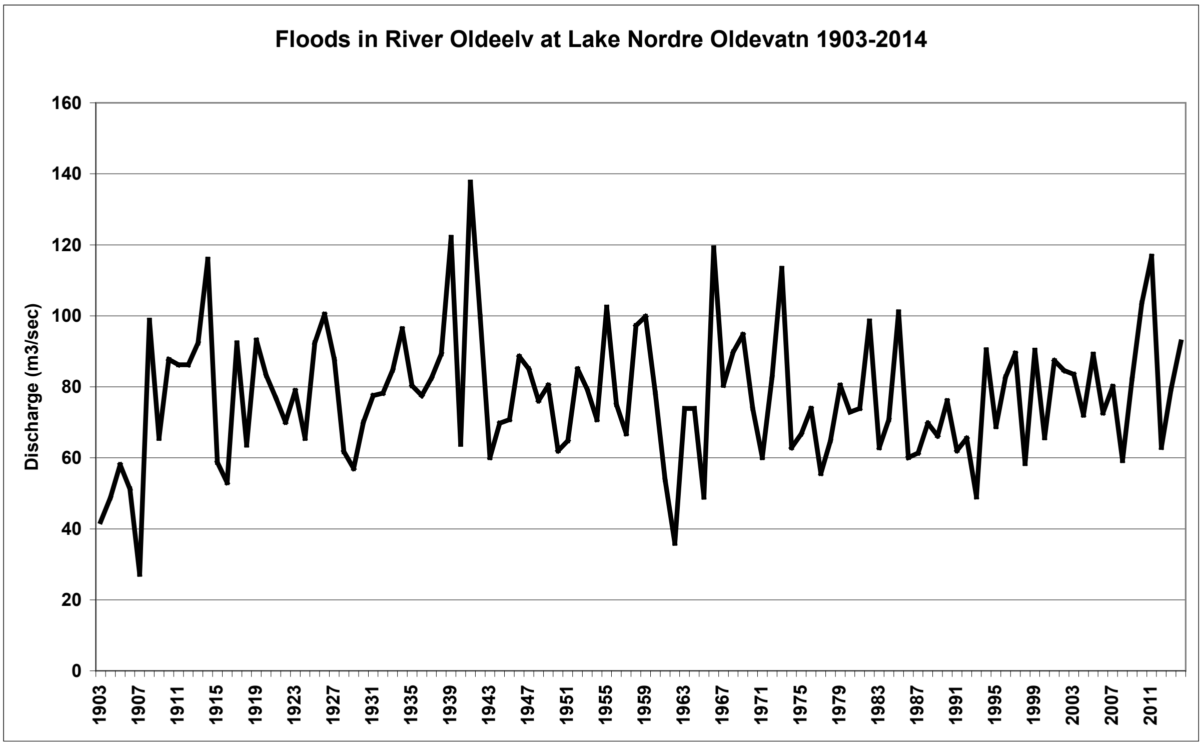


Figure 2.8.2 The annual floods (daily values) obseved in River Oldeelv at Lake Nordre Oldevatn.

2.8.4 RIVER LOELV AT LAKE LOVATN

Lake Lovatn is fed by glacial meltwater from Bødalsbreen and Kjenndalsbreen, two western branches of the Jostedalsbre glacier. Ramnefjell is located at the southern end of Lake Lovatn west of the farm Nesdal causing disastrous rockslides in January 1905 and in September 1936, resulting in tsunamis in Lake Lovatn with maximum heigths of 40 and 74 meters. The tsunamis resulted in 61 and 74 fatalities. Both mountain slides occurred after heavy precipitation. A second slide occurred in November 1936, causing a tsunami of the same height as the slide in September, but no one was living next to the lake at that time. Another rock fall in 1950 did not cause another tsunami because the lake was filled up below Ramnefjell by debris from the earlier slides. Table 2.8.6 lists large flood events known from historical sources (Guddal, 1967).

The station 88.4 Lovatn has been operating since 1900. The catchment characteristics are given in Table 2.8.7. The percentage of glaciers was probably higher in the early 20th Century. The annual flood occurs in 45 percent of the years in July, 35 percent in August and 8 percent in June and in September. The dates and ranks of the ten largest floods are given in Table 2.8.8 and the discharge of the largest daily value in Table 2.8.8. The annual floods 1900-2014 is shown in Figure 2.8.9.

Table 2.8.6 Large floods in River Loelv known from historical sources.

Year	Date	Remarks
1664		Slide and river bank failure at Bødal
1692		Slide and river bank failure at Bødal
1693		Flood in River Hagedøla at Tjugen
1693		Outfalling glacier ice and flood at Bødal and Nesdal
1702		Erosion in the glacier stream at Bødal
1722	3 August	Flood at Tjugen and Helset
1743	5-12 December	Extreme flood at Raudi and most rivers
1905	14-15/1	Rockfall from Ramnefjell
1913	19/10	Moderate flood

Table 2.8.7 The catchment characteristics of Teita bru, Oldevatn and Lovatn.

Station	87.3/10 Teita bru/Bergheim	88. 2/30 Oldevatn	88.4 Lovatn
	Basin characteristics		
Catchment area (km^2)	217,13	203,1	234,9
Station altitude (m.a.s.l.)	138	33	52
Mean altitude (m.a.s.l)	1045	1305	1337
Top altitude (m.a.s.l.)	1823	1953	2071
Lake (%)	1,15	4,21	5,12
Bog (%)	0,26	0	0,01
Forest (%)	16,16	17,51	14,9
Mountain (%)	51,27	32,84	40,31
Glacier (%)	19,17	40,25	36,8

Table 2.8.8 The dates and ranks of the ten largest annual floods (daily values) observed at Teita bru, Oldevatn and Lovatn.

87.3/10 Teita bru/Bergheim			88. 2/30 Oldevatn			88.4 Lovatn		
1971-2014			1903-2014			1901-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1973	9/9	4	1914	8/7	5	1901	25/7	2
1976	6/9	6	1926	15/7	10	1908	4/10	5
1978	6/11	5	1939	8/8	2	1914	7/7	4
1979	15/8	9	1941	14/7	1	1925	27/7	7
1982	19/9	7	1955	18/7	8	1926	15/7	3
1983	27/10	2	1966	8/6	3	1927	3/8	8
1985	1/10	1	1973	8/7	6	1939	11/8	6
2005	14/9	8	1985	2/10	9	1941	14/7	1
2011	29/6	10	2010	22/7	7	1973	8/7	9
2014	28/10	3	2011	30/6	4	2011	10/6	9

Table 2.8.9 The largest discharge (daily values) observed at Teita bru, Lake Oldevatn and Lake Lovatn.

Station	87.3/10 Teita bru/Bergheim	88. 2/30 Oldevatn	88.4 Lovatn
Year	1985	1941	1941
Date	1/10	14/7	14/7
q (m^3/sec)	430,69	137,64	144,76
qsp (l/sec km^2)	1964	678	616
qsp (mm/day)	169,7	59	53,2

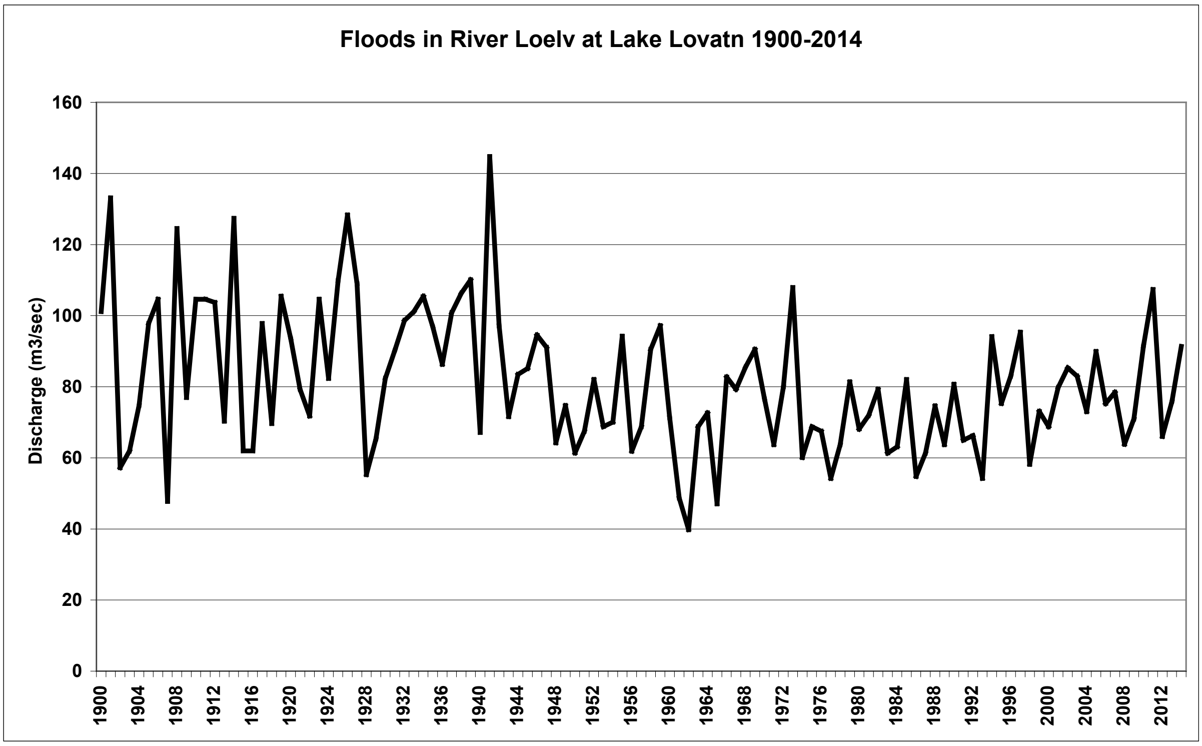


Figure 2.8.3 Annual floods (daily values) in River Loelv at Lake Lovatn 1900-2014

2.8.5 RIVER STRYNSELV

River Strynselv is flowing westwards from the water divide towards River Otta. River Erdalselv is a tributary, flowing northwards from Vesledalsbre and Erdalsbre, parts of the Jostedalsbre glacier, joining the main river in Lake Strynsvatn. The farms around Lake Strynsvatn and upstreams in Hjelledalen has suffered repeatedly from avalanches, rockfall, landslides and floods. Table 2.8.10 lists large historical flood events in River Strynselv (Guddal, 1967). Some farms below the lake were ravaged by large slush avalanches in 1868, killing 22 people. Upstreams the lake, a farm located at Sunndalen has suffered from avalanches in Sunndal in 1718, 1726, 1778, 1868, 1886 and 1901 causing great loss of lives. Torrential summer and autumn rainfall have caused large floods in Hjelledalen in 1702 and 1726.

Some gauging stations have been operating at locations around the lake 88.1, 88.10, 88.11, 88.12. These series have been joined into a discharge series covering the period 1900-2014, although with a gap 1925-1966. Short series has been observed at 88.6 Skjæringsdøla, 88.7 Sunndøla, 88.15 Grasdøla and 88.16 Hjelledøla. The gauging stations downstream the Erdalsbre and Vesledalsbre was active during the monitoring of the rivers in expectation of hydropower development. These stations were closed down when the planned hydropower development was cancelled.

Catchment characteristics of the Strynsvatn catchment is given in Table 2.8.11, the dates and ranks of the ten largest floods (daily values) in Table 2.8.12 and the date and discharge (daily value) of the largest observed flood in the joint series.

Table 2.8.10 Large floods in River Strynselv known from historical sources.

Year		Date	Remarks
1677			Flood and slide at Nesi
1687			Avalanches, flood and bank failure at Oppstryn
1693		October	Flood and bank failure at Sandvik
1697			Flood and rockfall at Sandvik
1702		26-28 October	Heavy rainfall and flood at Skåre
1722		3-4 April	Flood from bursting snow dam at Flo 4 fatalities
1722			Flood at Hjelle
1724			Slide and flood at Nesi
1726		Summer	Flood at Bolstad, Folven, Skåre and Hjelle
1737			Slide dammed river at Tunold
1769		Winter	Flood at Grønfur
1805		30 September	River dammed at Stauri
1868		11 and 26 February	Slush avalanches at Gjørven, Tenden with 22 fatalities
1905		4 July	Large flood in Lake Strynsvatn

2.8.6 RIVER EIDSELV AT LAKE HORNINDALSVATN

River Eidselv is located north of Nordfjord with a catchment area of 422 square kilometers. The watercourse flows from the water divide towards Sunnylven at Sunnmøre in northeast towards the eastern end of Lake Hornindalsvatn. An east-west running mountain ridge with peaks up to 1200 m.a.s.l. separates the lake from the fjord until the outlet of the lake. A short river reach connects the lake with the fjord at Nordfjordeid. The mountain ridge is known for occasional avalanches from the crest northward across the main road and into the lake at Skredestranda.

The main gauging station 89.1 Hornindalsvatn is located near the outlet of the lake. The catchment characteristics are given in Table 2.8.11. Lake Hornindalsvatn is typical of former parts of the fjord system, which has been cut off because of isostatic lifting of the land after the ice age. It is the deepest lake in Norway with a maximum depth of 514 meter. The flood regime differs from the regime of the rivers in Stryn, Loen, Olden and Breim, which drains parts of the large glaciers in the region. Since there are hardly any glaciers within the catchments, the flood regime is more comparable to that of lowland catchments in the district.

The annual floods from Lake Hornidalsvatn are shown in Figure 2.8.3. The date and ranks of the ten largest annual floods are shown in Table 2.8.12. The largest discharge (daily value) is shown in Table 2.8.13.

The discharge is moderately modified by regulations. In 1966 subcatchments of 19,8 square kilometers were diverted to the Tussa power plant to the north at Hjørungfjord at Sunnmøre.There is a long-term precipitation station in Hornindal 58960 Raftevoll, located close to the water divide towards Langedøla at Sunnmøre.

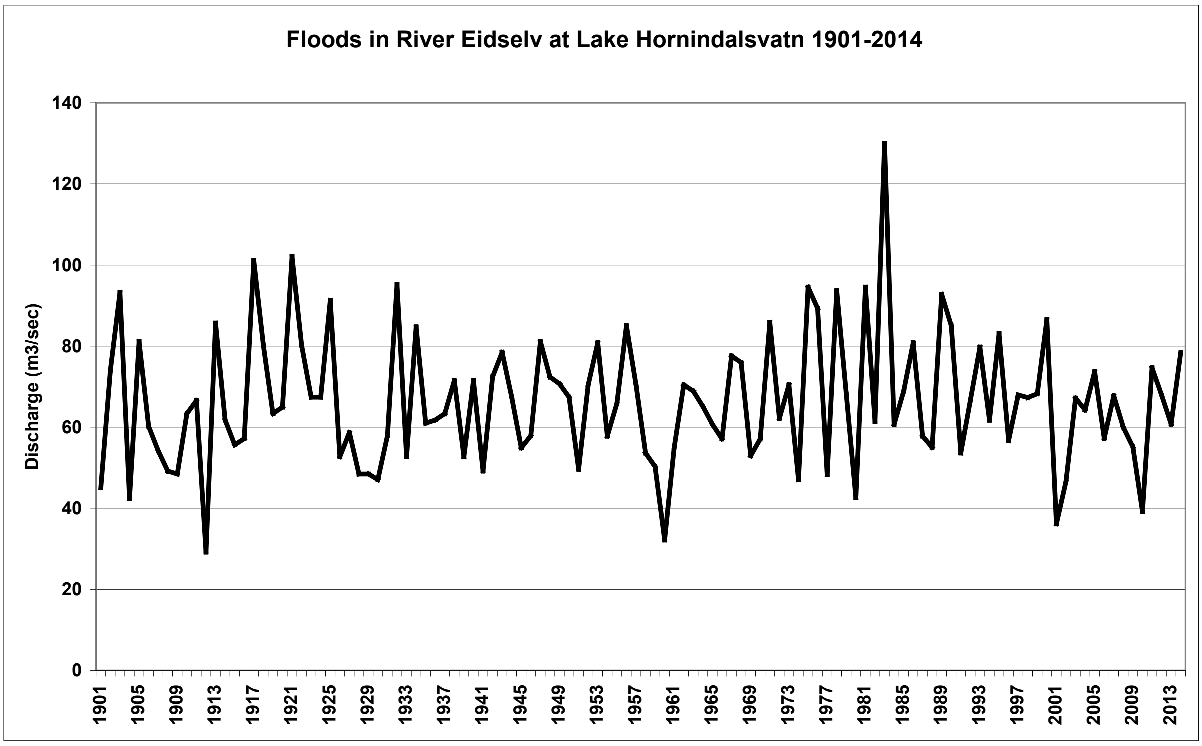


Figure 2.8.4. Annual floods (daily values) in River Eidselv at Lake Hornindalsvatn 1901-2014.

2.8.7 RIVER MØRKEDALSELV AT LAKE DALSBØVATN

River Mørkedalselv is a small watercourse flowing westwards to the sea at Ervika at Stadtlandet. The catchment is 320 square kilometres. The gauging station 91/1/2 Dalsbøvatn has been operating since 1934. Annual floods (daily values) are shown in Figure 2.8.4. Catchment characteristics are given in Table 2.8.10. The catchment is extremly maritime, and many of the floods occur at different times to floods in catchments further inland. Floods occur at all times of the year, but the annual flood occurs most frequently from September to December. The date and ranks of the ten largest floods are given in Table 2.8.11. The date and discharge of the largest flood is given in Table 2.8.12.

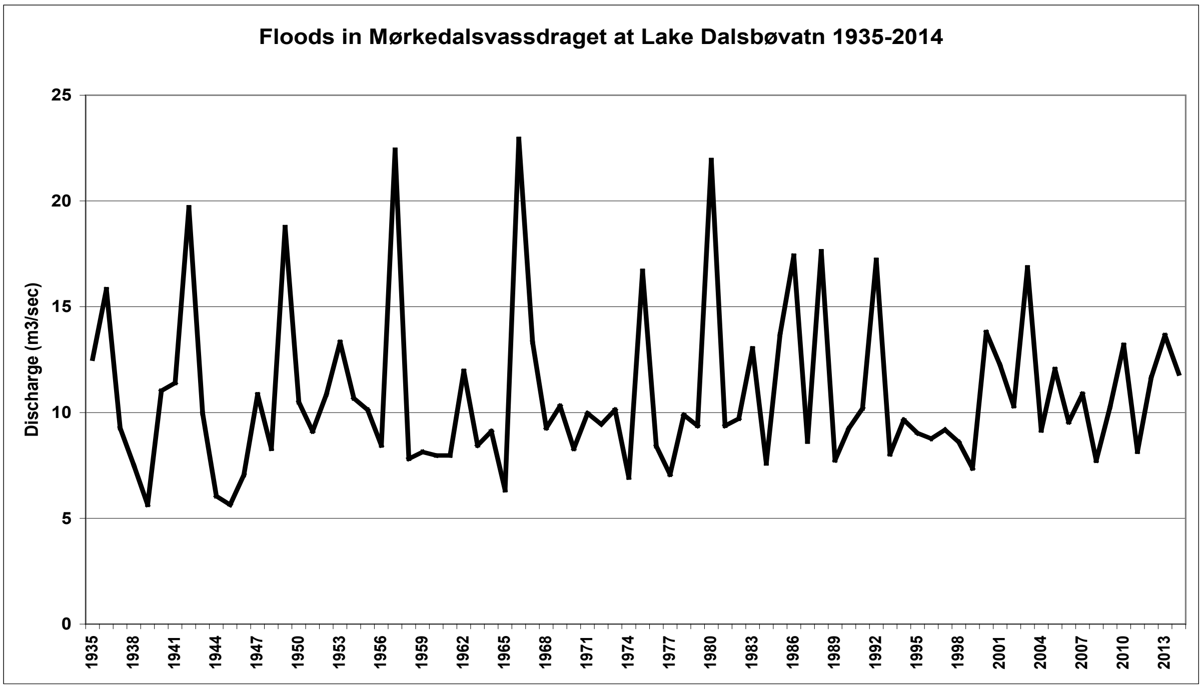


Figure 2.8.5 Annual floods (daily values) in Mørkedalsvassdraget at Lake Dalsbøvatn 1935-2014.

Table 2.8.11 The catchment characteristics of the gauging stations in Lake Strynsvatn, Lake Hornindalsvatn and Lake Dalsbøvatn.

Station	88.1/12 Strynsvatn	89.1 Hornindalsvatn	91.2 Dalsbøvatm
	Basin characteristics		
Catchment area (km^2)	482,0	380	25,57
Station altitude (m.a.s.l.)	29	53	47
Mean altitude (m.a.s.l)	1129	480	252
Top altitude (m.a.s.l.)	1933	1510	527
Lake (%)	6,24	14,84	10,19
Bog (%)	0,04	3,65	3,03
Forest (%)	14,71	40,77	3,6
Mountain (%)	53,74	32,51	66,5
Glacier (%)	17,54	0,46	0

Table 2.8.12 The dates and ranks of the ten largest annual floods (daily values) observed in Lake Strynsvatn, Lake Hornindalsvatn and Lake Dalsbøvatn.

88.1/12 Strynsvatn			89.1 Hornindalsvatn			91.2 Dalsbøvatm		
1902-23, 1968-2014			1901-2014			1935-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1905	4/7	5	1903	4/6	8	1942	25/3	4
1906	2-3/9	10	1917	30/8	3	1949	10/9	5
1908	4/10	1	1921	4/11	2	1957	25/11	2
1910	15/6	8	1925	19/1	10	1966	8/9	1
1914	7/7	2	1932	29/1	4	1975	23/9	10
1923	13/7	4	1975	8/10	5	1980	21/11	4
1968	4/7	9	1978	11/11	7	1986	1/10	7
1973	9/7	3	1981	23/5	5	1988	20/9	6
2005	7/7	7	1983	31/10	1	1992	14/1	8
2011	30/6	6	1989	20/1	9	2003	26/9	9

Table 2.8.13 The highest observed discharge (daily values) at three gauging stations in Lake Strynsvatn, Lake Hornindalsvatn and Lake Dalsbøvatn.

Station	88.1/12 Strynsvatn	89.1 Hornindalsvatn	91.2 Dalsbøvatm
Year	1908	1983	1966
Date	4/10	31/10	8/9
q (m^3/sec)	216,92	129,98	22,93
qsp (l/sec km^2)	450	336	892
qsp (mm/day)	38,9	29,4	77,0

3 *Large floods in West Norway*

3.1 A severe flood in Vosso and at Ombo in September 1719.

Kindem (1933) mention that on the ninth Sunday after Trinity (August 1719) an exceptional flood occurred in Lake Vangsvatn at Voss. The water level was described as reaching four alen (2,40 meter) on the walls of the buildings of the vicarage. It was possible to row a boat to the altar inside the church. The stables near the church drifted to the churchyard.

Two farms in Jelsa at Ryfylke suffered also damages from floods and slides in August this year. There is no direct information about the cause of this flood, but the time of the year and the fact that the flood struck at locations as far as Voss and Ryfylke indicates that the flood possibly was caused by remnants of a tropical cyclone. The winter 1718 was one of the severe avalanche winters in western Norway, and it is likely that melting of surviving snow in the upper parts of the catchment from 1718 may have contributed to the flood.

3.2 The disastrous floods and slides in West Norway in the 1720s.

Many floods and slides occurred in West Norway in the 1720s. Intense rainfall caused a large flood in River Flåmselv in the autumn 1722. The flood took mills at Dalsbotn and Berekvam. The farm Dyrdal north of the Nærøyfjord suffered damages to the fields, grassland and grain mill. The worst of these events occurred in the autumn of 1723, especially in the Hardanger district, when many farms suffered badly from floods, avalanches, landslides and rockfalls.

Cause of the events:

After heavy snowfall, mild weather with abundant rainfall must have caused widespread snowmelt and large floods in many rivers on both sides of Sørfjorden.

Flood and slide damages:

At Granvin the farms Røynstrand and Eide suffered damages. The damages were mapped, and tax deductions were granted.

At Jondal the farm Flatabø was ravaged for the second time, causing damages which were impossible to repair.

At Eidfjord the farms at Lægereid and Øydvin suffered damages. The farm Hjølmo was possibly destroyed by slides at the same time. The damages were evaluated, and tax deductions were granted 1 August 1784.

At Ullensvang the farms Rogdo, Åkre, Gjertveit, Måge, Fresvik, Opedal, Århus, Ringolvsnes, Øvste- and Midt Sekse, Bråvoll, Vikje, Aga, Velure, Kråkevik, Øvre Bøvre and Ytre Jåstad all suffered from floods, avalanches and landslides. The damages were evaluated in July 1724, and tax deductions were granted. The farms Ringøy and Lutro suffered from avalanches in 1725 and 1726.

At Odda the farms Prestegard, Bustetun, Bakke, Vasstun Mannsåker and Freim suffered damages. A major rockfall occurred at Kvitur. The farm Mannsåker suffered from another landslide in 1724.

3.3 Storeflaumen in December 1743 - the counterpart to *Storofsen* at Vestlandet.

One of the most severe spells of the Little Ice Age occurred from 1740 to 1742 in Norway. The winters were mild in the west with abundant precipitation. The snow cover in the lowland melted repeatedly during mild spells in the lowland spoiling the fields next to the fjords (Strøm, 1768). Episodes of severe killing frost occurred both in the spring and in the autumn. The sea fog was abundant on the coast in the summer, and penetrated deeper into the fjords than usual. Further south and east of the water divide it was cold and dry. Because of the abundant precipitation in the west, the glaciers grew to their largest extension probably since the last ice age.

Just before or just after the most severe years, some severe floods occurred as a result of the weather conditions. A large rainfall flood occurred in the lower Glomma catchment in August 1740. Most notable was *Storeflaumen* in early December 1743 in West Norway.

The extreme weather had a severe social impact. Failing crops caused widespread starvation leading to excessive mortality. The worst affected part of the population was unable to pay their taxes. The government in Copenhagen requested the priests and civil servants to write reports about the conditions in their respective parishes or districts in early 1743. They had to answer 43 questions, and the reports were forwarded to the Ministry of Finance (Rentekammeret). The reports are now published in "Norge in 1743" in five volumes by Riksarkivet and Solum forlag.

Initial conditions:

Several spells of difficult weather conditions are known in West Norway during the Little Ice Age since the late 16th Century. The two cold years in 1600-1601 produced spectacular sunsets seen in Bergen caused by volcanic dust in the stratosphere from the Hyuaputino eruptions in Peru. In 1630 the weather destroyed the crops in West and North Norway in combination with failing fisheries, causing excessive mortality. Severe complaints were forwarded at a "Herredag" in Bergen in 1631, causing King Christian IV to appoint a committee to examine the conditions in 1632. The commission received letters with complaints from all districts from Vest-Agder to Finnmark. The system of tax collection was revised as a result of this event. Several cold spells occurred later in the Century causing the Danish-Norwegian State to lose districts to Sweden. The worst spells of the Little Ice Age ocurred in the 1690s.

Heavy snowfall has caused widespread avalanches, causing numerous fatalities. One of this avalanche years occurred in 1718. The autumn of 1743 was probably cold, allowing layers of frozen soil in the ground to develop in Hardanger. Layers of ice in the ground when the topsoil is saturated can cause severe slides, such as in Gudbrandsdalen under *Storofsen*. The snowfall seems to have been abundant in November.

The flood:

Mild weather must have penetrated from southwest 3 December, causing the temperatures to rise excessively. There are no meteorological data available to determine the weather type causing this disaster. It is likely that the warm air masses did originate in the hurricane belt in far south in the North Atlantic. The snow started to melt and avalaches started to run. Heavy rainfall caused the rivers to grow fast. The flood peaked in Vosso and at Sunnmøre in the night between 4-5 December, but the mild weather lasted untill 11 December.

The flood extended from Ryfylke to Nordmøre and seems to have been most severe halfway into the fjords at Vestlandet. The mild weather penetrated also into Bøverdalen at Lom and in Skjåk east of the water divide, causing severe ice runs in River Bøvra and Otta.

A secondary outbreak of mild weather reached the coastal districts of Vestlandet between Hordaland and Sogn 20 December causing local floods in rivers, which had avoided damages earlier in the month.

Flood damages:

Ryfylke: The floods in River Stor-Ånå and in its tributaries at Årdal skiprede are the largest known in the watercourse. Nine farms suffered severe damages because of riverbank failures and deposition of large masses of gravel on the farmland. The farms Svadberg, Øvre and Nedre Mæle, Nedre and Øvre Vadheim, Soppeland, Østre Sedberg, Riveland, Nes, Egland, Kirkhus, Yttervold, Borgen, and Tjentland obtained a tax deduction of 8,8 to 40 percent. River Nordelva shifted to a new channel at Søfde (Sauda) skiprede. Ice had formed in the rivers at Sauda because of the cold weather prior to the flood. An ice barrage formed at Bruhølen during the heavy rainfall, forcing the water into a new channel towars River Storelva and to the fjord. The farms Fløgstad, Åbo and Øye suffered damages and obtained a tax deduction of 11 to 50 percent. One farm in Jelsen skiprede and two in Vikedal skiprede suffered also damages.

Sunnhordaland: The flood in River Etneelva was also the largest known in the watercourse. A total of 23 farms with 46 farmers suffered damages. The farms downstream Lake Stordalsvatn suffered from riverbank failures and inundation of the farmland. Farms upstream, closer to the mountain sides suffered also from slides. The tax deductions varied from 20 to 80,4 percent. Six farms suffered damages in Strandebarm, Fjellberg and Skånevik skiprede. Another flood occurred early in the winter 1770 causing damages to many farms in Etne both from flood and slides.

Hardanger: The damages were extensive in Hardanger, just as in the autumn 1723. At Odda eight farms with 17 farmers suffered damages. One of the farms suffered only from the flood; the other from both slides and flood. The tax deduction ranged between 14,3 and 66,7 percent.

At Ullensvang six farms with 40 farmers suffered damages from flood and slides. The slides started as avalanches, turning into slush avalanches and finally into landslides. The farm Aga was struck by no less than six slides. At Øvre Bøvre most of the houses were destroyed by slides. River Opo was dammed by nine or ten slides, forming a lake upstream in the valley. The river took a new channel when the water broke through the dam. The farms obtained a deduction from 22 to 43 percent.

Two farms at Kinsarvik suffered severe damages from flood and slides and obtained a deduction of 58 percent. Several slides formed a dam in River Kinso at Husedalen. A large flood wave moved towards the village Kinsarvik when the dam was broken. River Kinso is said to have undermined parts of the church, a stone church built around 1160. The farmers managed to save the church, but they were unable to save the churchyard. Coffins were according to the tradition floating in the fjord, and one farmer came drifting back to his own farm a short time after the funeral. The farm of the priest at Kinsarvik, Bråvoll, was damaged by three slides from the mountains, destroying much of the forest.

Six farms with 18 farmers was damaged by floods and slides in Eidfjord obtaining a deduction fron 17,4 to 75 percent. Three farms were damaged at Ulvik, obtaining deduction from 33 to 46 percent.
Nordhordaland and Voss: Two farms with four farmers at Hosanger at Vaksdal suffered damages, but the deductions were moderate, ranging from 1,8 to 20 percent. Two farms with

11 farmers, suffered damages at Arna skiprede, ranging from 1,1 to 16,7 percent. At Modalen and Steinsland four farms with 15 farmers suffered damages, mostly caused by inundation and some riverbank failures. The deductions were from 6,3 to 30 percent. Inundation and riverbank failures damaged three farms with eight farmers in Gulen skiprede, obtaioning deductions from 25 to 28,6 percent.

The flood in Vosso was compared to a large flood in August 1719. Kindem (1933) quotes several sources telling that the water in Lake Vangsvatnet reached to the choir within the church at Voss and that was possible to row in a boat to the altar. The water is said to have had a depth of 4 alen (2,40 meter) around the houses in the village, and that water was pouring through the windows into the houses. Some wooden houses to the west of the house of the sexton drifted into the churchyard.

Ytre Sogn: Inundation caused damages at seven farms with 19 farmers at Klevold skiprede (Høyanger). The farm Instefjord with five farmers was damaged at Lavik skiprede.

Seven farms with 15 farmers were damaged at Tjugum skiprede (Vik kommune). Most of the buildings at the priest farm in Aurland were damaged.

Indre Sogn: Five farms with seven farmers were damaged by landslides and rockfalls at Lærdal, obtaining a deduction ranging from 13,3 to 48,3 percent.

Six farms suffered damages in Årdal skiprede from riverbank failures and mountain slides. Dedections ranged between 14,3 and 50 percent

Two farms with three farmers suffered damages from rockfall at Borgund skiprede. The deductions ranged between 20,8 and 44 percent.

Three farms with ten farmers were damaged from rockfalls and landslides at Sogndal skiprede, obtaining deductions from 18,2 to 33,3 percent.

Three farms with ren farmers suffered damages from mountain slides at Norun skiprede, obtaining deductions ranging between 13,5 and 35,9 percent.

Five farms with seven farmers were damaged at Marifjøra skiprede from mountain slides and riverbank failures obtaining deductions ranging from 13,5 to 35,9 percent.

The farm Heltne obtained a deduction of 40 percent at Luster skiprede, where several deductions were granted the year before because of the large advance of the glaciers in Jostedalen.

Sunnfjord: Two farms were damaged by the flood in River Jølstra at Jøster, but the damages were insignificant compared to the damages elsewhere at Vestlandet.

In Holsen skiprede five farms were damaged. The farm Hårklau obtained a deduction and 75 percent because much and the farmland and the farm buildings were washed into Lake Jøstervatn.

The damages were examined at six farms in Ålhus parish, but only two farms obtained deduction of 9 and 21 percent. The flood and slides caused damages at six farms in the neighbour parish Helgheim, where four farms obtained deductions rangibng from 13 to 18,4 percent.

The damages were examined at nine farms at Guddal because of inundation and riverbank failures. Deductions were granred to five farms ranginining between 6,3 and 41,7 percent. Three farms with eight farmers were damaged by inundations and mountain slides. Deductions were granted for the farms where slides had caused the damages ranging from 20,8 to 45,8 percent.

Nordfjord: The most disastrous damages occurred in Olden skiprede. The farm Tungøen lost everything and the farm Forr suffered also a total loss. Eight farms received grants of deductions ranging from 8,2 to 100 percent because of flood, riverbank failures and mountain slides. The neighbour parish Loen suffered damages at two farms, obtaining deuctions of 30,8 and 50 percent.

Twelve farms with 42 farmers suffered damages caused by riverbank failures, inundations and mountain slides at Oppstryn skiprede. Deductions were granted ranging from 5,6 to 42,9 percent. Only three farms were damaged by riverbank failures and mountain slides at Nedstryn skiprede.

Sunnmøre: River Langedøla formed a new channel from the waterfall to the sea at Hellesylt at Sunnylven. This was probably caused by a flood wave as a dam resulting from a landslide further upstream suddenly burst. River Holedalselv dug four or five new channels through the fields at the farms at Bjørdal in Sunnylven, where six farms and 19 farmers suffered damages. The deductions ranged between 17,1 and 37,5 percent.

The flood caused damages at four farms with 11 farmers at Geiranger. The tax was deducted by 35,7 to 62,5 percent.

The boathouse and a mill were destroyed at Bjørkedalen in Volda. Damages occurred also at several locations along Austefjorden in Volda. Farms at the bottom of the Hjørundfjord suffered also from flood and landslides.

Romsdal: A severe flood caused damages in Holm parish on the south side of Langfjorden in Romsdal. River Herjeelv destroyed a sawmill and a grain mill at the farm Indre Herje. River Slemma destroyed the grain mill at the farm Indre Slemma. The farms at Staurset, Dale and Indre Mittet were damaged by landslides.

The heavy rainfall did probably weaken the mountain side next to the farm Tjelle, where a fissure in the ground was opening. The large mountain slide "*Tjellefonna*" fell into the fjord during another long-term rainstorm 22 February 1756.

Two major landslides occurred at the neighbour farms Fredsvik and Kvennset in Nesset towards the Tingvoll fjord. Both farms obtained a deduction of 50 percent.

Nordmøre: The farm Virum at Virumsdalen at Nordmøre was severely damaged by landslide.

Gudbrandsdalen: Five farms in Bøverdalen, Runningen, Gaupar and Uppigard and Nigard Sulheim was damaged by ice run floods in River Bøvra. The large farm Ånstad at Skjåk obtained a deduction of 50 percent. The farmer and three farm workers moved the farm animals to an island in River Otta when the snow melted. An ice-run started when the water level rose. The ice carried away 11 cattle and 18 goats as well as the bridge (Berg (1936). The four men succeeded to escape to another island in the river, from where they later were rescued.

3.4 The large rainfall flood in Røldal and Ryfylke 26-27 August 1763.

The farmers living in Røldal woke to a terrible thunderstorm during the night between Friday 26 and Saturday 27 August 1763. Brooks were flooding all over, landslides started to run, and the valley was soon inundated (Dalen & Dalen, 1960).

The tributary Tufteelva flooded first. This river flows into Lake Røldalsvatn from the north through a steep valley. The flood eroded deposits of rocks and gravel on the riverbank, which had accumulated over severl years from landslides. Rocks and gravels were deposited on the markedplace of the village and on the farms near the lake. The soil was eroded in many fields.

The main river flows from the southwestern corner of the Hardangervidda mountain plateau through an upstreams valley, Valldalen. This valley was used for chalets and summer farms by the population in Røldal. As the flood became more dramatic, people were fleeing up into this valley next to the river. Halfway into the valley they were met by wooden buildings, barrels, boxes and other farm implements, which came floating in the river.

The damages were assessed afterwards, and 18 farms obtained deductions in the tax to compensate for the loss of income for a number of years by a Royal decree granted i 1764.

The thunderstorms in August 1663 caused also damages at farms at Jelsa in Ryfylke. The damages were assessed in 1764, and rhe deduction was granted by Royal decree in 1665. One of the farms in Jelsa was damaged by another rainstorm and landslide 13 September 1667.

3.5 The autumn flood in Aurland in October 1793.

Abundant rainfall caused a severe flood in River Aurlandselv in late October 1793. Flood and landslides caused damages at several farms in Aurland. The farms Bedle, Tero, Laoi, Prestegarden, Tokvam and Skai suffered from the flood. At Tokvam grassland producing fodder, sufficients for 12 cows was lost, and at Skaim farm buildings, fields, grassland and crop were lost (Onstad, 1962).

3.6 The flood in Vetlefjord in Balestrand 19 July 1820.

Vetlefjord is a small branch west of Fjærlandsfjord in Sogn. A valley runs northwards from the fjord with a river flowing towards the fjord. The sources of the river are partly small glaciers at the water divide towards River Gaular to the west and rivers draining directly into the Fjærlandsfjord to the east. The sides of the valley are steep, and avalanches occur frequent in the winter. There are a number of farms in the valley, which suffer damages from these avalanches, as well as from droughts in the early summer and floods in the river and early frost in the autumn. There was a glacier arm damming an upstream lake at this time. Heavy rainfall could cause water to flow under the glacier ice as a jøkullhlaup. The resulting flood could cause severe damages at the farms in the valley.

Water started to flow from the glacier 18 July at 21:00. The flood grew rapidly through the night and was over at 16:00 19 July. The farmers lost 28 cattle at a mountain farm. The flood caused severe damage to the farmland as well as to the woodland belonging to the five farms which was affected by the flood.

3.7 The severe flood in inner Sogn (Storeflaumen) 11 July 1826.

A severe flood caused extensive damages in Aurland and in Årdal in July 1826. This flood is the largest known flood in River Aurlandselv and River Årdalselv together with the severe flood occurring in June 1860. The flood levels are not known, but the damages are known both in Aurland and in Årdal.

The water level rose abruptly in River Aurlandselv, destroying the large bridge at Veum-Bedle and seven other bridges (Onstad, 1962). A number of farms suffered from inundations, bank failures and slides.

The tributaries Utla and Tya to River Årdalselv went bankfull and inundated farmland and grassland severely at many farms (Ve, 1971). The location of the farms damaged by the flood are shown in Figure 3.7.1. Numerous ban failures caused also severe damages. A substantial part of the farmland was eroded at the smallholding Øygarden belonging to Hjelle farm as well as the smallholding Hagøyni belonging to Svalheim farm. The latter property was almost completely destroyed. The farmer was rescued by his son from the roof of his house. The buildings were rebuilt further away from the river afterward.

Another smallholding, Ålmennhagen belonging to Midttun farm, was completely destroyed and was afterwards abandoned. The smallholding Kiærøen belonging to Øvstetun farm, which was located on the bank of River Utla, was also severely damaged.

River Tya carried large boulders, gravel, sand and soil from landslides, which occurred in the Moa valley. The debris dammed the river downstream the lowest waterfall, causing the river to shift to a new riverbed. The farm Moa, which was located by the river, lost most of the farmland as well as the buildings. The debris from the river Storelvi caused most of the damages to the farms further downstream.

The damages were assessed in November 1826, and deductions were granted, as shown in Table 3.7.1.

Table 3.7.1 Summary of the deductions for flood damages in Øvre Årdal July 1826.

Farm and farmer	Temp. deduction	Number of (years)	For ever	Remarks
Ve	1/30	10	1/36	
Moa			1/3	Riverbank failure
Svalheim med Hagøyni	½	4	1/3	Rockfall
Hjelle med Øygarden			1/5	
Øvstetun			1/9	
Midttun, Lars Erikson m/Ålmennhagen			1/18	
Øren, Jon Jørgenson	1/4	4	1/6	
Øren, Helge Jonson	1/10	4	1/12	
Hestetun, Olav Endreson	1/30	4	1/12	
Hestetun Olav Torleivson	1/12	4	1/54	Rockfall

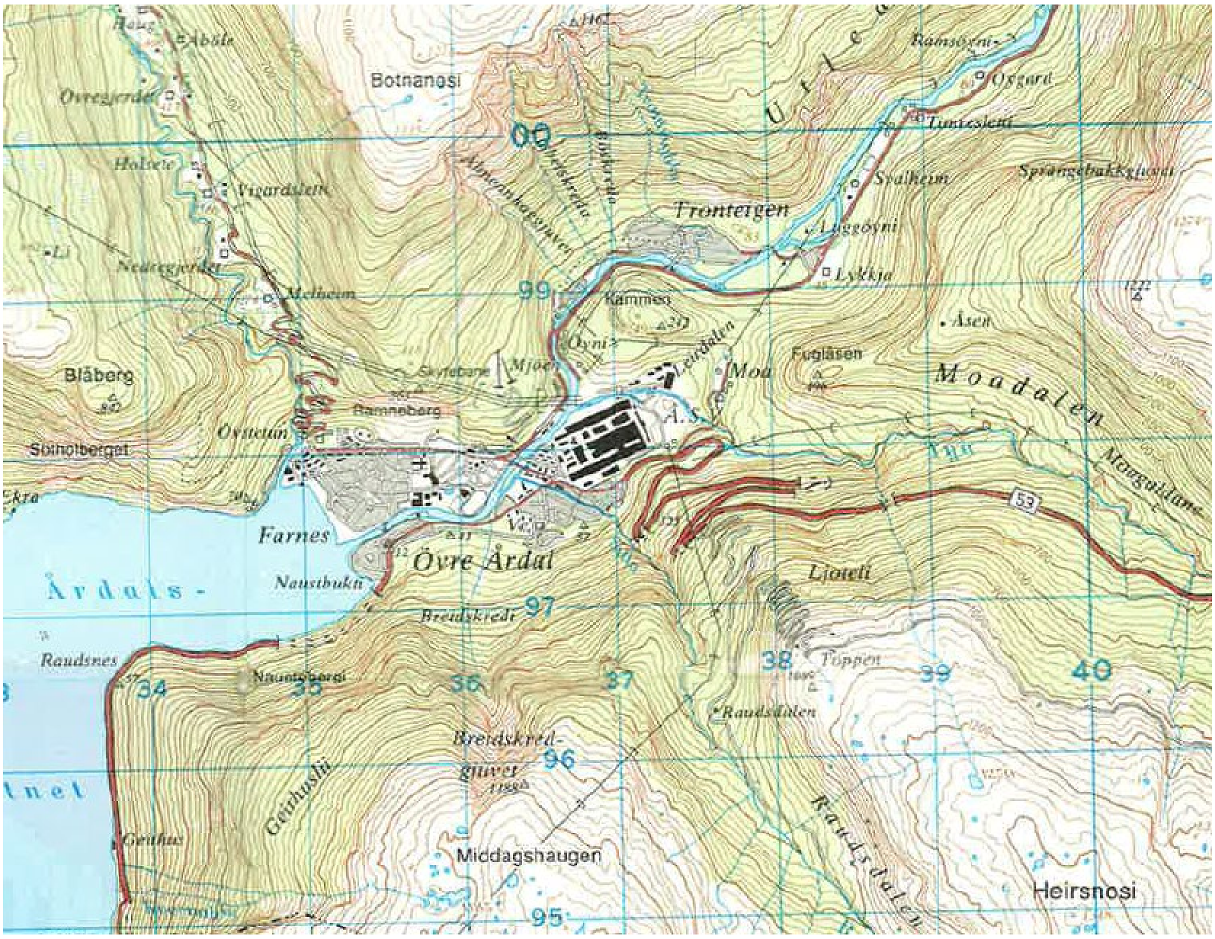


Figure 3.7.1 Map of Øvre Årdal showing the locations of most of the farms affected by the flood in 1826.

3.8 The extreme flood in Lærdal and Årdal in June 1860.

The severe flood in June 1860 affected most severely in East Norway as described in Volume 2. The flood was caused by extreme snowfall in the western parts of East Norway, a late and cold spring and high temperatures and thunderstorms in June. The flood penetrated to rivers flowing westward from the water divide to the bottom of the fjords at Hardanger, Sogn and Sunnmøre. River Sima flowing towards the Hardangerfjord has suffered repeatedly from severe floods caused by jøkullhlaups from Lake Demmevatn. Prior to 1860, a landslide from the left-hand side of the valley moved the riverbed to the right, causing severe loss of farmland from erosion of the riverbank at the farm Sæd. The damages in 1860 was assessed as it proved impossible to prevent the erosion by construction flood protection works (Kanalvæsenets historie IX B3).

The banks of River Lærdalselv have always been unstable and prone to failure from erosion causing the riverbed to shift. Increasing utilization of the flood plain for farming upstreams the farm Ljøsne, has suffered from riverbank failures. The extreme flood in 1860 initiated increasing damages resulting in loss of 1/20 of the farmland within the valley. The flood caused the riverbed to shift just upstream the farms Ljøsne and Mo. The river cut into a 50 meter tall hill at Mo where a large volume of soil was eroded (Helland, 1901a,1901b).

The flood was also severe in River Årdalselv (Ve, 1971). The water levels in the rivers and in Lake Årdalsvatn, has probably never been higher in living memory. River Tya eroded even more at the farm Moa, which suffered severe damages during the flood in 1826. The debris carried by the rivers, accumulated in the river channel, threathening the farms Ve and Farnes. The main river split into several branches befor reaching the lake. A comparison of the floods in 1826 and 1860 indicates that the second flood was the largest. The flood in 1826 caused, however, more severe damages. There is a flood mark cut into a rock face near the marina at Børtnes in øvre Årdal. Whether this marks the level of the 1860- flood or another large flood is not known.

3.9 The severe flood in Jostedalen 15 August 1898.

Farmland located at the bottom of Jostedalen between Myklemyr and Sperle-Fossøy suffered from a severe rainstorm 15 August 1898.

Cause of the flood:

Prior to the rainfall event an anti-cyclone was located on the European mainland with mild and humid air moving towards the coast of Norway along the flank of the anti-cyclone from south southwest. Warm and humid air from south penetrated into Jostedalen, causing the heavy rainfall 13 and 14 August. The position of the anticyclone moved towards UK 14 August cutting off the transport of humid air from the south, similar to the weather causing the later fllod 15 August 1979. At Fåberg in Jostedalen 17,4 mm was observed on the 13th and 41,9 mm on the 14th. The rainfall was probably higher elsewhere in Jostedalen, and glacial melting is likely to have contributed to the flood because of high temperatures.

The weather types were: 10-13 August **HM** and 14-16 August **BM** (Grosswetterlagen) and 10-14 August **SW SW S SW S** (Lamb-Jenkinsson).

Flood damages:

The local vicar, Theodor Børresen, wrote a description of the flood in the newspaper. Morgenbladet, appealing for a collection of money to help the flood victims in Kristiania. Flood water rose to 2 alen inside farmhouses at the flood plainFour bridges were destroyed near Fossøy. At Myklemyr 11 families with 60 members had to spend the night at the loft of the farmhouses, and at Sperle-Fossøy 6 families with 40 members. The farmland was flooded, and the flood water deposited a thick layer of glacial sediments on the crops. The loss of farm produces was estimated to 7400 NOK.

3.10 The rockfall and tsunami in Lake Lovatn 15 January 1905.

Upstream Lake Lovatn the mountain Ramnefjell steep is facing the farm Nesdal. The side of the mountain is dark and steep, threathening the farms located next to the Lake. The winter 1904/1905 was very wet. Figure 3.10.1 show observed daily precipitation observed at three meteorological stations within the district. 110 mm precipitation was observed 2 January at the station in the next valley, Briksdal. Another 95 mm fell on 8 January and some more before the disastrous rockfall Sunday 15 January just before midnight, which caused a 40+ meter tall tsunami from the rocks falling into the upper end of the lake and killing 61 of the inhabitants of the valley. The slide fell into the lake near Nesodden, where two resulting waves moved towards Bødal and Ytre Nesdal. At Bødal 27 persons perished, and at Ytre Nesdal 34 persons. No-one perished at Indre Nesdal, but there were material damages to the farm. The steamboat "Lodalen" was taken by the tsunami and was left on dry land.

The figure shows also the observed water levels at the outlet of the lake, where a gauging station had been operating since 1900.

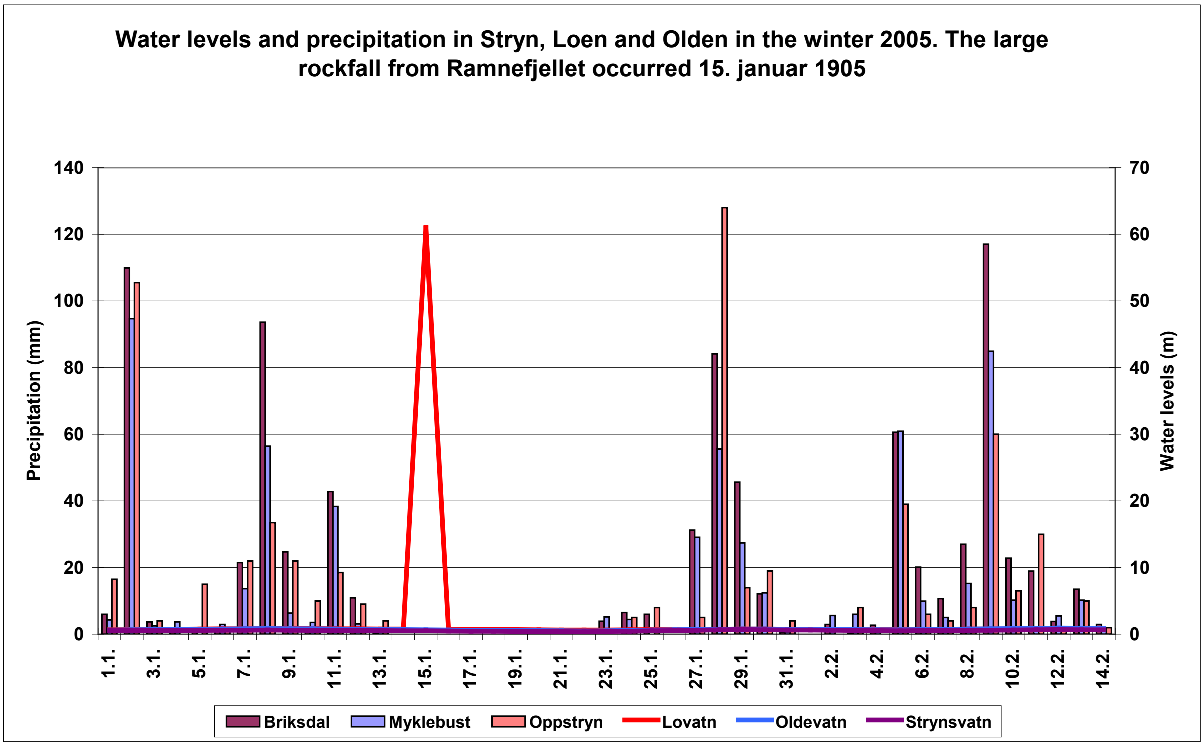


Figure 3.10.1 Observed water levels and precipitation in Stryn, Loen and Olden in the winter 1905.

Observed temperatures at Stryn and observed snowdepths at Myklebust, Briksdal and Oppstryn is shown in Figure 3.10.2.

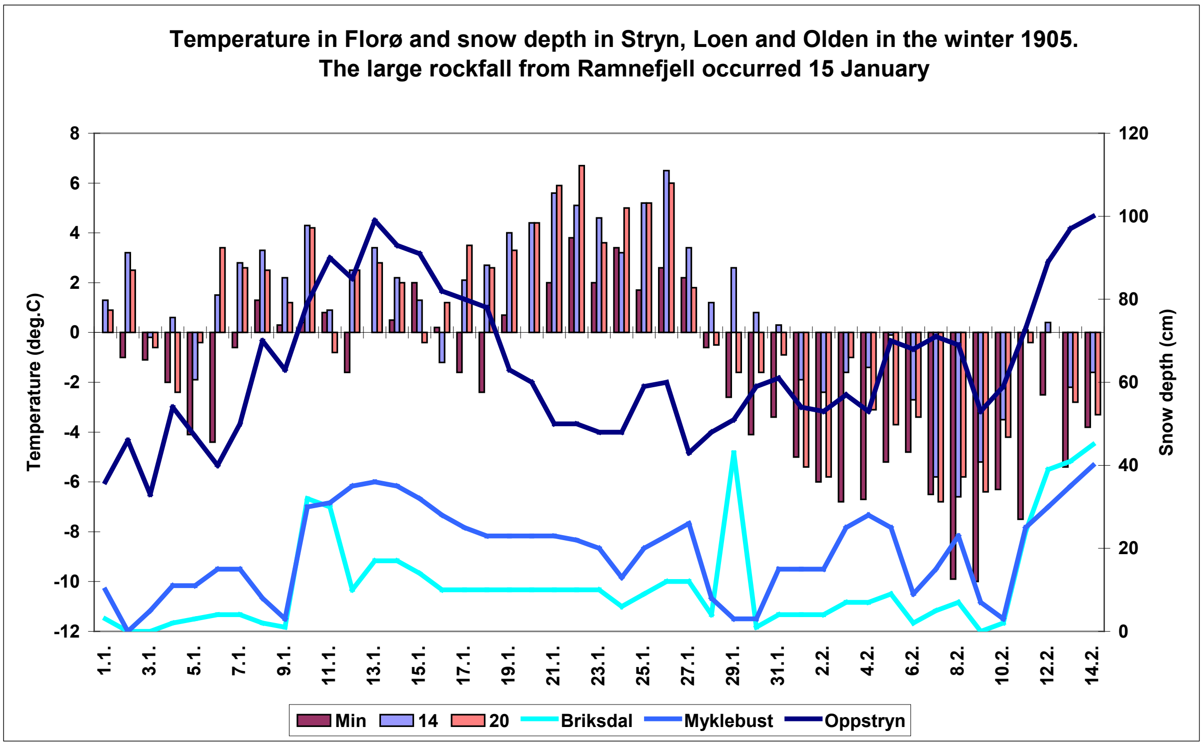


Figure 3.10.2 Observed temperature and snow depths and Stryn, Loen and Olden in the winter 1905.

The figure shows that the snow depth peaked 13 January, 2 days prior to the rockfall. The slide occurred during a mild spell. Excessive water pressure after a period of fracturing because of frost is likely to have initiated the slide.

3.11 A large flood at Vestlandet 16-18 August 1906.

Rainfall caused a large flood 16-18 August in River Aurlandselvi, River Årdalselv and River Eidselv at Hornindal. The flood was second largest in Lake Årdalsvatn 1900-2014 and fourth largest in Lake Hornindalsvatn 1901-2014. The observations in River Aurlandselv and River Lærdøla started in 1908. The level of these rivers was not known during the flood in 1906, but there must have been a large flood in these rivers at the time. Figure 3.11.1 show daily precipitation and discharge at Årdal.

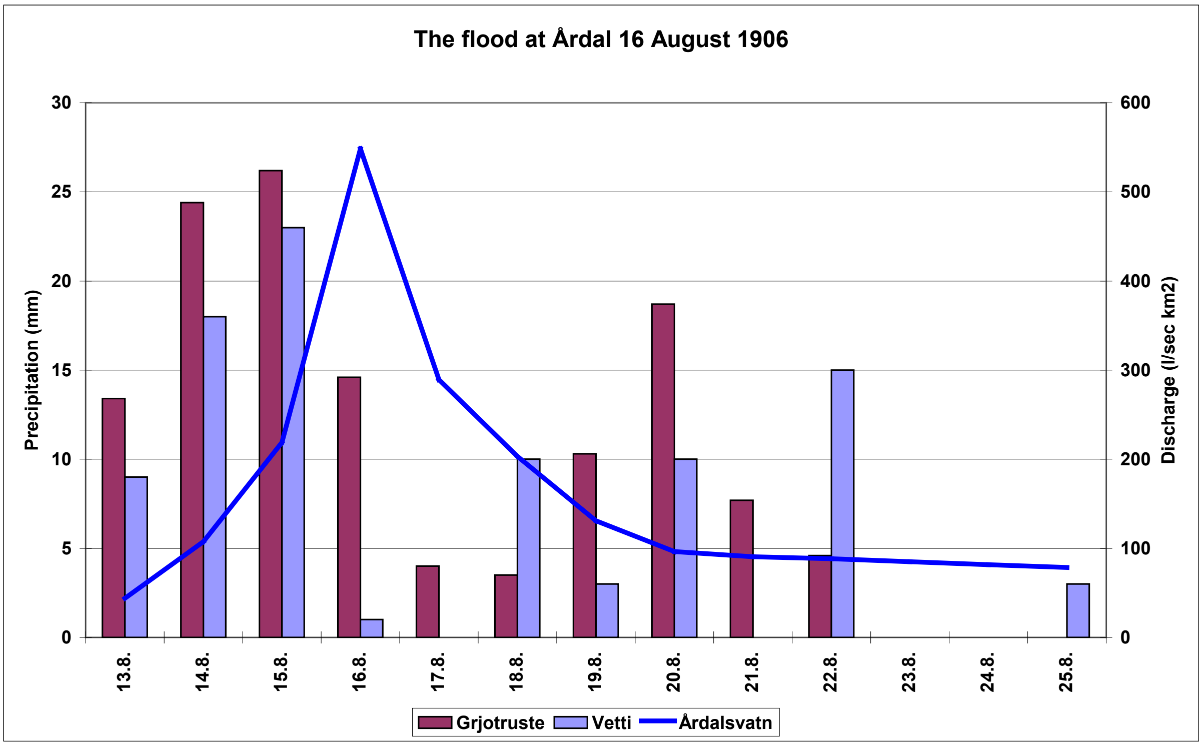


Figure 3.11.1 Observed daily rainfall and discharge at Årdal in Sogn August 1906.

Cause of the flood:

A depression over Great Britain directed mild and humid air from south over the southern coast of Norway 13-16 August. Although most of the rainfall occurred in Telemark, some rainfall may have penetrated into the upper part of the catchments from East Norway. The one-day rainfall observed from Telemark to Agder ranges from 20 to 98 mm. The rainfall observed at stations on the western side of the water divide ranges from 10 to 48 mm. Melting of snow remaining at high altitudes is likely to have contributed to the flood at Årdal. The weather types were: **TB** (Grossewetterlagen) and **C** (Lamb-Jenkinson).

Flood damage:

The flood destroyed four bridges at Øvre Årdal (Ve, 1971).

3.12 A severe rainfall flood at Vestlandet 22-25 November 1906.

Heavy rainfall caused severe floods in several rivers in Sogn and Fjordane 22-23 November and at Sunnmøre 23-25 November 1906. Before the rainstorm very little snow had accumulated, even at higher levels in the south. Further north, however, snow had accumated in the mountains near the inner fiords. The resulting flood was mostly a rainfall flood, but with some contribution from melting snow. The snow cover started to build up further south27 November. Observed precipitation and discharge at Vestlandet 20-30 November 1906 is shown in Figure 3.12.1.

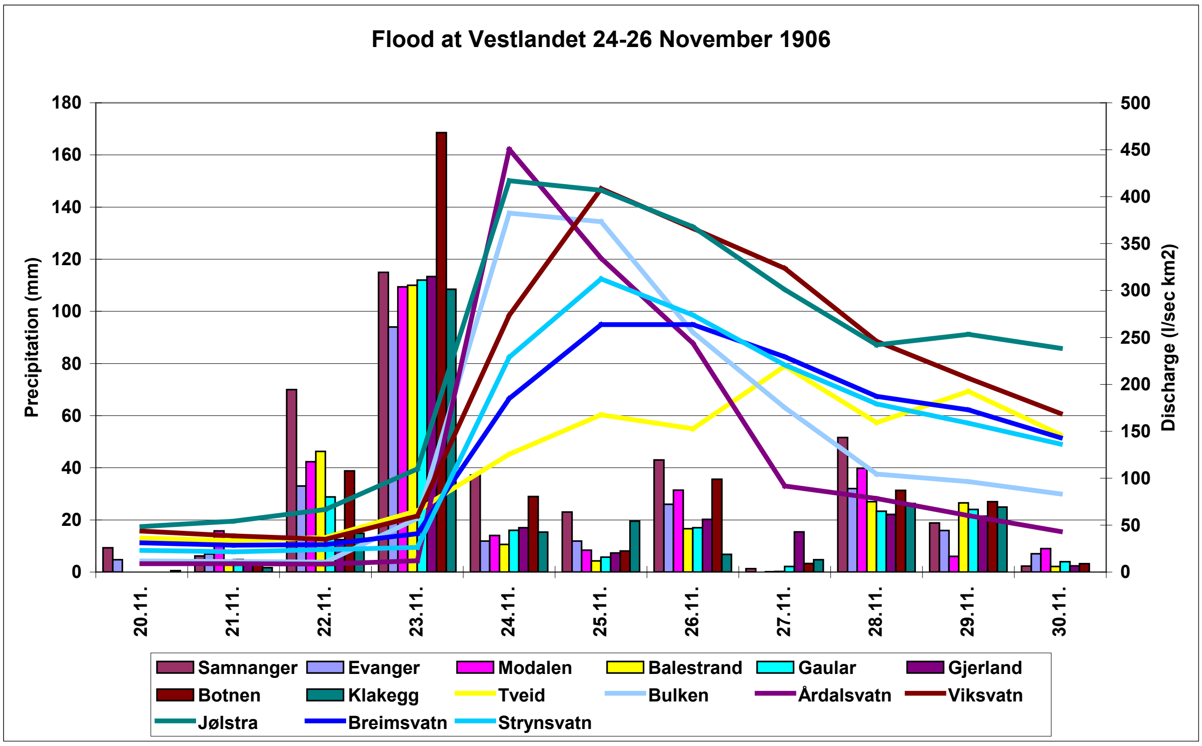


Figure 3.12.1 Observed precipitation and daily discharge in West Norway during the rainfall flood in November 1906.

The one, two and three day rainfall is comparable with the rainfall at the large long-term rainstorm in November 1940, but the duration was shorter in 1906 than in 1940. At Samnanger the one, two and three-day rainfall was 115/185/222 mm, at Masfjord 144/189/219 mm, at Botne at Førde 169/208/237 mm. In Sogn 139 mm fell at Dale at Høyanger, 150 mm at Kirkebø, 183 mm at Lavik and 198 mm at Solheim at Gloppen. No less than 19 stations observed rainfall in excess of 100 mm 23/11. The flood, however, caused more damages than the rainstorm in August.

Between an anticyclonic ridge from the Iberian penninsula to East Europe, and a large low in the Atlantic south of Iceland with a through extending southwestward into th Central Atlantic a mild and humid air was streaming from the Atlantic over Great Britain toward Norway 22-23 November. After the frontal passage causing the rainfall, the ridge moved northwards into the North Sea forcing the air stream toward the coast of Norway to shift to west. The weather types 22-23 November were: **HM** (Grosswetterlagen) and **SW** (Lamb-Jenkinsson).

Flood damage:

The rainfall and flood caused River Hæreidselv at Årdal to shift into a new bed after riverbank failures caused by erosion (Ve, 1971). The flood caused landslides at River Seimselv at Årdal. Bridges and mills were taken by River Vikedalselv. A bridge was also taken at Tokvam in Aurland.

The flood in River Sulka at Førde caused riverbank failure. River Langedøla and Øyeelv at Sunnylven damaged six bridges and took many mills (Lillebø, 1941, 1999). The flood was considered as the most severe flood known at inner Sunnmøre together with the 1743 event.

3.13 A locally large rainfall flood at Vestlandet and Mid-Norway in August 1909.

Heavy rainfall occurred at Vestlandet from Søyland at Gjesdal to Verdal and Meråker in Nord-Trøndelag and Å in South-Trøndelag 12-14 August 1909. Most of the rainfall fell 13 August at Romsdal and at Nord-Møre. Locally 113 mm fell at Reitan in Eresfjord/Vistdal, 153 mm at Tingvoll, 108 mm at Brekken at Stangvik, 116 mm in Surnadal, 89 mm at Langlien in Rindal, 82 mm at Sognli at Orkla, 127 mm at Hemne and 84 mm at Lysvatnet at Å den 13. At Sunnmøre and in the rest of Romsdal the rainfall varied from 40 to 79 mm and in the rest of Trøndelag from 27 to 62 mm. The amount of rainfall is comparable to the rainfall 14 August 2003 even though the largest intensities mostly fell at other stations in the district. Local rainfall was the cause of the largest known flood in River Todalselv 1908-1938 as well as a large flood in River Surna and River Gaula. Observed precipitation and discharge at selected stations are shown in Figure 3.13.1.

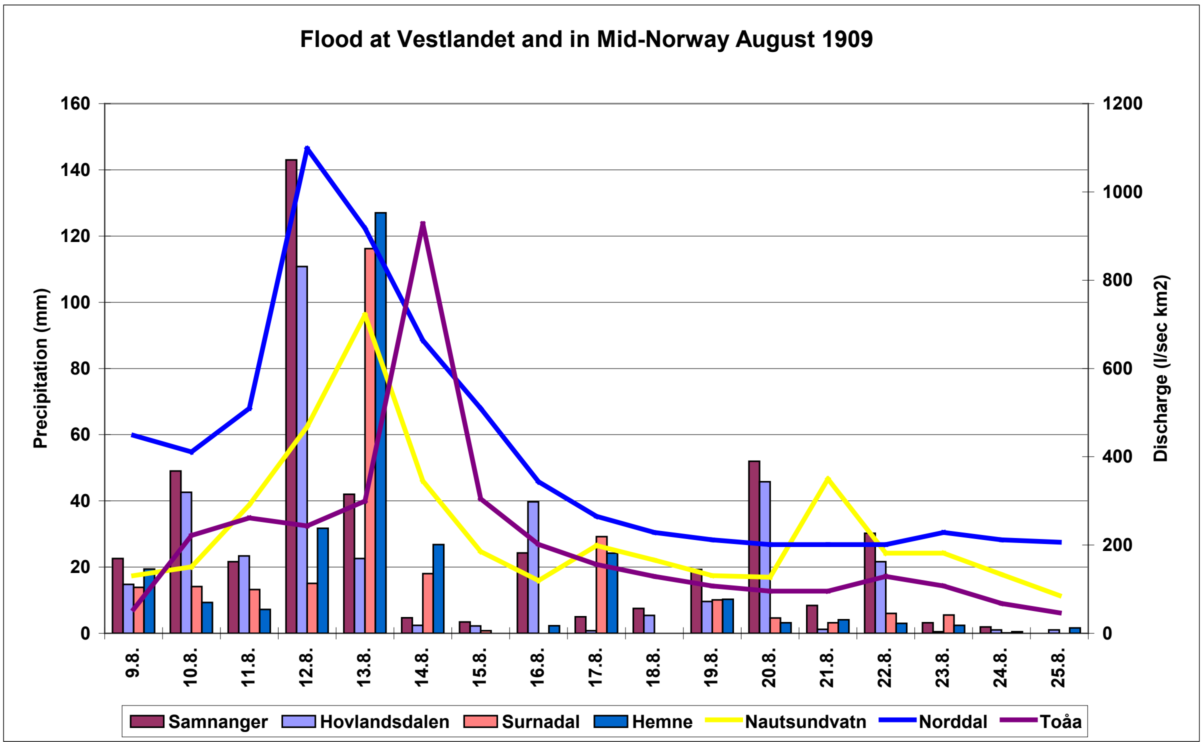


Figure 3.13.1 Observed precipitation and daily discharge at Vestlandet during the rainfall flood in August 1909.

Cause of the flood:

An anti-cyclone was located west of Great Britain and depressions from Greenland over Iceland towards Norway. A low moved eastward over Mid-Norway 13 August and causing rainfall from Nordhordaland to Kråkmo at Nordland.

The weather types 12-13 August were: **NWA** (Grosswetterlagen) and **A/N** (Lamb/Jenkinsson). The observed rainfall and discharges are similar to those observed at the same time the year in 2003, however from a different atmospheric circulation.

3.14 A severe rainfall flood at Vestlandet October 1913.

A large rainfall flood occurred at Vestlandet from Nordhordaland to Sunnmøre 18 October 1913, causing local damage at Fardal at Årdal in Sogn and at Sunnylven and Geiranger at Sunnmøre. The flood occurred both in coastal rivers and rivers in the inner fjord districts. Figure 3.14.1 show daily rainfall and discharge at stations which were active at the time of the flood.

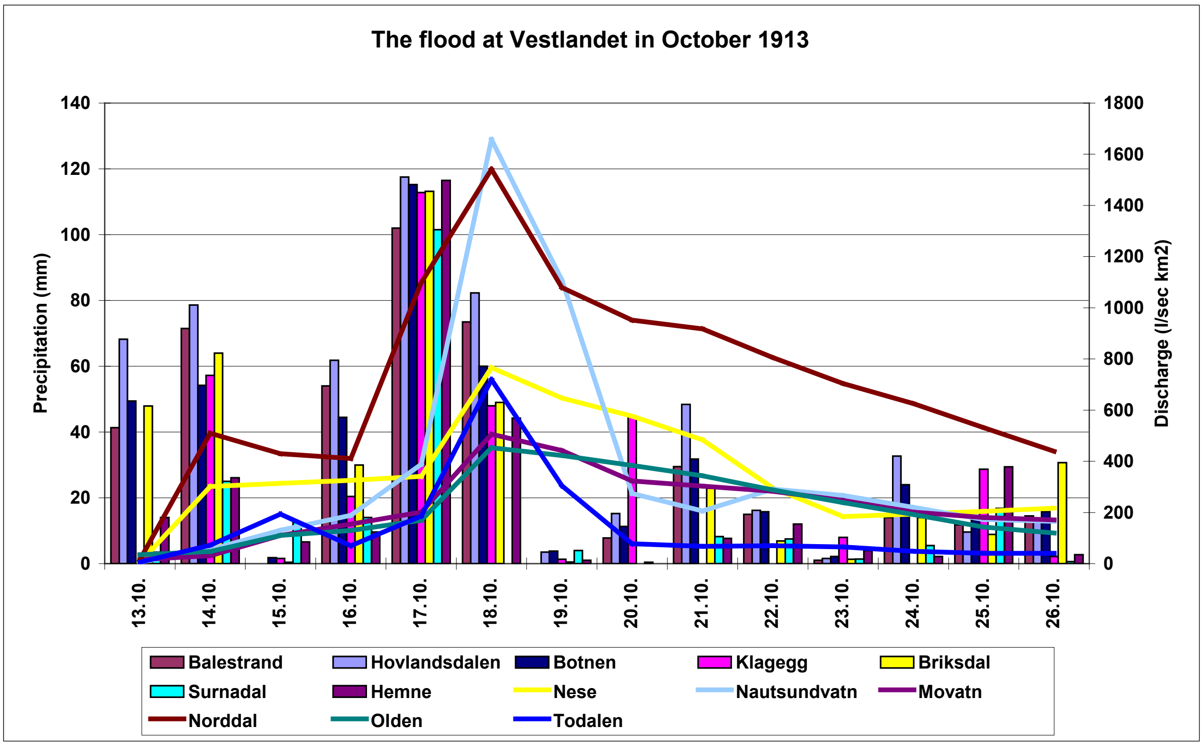


Figure 3.14.1 Observed precipitation and daily discharge at Vestlandet during the rain flood in October 1913.

The flood ranks as the 27th largest in 98 years at Nese in River Eksingedalselv, the ninth largest in 95 years at Lake Årdalsvatnet, the fourth largest in 102 years at Lake Nautsundvatn, the third largest at Lake Viksvatn in Gaular 1902-2014, the second largest in River Jølstra 1902-1951, the fourth largest 1907-1987 in River Norddalselv in Sunnfjord, the second largest in River Breimselv 1900-1990, the 17th largest at Lake Oldevatn in 109 years and the 12th largest at Lake Strynsvatn in 57 years. Observations had not started at Øye in River Bygdaelva in Sunnylven. The flood in the tributary Holedalselva caused severe damages. The flood at Øye was probably at least as large at the flood 22 October 1956.

Cause of the flood:

The flood was caused by heavy precipitation. The second part of October was mild at Vestlandet, especially 17– 21 October and 27– 31 October. The temperature in Bergen was 18,1 °C 29 October. September was also mild, and little or no snow har fallen in the lowlands. The flood penetrated unusually far inland. Snow fields and glaciers at high altitudes have contributed to the flood in the inner fjords. Between a cyclone over Iceland and an aticyclone over France, the Netherlands and Germany varm and humid air masses from the central Atlantic were streaming towards Vestlandet causing heavy rainfall. Most precipitation was observed in the morning 17 October. The anticyclone moved eastward to Central-Europe in the two subsequent days. The transport of varm air was temporary reduced, but it was reinforced at the end of the month. The weather types 16–19 October were **HM** (Grosswetterlagen) and **SW** (Lamb-Jenkinson).

Flood damage:

Årdal

River Fardøla or Øvstetunelvi at Øvre Årdal ruined 40 meters of a flood protection wall, which was constructed three years earlier. The failure caused loss of some farmland. River Seimdalselva in Øvre Årdal caused riverbank failure as a result of the large flood. The river shifted to a new channel to the fjord (Ve, 1971).

Sunnylven

River Holedalselva shifted to a new channel upstreams the houses at the Bjørdal farm through the fields and grassland and through the gardstun belonging to Knut and Tomas Bjørdal during the large flood 17-18 October 1913. The river started to undermine the walls of the houses. 80 neighbours from other farms in the valley succeeded, however, to divert the water and thus save houses (Lillebø, 1941, 1999).

3.15 An atmospheric river caused heavy rainfall and autumn floods at Vestlandet in 1917.

Westfacing coasts near the Atlantic and the Pacific Ocean on the northern hemisphere are in some years exposed to long duration transport of warm and humid air masses, which produces many large floods. This stream of humidity has been compared to rivers pouring in water over the coastal region and has been called *Atmospheric Rivers.* The coast of west and North Norway are examples of districts, which suffer from this phenoma. This weather type occurs mostly in the autumn and early winter and may last between one and several months. Some years when this occurred were 1743,1906, 1913, 1917, 1932, 1940, 1975, 2005 and 2014.

The transport of warm and humid air lasted from September to December in 1917, resulting in larger or smaller floods 25-29 September, 5-6 November and 7 December which are described below.

3.16 The rainfall flood 25-29 September 1917.

Longterm rainfall from 8 September to 6 October caused several small floods in many rivers from Ryfylke to Sunnmøre. The most intense rainfall occurred from 25 to 29 September when the largest of the floods culminated. Figure 3.16.1 show observed rainfall and daily discharge 8 September –12 October 1917.

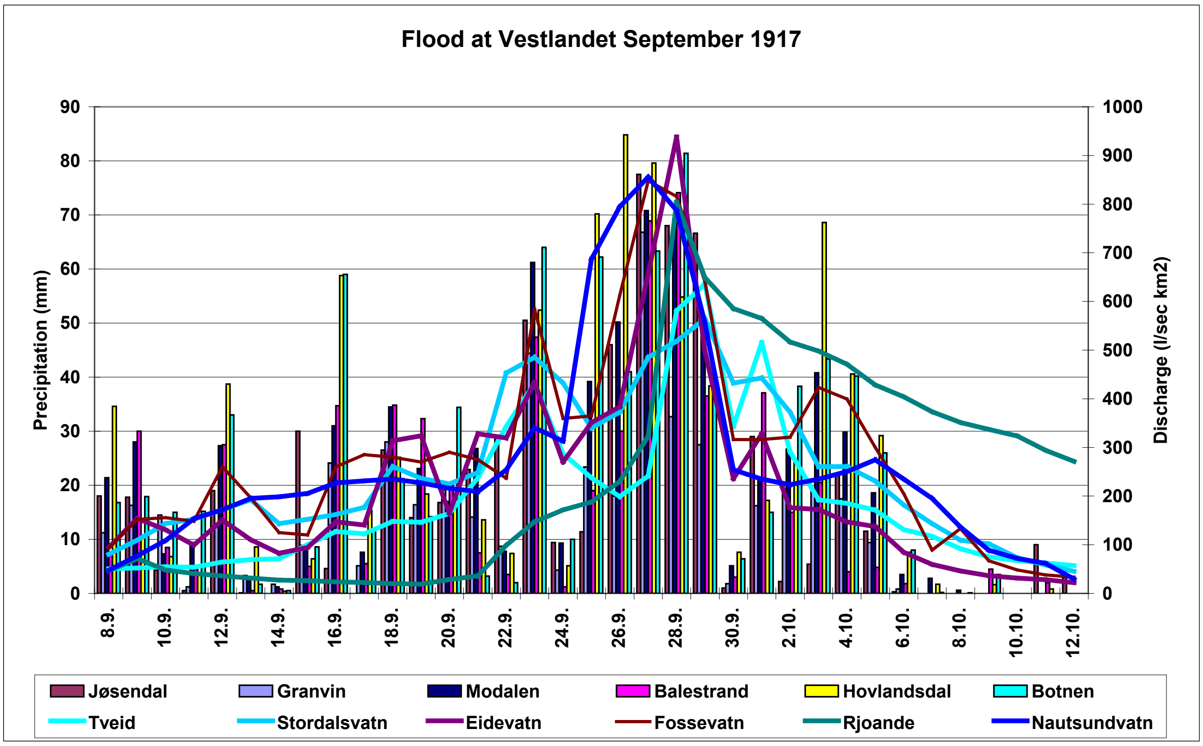


Figure 3.15.1 Observed precipitation and daily discharge during long-term rainfall at Vestlandet in September 1917.

The flood was the second largest observed in River Ulla at Hauge bru (905-2008, River Blåelv at Lake Fjellhaugvatn 1908-1920, River Opo at Lake Sandvenvatn 1908-2014 and River Gaular at Lake Viksvatn 1902-2014. It was the third largest in River Breimselv at Lake Breimsvatn 1900-1990, in River Eidselva at Lake Hornindalsvatn 1900-2014 and the third largest inflow flood in River Suldalslågen at Suldalsoset 1904-1990. The flood ranks only as the 46th largest in 96 years in River Etneelv at Lake Stordalsvatn.

Cause of the flood:

The wet period started when the remnants of a tropical hurricane from the Atlantic moved into the Norwegian Sea 6 September. The hurricane was the third of 1917 and was a major category 3 hurricane. The hurricane did not cause heavy rainfall in Norway, but it startet a stream of mild and humid air masses from the hurricane belt Atlanterhavet or an atmospheric river, similar to the autumn 2005 when the remnants of hurricanes Maria and Nate or the extreme weathers Kristin and Loke caused heavy rainfall, floods and slides at Vestlandet. The largest one day rainfall observed at Hovlandsdalen in Sunnfjord was 84,8 mm in September 1917, which is far from an extreme one day rainfall at this station. In two days 164,4 mm fell, in 3 days 234,6 mm and in four days 289,4 mm. From 8 September to 12 October a total of 849,5 mm fell at Hovlandsdalen, 795 mm at Botnen in Førde and 749,9 mm in Modalen. The abundant rainfall in the two weeks prior to the flood filled up the groundwater storage. This contributed to the flood. No snow was present in the catchments prior to the flood.

An anticyclone over Central Europe extended a ridge towards southwest over the Iberian Penninsula and into the Atlantic 25-30 September. Polar front depressions in the Norwegian Sea moved northeast towards the coast of Northern Norway on the northern flank of the mild air streaming from the southwest Atlantic. This weather type dominated the period of heavy rainfall. 28 and 29 September the wind temporary turned northwest in the rear of the depression producing the heaviest rainfall. Another depression caused heavy rainfall and a locally large flood in coastal rivers at Helgeland.

The weather type 25-29 September was: **WA** (Grosswetterlagen) and **W**, **AW**, **AW** and **A** (Lamb/Jenkinson).

3.17 Extreme rainfall 5- 6 November 1917 did not cause extreme flood in major rivers at Vestlandet.

The transport of mild and humid air from the hurricane belt continued through the autumn. At 6 November fell from 65 to 154 mm rain in a day at stations in the Bergen district, and as much as 90 and 191 mm further south at Søyland and Helleland in Rogaland. Hardly any snow fell at high altitudes. The rainfall caused a number of smaller floods in many streams, without causing the highest flood of the year in any rivers with hydrological observations.

The weather type 5 and 6 November was: **BM** and **TRW** (Grosswetterlagen) and **W** (Lamb/Jenkinson).

3.18 Floods in coastal rivers in Hordaland, Sogn and Sunnfjord 7. December 1917.

Another flood occurred 6-8 December at Vestlandet. Figure 3.18.1 show observed precipitation and daily discharge at some stations in Hordaland, Sogn and Sunnfjord. The flood was not the largest this year at any of the stations vhere hydrological observations are available.

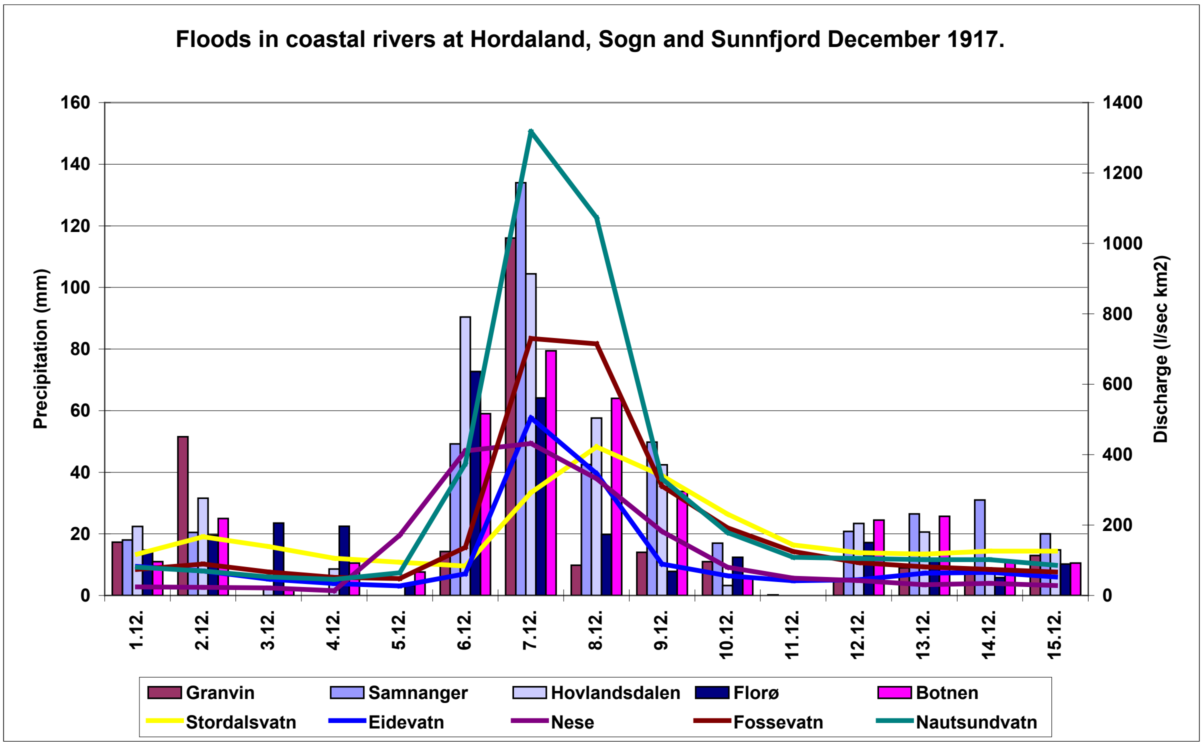


Figure 3.18.1 Observed precipitation and daily discharge during the flood in coastal rivers at Vestlandet in December 1917.

Cause of the flood:

Initial conditions

Later in November 1917 the temperatures started to drop, and snow started to accumulate in the mountain and inland catchments at Vestlandet unto 4 December 1917. Figure 3.18.2 show observed snow depths at Jøsendal at Opo in Odda (345 m.a.s.l), Øvsthus at Vosso (630 m.a.s.l), Moelvi at Modalen (108 m.a.s.l), Selseng at Sogndalselvi (415 m.a.s.l) and Jølstra at Botnen at Førde (257 m.a.s.l).

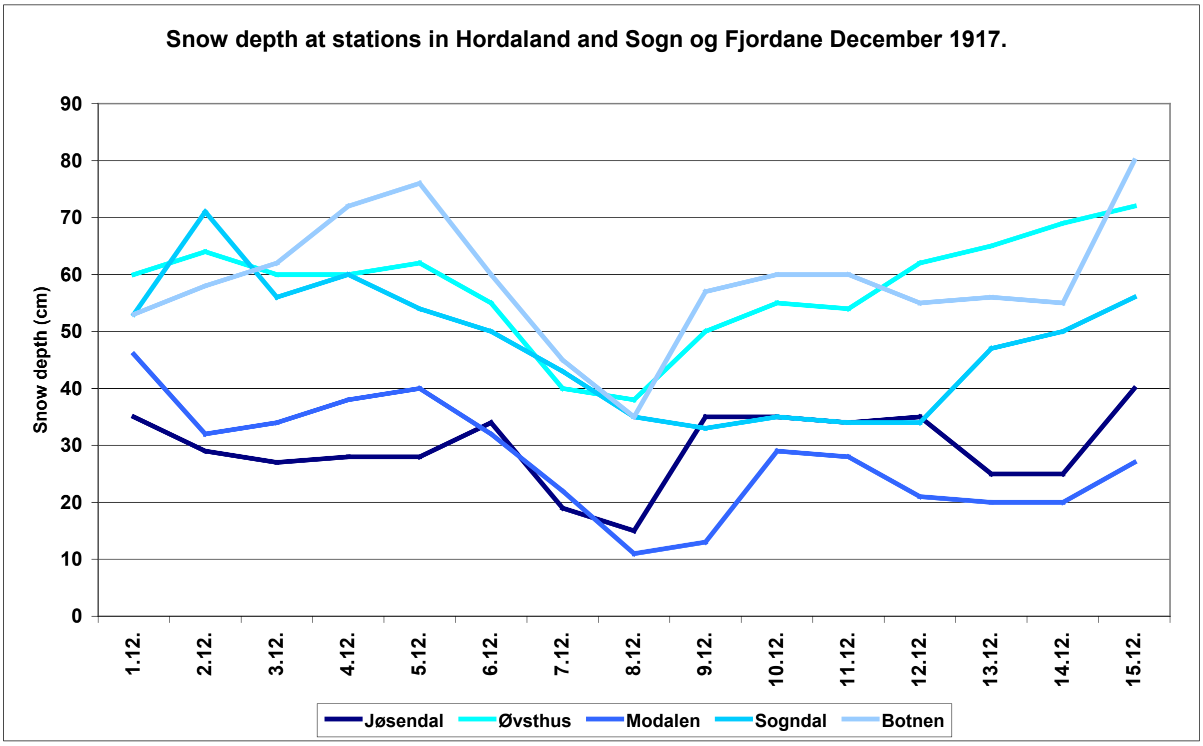


Figure 3.18.2 Observed snow depth at stations in Hardanger and Sunnfjord in early December 1917.

Figure 3.18.3 show the temperature observed at Florø in early December 1917. The snow depth was reduced 5 December both because the snow cover setteled as rain started to fall and because of some melting. Melting snow contributed to the flood, but the heavy rainfall was the primary cause of the flood in the coastal rivers.

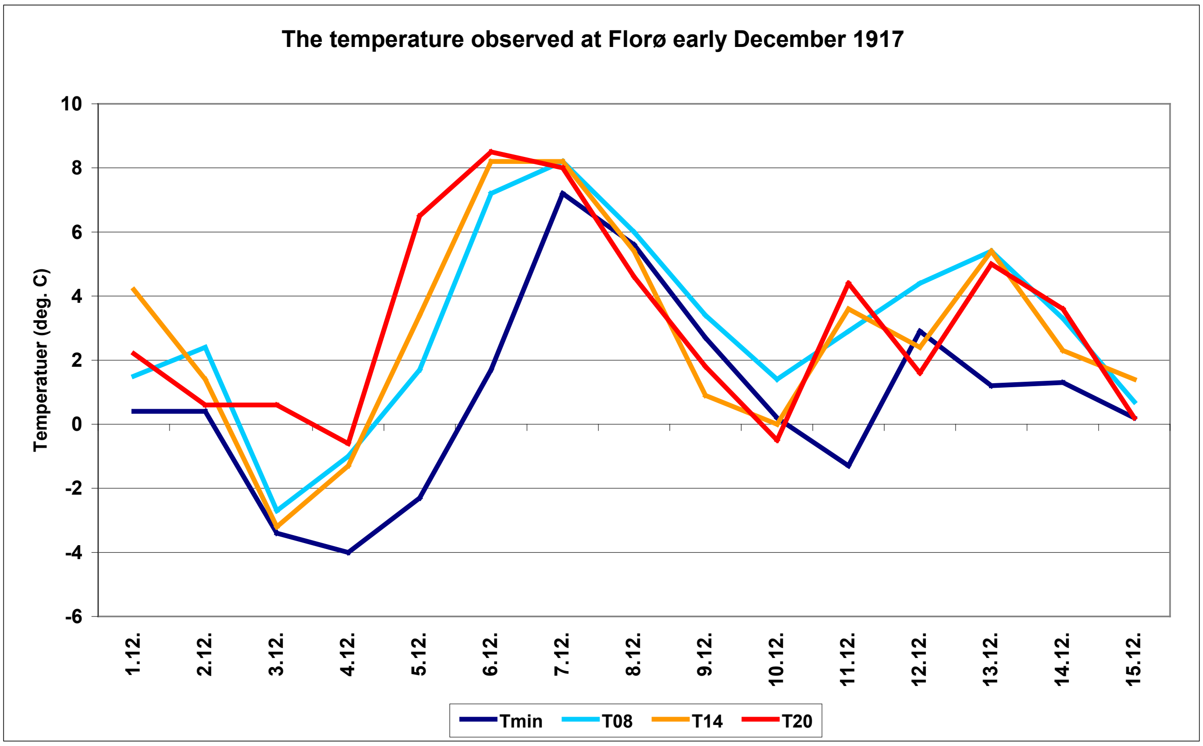


Figure 3.18.3 Temperatures observed at Førde in early December 1917.

The weather conditions

The anticyclone, which set up the atmospheric river, was again located over Germany and Denmark with a ridge extending southwest over the Iberian penninsula to the Central Atlanterhavet. North of the ridge a trough was situated from south of Kapp Farvel towards Iceland and the coast of Troms causing a stream of humid and mild air masses towards the west coast of Norway from southwest. The depression moved near the coast of Mid-Norway 7 December. The rainfall was caused by a frontal passage over Vestlandet 7 December.

Weather type 6 and 7 December: **HM** (Grosswetterlagen) and **SW** and **W** (Lamb/Jenkinson).

3.19 The largest flood observed in Vosso 10-11 October 1918.

A major flood occurred in Hordaland in October 1918. The flood magnitudes are known in River Vosso at Bulken from 1892. There is, however, information about previous floods in Lakes Vangsvatn from the 1800th and 1900th Century, which has exceeded the peak in 1918. Figure 3.19.1 show observed daily rainfall and discharge during the flood in 1918 from selected stations.

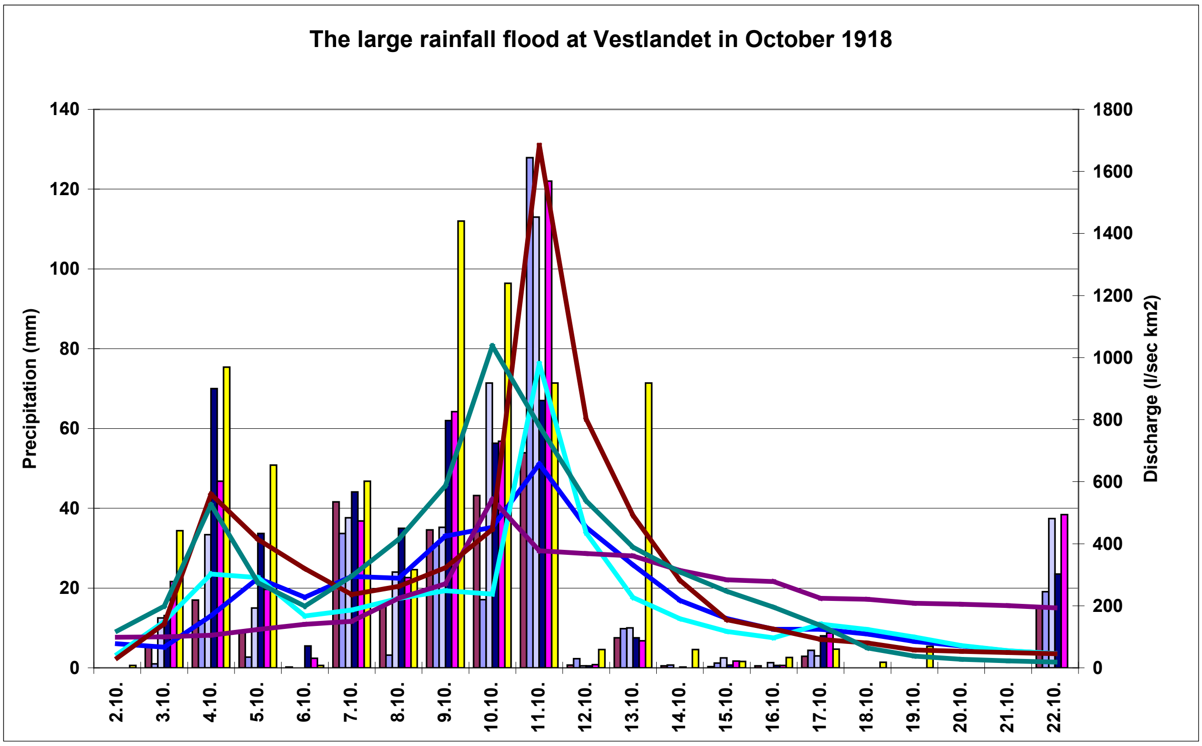


Figure 3.19.1 Observed precipitation and daily discharge during the large flood 10- 11 October 1918 at Vestlandet. This flood is the largest in the data series from Vosso prior to the flood in October 2014.

The flood was moderate at Jæren, and in River Suldalslågen at Ryfylke it was the eigth largest naturalised flood in 92 years. The flood was also moderate in River Etneelv at Lake Stordalsvatn where it was the 38th largest in of 98 years, but in River Opo at Lake Sandvenvatn the flood was second largest in 102 years. At River Vosso, the flood was the largest since the start of observations in 1992. Some information exists about 12 larger floods, which occurred in the 18th and 19th Century (Kindem, 1933; Kanalvæsenets historie 9, 1988). The flood was most intense in River Raundalselven at Voss. Further north at Vestlandet the flood was smaller and does not rank among the largest there.

Cause of the flood:

An anticyclonic ridge across northwest Europe and a depression between Vestlandet and Iceland a current of warm air was streaming north-eastward from the Central Atlantic 10-12 October. This weather type has caused many large rainfall floods at Vestlandet.The weather types were: **BM** (Grosswetterlagen) and **SW/CNW** (Lamb/Jenkinsson).

3.20 Heavy rainfall on top of a large snowpack caused multiple slush avalanches in Hordaland and Sogn in February 1928.

Slush avalanches at Vestlandet caused 50 fatalities and extensive damages at buildings, roads and the railway in February 1928. The damages were most severe in Hordaland and Sogn, but Vest-Agder, Rogaland, Sunn- and Nordfjord did not escape either. The slides were caused by heavy rainfall on the top of deep snow and extended as far north as at Ørskog at Sunnmøre.The floods were largest in smaller rivers without gauging stations in operation as early as in 1928. Figure 3.20.1 show observed daily rainfall and discharge at a few stations, which were operating at the time.

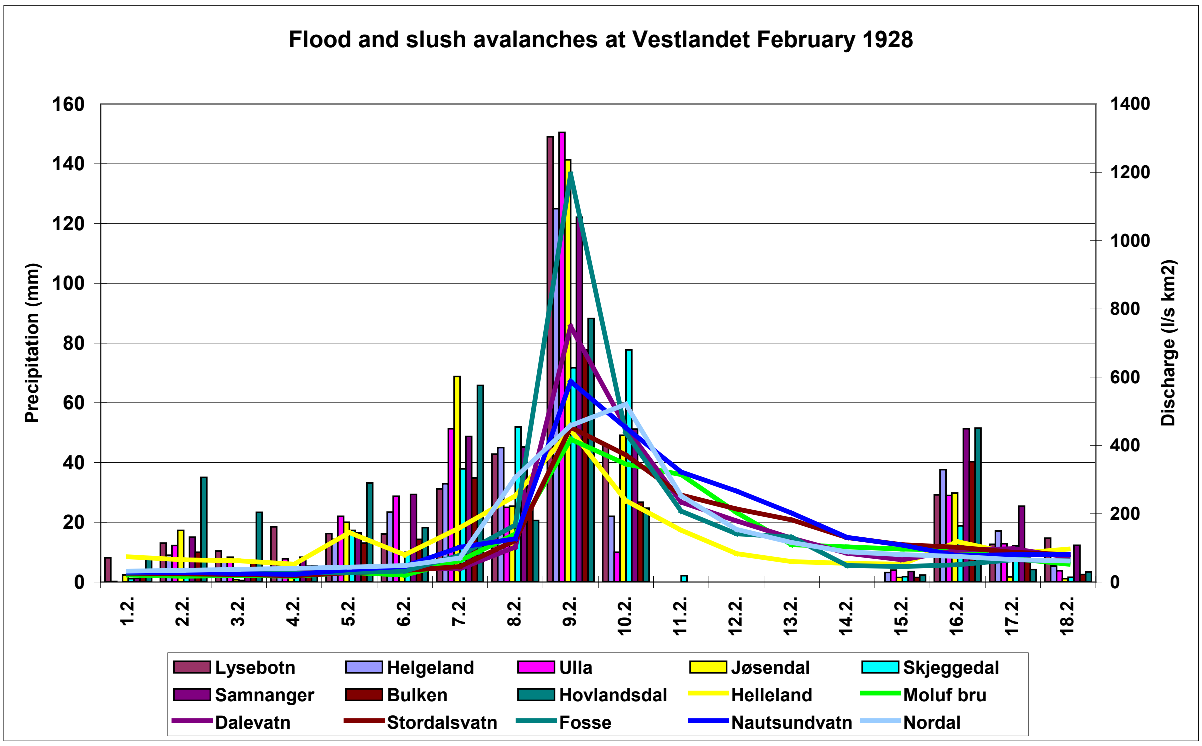


Figure 3.20.1 Observed daily precipitation and discharge at a few stations in Hordaland, Sogn and Sunnfjord in February 1928.

The flood in River Ullebøelv was typical for the floods in many of the smaller rivers without a gauging station in 1928. The flood was the second largest observed at the station 1927-2014, only exceeded by the flood in early November 1971, which ravaged Høyanger.

The cause of the floods and slush avalanches:

Initial conditions:

The winter 1927/1928 started with severe frost untill the end of December. January and February were mild and with abundant precipitation at Sørlandet and Vestlandet. Up to 2 meters snow fell at Vestlandet during January. Figure 3.20.2 show observed snowdepth and precipitation at some stations at Vestlandet. The amount of precipitation increased from 5 February. The precipitation fell as snow unto 8 February when the temperature rose and the precipitation turned into heavy rainfall.

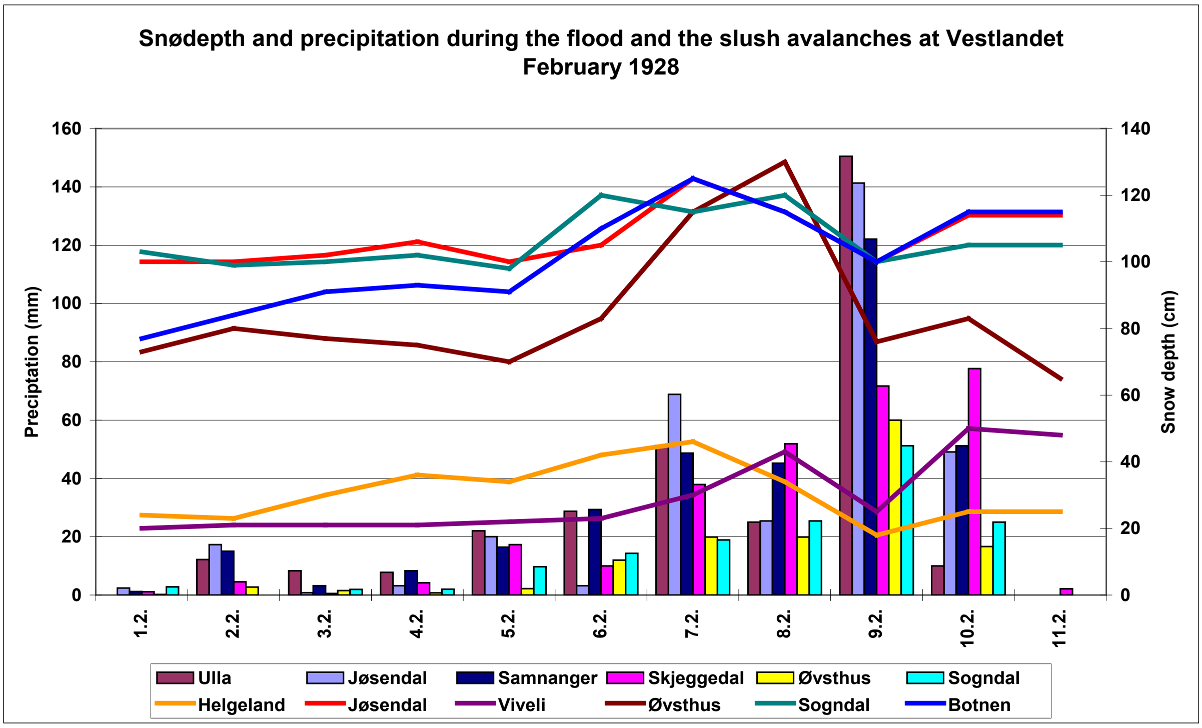


Figure 3.20.2 Observed snow depths and precipitation at stations at Vestlandet in early February 1928.

The weather during the disaster:

Depressions over Northern Norway and over Iceland set up a mild and humid air stream from southwest causing the heavy rainfall in West-Norge 8-9 February. The weather types were: **BM/SW** (Grosswetterlagen) and **SW/W** (Lamb/Jenkinsson). Figure 3.20.2 show observed snow depth at two stations at Vestlandet. A considerable amount of snow remained much at the start of the mild weather.

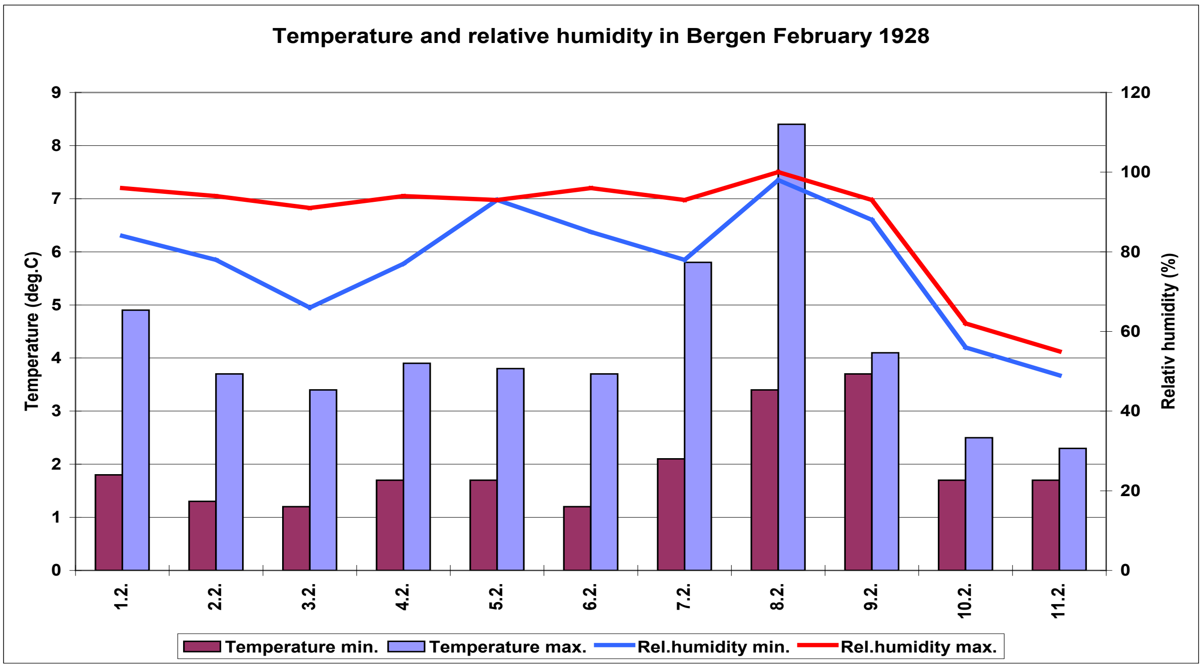


Figure 3.20.3 Observed air temperatures and relative humidity in Bergen 1-11 February 1928.

Figure 3.20.3 show that temperature rose by 4 °C when the heavy rainfall started. Strong wind, high temperatures and saturated air provides optimale conditions for intensive snowmelt.The snow pack was quickly saturated from meltwater and the intense rain. This was the reason for numerous slides from Vest-Agder to Sogn and Fjordane. The discharge increased in many rivers causing minor floods as shown in Figure 3.19.1. Some of the slides caused temporary damming of the rivers with subsequent dam breaks.

Damages:

None of the floods ranks among the largest observed at Vestlandet.

People perished in the slush avalanches from 8-13 February at Åseral in Vest-Agder, at Suldal in Ryfylke, at Røldal and Odda in Hardanger, at Voss and Vaksdal in Nordhordaland, at Vik, Årdal, Luster, Sogndal and Balestrand in Sogn. Six large avalanches occurred almost sumultaneously at Øyri, Sandnes, Ytre and Indre Ese and at Tue in Balestrand. Slush avalanches dammed the river at Bruhjell resulting in five fatalities when Kafe Jotunheimen was swept on the fjord. Lives were also lost at Gloppen in Nordfjord.

Many farmhouses were destroyed by the avalanches in Hordaland and Sogn. Many farm animals perished when the cowsheds were destroyed. A total of 80 large houses in Hordaland and 70 in Sogn were destroyed.

The road in Teigdalen was blocked by large slides. The road between Voss and Mjølfjell was blocked by five slides. A slide dammed a small stream at Gaular in Sunnfjord, threathening some farms. To weeks later another slide blocked the main road. Several bridges were taken on the railway line between Bergen and Voss and the traffic was stopped for 14 days. The damages was estimated to 800000 NOK in Hordaland and Sogn og Fjordane.

3.21 Winter floods on the west coast in 1932.

Few if any years have had so many winter floods both at the start and the end of the year as 1932.Winter floods occurred at Vestlandet 17-20 January, 28-29 January, 30 November and 18-20 December. Observed daily rainfall and discharge is shown at selected station for the event 17-20 January in Figure 3.21.1, and for the the days 28-29 January in Figure 3.21.2.

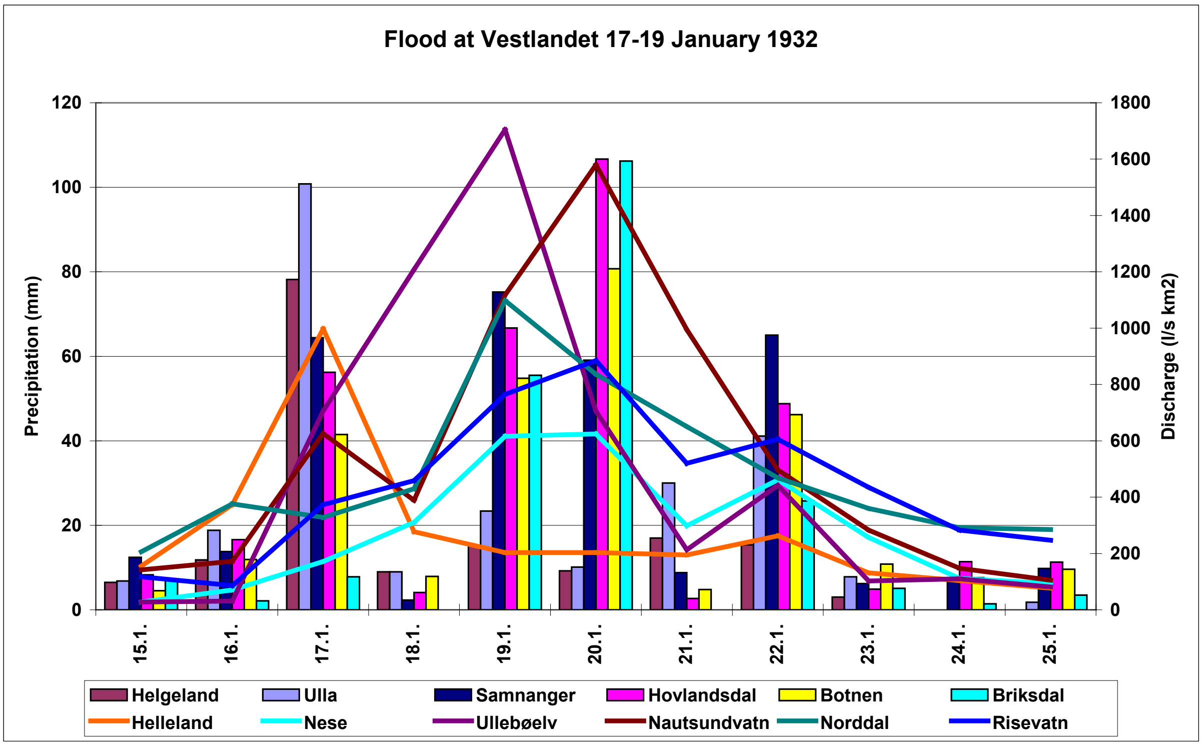


Figure 3.21.1 Observed precipitation and daily discharge from Agder to Sunnfjord 17-20 January 1932.

None of the floods 17-20 January ranks, however, among the highest annual floods at the stations included in the graph.

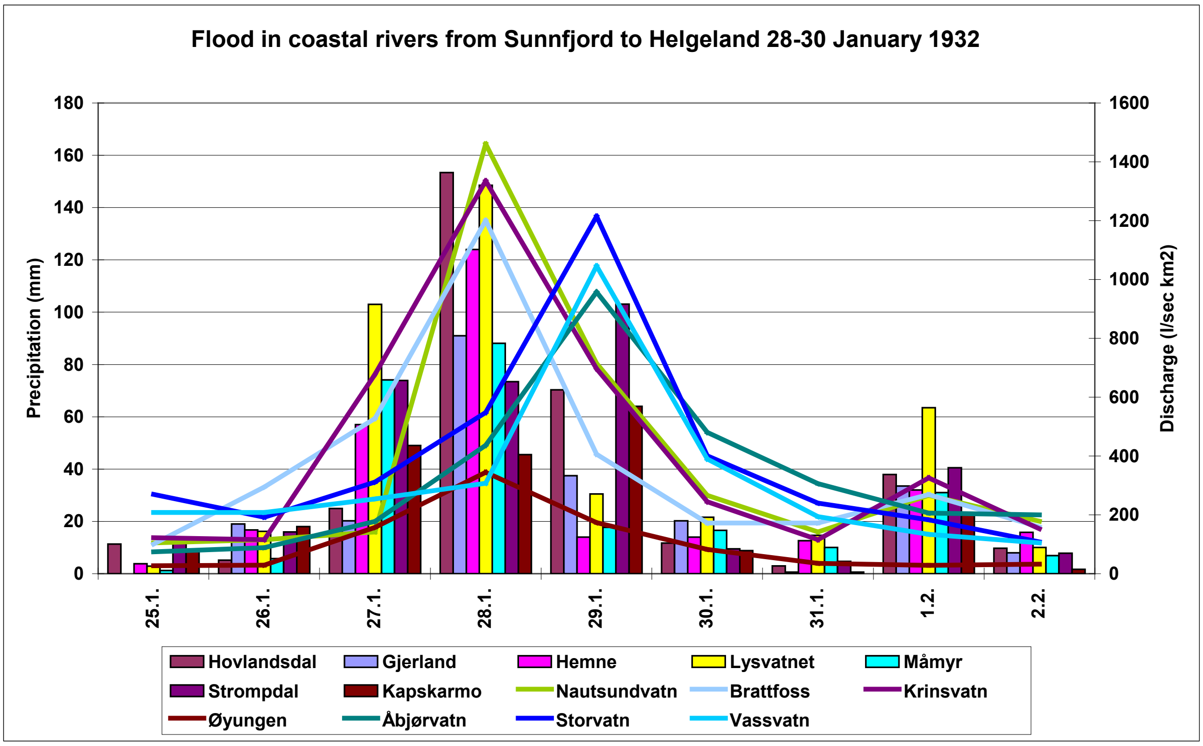


Figure 3.21.2 Observed precipitation and daily discharge from Agder to Sunnfjord 28-29 January 1932.

The flood 28-29 January was the second largest flood observed at Håland bru in Sunnfjord. It was also the second largest observed in rivers in Trøndelag and Helgeland only exceeded there by the flood in January 2006, see Volume 4.

Cause of the floods:

January and February 1932 were exceptionaly mild with abundant precipitation. The temperature at Trøndelag was 3 -5,7° above the normal in January and 2,6-6,0° over the normal in February. The surplus at the coast of Fjordane was 3,1-4,9° in January and 1,8- 2,6° in February. From West-Agder to Rogaland the surplus in January was 3,2-4,6° and 1,4 to 3,2° in February. The precipitation had a surplus 14-169 percent in January and 13-116 percent in February in Trøndelag, 36-248 percent at the coast of Fjordane in January and 37-149 percent in February and in January from West-Agder to Rogaland where the precipitation had a deficit of 55-116 percent in February.

The weather types 17-20 January were: **SWA/HM** (Grosswetterlagen) and **SW/A** (Lamb/Jenkinsson) and 28-29 January: **HNFA/ASW/AW** (Grosswetterlagen) (Lamb/Jenkinsson).

3.22 Autumn floods in West Norway in November-December 1932.

Heavy rainfall 29-30 November 1932 caused a short duration flood in some rivers in Hordaland to Sunnfjord. Observed precipitation and discharge is shown in Figure 3.22.1.

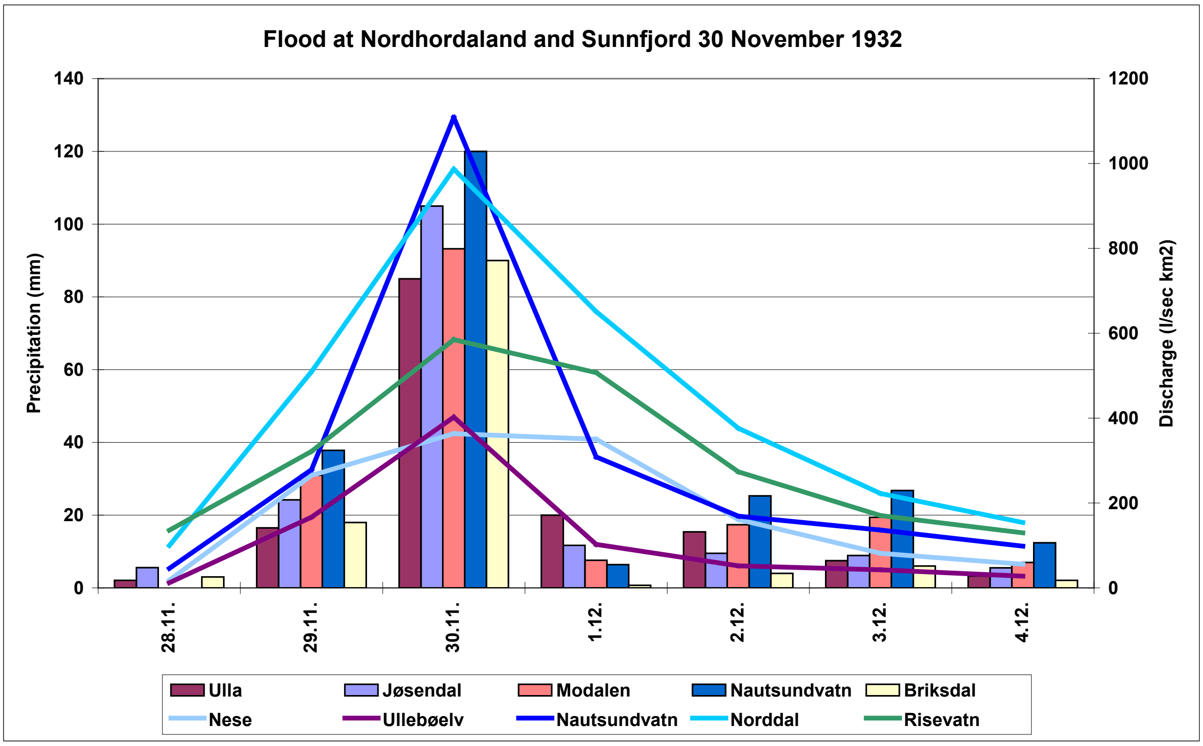


Figure 3.22.1 Observed precipitation and daily discharge at Nordhordaland and Sunnfjord 30 November 1932.

The flood was not the largest flood on the stations with observed discharges except in River Tordalselv at Fosse. The second flood occured as a result of heavy rainfall 18-19 December in coastal rivers in Vest-Agder, Rogaland, Hordaland and Sunnfjord. Figure 3.22.2 show observed daily rainfall and discharge during this flood.

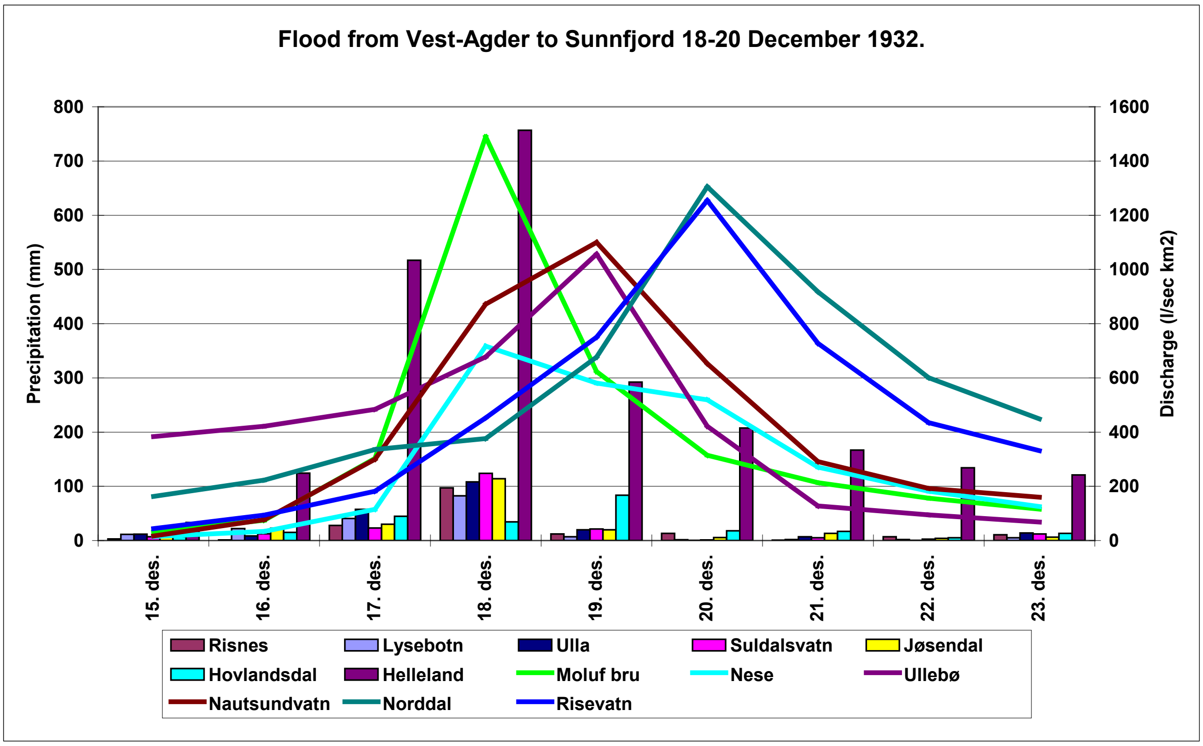


Figure 3.22.2 Observed precipitation and daily discharge in West Norway 18-20 December.

The flood was the largest observed in River Sira at Lake Valevatn 1925-1967, otherwise the rank was from fourth to sixth from River Mandalselva to rivers in outer Sunnfjord.

Cause of the flood:

After the flood 30 November had receeded West Norway had a dry spell before the frontal activity resumed the transport of mild and humid air towards the west coast of Norway. December 1932 was extremely mild. The temperature surplus in Nordland was 4,1 til 7,2° and in West Norway from 1,6 til 3,4°. The surplus in precipitation was between 42 and 152 mm in Nordland in December. Districts from Trøndelag to Nordfjord had a deficit in precipitation of 17 to 76 mm. The surplus in West Norway from Sunnfjord to Bergen was between 24 til 94 mm at stations near the coast with a deficit in the inner fjords. There was also a surplus in Rogaland and Vest-Agder.

The weather type was initially similar to the type causing the large floods in January 1932. An anticyclonic ridge from Sibiria extended towards the Mediterranian while depressions in the Atlantic, the Denmark Strait and the Norwegian Sea set up a stream of mild and humid air from southwest towards the coast of Norway. The weather types 17-19 December were: **SWA** (Grosswetterlagen) and 27-30 Desember: **SW** (Lamb/Jenkinsson) og **HM** (Grosswetterlagen) and **SW/W** (Lamb/Jenkinsson).

3.23 Winter floods at Vestlandet in February 1934.

From late January and in February 1934 mild weather several frontal passages from the west caused some short duration floods in coastal rivers at Vestlandet and at Helgeland. Figure 3.23.1 show observed precipitation and discharge flood at Vestlandet 6 February. A second flood occurred at Vestlandet 24 February as shown in Figure 3.23.2.

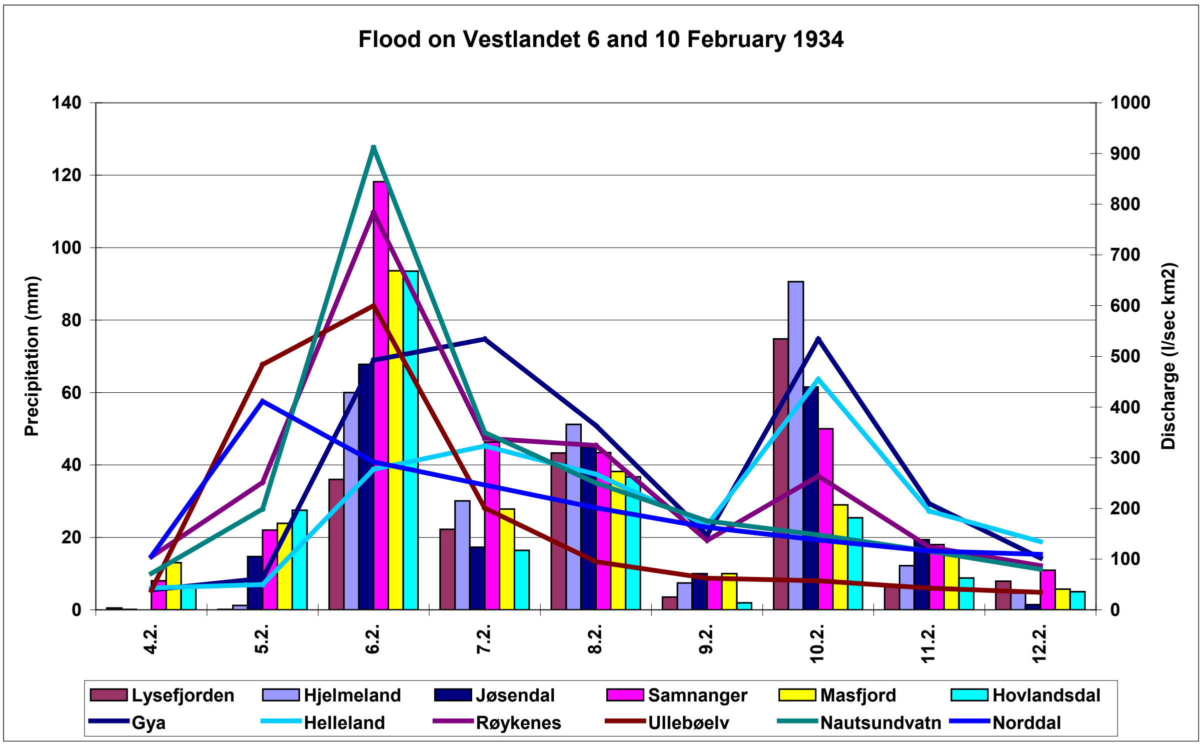


Figure 3.23.1 Observed precipitation and daily discharge at Vestlandet 6 and 10 February 1934.

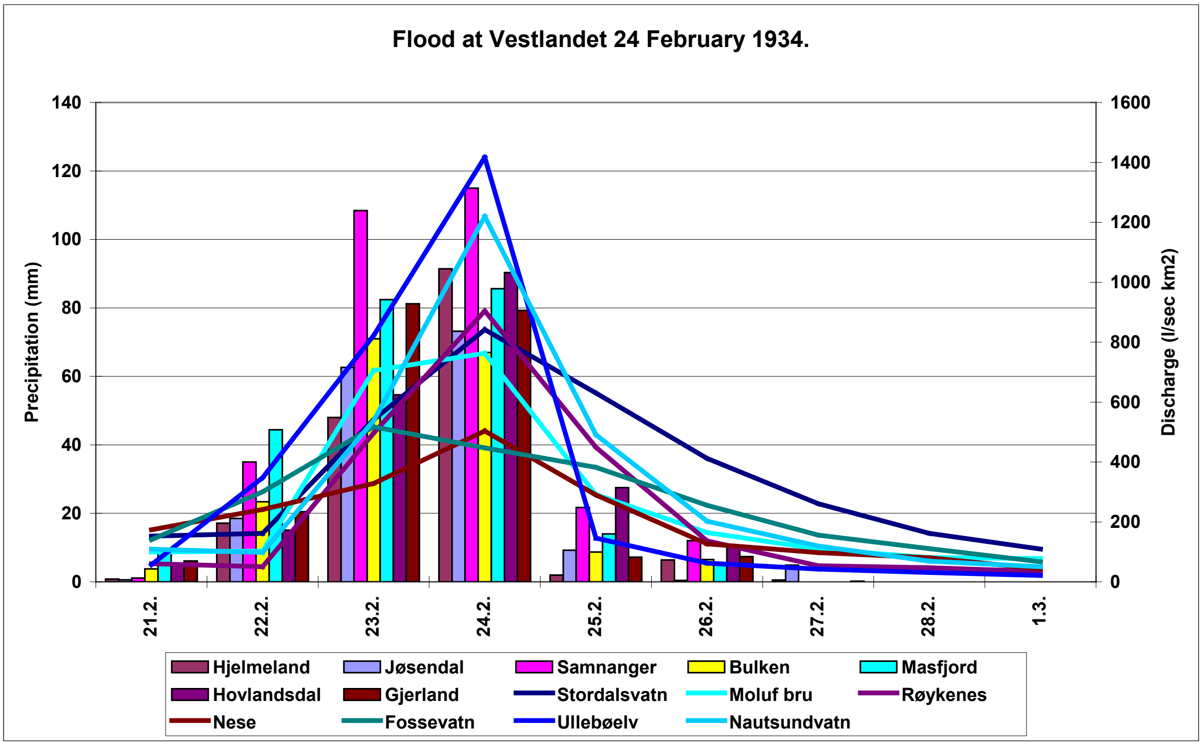


Figure 3.23.2 Observed precipitation and daily discharge at Vestlandet 24 February 1934.

None of the floods ranks among the larger floods in the rivers. These events can nevertheless cause damages, because they can cause either slush avalanches or landslides, which block the roads and can threathen buildings and farms.

Cause of the flood

The floods was caused by a combination of snowmelt and fairly heavy rainfall. Oberved snowdepths at three meteorological stations are shown in Figure 3.23.3. An anticyclonic ridge extended from the Atlantic towards Eire and the southern part of the UK 5-6 February. A depression moved from Spitsbergen to the Kola Penninsula. The western coast of Norway was affected by a wind field from northwest. The weather type of the first event (5-6 February) was **BM** (Grosswetterlagen) and **A/ANV** (Lamb-Jenkinson). During the second event 23-24 February, an anticyclonic ridge extended from New Foundland across the Atlantic towards France and to Greece. North of the ridge, a depression was located near the Kola Penninsula and another depression moved eastward from Iceland towards Norway. Between the ridge to the south and depressions to the north mild air masses was streaming towards the coast of west Norway. The weather type of the second event was **WA** (Grosswetterlagen) and **AW/CW** (Lamb-Jenkinson).

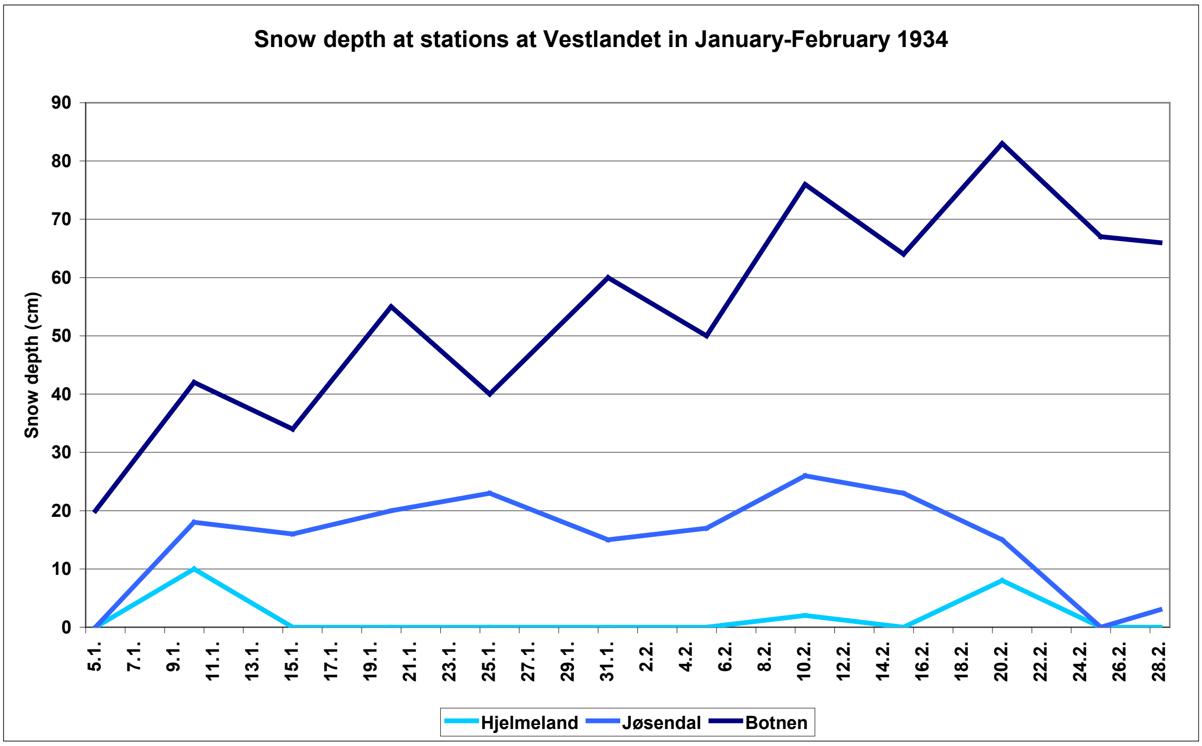


Figure 3.23.3 Observed snow depth at stations in West Norway in January-February 1934.

3.24 The autumn flood at Vestlandet in November 1934.

In late November 1934 heavy rainfall caused floods at Vestlandet in coastal rivers from Oselva at Bergenshalvøya to Sunnfjord. Figure 3.24.1 show daily precipitation and discharge at selected precipitation and gauging stations at Vestlandet. This is the third flood, which has occurred at more or less the same time of the year, causing large floods somewhere at Vestlandet, such as the floods in November 2006 and in November 1940.

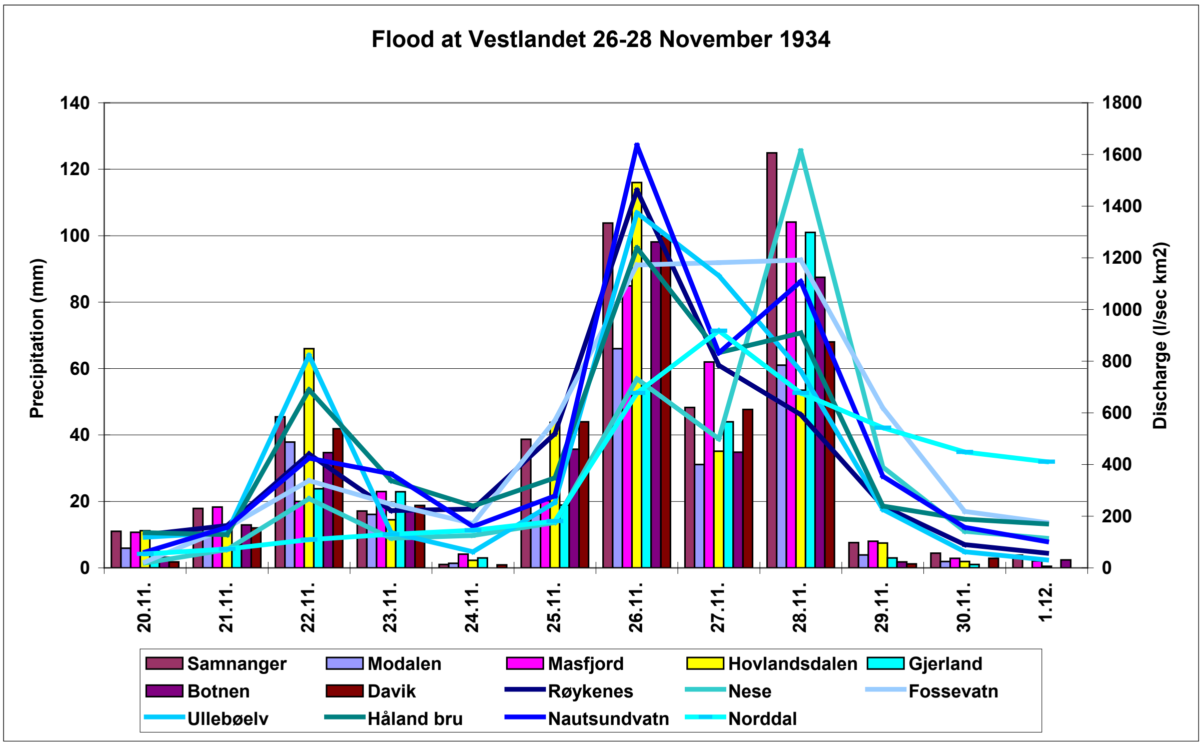


Figure 3.24.1 Observed precipitation and daily discharge at Vestlandet in November 1934.

The flood was sixth largest in River Oselv at Røykenes 1934-2010, seventh largest naturalised flood in River Matreelv at Fossevatn (-), fifth largest in River Guddalselv at Lake Nautsundvatn 1908-2010, fifth largest in River Gaular at Eldal 1931-1956, eight largest in River Jølstra at Jølstervatn 1902-1951, 16th largest in Riseelv at Risevatn and 18th largest in River Bygdaelva at Øye at Sunnmøre 1916-2010. Further inland the spring flood 8-10 May was the largest this year simultaneous with the spring flood at Østlandet.

Cause of the flood:

Initial conditions:

Figure 3.24.2 show observed snow depths at some stations at Vestlandet in November. The first days of November were relatively cold, but the temperature in Bergen rose gradually through the month peaking 26-28 November as shown in Figure 3.23.4, simultaneously with the most intense precipitation. Some snow was present at the start of the flood, men it had melted when the intense rainfall started. The flood was therefore primarily a rainfall flood.

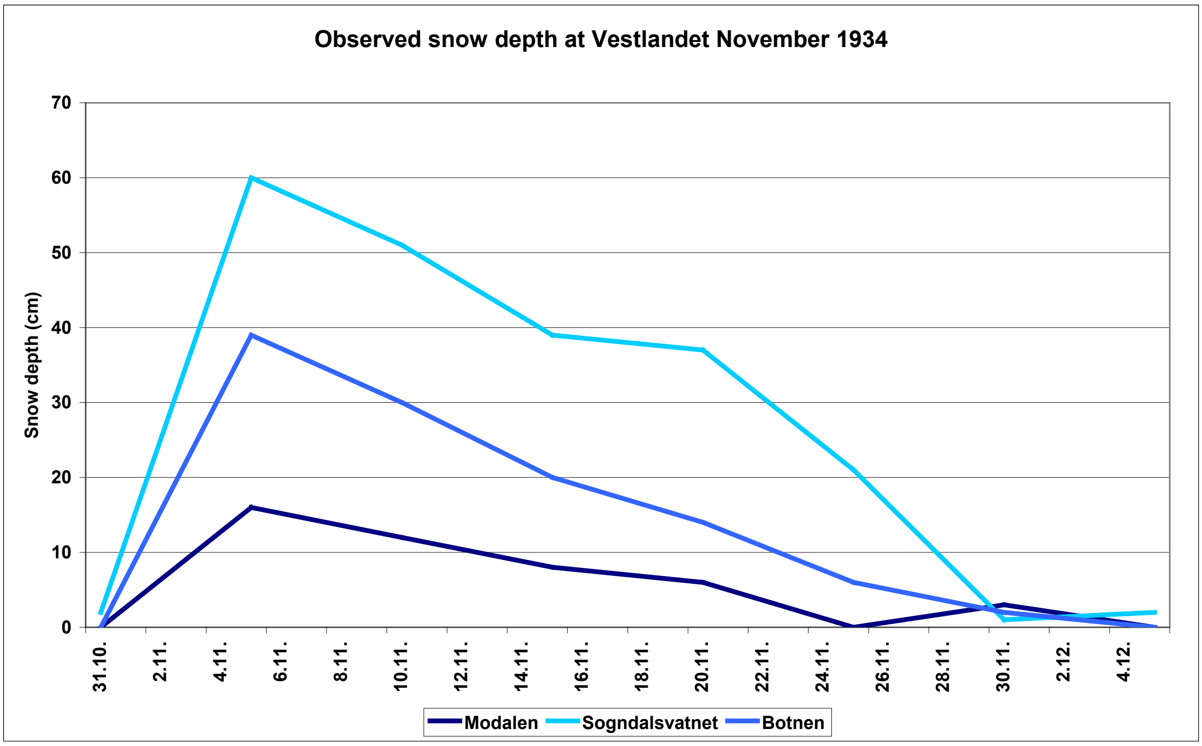


Figure 3.24.2 Observed snow depth at Vestlandet in November 1934.

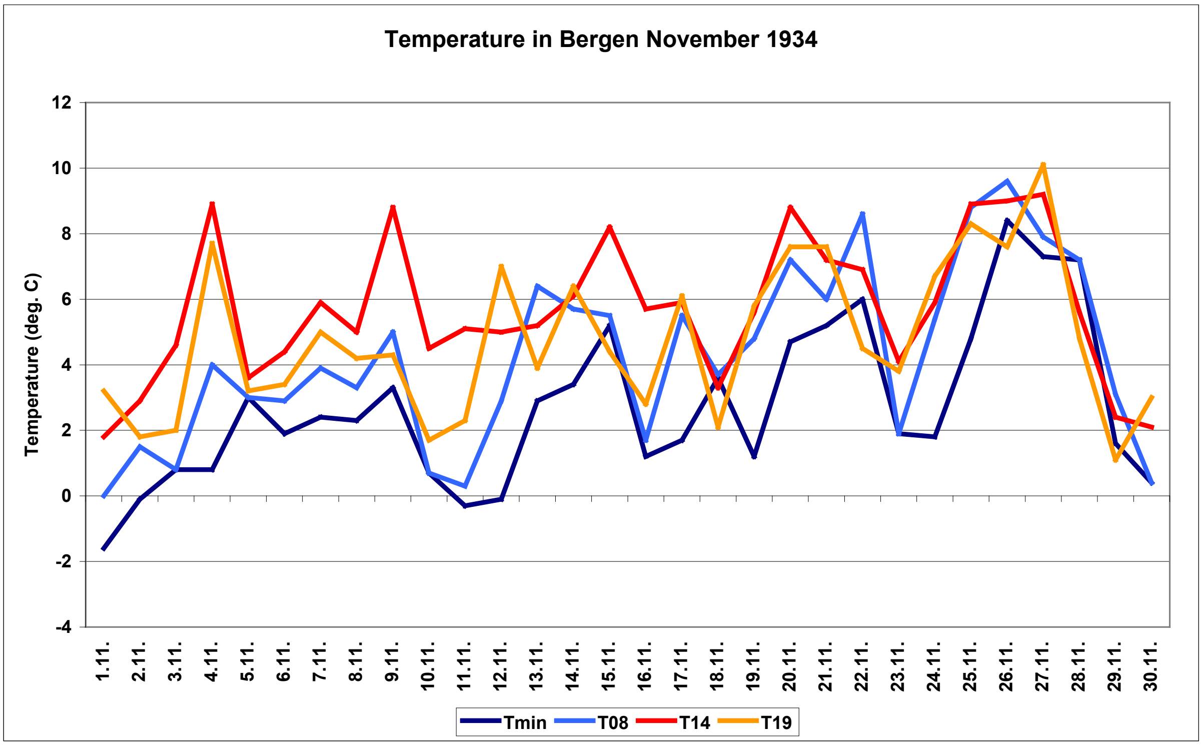


Figure 3.24.3 Observed temperatures in Bergen in November 1934.

The weather conditions:

Between an anticyclone over Great Britain and the European mainland and depressions in the Norwegian Sea varm fronts on the polar front moved in over the coast of Vestlandet. The weather types were **NWA** (Grosswetterlagen) and **AW/ A** (Lamb-Jenkinsson).

3.25 Winter floods at Vestlandet in January and February 1935.

Two floods occurred in coastal rivers at Vestlandet in the winter 1935. Figure 3.25.1 show observed daily precipitation and discharge during the flood 11-12 January and Figure 3.25.2 for the flood 18-19 February 1935. Figure 3.25.3 show the development of the snow depth at stations at Vestlandet, and Figure 3.25.4 show the air temperature observed in Bergen.

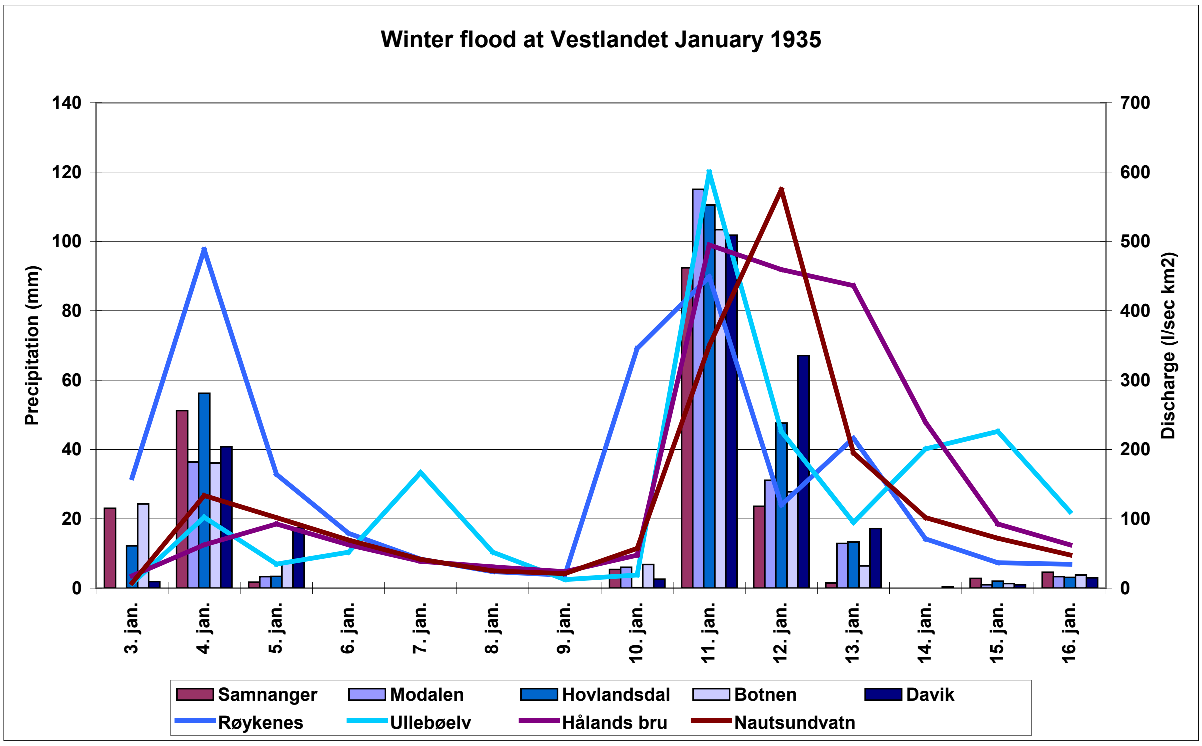


Figure 3.25.1 Observed precipitation and daily discharge at Vestlandet in January 1935.

The flood does not rank among the larger floods in the rivers with observed discharge in 1935.

The cause of the flood:

Initial conditions:

The snow reservoir was very low in the coastal districts at Vestlandet during the first flood 11- 12 January. The temperature rose above zero degrees 9 January and fell below zero 13 January. The flood was therefore caused by rainfall with an insignificant contribution from snowmelt.

Weather conditions during the flood:

Between an anti-cyclone over East Europe and a strong low near Iceland mild and humid air was streaming towards northeast from the Atlantic 9-12 January. The rainfall 11 January was caused by a frontal passage, followed by an air stream from northwest with falling temperatures. Weather type 11 January were **BM** (Grosswetterlagen) and **CSW** (Lamb/Jenkinson).

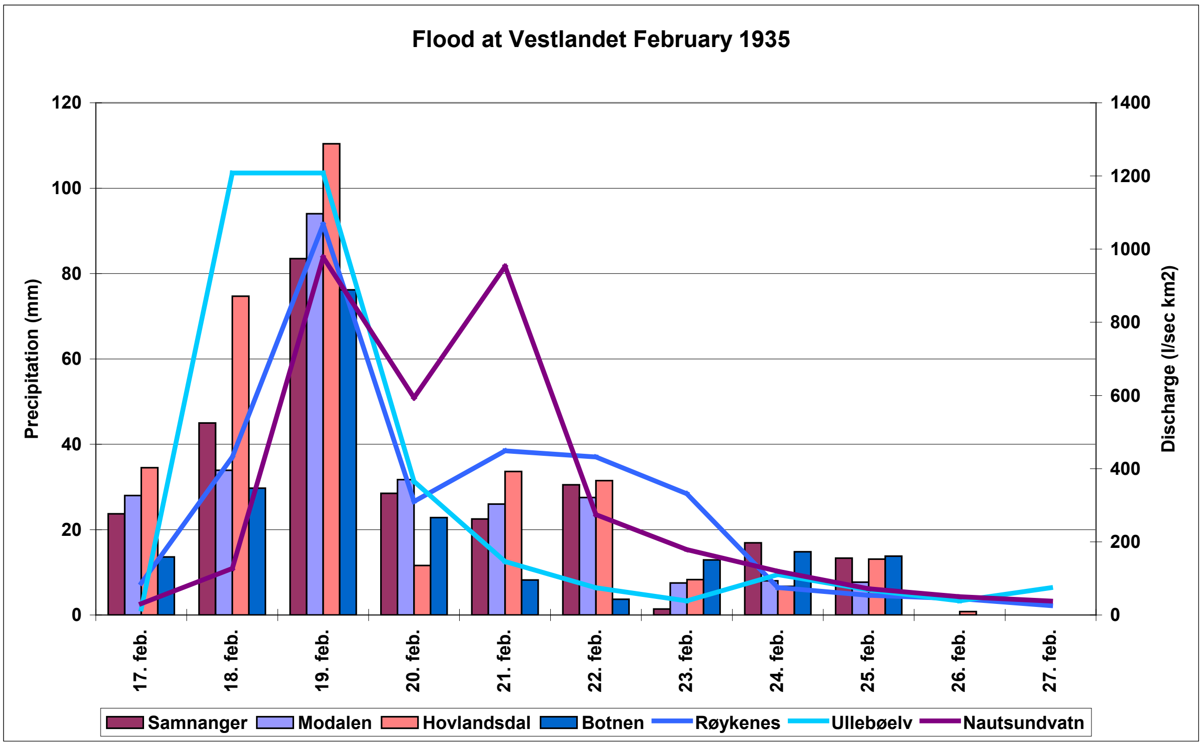


Figure 3.25.2 Observed precipitation and daily discharge at Vestlandet in February 1935.

The second flood neither ranks among the larger floods in the coastal rivers at Vestlandet, but these winter floods are usually caused by mild weather and heavy rainfall. Figure 3.25.3 show observed snowdepths at stations in West Norway in January-February 1935. If a lot of snow has fallen prior to the mild weather, slush avalanches can cause extensive damages and put many lives at risk such as during the floods at Vestlandet in January 1928. At the time of the second rainfall, more snow had accumulated, but the rainfall was probably not large enough to cause widespread slides. The flood peak occurred 18-19 February. The snow depth sank during the flood. Melting snow has probably contributed more to the flood than in January, but some rainwater had probably been bound in the snowpack without contributing to the flood. The temperature peaked 17-20 February with colder weather prior to and after the flood as seen from Figure 3.25.4.

Weather conditions during the second flood:

Between an anticyclonic ridge over South Europe and the Mediterrainian and a low south and later southeast to east for Iceland mild air from the Atlantic was streaming towards Vestlandet18-21 February. Weather type 18-19 February were **WZ** (Grosswetterlagen) and **W/SW** (Lamb/Jenkinson).

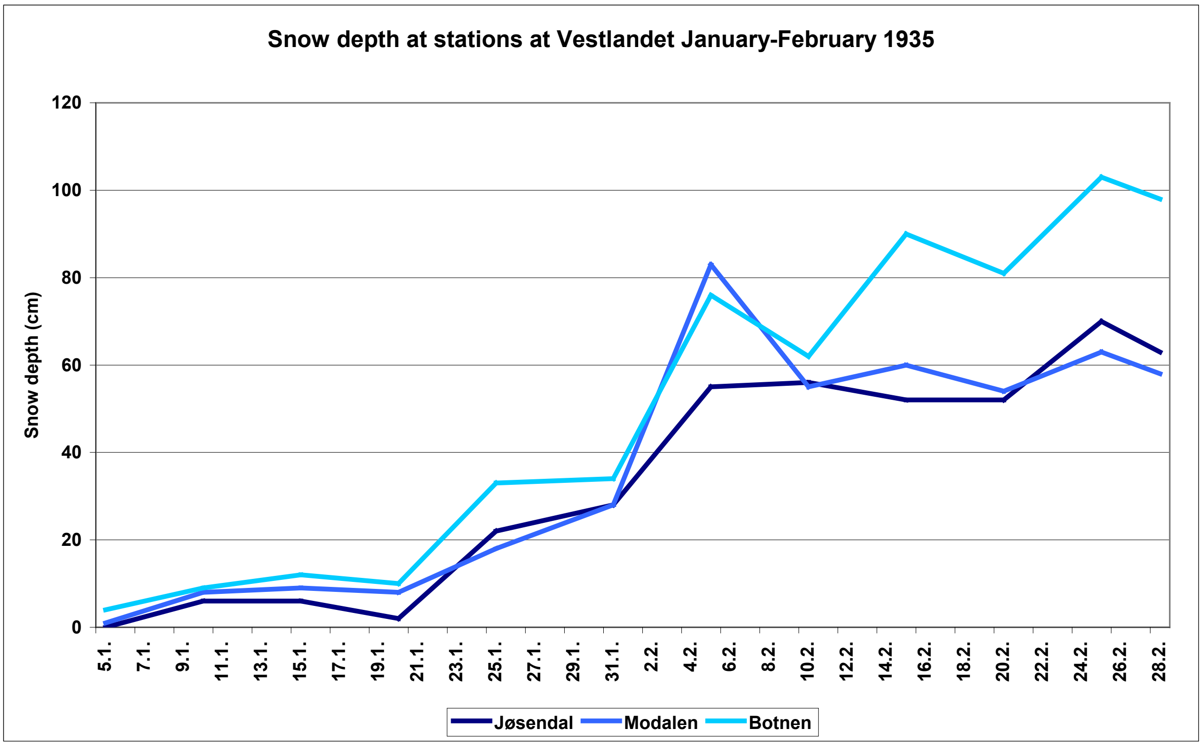


Figure 3.25.3 Observed snow depth at stations at Vestlandet in January-February 1935.

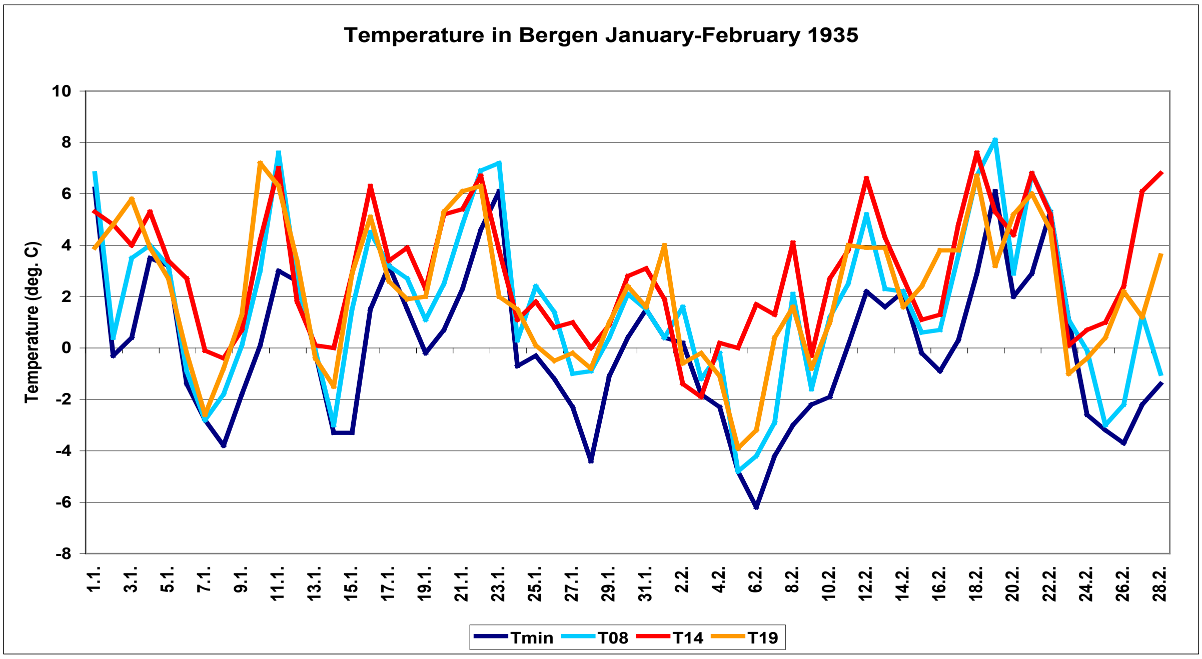


Figure 3.25.4 Observed temperatures in Bergen in January-February 1935.

3.26 The rockfall and tsunamis in Lake Lovatn in the autumn 1936.

A second disastrous rockfall occurred from Mount Ramnefjell in September 1936 into Lake Lovatn. The rockfall caused a tsumami 74 meters tall, which killed 74 of the inhabitants living near the lake. The rockfall occurred x days after a spell of rainfall in late August causing a flood with a return period of 10 years out of the lake as seen from Figure 3.26.1. The tsumani caused severe damages near the lake and destroyed also the gauging station. Late October and early Nowember was also wet, and some additional rockfalls occurred. The largest occurring

10 November caused another tsunami as tall as the one in September. This tsunami did not cause additional losses, as the valley was completely evacuated at the time.

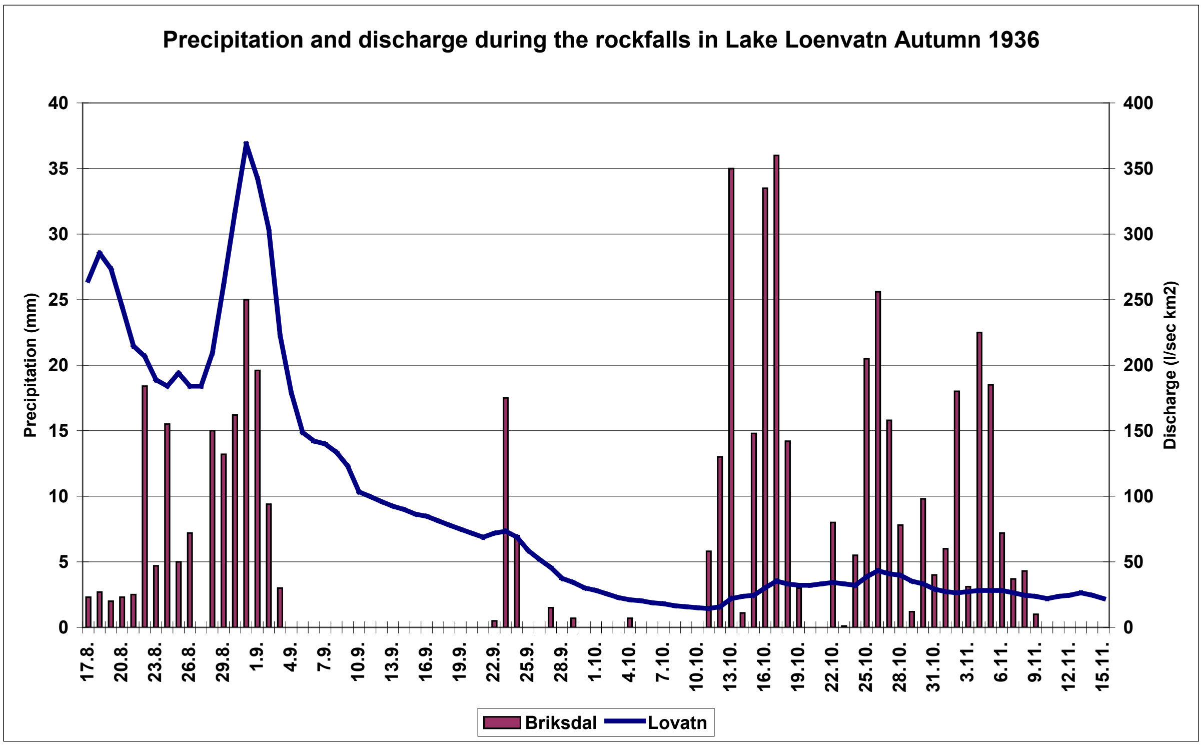


Figure 3.26.1 Observed discharge and daily rainfall at Lake Loenvatn in the autumn 1936.

3.27 Winter floods at Vestlandet in December 1936.

Intense rainfall caused a flood in coastal rivers in Rogaland and Hordaland 14-15 December 1936. Less intensive rainfall caused new floods 20-23 December as shown in Figure 3.27.1.

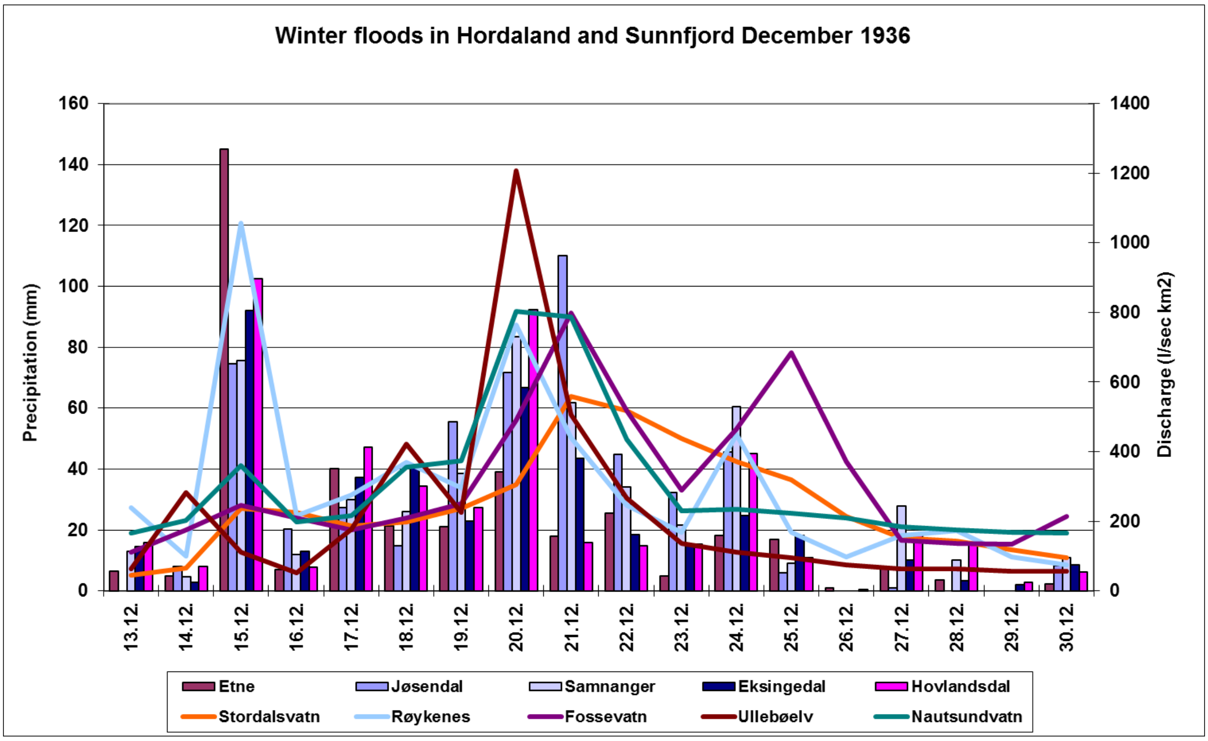


Figure 3.27.1 Observed precipitation and daily discharge in Hordaland and Sunnfjord in December 1936.

Cause of the flood:

Mild and humid air masses moved in from southwest 13-22 December south of the polar front which caused the long tern rainfall. The intense rainfall 15 December moved in from south over South-Vestlandet. 173 mm rainfall was observed at Ørsdalen at Bjerkreim 15 December. More than 150 mm was observed at three stations from Kvinesdal to Bergsdalen in Hordaland and more than 100 mm at 16 stations. The weather types were **SWA** (Grosswetterlagen) and **SW** (Lamb Jenkinsson) 15 December and **HM** (Grosswetterlagen) and **SW/W** (Lamb-Jenkinsson) 20-22 December.

November 1936 was generall mild, but cooler weather occurred in the first days of December. The snowdepths observed each fifth day in November- December 1963 at five meteorological stations in West Norway is showen i Figure 3.27.2. The air temperatures observed in Bergen is shown in Figure 3.27.3. Some snow fell even in the lowlands, but it disappeared as the temperature rose 7 December. 23-30 cm snow was accumulated at Jøsendal (345 m.a.s.l). The snow depth at Viveli (876 m.a.s.l) increased from 24 cm 5 December to 42 cm 15 December and 68 cm. 20 December. Snowmelt has contributed to the flood in Hordaland and Sunnfjord, but the flood was mostly caused by rainfall.

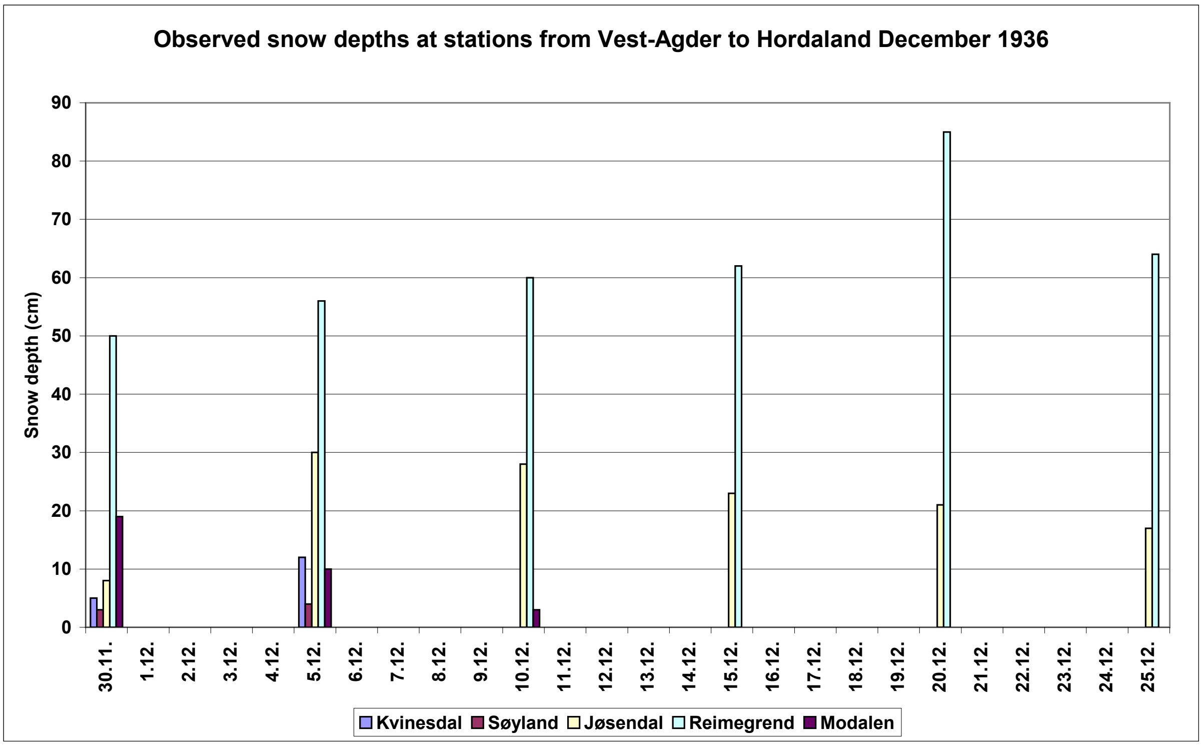


Figure 3.27.2 Snowdepths observed each fifth day at five meteorological stations in West Norway.

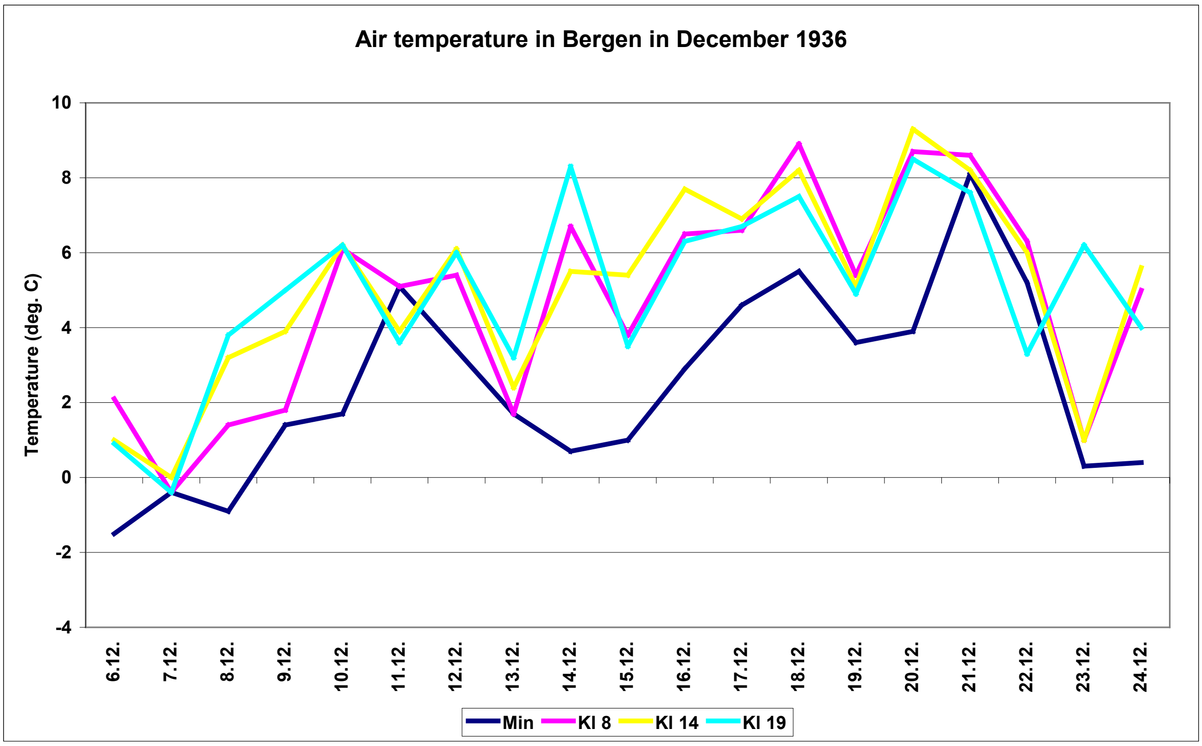


Figure 3.27.3 Daily temperatures observed i Bergen in December 1936.

3.28 Autumn floods in Hordaland in November 1938.

A large flood occurred at Hordaland, Sogn and Sunnfjord 13-15 November 1938. Figure 3.28.1 show observed daily precipitation and discharge during the flood.

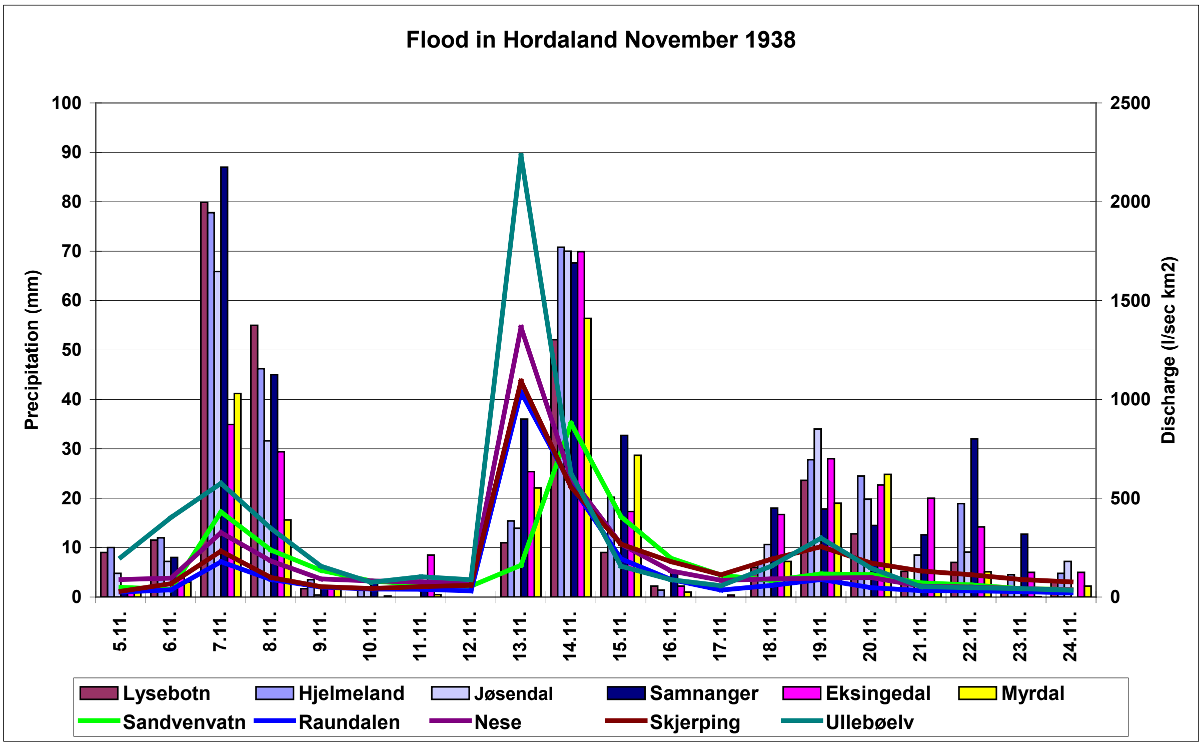


Figure 3.28.1 Observed precipitation and daily discharge during the large flood in Hordaland in November 1938.

The flood was fourth largest in River Opo at Lake Sandvenvatn and at Lake Reinsnosvatn. A large flood caused damages at Granvin, but observations are not available in River Granvinelv. In River Vosso at Austmannshølen the flood was fifth largest and in River Eksingedalselv at Nese fourth largest. River Nærøyelv at Skjerping, Ullebøelv and Riseelv in Sunnfjord had all large floods (Lunde, 1995).

Cause of the flood:

The flood was caused by large snowmelt at high altitudes combined with heavy rainfall at lower levels. The rainfall peaked 7-8 November from Lysebotn to Samnanger with a secondary peak from Kvinesdal in West-Agder to Myrdal and Gaular in Sunnfjord 14 November. The rainfall did not penetrate significantly to the inner fjords.

A low south of Iceland moved towards northeast. Mild and humid air streamed towards the coast of Norway from southwest 12-13 November. An anticyclone over Southeast Europe contributed to maintaining the transport of mild oceanic air over Vestlandet. The wind direction turned to west and later northwest 14-15 November. Weather types were **SWA** (Grosswetterlagen) and **S/SW/W** (Lamb/Jenkinsson).

Flood damages:

The buildings at Arnehus at Dyrdal near the Nærøyfjord were taken by the river and ended into the fjord 13 November. The bridge at Skjerpi was taken by River Nærøyelv.

3.29 Winter floods at Vestlandet in February 1939.

Long-term rainfall caused moderate floods in a number of coastal rivers occurred between 10 and 13 February in West Norway as shown in Figure 3.29.1 and 3.29.2.

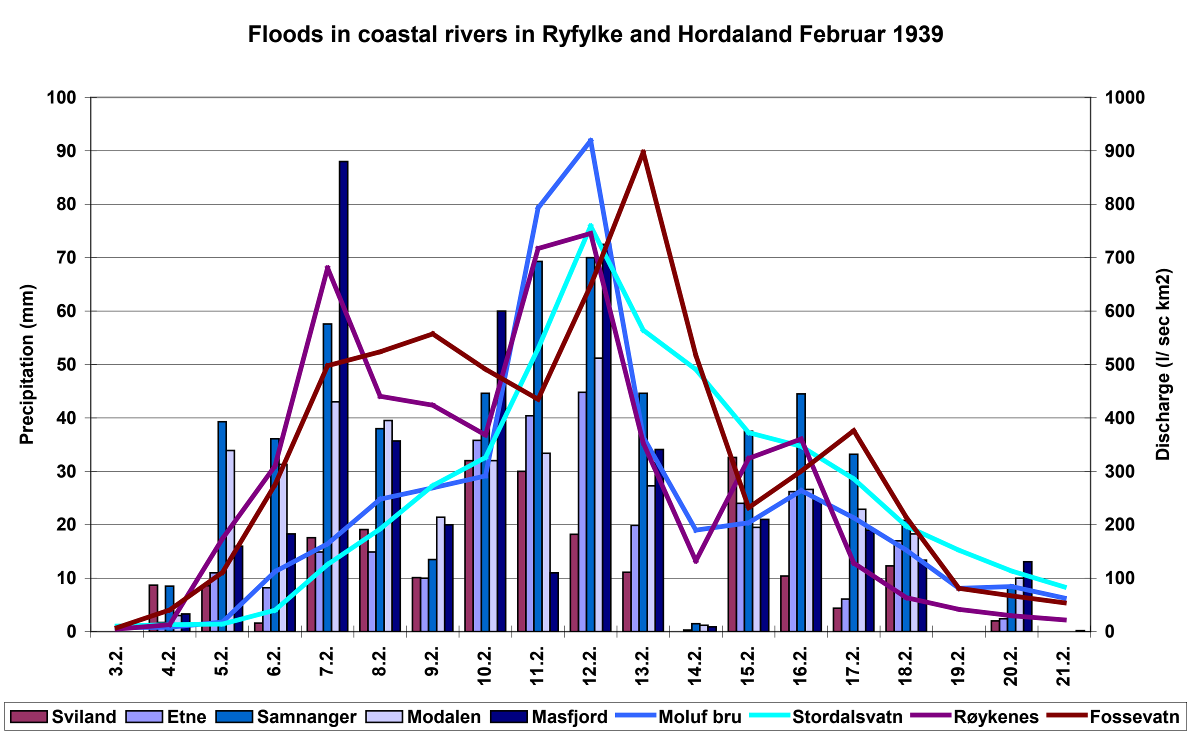


Figure 3.29.1 Observed precipitation and daily discharge in coastal rivers in Ryfylke and Hordaland in February 1939.

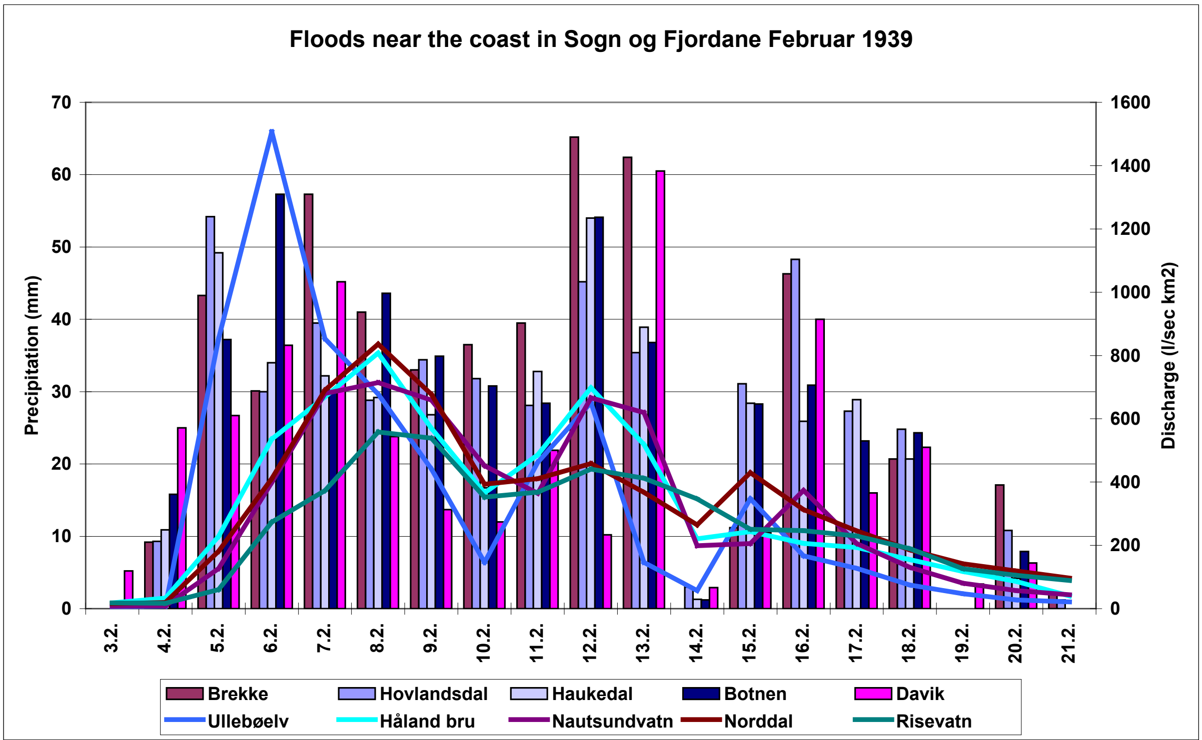


Figure 3.29.2 Observed precipitation and daily discharge at coastal rivers in Sogn og Fjordane in February 1939.

The flood did not rank among the large floods in these catchments.

Cause of the flood:

The precipitation showed a surplus in the outer and the middle districts in West Norway in February 1939. Figure 3.29.3 show observed snow depth at some stations near the coast in January and February 1939. After a peak mid-January, the snow depth decreased until reaching a minimum 9-16 February when the flood peaked. Figure 3.29.4 show observed air temperatures in Bergen. After some cool days until 7 February, the temperature increased to +5°C from 8 February. The most of remaining snow melted.

The event is typical of an *atmospheric river* pumping mild air masses from southwest towards the west coast of Norway between an anticyclone over the European mainland and a nuber od cyclones over Iceland and the Norwegian Sea. The weather types were 5-9 February **HM** and 10-13 February **WA** (Grosswetterlagen) and **W/SW** (Lamb-Jenkinsson).

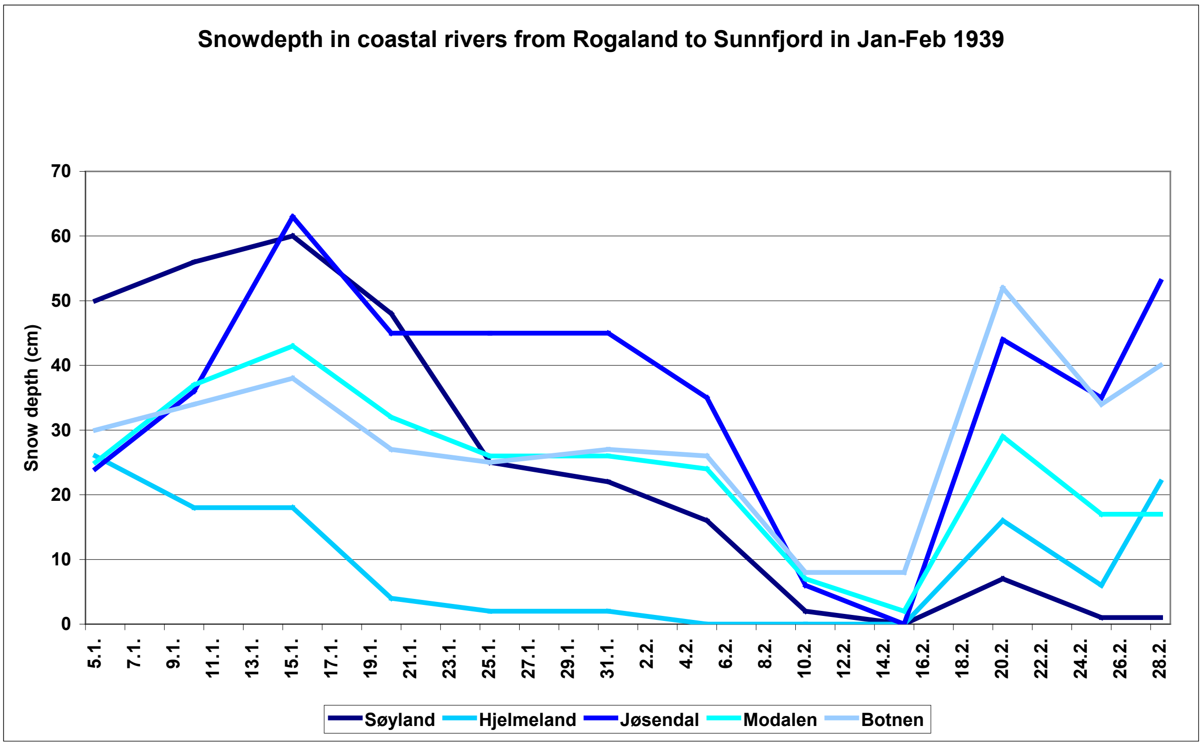


Figure 3.29.3 Observed snow depth in coastal rivers from Ryfylke to Sunnfjord in February 1939.

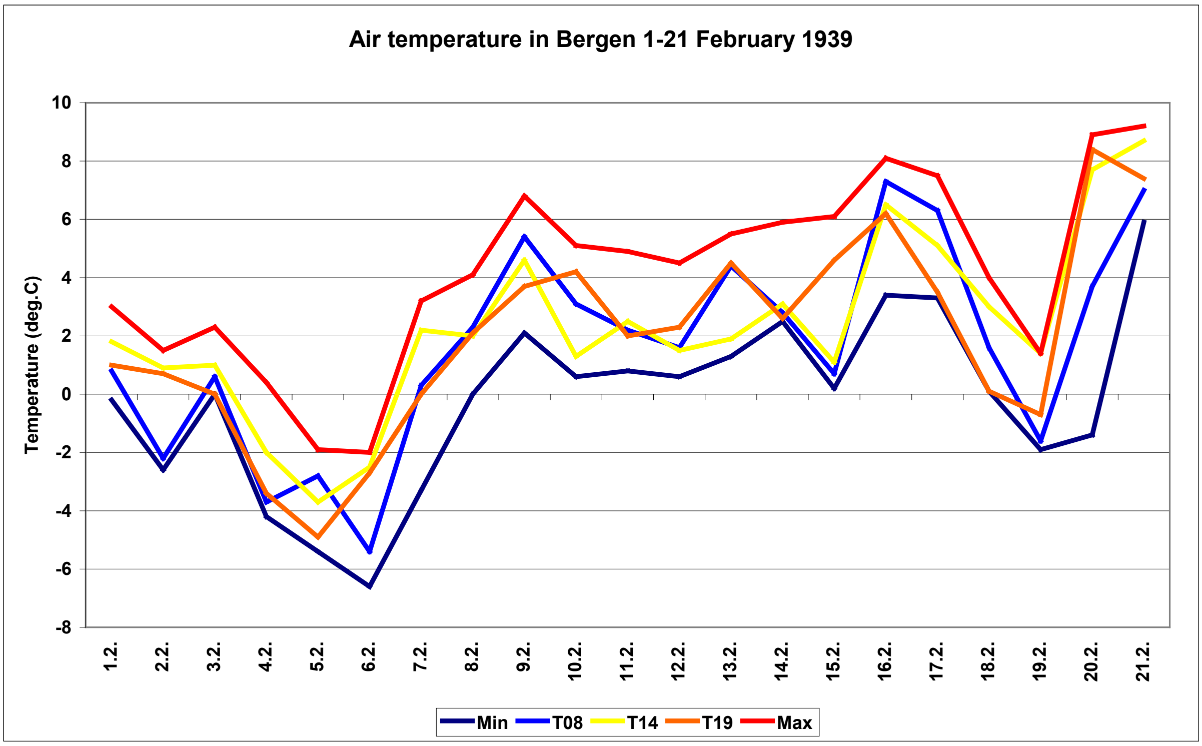


Figure 3.29.4 Air temperature in Bergen in February 1939.

The weather types were 2-9 February **HM** 10-13 February **WA** (Grosswetterlagen) and 3-12 February **ASW** / **SW** / **W** (Lamb/Jenkinsson).

3.30 Spring flood at Vestlandet in April 1939.

A moderate rainfall event 19-20 April 1939 caused moderate floods in coastal rivers in Hordaland and Sogn og Fjordane. Figure 3.30.1 show observed daily precipitation and discharge at stations in Hordaland and at stations from Sogn to Nordfjord in Figure 3.30.2.

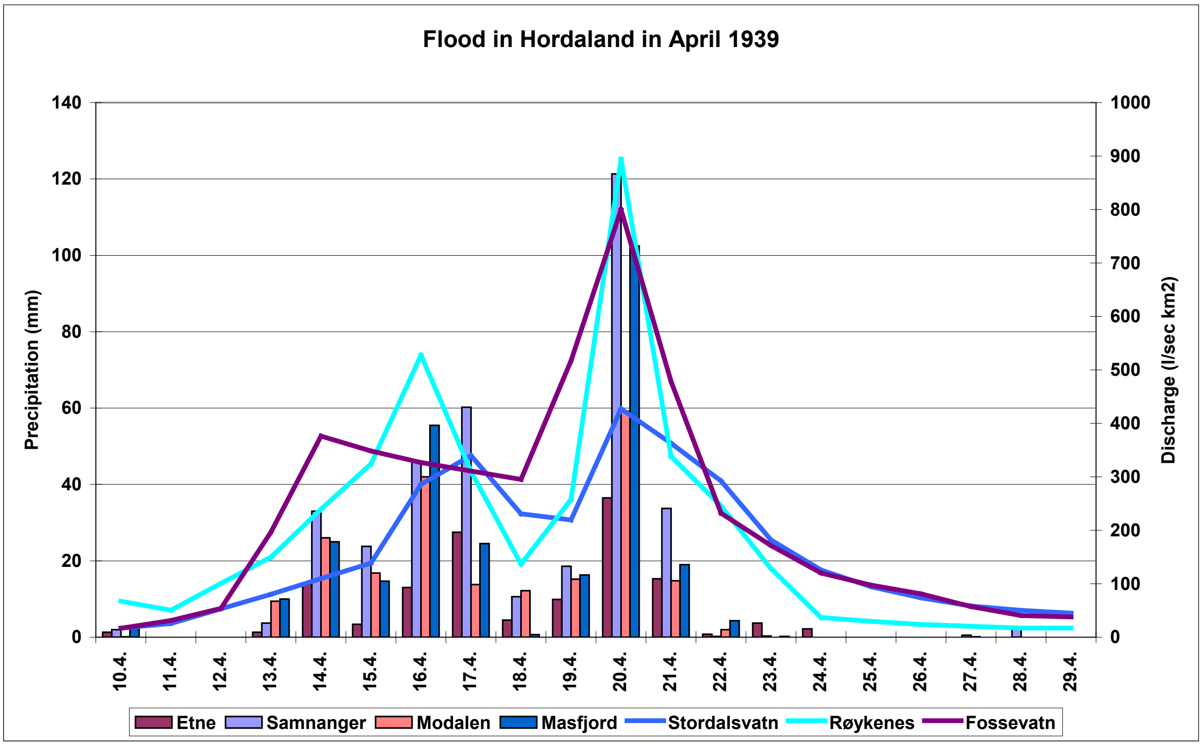


Figure 3.30.1 Observed precipitation and daily discharge in Hordaland in April 1939.

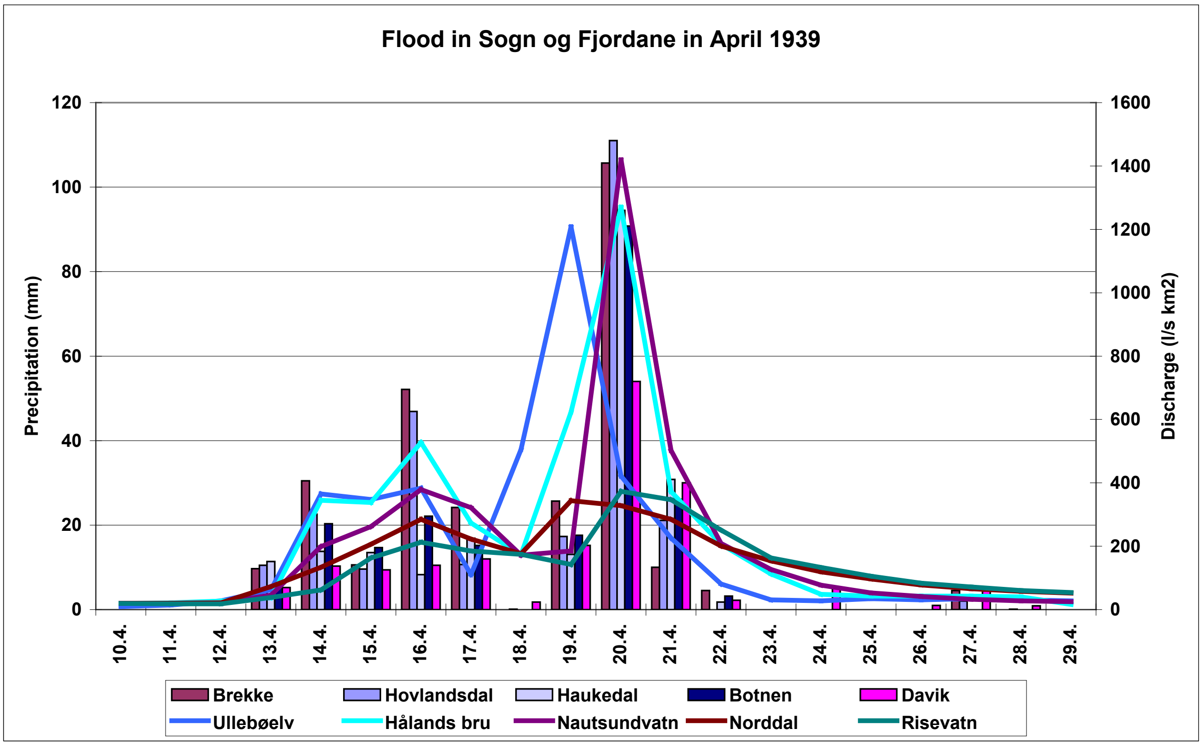


Figure 3.30.2 Observed precipitation and daily discharge in Sogn and Fjordane in April 1939.

The flood ranks as the 40th largest in River Oselv at Røykenes and the seventh largest in River Vassdalselv at Hålands bru in spite of high rainfall intensity.

Cause of the flood:

An anticyclone over Great Britain and depressions near Iceland and in the Norwegian Sea set up a stream of humid air from southwest towards the coast of West Norway 19-20 April 1939. The air temperatures were high in Bergen prior to the flood and much of the remaining snow had melted. The contribution to the flood from melting snow was therefore insignificant compared to the contribution from the rainfall. The weather types were **NWA** (Grosswetterlagen) and **AW/W** (Lamb/Jenkinsson).

3.31 The spring flood in West Norway in June 1939.

Catchments near the water divide between East and West Norway as well as mountain catchments in North Norway were simultaneously affected by a large spring flood 19-20 June 1939. In Figure 3.31.1 daily precipitation and discharge in rivers draining from Hardangervidda towards Sørfjorden, in Figure 3.31.2 for catchments draining from the water divide to the bottom of the other fjords in West Norway.

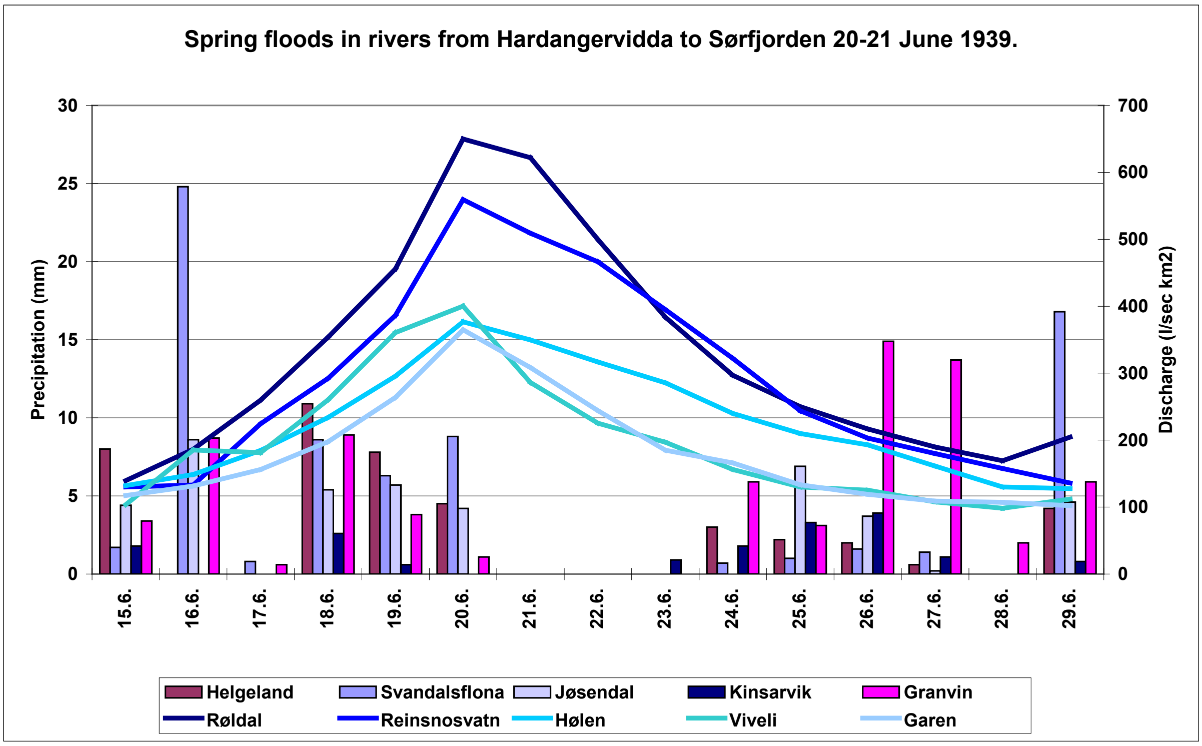


Figure 3.31.1 Observed daily preciptation and discharge in rivers draining Hardangervidda towards Sørfjorden in Hardanger during the spring flood in June 1939.

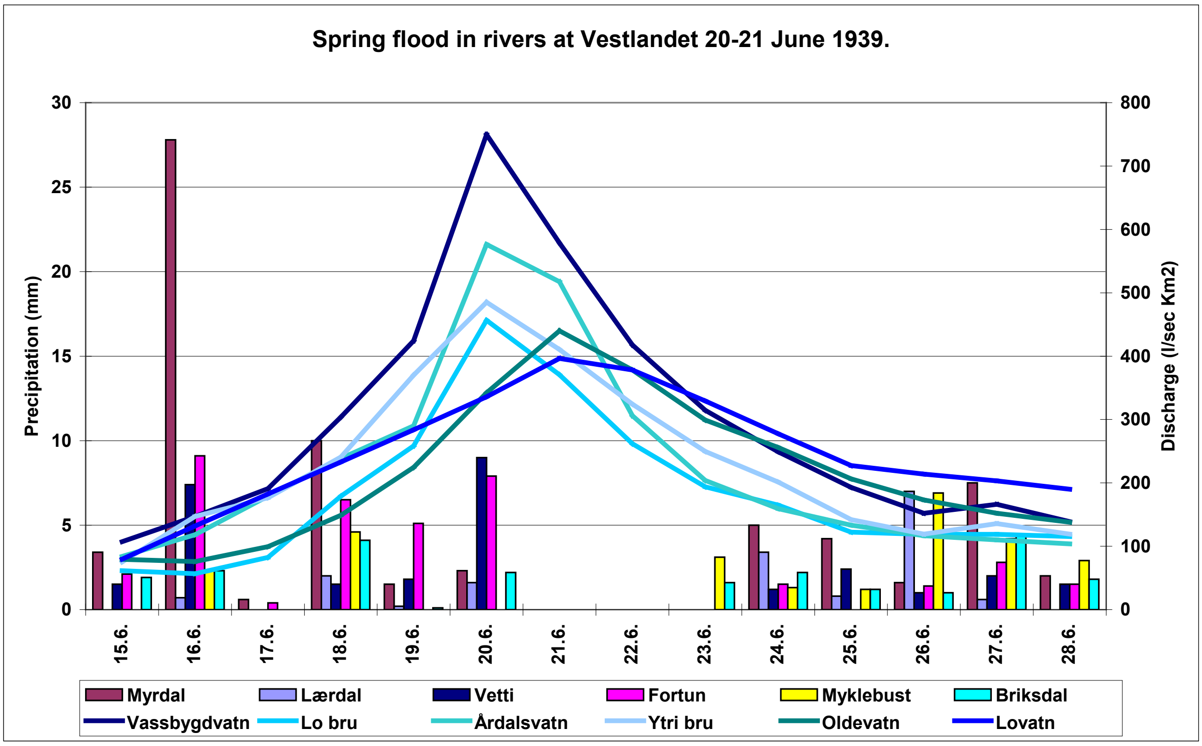


Figure 3.31.2 Observed precipitation and daily discharge in other rivers at Vestlandet in June 1939.

3.32 A secondary flood from Hardangervidda to Sørfjorden in July 1939.

As a result of heavy rainfall combined with melting of the remaining snow at Hardangervidda, rivers draining the plateau had a second mountain flood 18-19 July. Figure 3.32.1 show observert daily rainfall and discharge to the east and Figur 3.32.2 on the west of the water divide at Hardangervidda.

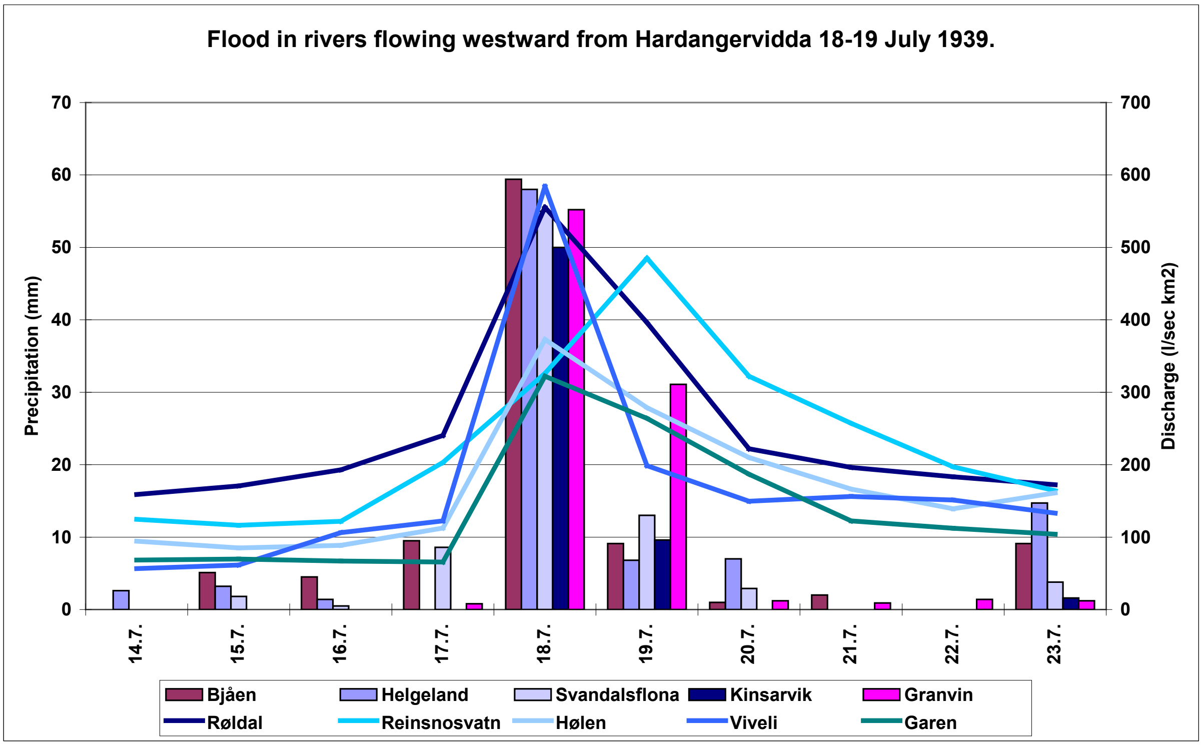


Figure 3.32.1 Observed rainfall and daily discharge in rivers draining westward from Hardangervidda to Sørfjorden.

The flood 18 July was the third largest in Heddøla at Omnesfoss 1921-2010 and the fourth largest in River Hjartdøla 1919-1990 draining eastwards and the second largest in River Veig 1915-2010 and the third largest in River Eio at Garen 1928-1975 draining westwards.

Cause of the flood:

The flood was primarily a rainfall flood, but remaining snow can have contributed to the flood. A depression was located over Great Britain and mowed into the North Sea. The precipitation which fell 17 and 18 July was frontal. The weather types were: **TB/TRW** (Grosswetterlagen) and **C** (Lamb/Jenkinsson).

3.33 The large rainfall flood in West Norway 24-26 November 1940

The coast from Vest-Agder to Nordfjord suffered from a long duration and extreme rain flood in November 1940. The daily precipitation and discharge in Rogaland and Agder are shown in Figure 3.33.1, in Hordaland in Figure 3.33.2 and in Sogn and Fjordane in Figure 3.33.3.

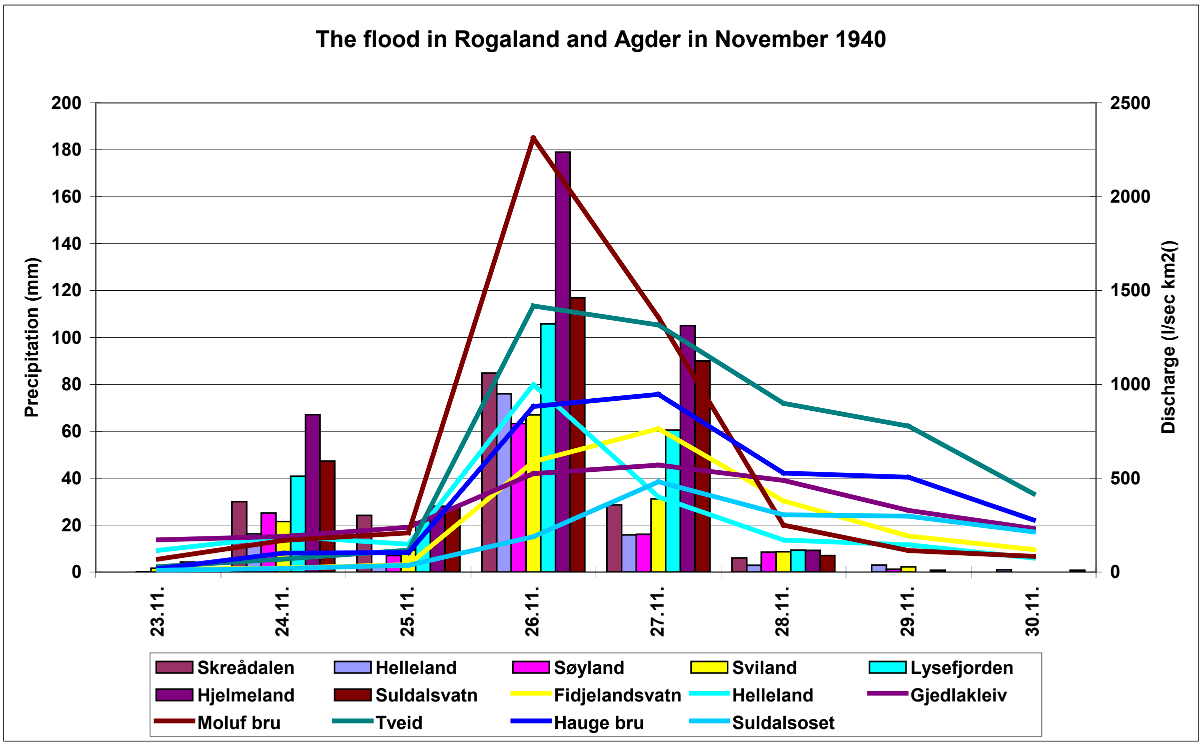


Figure 3.33.1 Observed precipitation and daily discharge in rivers in Rogaland and Agder during the large rainfall flood in November 1940.

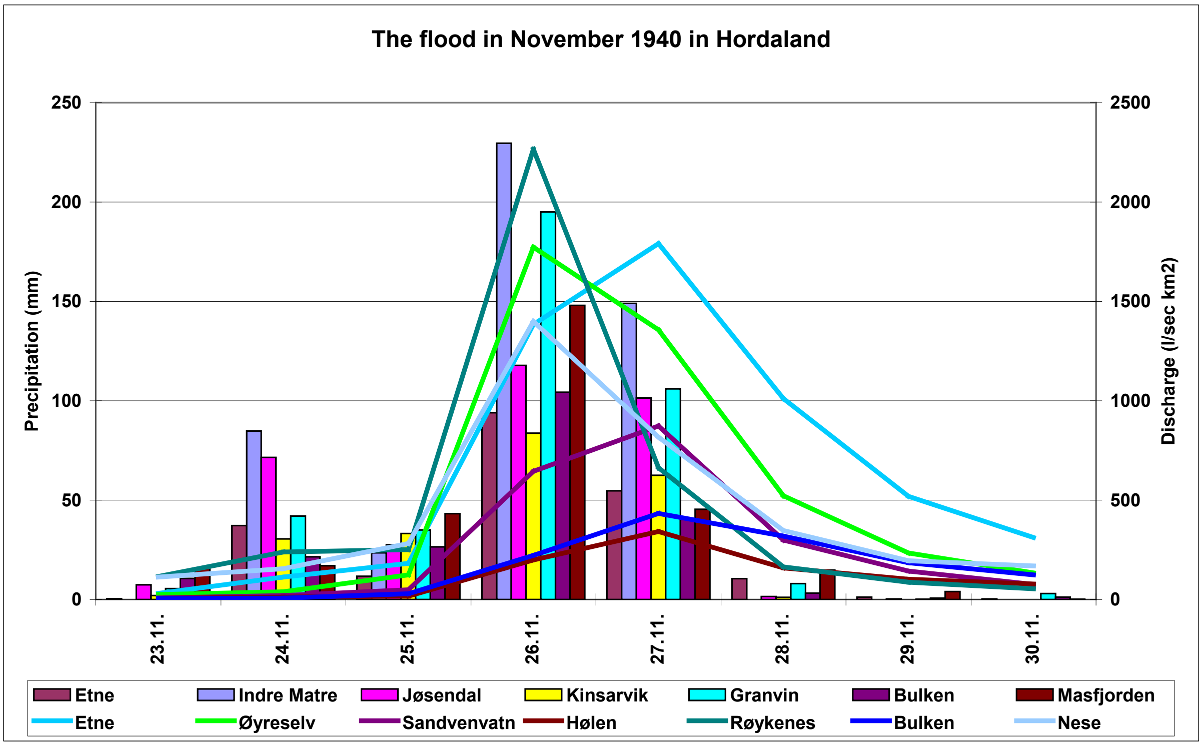


Figure 3.33.2. Observed precipitation and daily discharge in rivers in Hordaland during the large rainfall flood in November 1940.

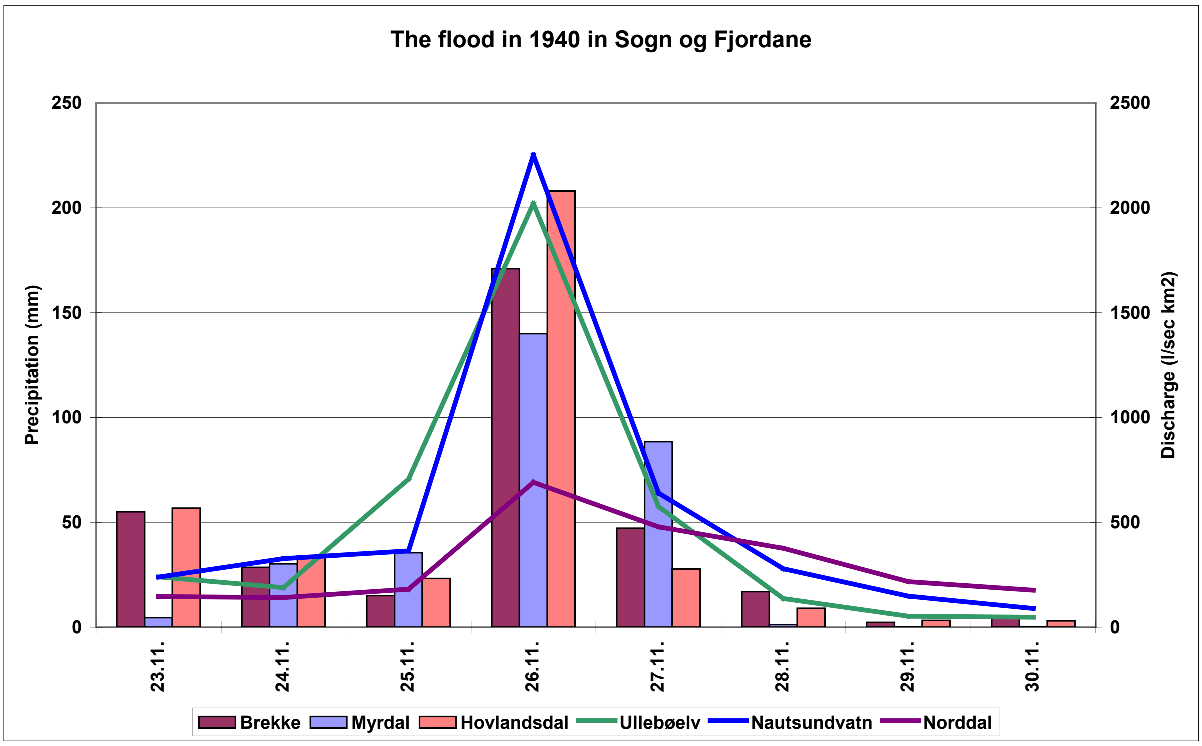


Figure 3.33.3 Observed precipitation and daily discharge in rivers in Sogn and Fjordane during the large rainfall flood in November 1940.

The flood was second largest in River Sira at Dorgefoss since 1913 and largest at Lake Fidjelandsvatn since 1919, sixth largest in River Hellelandselv 1896-2008, den 12th largest Bjerkreimsvassdraget since 1896, largest in River Frafjordelv at Moluf bru 1914-1950 and in River Årdalselv at Tveid since 1896. In River Ulla the flood was the largest naturalised flood 1905-2002 and in River Suldalslågen at Suldalsoset second largest 1904-1990. In Hordaland the flood was the largest in River Etneelv at Lake Stordalsvatn 1916-2013 and second largest in River Øyreselv 1921-1982 and in River Jondalselv at Lake Eidevatn since 1908. Data were not available from the rivers at the north side of Åkrafjorden where the largest one-day rainfall on record in Norway was observed 26 November of 229,6 mm. The flood was fifth largest in River Opa at Sandvenvatn 1908-2013 and second largest in River Oselv at Røykenes 1934-2013. In River Vosso the flood was the 11th largest 1892-2013. It was the third largest naturalised flood in River Eksingedalselv since 1909 and largest in River Matreelv since 1917. The flood was sixth largest in River Ullebøelv in Sunnfjord 1927-2013 and largest in River Guddalselv at Lake Nautsundvatn 1912-2013 and in River Mørkedalselv at Lake Dalsbøvatn 1934-2013.

Cause of the flood:

A strong depression at Iceland set up a strong air stream from south-southwest over Vestlandet. This is another example of *an atmospheric river* causing floods in West Norway such as in 1917 and 1932. The air temperature was relatively high after some cold days 7-10 November. As much as 229,6 mm fell 26 November at Indre Matre in Sunnhordaland. This is the highest one day rainfall observed from 08 on the previous day to 08 on the day when the rainfall sum is noted in the database. However, as much as 311 mm was observed at Samnanger 10-11 October 1953 when the rainfall was measured in the morning of two subsequent days. The extreme rainfall did in reality fall within 24 hours. From 24 to 27 November 1940 487 mm fell at Indre Matre.

The weather types were **BM** (Grosswetterlagen) and **W/SW/NW** (Lamb/Jenkinsson).

Flood damages:

The flood caused widespread damages in Rogaland, Hordaland and Sogn og Fjordane (Aftenposten 27, 28 and 29 November 1940.

Rogaland

The rainfall was very heavy at **Hjelmeland** in Ryfylke as shown in Figure 3.28.1. The resulting flood eroded the old churchyard, and most of it was taken by the river. Nearby ten buildings were taken by the flood. The eroded material filled up the harbour, and several fishing boats were resting on dry land formed by the deposits. The loss of soil was estimated to 10.000 cubic metres. Food from the foodstore was taken onboard a couple of vessels. Documents were floating in the bay, and further out in the fjord all kinds of furniture were floating. One building taken by the flood at Jøsenfjord drifted back on dry land and escaped with minor damages. The power station in River Steinslandselv had to close when water penetrated the station. The wooden intake to the station was smashed by a rockfall. The station lost copper cables worth 30.000 NOK. The total loss at Hjelmeland was estimated to several hundred thousand NOK.

The flood was also large in River **Årdalselv** as shown in Figure 3.28.1 for the gauging station 33.2 Tveid. The flood caused landslides at Kalltveit, Egland and Dirdal. Farmland of most of the farms rear the river, was partly inundated, causing some loss of farm animals.

The local police chief warned the inhabitants at **Tau** to prepare for evacuation because of raising water levels in Lake Tysdalsvatn. A failure of the flood protection works could cause severe flood into Lake Bjørheimsvatn and through the center of the Tau village. The flood fortunately started to decline before the flood protection works failed.

The flood was severe in **Sauda**. River Nordelva damaged the new Nordelv bro, which was cosed to traffic. The flood was as large in River Storelva where the water level reached the bottom of the bridge. The inhabitants living between the two rivers had to be evacuated by boat. The roakd westwards to Ølen was broken at Svandalsfossen and Brudesløret.

Hordaland

The flood at Rosendal took three bridges, three large and several smaller buildings. The larms lost much soil and the fields were covered by fallen threes and other debris when the flood retired.

The flood was severe in Hardanger. A landslide occurred at Eitrheim in Odda. The flood destroyed a water wheel, a pedestrian bridge and three grinding stones (Tokheim, 1962). The water broke through the main road as well. Downstream Tyssedal and through Ullensvang to Eidfjord the road was damaged at many locations.

The railway line from Oslo to Bergen was broken at several locations, by an avalanche at Hallingskeid, slide between Upsete and Myrdal and large flood between Evanger and Dale. The Stanghelle bridge at Dalevåg was considered unstable, and trains were halted at Voss. Farmers along Lake Vangsvatn had part of their fields inundated. Some buildings in Voss had their basements flooded.

Sogn og Fjordane

The flood caused also damages in Sunnfjord.

3.34 The flood at Stryn in July 1941 *(Fløda)*.

The summer of 1941 was hot and in early July dry weather had caused the glacier streams in Loen and Olden to flood, while rivers with our glaciers in their catchments dried up. The air temperatures observed in Bergen in July 1941 is shown in Figure 3.34.1. Some rain fell 4-7 July. The weather changed abruptly in the afternoon 12 July 1941 when an intense rainstorm ravaged Randabygda on the northern side of Nordfjord west of the village of Nedstryn. The rainstorm and flood have been described by Henden (2007). The flood was later named locally as *Fløda*. There are unfortunately no observations either of the rainfall or the discharge in the district where the rainstorm struck. The area is more or less the same as was devastated by a similar rainstorm 25 July 2011.

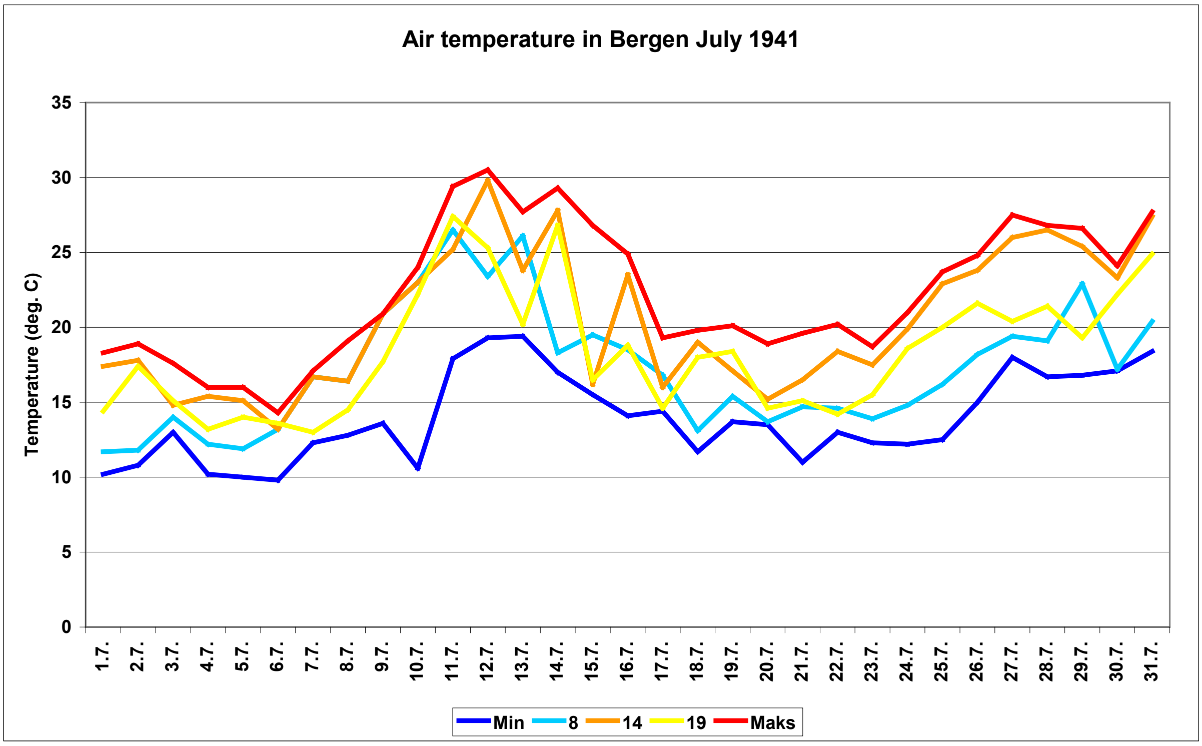


Figure 3.34.1 Observed air temperature in Bergen in July 1941.

The rainstorm heralded a shift towards a wetter weather type. 30-40 mm rain fell in Jostedalen, Stryn and Olden 12-14 July, causing the largest floods observed in River Oldeelv and Loelv 14 July 1900-2007 as shown in Figure 3.34.2. Both rivers are fed by meltwater from the western side of Jostedalsbre glacier.

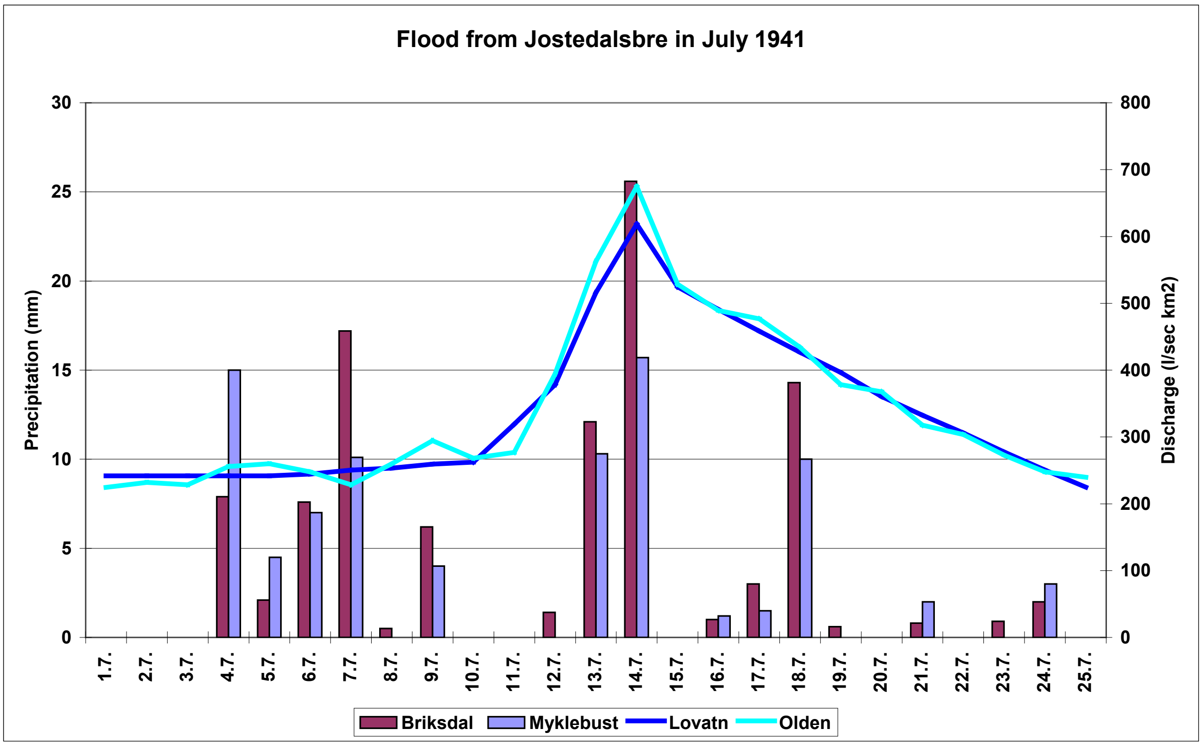


Figure 3.34.2 Observed precipitation and discharge during the flood in Loen and Olden in July 1941.

The weather types were **TRW** (Grosswetterlagen) and **CE** (Lamb-Jenkinsson).

3.35 Two winter floods occurred at Vestlandet in December 1941.

In December heavy rainfall caused two floods in coastal rivers at Vestlandet. The first flood occurred 11 December and the second 22 December. Figure 3.35.1 show observed daily precipitation and discharge for the two December floods occurring 10-11 December and 21-22 December.

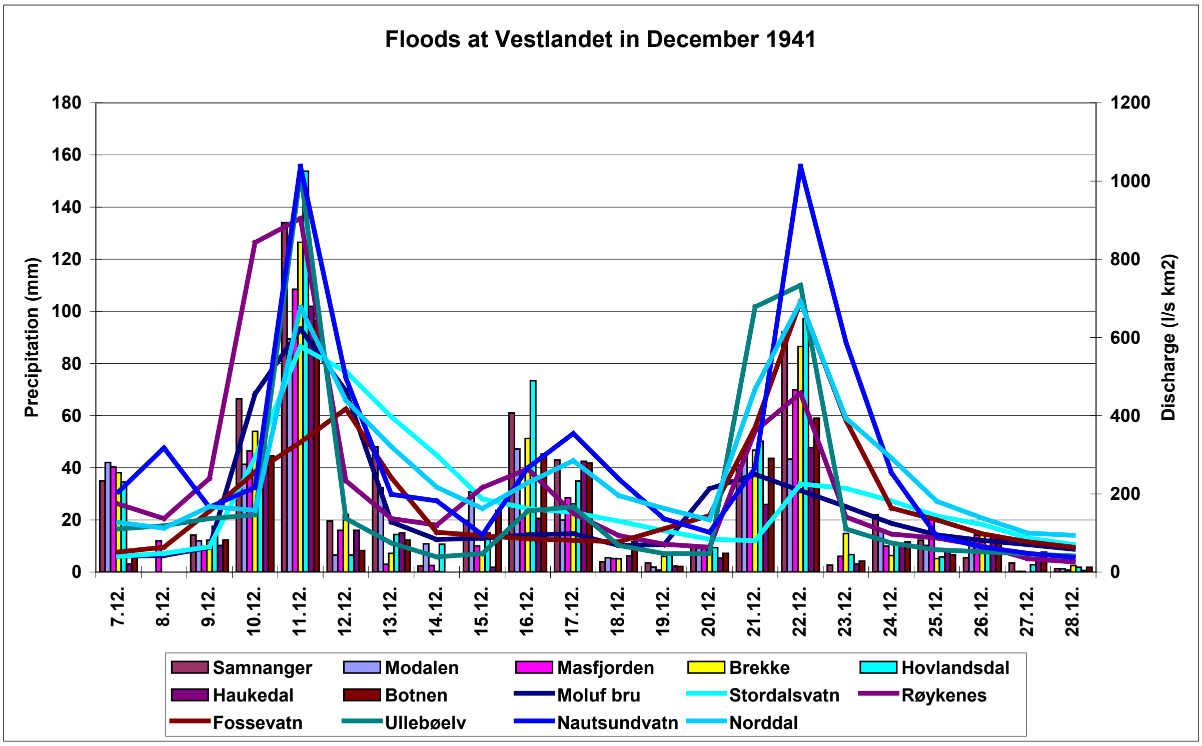


Figure 3.35.1 Two winter floods in Hordaland and Sogn and Sunnfjord in December 1941.

The floods did not rank among the largest in spite of high rainfall intensities.

Cause of the flood:

Initial conditions

Figure 3.35.2 show observed snow depths at some stations at Vestlandet in November-December 1941. Some snow was accumulated in early November, but the snow depth was reduced towards the end of the month. In December more fell especially at higher levels peaking after the first event 15 December when the temperature had dropped, as seen from Figure 3.35.3 which shows the December temperatures observed in Bergen. The snow depth declined through the second event, but started to increase as cold air moved in behind the front 22 December. Snow melt did contribute to the flood but the main cause of the flood in the coastal rivers was the rainfall.

The weather sequence

A strong depression moved towards the Norwegian coast from the Norwegian Sea, directing strong wind from south along the coast of Vestlandet 9 December, and causing the temperatures to rise. The first rainfall event was caused by a frontal passage 10-11 December. Weather types 10-11 December were **WZ** (Grosswetterlagen) and **SW/AW** (Lamb-Jenkinsson). The wind direction shifted to northwest behind the front.

Another front caused some rain and a minor flood in some coastal rivers 16 December. Further inland and at higher altitudes the precipitation fell as snow.The temperature fell behind this frontal passage 18 December, but started to rise as another depression further north in the Norwegian Sea set up a stream of mild and humid air from southwest towards the coast of Vestlandet. An anti-cyclonic ridge mowed in from the European mainland over Britain. The depression moved towards the coast of Møre and Romsdal 21 December, and the subsequent frontal passage caused the heavy rainfall and the second large floods in December in the coastal rivers. Behind the fromt the wind direction shifted towards northwest causing the temperatures to drop. The weather types 20-22 December were **BM/BM/NWA** (Grosswetterlagen) and **A/W/ANW** (Lamb-Jenkinsson).

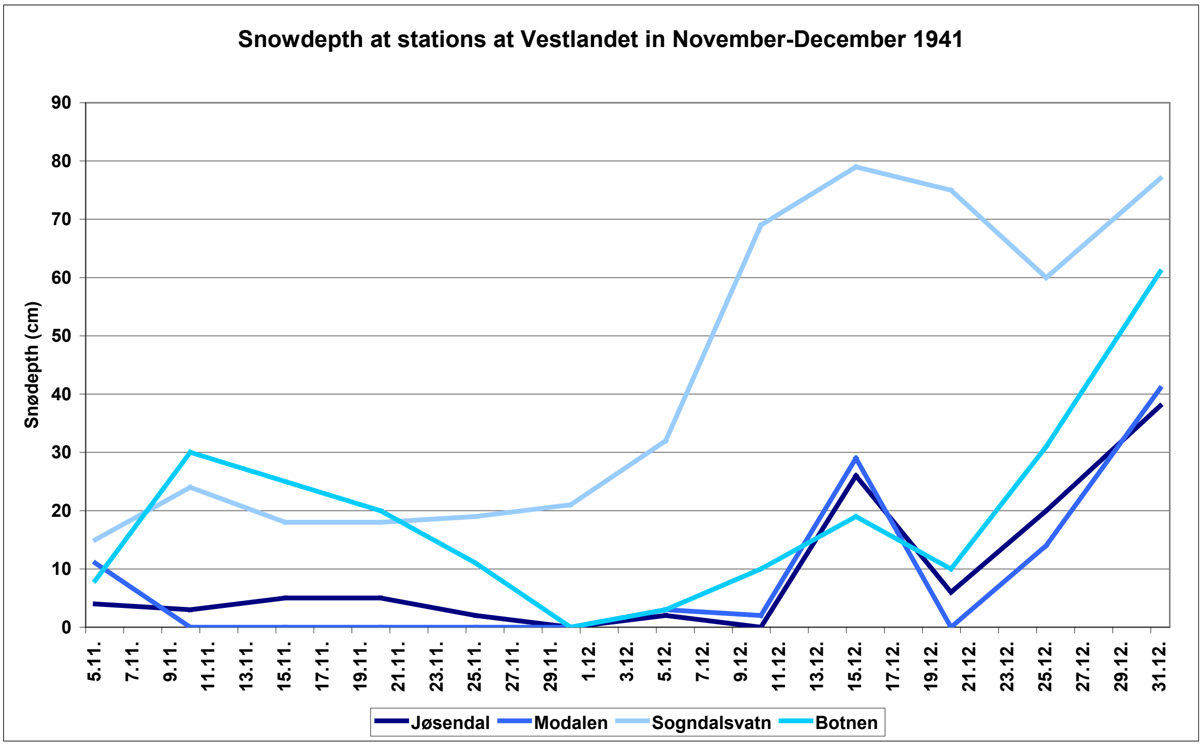


Figure 3.35.2 Observed snow depths at four stations in Nord-Hordaland, Sogn and Sunnfjord

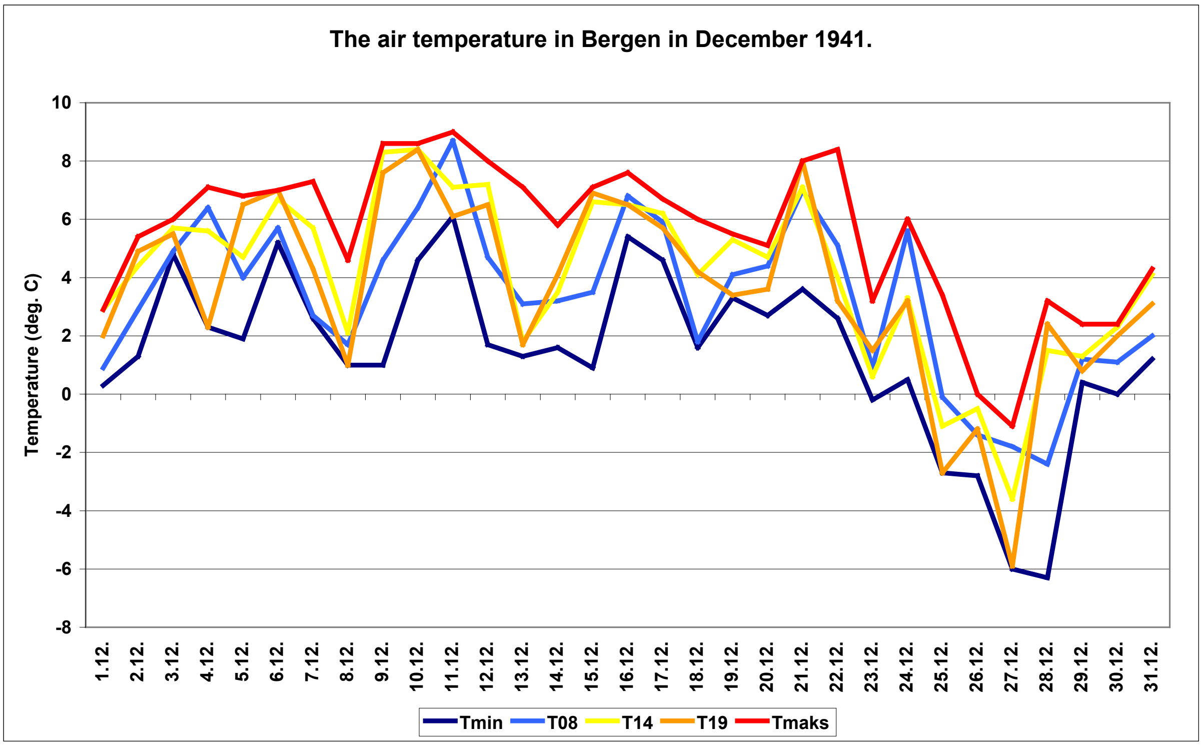


Figure 3.35.3 The air temperature in Bergen in December 1941

3.36 Rainfall floods at Vestlandet in August and September 1942.

In the late summer and the autumn 1942 rainfall floods occurred in coastal rivers at Vestlandet and at Helgeland. Figure 3.36.1 show daily rainfall and discharge for stations from Nord-Hordaland to Sunnfjord for a flood 18 August, Figure 3.36.2 for a flood 11 September and Figure 3.36.3 for a flood at Helgeland 12 September.

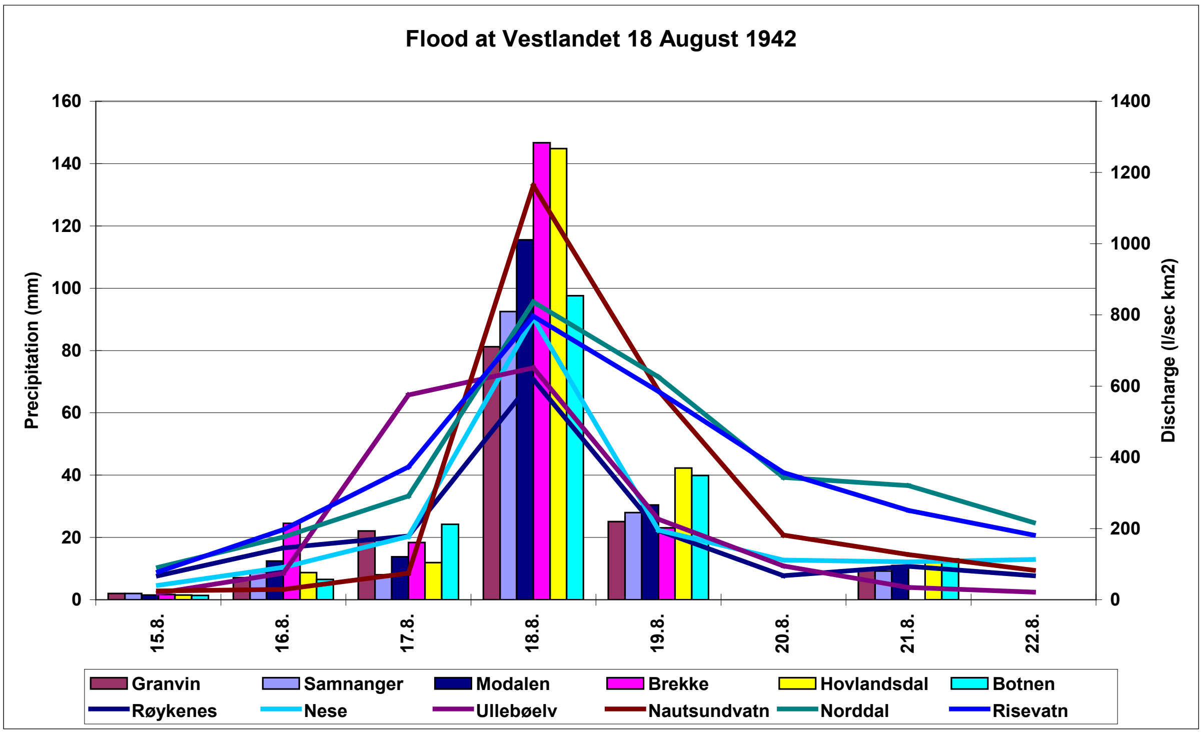


Figure 3.36.1 Observed precipitation and daily discharge at Vestlandet during the rainfall flood in August 1942.

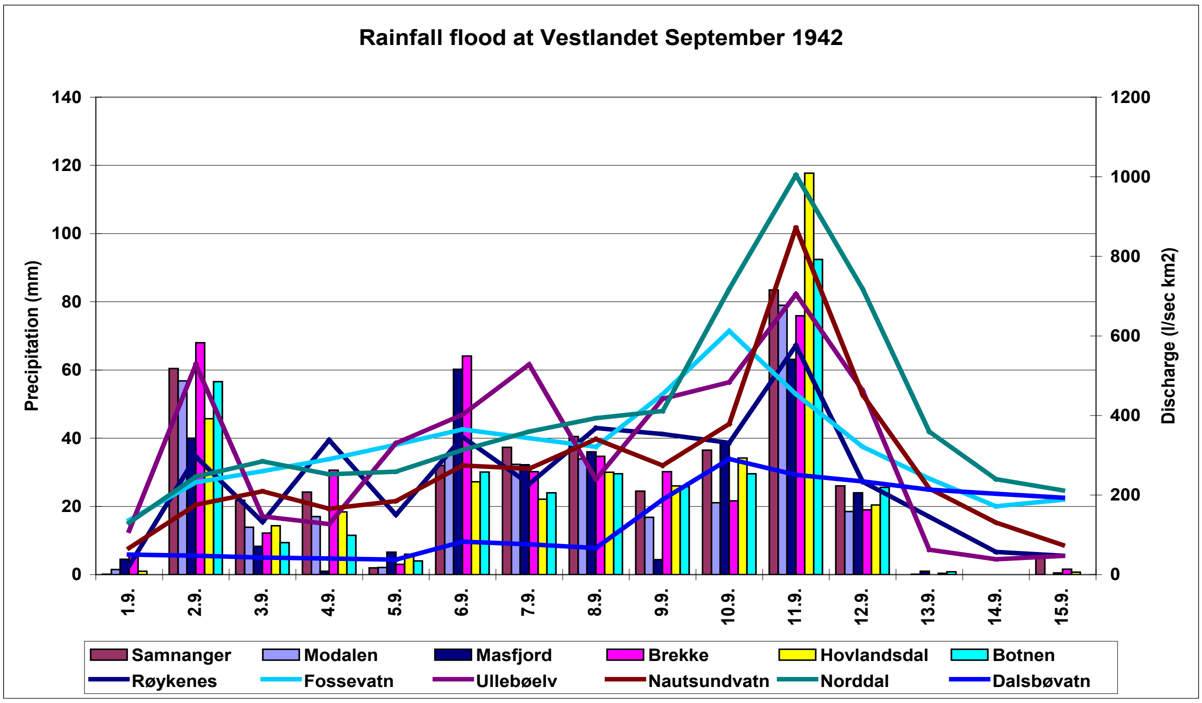


Figure 3.36.2 Observed precipitation and daily discharge at Vestlandet during the rain flood in September 1942.

Neither of the floods ranks among the largest floods at Vestlandet.

Cause of the flood:

These floods were typical rainfall floods occurring after some wet days and a frontal passage with high precipitation intensities. An anti-cyclonic was situated ridge from Russland across Central Europa, Great Britain and further westward into the Atlantic 15-20 August. Between this ridge and a low over Iceland, humid air masses were streaming from southwest towards the Norwegian coast. The low moved eastward to a position north of Scotland. The air stream towards Vestlandet shifted toward south. Weather types were **HM** (Grosswetterlagen) and **SW/S** (Lamb/Jenkinson)

During the September flood an anti-cyclone was located over Great Britain and the European mainland with a stream of humid air on northern flank towards the coast of Norge. A strong low moved over Lofoten 11 September. A frontal passage in the nighth of 12 September caused the heavy rainfall. Behind the front the wind shifted to northwest. Weather type: **BM** (Grosswetterlagen) and **A** (Lamb/Jenkinson).

3.37 A long-term winter flood in coastal basins from Hordaland to Fosen in February 1943.

Long duration rainfall caused a flood in coastal rivers at Vestlandet and in Trøndelag. Figure 3.37.1 show observed precipitation and daily discharge in rivers from Hordaland to Fosen.

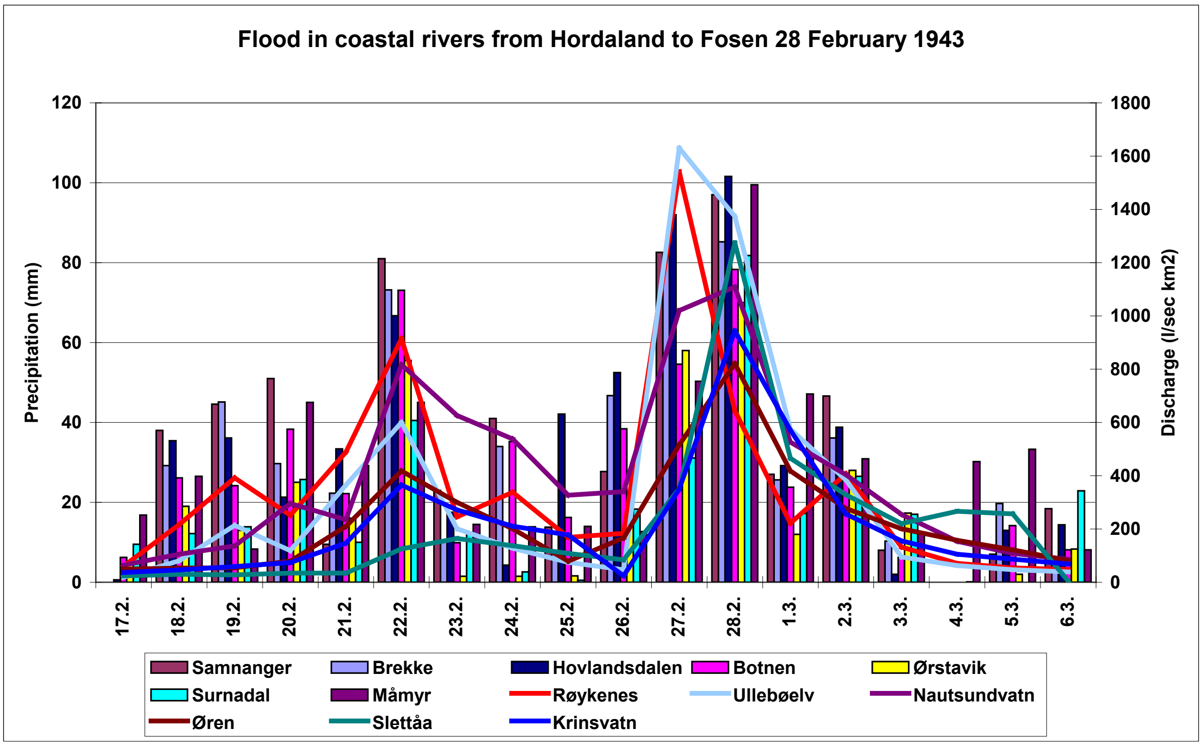


Figure 3.37.1 Observed precipitation and daily discharge at Vestlandet during the longterm flood in February 1943.

The flood was the fourth largest observed in River Oselv at Røykenes since 1934 and second largest in River Engesetelv at Sunnmøre since 1924.

Cause of the flood:

The flood occurred in a mild period starting 19 February. A little snow had fallen in the catchments on the coast. Snowmelt contributed only marginally to the flood which was primarily a rainfall flood. The snow cover increased during the periode at higher levels, but not at the coast. An anticyclone over Central Europe to Great Britain and cyclones in Norwegian Sea set up a stream of maritime air towards the coast of Vestlandet. A frontal passage caused the heavy rainfall and subsequent flood 28 February. The weather types were **BM** (Grosswetterlagen) and **A** (Lamb/Jenkinsson).

3.38 The large rainfall flood at Vestlandet in September 1948.

September and October 1948 had abundant rainfall at Vestlandet. The monthly rainfall exceeded 200 percent of the normal at several stations in both months especially on the coast. Several events occurred with high daily rainfall at one or more stations, resulting in floods in several rivers. Figure 3.38.1 show observed rainfall and daily discharge in selected rivers at Vestlandet. Most rainfall was observed 18 September at Vestlandet. Floods occurred in some rivers 8 and 14 September, 22 October and/or 22 November after locally large rainfall.

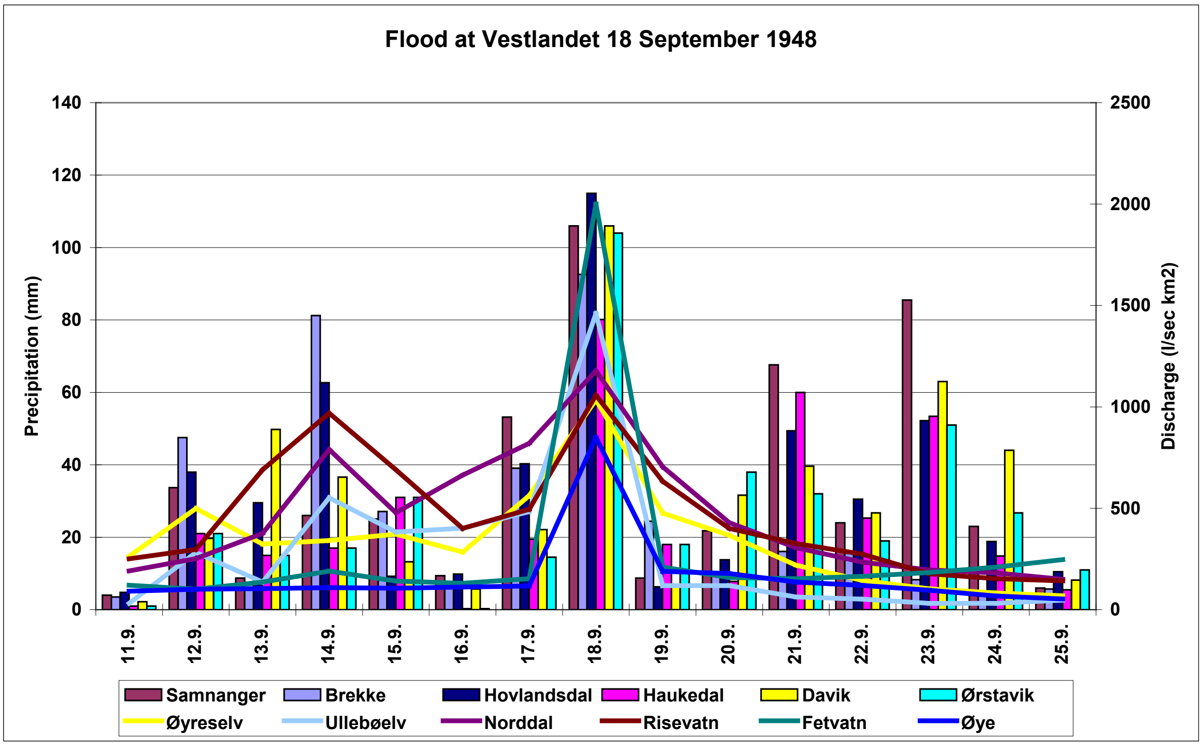


Figure 3.38.1 Observed precipitation and daily discharge at Vestlandet during the rainfall flood in September 1948.

The flood was the largest observered in River Fauseelv at Stranda 1920-1956 and the second largest in River Bygdaelva at Øye at Sunnylven 1917-2010 and at River Velledalselv at Lake Fetvatn at Sykkylven 1946-2010. The flood was less extreme in rivers south of the Stadt peninsula; in Sunnfjord it was the 13-14 largest flood in 78 years.

Cause of the flood:

Between an anticyclone south of Great Britain and a strong depression near Jan Mayen maritme air masses were streaming towards the west coast of Norway. A secondary depression over the coast of Nord-Trøndelag caused heavy rainfall at the northern part of Vestlandet especially at Sunnmøre 18 September. The weather types were **WA** (Grosswetterlagen) and **W** (Lamb/Jenkinsson) 18 September. This weather type had dominated since 12 September and lasted with subclasses (**SWA/NWA**) unto 5 October when an anticyclone over the European continent (HM) led to re-inforced transport from west towards Vestlandet.

3.39 The mountain flood in South Norway in June 1950.

Mountain rivers at the western side of the water divide at Vestlandet had one of the larger spring floods in June 1950. The flood was especially large in rivers draining the Hardangervidda plateau. Rivers running eastward from the water divide had also floods, but these floods were mostly moderate. Figure 3.39.1 show observed daily precipitation and discharge in some rivers east of the water divide, and Figure 3.39.2 in catchments west of the water divide.

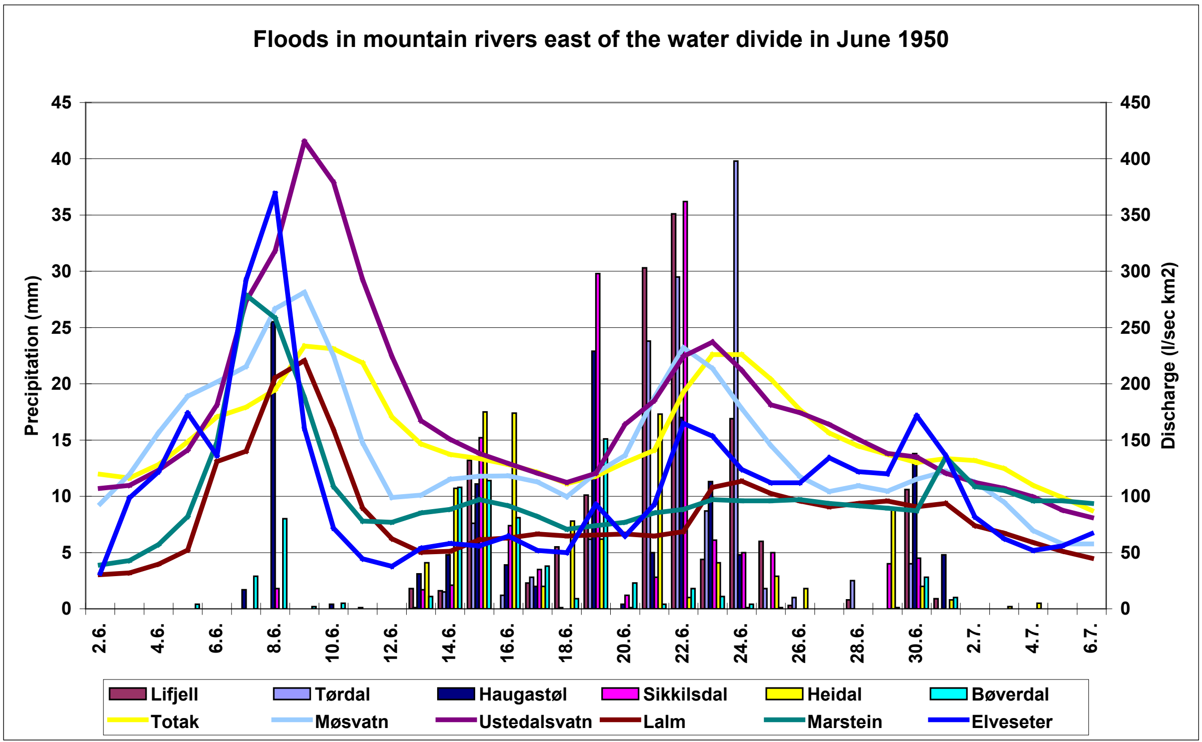


Figure 3.39.1 Observed daily precipitation and discharge under the flood in June 1950 in catchments east of the water divide.

The flood was second largest in River Usta at Ustedalsvatn 1909-1965. The flood was the largest flood of 1950 in most og the rivers draining eastwards, but does not rank among the largest floods observed in these rivers.

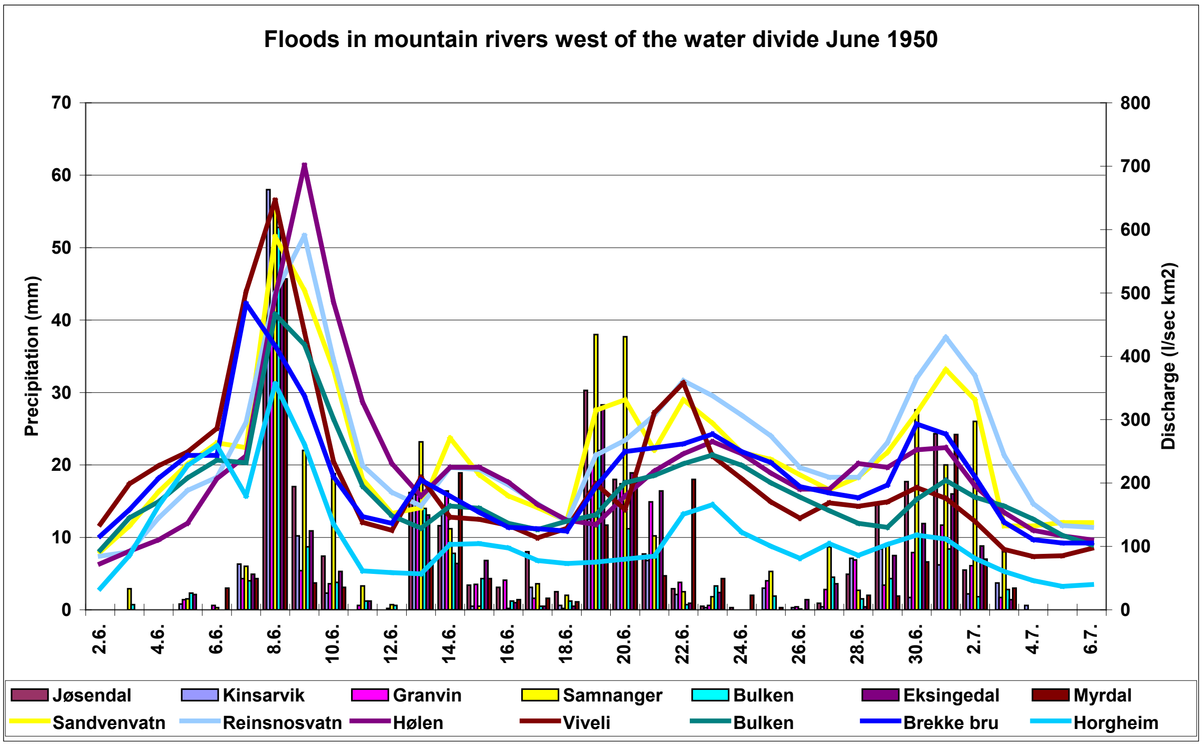


Figure 3.39.2 Observed precipitation and discharge in mountain streams in western Norway in the summer 1950.

The flood was the largest observed in River Eio at Lake Eidfjordvatn since 1928, in River Veig at Viveli since 1915 and in River Kinso at Hølen since 1923. It was fith largest in River Austdøla at Lake Reinsnosvatn since 1917 and the sixth largest in River Vosso at Bulken since 1892. It was the ninth largest flood in Flåmselv at Brekke bru at 68 years. In River Lærdalselv and Årdalselv the floods were 19th largest in 92 years and 14th largest in 95 years respective.

The flood was caused by both snowmelt and precipitation. The peak occurred 8-10 June at both sides of the weater divide. June started with anti-cyclonic weather and high temperatures causing the snow to melt fast. A low caused heavy precipitation west of the water divide 8 June causing the flood peak from Hardangervidda. The precipitation did not penetrate east of the water divide except at Ustedalen. The peak in the east was therefore caused by melting snow at the highest levels. Frontal passages from the west 13-14 June, 19-21 June and 28 June-2 July caused some smaller floods in the west. The weather types 8 June were **HB** (Grosswetterlagen) and **NW** (Lamb-Jenkinsson).

3.40 Flood and rainfall during the rockfall in Lake Loenvatn in June 1950.

Another major rockfall from Ramnefjell at Loen occurred in June 1950. The lake near Nesdal was filled with debris from the previous rockfall. The rockfall did not, therefore, cause another tsunami. Observed rainfall and discharge is shown in Figure 3.40.1.

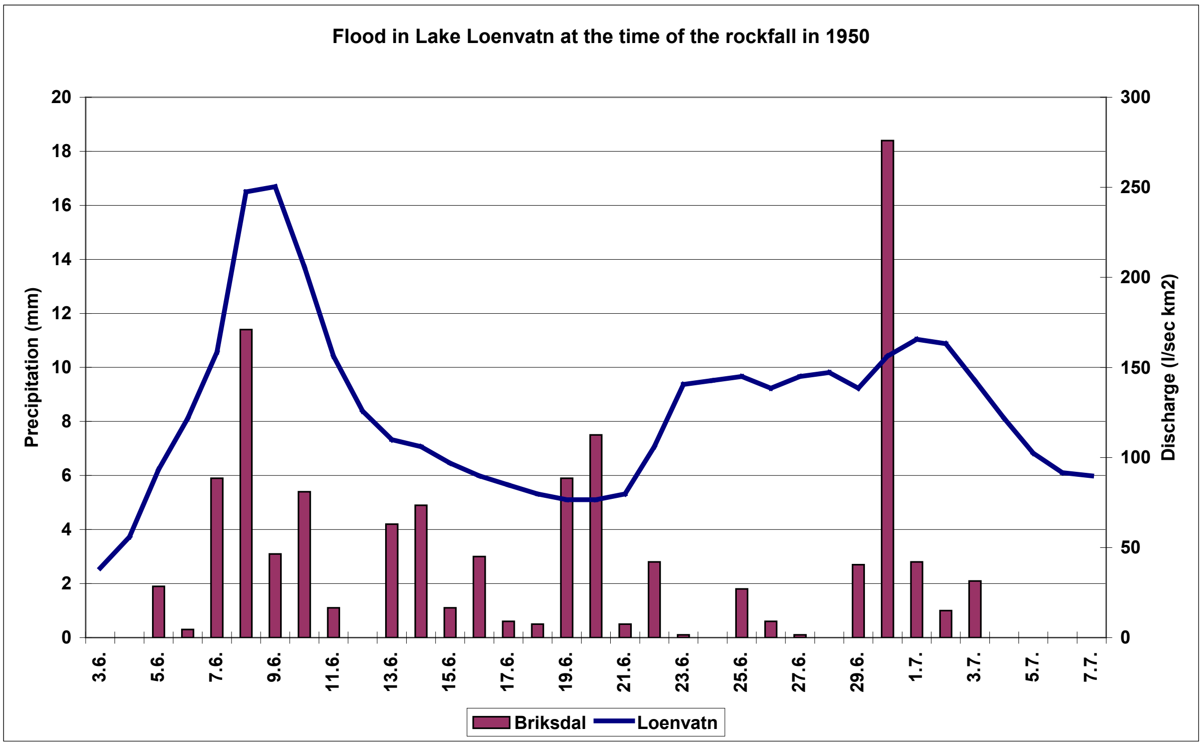


Figure 3.40.1 Observed discharge and precipitation in Lake Lovatn during the third major rockfall into the Lake in June 1950.

3.41 Extreme rainfall on the Bergen Penninsula 10-11 October 1953.

An extreme rainstorm occurred at the coast of Hordaland and Sunnfjord 10-11 October 1953 The rainstorm and subsequent did also reach Sunnmøre where River Velledalselv at Sykkylven and River Bygdaelv in Sunnylven had floods. The rainfall intensity was most extreme on the Bergen peninsula. At Samnanger 156 and 155 mm rainfall was observed in the 08:00 in two consequtive days. This rainfall fell actually during 24 hours.The resulting flood in River Oselva exceed by far the two next largest floods observed in the River, both extreme events, ie the flood in November 1940, and the flood caused by the extreme weather Kristin 14 September 2005. Figure 3.41.1 show observed daily rainfall and discharge during the flood.

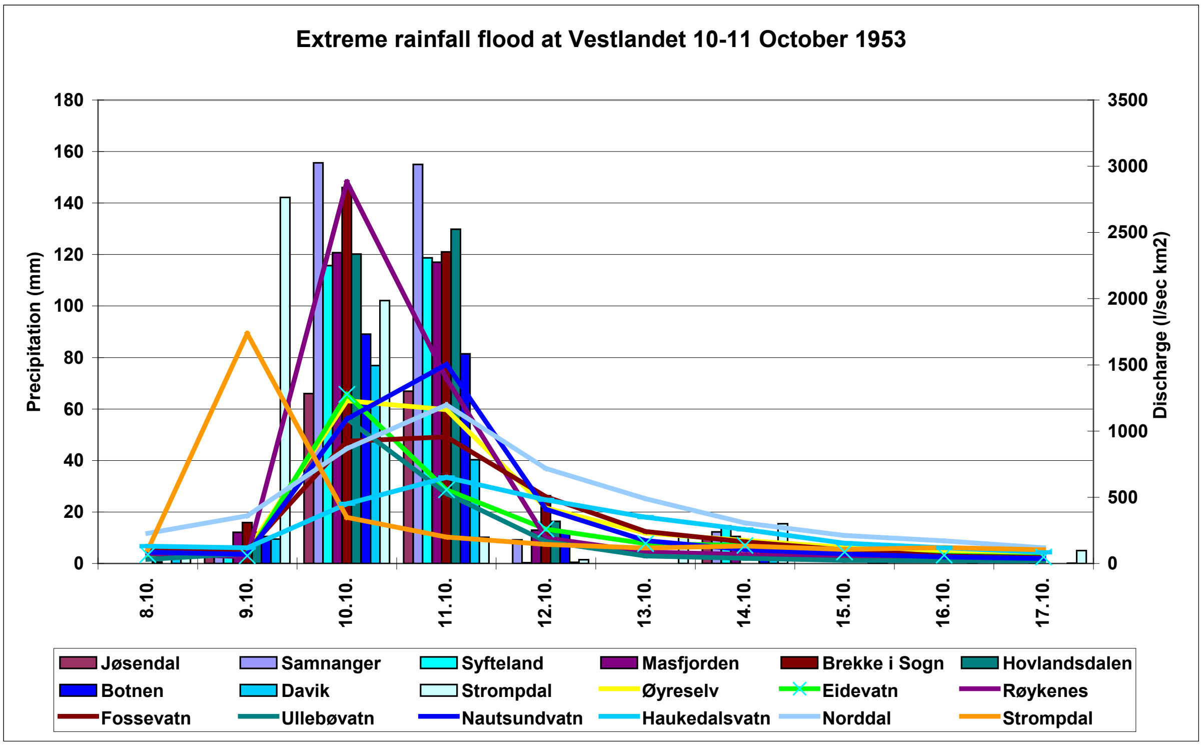


Figure 3.41.1 Observed precipitation and daily discharge at Vestlandet during the extreme rainfall in October 1953.

The flood was the largest observed at River Klyvtveitelv at Lake Kløvtveitvatn since 1916, the eigth largest in River Eksingedalselv in 100 years and in River Kinso the 11th ellevte largest in 85 years. In River Guddalselv the flood was the tenth largest in 100 years and in River Gaular the sixth largest in 108 years. The flood ranks not among the larger flood further inland and at the inner fjords.

Cause of the flood:

A tropical depression appeared 3 September in the hurricane belt far south in the North Atlantic. The depression moved first northwestwards, but turned later towards northeast near Iceland where it joined a polar front low 11 October. The low moved towards the coast of Vestlandet where it caused the extreme rainfall observed at the Bergen peninsula. Weather types were **HM** (Grosswetterlagen) and **SW/ASW** (Lamb/Jenkinsson)

3.42 A December flood at Ytre Sunnfjord in 1954.

A flood occurred in costal rivers at Hordaland and Sunnfjord in December 1954. Observed precipitation and daily discharge is shown in Figure 3.42.1.

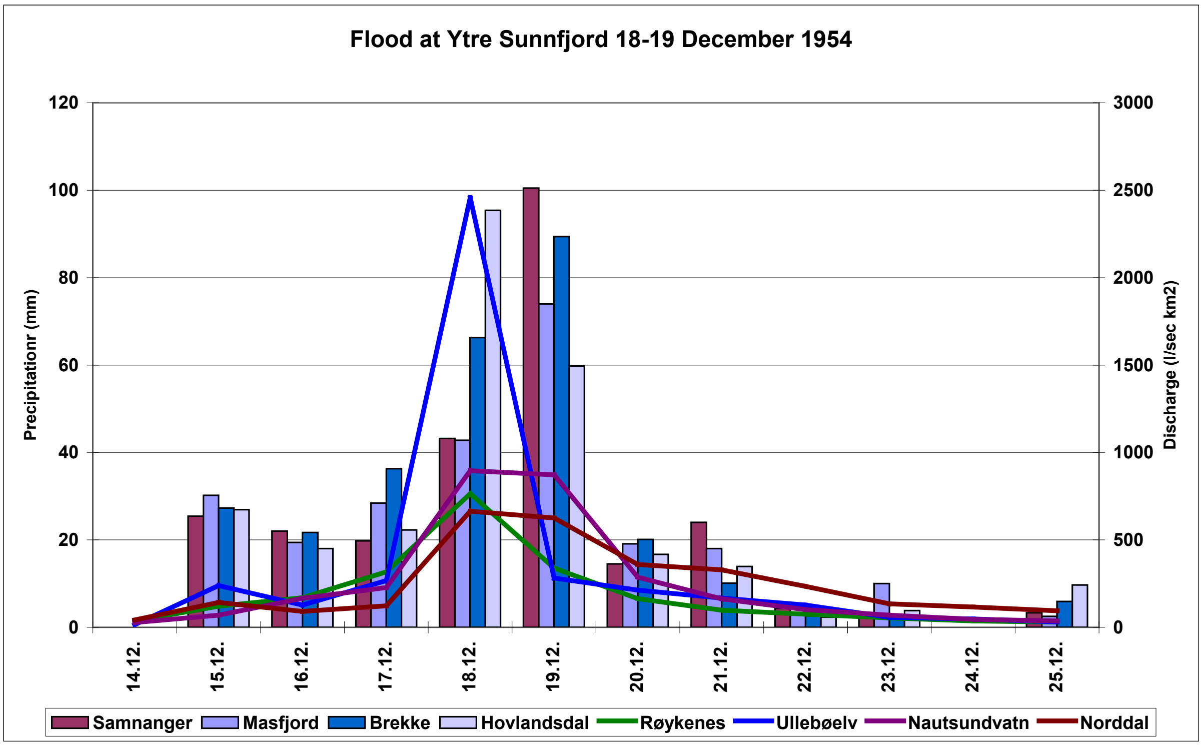


Figure 3.42.1 Observed precipitation and daily discharge on the coast of Sunnfjord during the December flood in February 1954.

Mild weather prevailed from late November to 20 December at Vestlandet. The snow was therefore mostly absent on the coast, where the flood was mostly caused by rainfall. Further inland and at higher levels most of the precipitation fell as snow. Mild and humid air masses came streaming from southwest south of a low over Iceland. Colder air moved in behind the front from northwest causing a drop in temperatures and snowfall at most of the coast. The weather type 18-19 December was **BM** (Grosswettterlagen) and **W** (Lamb-Jenkinsson).

3.43 The long-term rainfall flood at Vestlandet 6 December 1955

Intense rainfall at coastal districts of Rogaland, Hordaland and Sunnfjord 6 December 1955 caused locally large floods in smaller rivers. Figure 3.43.1 show observed precipitation and daily discharge in some selected rivers.

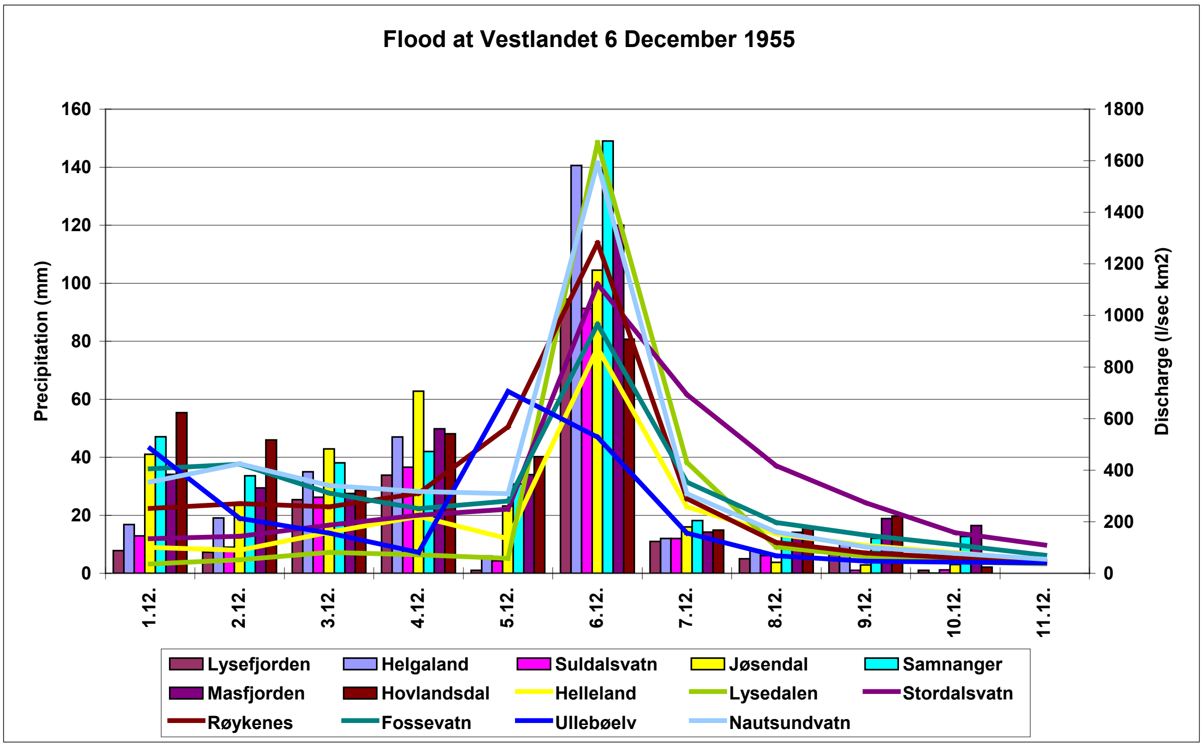


Figure 3.43.1 Observed precipitation and daily discharge at Vestlandet during the December flood in February 1955.

The flood was the second largest in River Jørpelandselva at Lake Liarvatn and in River Etneelva at Lake Stordalsvatn since 1912.

Cause of the flood:

The air temperature in Bergen varied between 3,1 and 9,9°C. Snow was probably abscent in the lowland catchments. It may however have contributed to the flood at higher levels. The intense rainfall was caused by an intense low near the coast of Nordland.

The weather type was **WA** (Grosswetterlagen) and **SW/W** (Lamb-Jenkinsson).

3.44 The large flood at Vestlandet 22 October 1956.

A widespread rainstorm caused floods at Vestlandet in October 1956. The flood was moderate for rivers south of Eksingdalen in Nordhordaland, but large for rivers further north. Figure 3.44.1 show observed rainfall and daily discharges at selected stations.

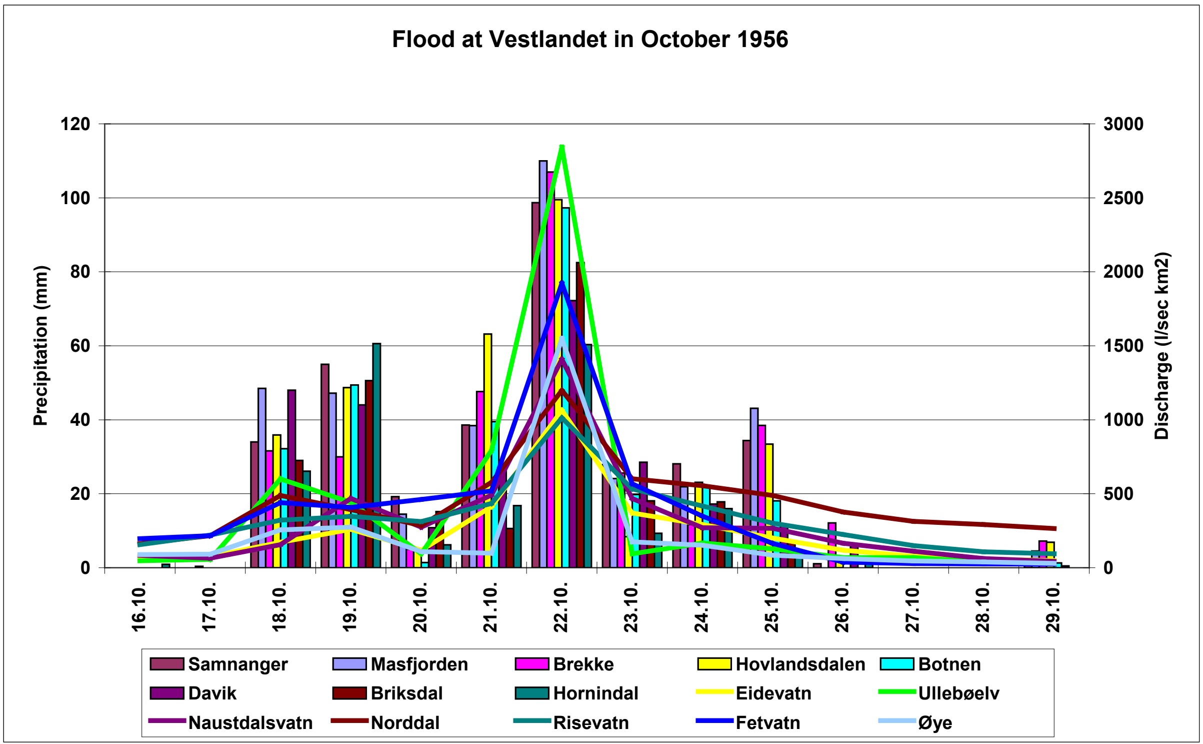


Figure 3.44.1 Observed precipitation and daily discharge at Vestlandet during the October flood in 1956.

The flood was the sixth largest nauralised flood in the regulated River Eksingdalselv since 1909. The flood was the third largest at Brydalselv and Flåmselv since observations started in 1917 and 1941. The flood was the fourth largest in River Årdalselv at Sogn and the second largest in River Ullebøelv since 1927. The floods were also large in River Guddalselv at Nautsundvatn, Gaular at Viksvatn and Jølstra at Sunnfjord and the largest naturalised flood in River Breimselv at Nordfjord since 1901. The flood was the third largest in River Velledalselv at Fetvatn and the largest in Bygdaelva at Øye at Sunnmøre.

Cause of the flood:

The flood was mostly caused by rainfall, but snowmelt from the alpine parts of the basins may have contributed to the flood. Mild air masses were streaming towards Vestlandet from southwest and later west-southwest because of a polar front low near Iceland. Weather type was **WA** (Grosswetterlagen) and **CW**/**AW**/**W** (Lamb-Jenkinsson). The flood was caused by longterm rainfall from 17-25 October, peaking on 22. The highest one-day rainfall was observed at Masfjord in Nord-Hordaland (110 mm). The highest discharge was observed at Ullebøvatn at Sunnfjord (2842 l/s km^2). This lake reacts fast to rainfall and has produced many floods with high specific runoff.

Flood damages:

The flood caused erosion damages at the banks of Rivers Sitla and Seimsdalselvi at Årdal at Sogn.

3.45 The large rainfall flood 9 January 1957 in West and Mid- Norway.

A large rainfall flood occurred in coastal rivers at Vestlandet and Mid-Norway from Matre in Nordhordaland to the Fosen peninsula. Figure 3.46.1 show observed precipitation and discharge for stations in Hordaland and Sogn and Fjordane and Figure 3.46.2 for stations from Sunnmøre to Namdalen.

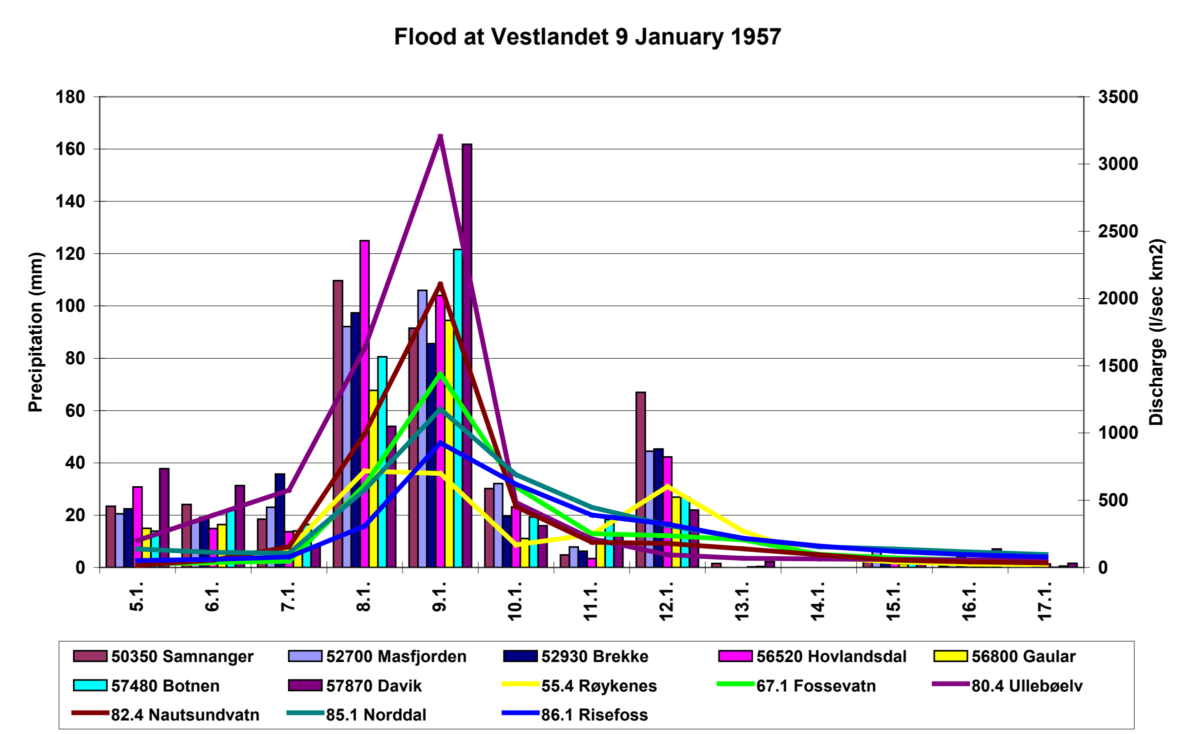


Figure 3.45.1 Observed precipitation and daily discharge at Vestlandet during the winter flood in February 1957.

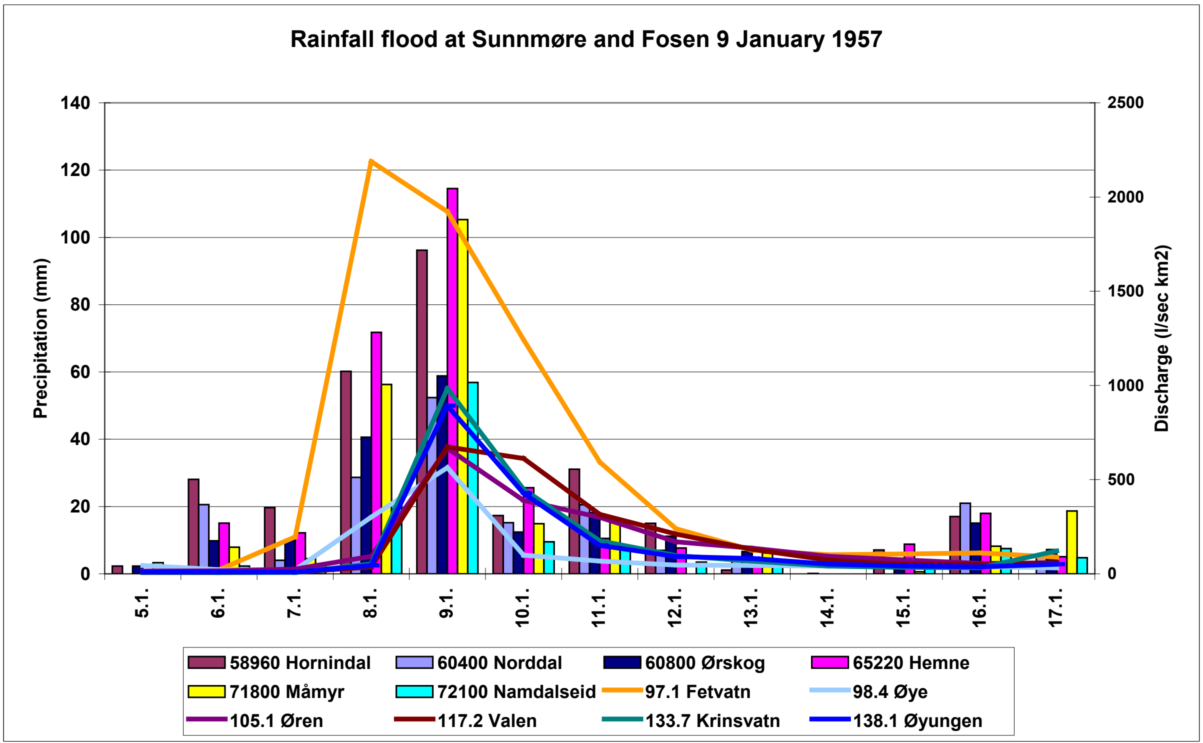


Figure 3.45.2 Observed precipitation and daily discharge at Vestlandet during the winter flood in February 1957.

The flood was second largest since 1917 in River Matreelva in Nord-Hordaland, den largest since 1927 in River Ullebøelva in Sunnfjord, den fifth largest since 1926 in River Vassdalselva, second largest since 1908 in River Guddalselva and second largest in River Oselva in Sunnfjord. The flood was moderate in Norddalselv and Riseelv in Outer Nordfjord and in Breimselv. The flood was the largest since 1946 in River Velledalselva at Sunnmøre. It was second largest since 1951 at Hitra and the fourth largest in Årgårdselva at Øyungen at Fosenhalvøya.

Cause of the flood:

The heaviest one-day precipitation was observed 9 January at Davik in Nordfjord at 162 mm. The two-day rainfall exceeded 200 mm at Samnanger, Hovlandsdal, Botnen and Davik. Eight stations from Samnanger to Måmyr exceeded 100 mm precipitation at the wettest day. The distribution of the precipitation is shown in Figure 3.45.3.

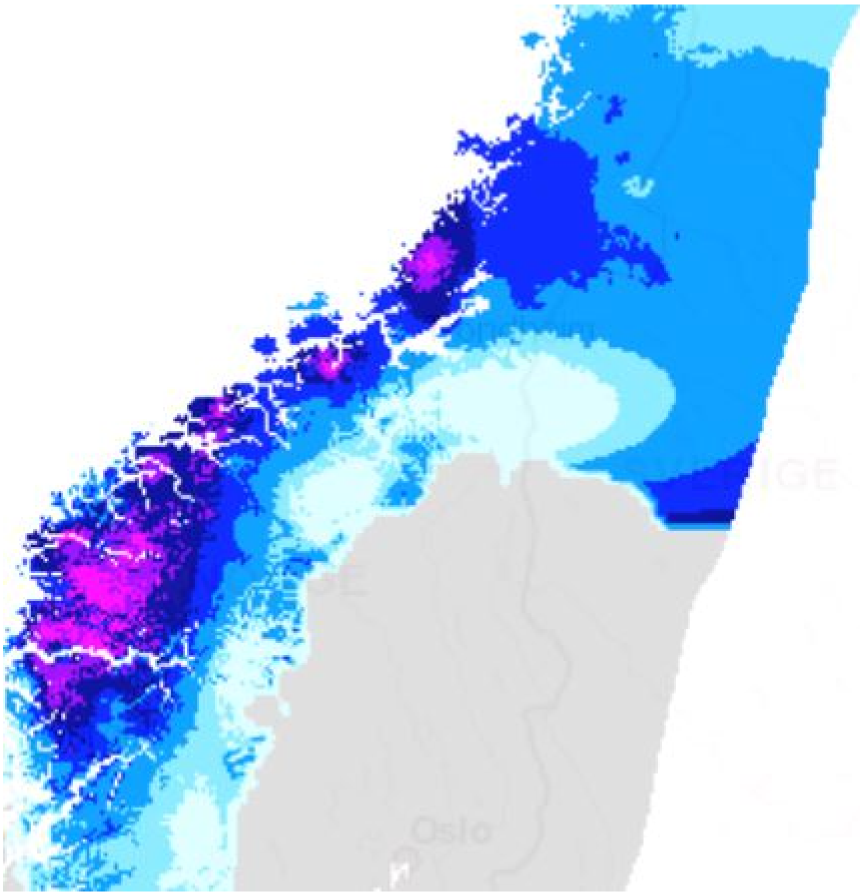


Figure 3.1.45.3 Distribution of the precipitation observed in the morning 9 January 1957 at Vestlandet and in Trøndelag

Between an anti-cyclone over southern Europe and a low near Iceland mild air masses from the Atlantic were streaming northeast towards Vestlandet 7-10 January. The weather types were **WA** (Grosswetterlagen) and **W** (Lamb/Jenkinsson).

3.46 Floods and wind storm at Vestlandet caused by remnants of Hurricane Faith 6-7 September 1966.

Heavy rainfall in combination with a severe windstorm caused large floods and wind damages to the fruitfarming in west Norway from Ryfylke to Nordfjord 6-7 September 1966. Figure 3.46.1 show observed daily rainfall and discharges in Rogaland, Figure 3.46.2 in Hordaland and Figure 3.46.3 in Sogn and Sunnfjord and Figure 3.46.4 in Nordfjord and Møre og Romsdal.

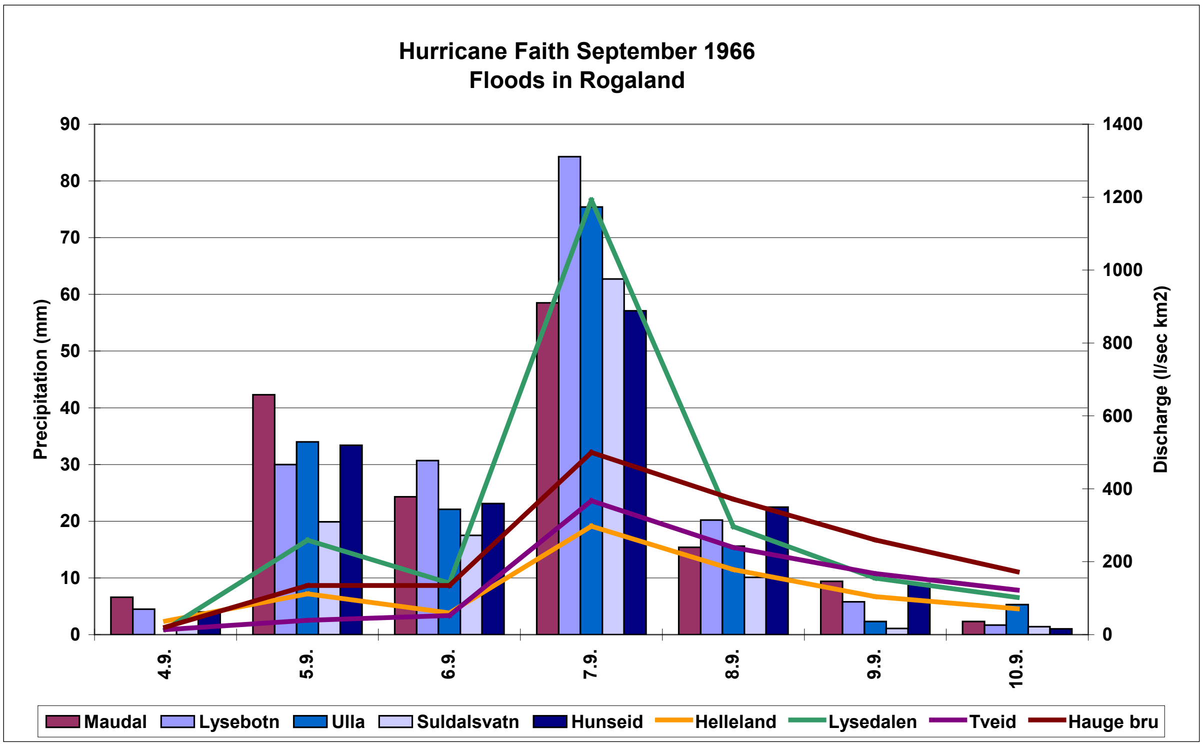


Figure 3.46.1 Observed precipitation and daily discharge in Rogaland caused by the remnants of Hurricane Faith.

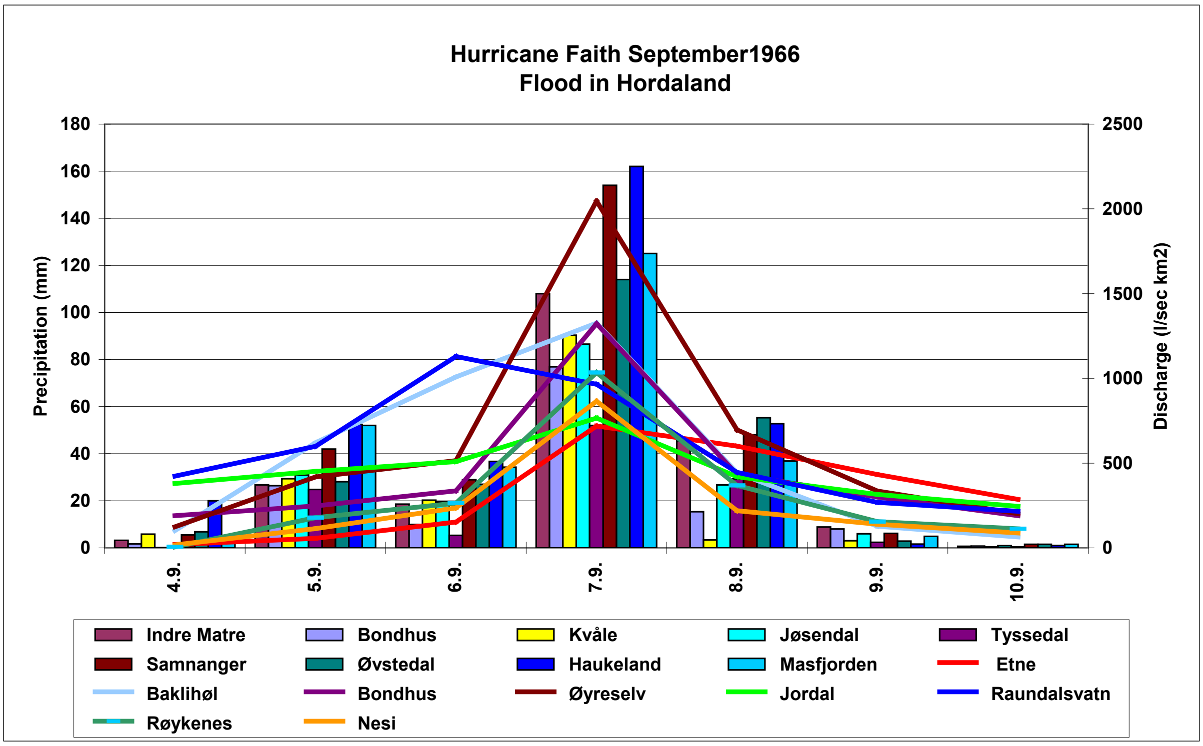


Figure 3.46.2 Observed precipitation and daily discharge in Hordaland caused by the remnants of Hurricane Faith.

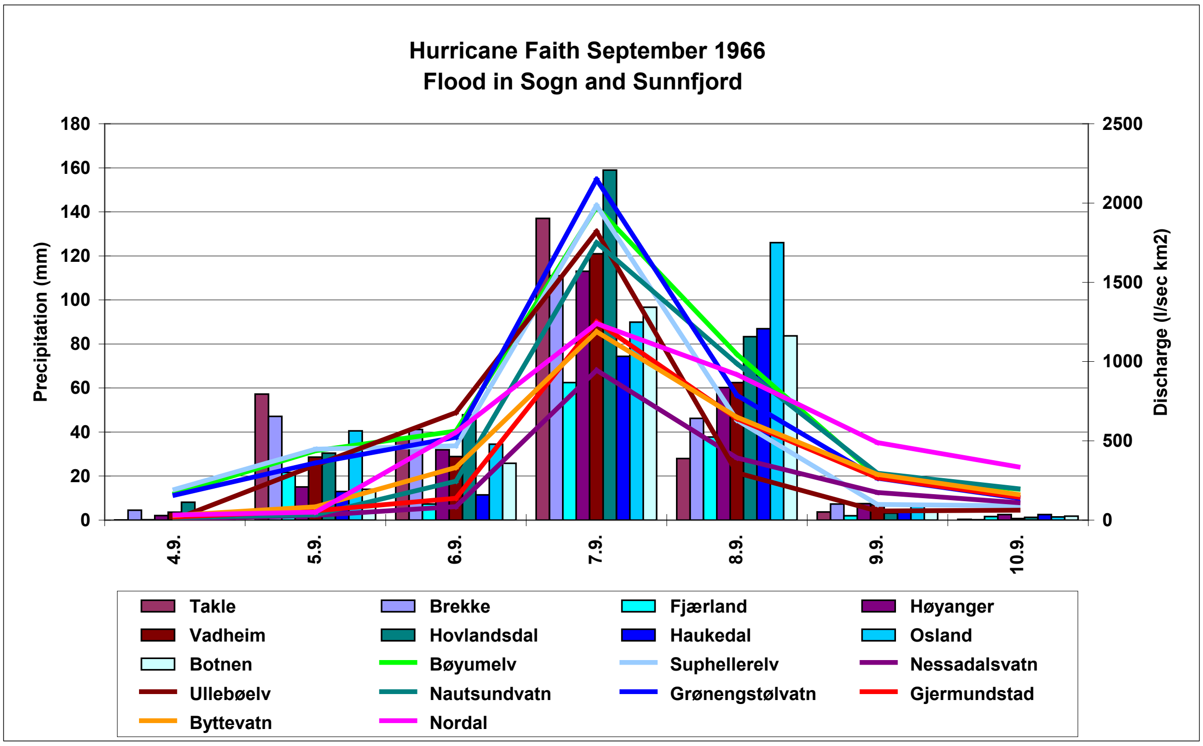


Figure 3.46.3 Observed precipitation and daily discharge in Sogn and Sunnfjord caused by the remnants of Hurricane Faith.

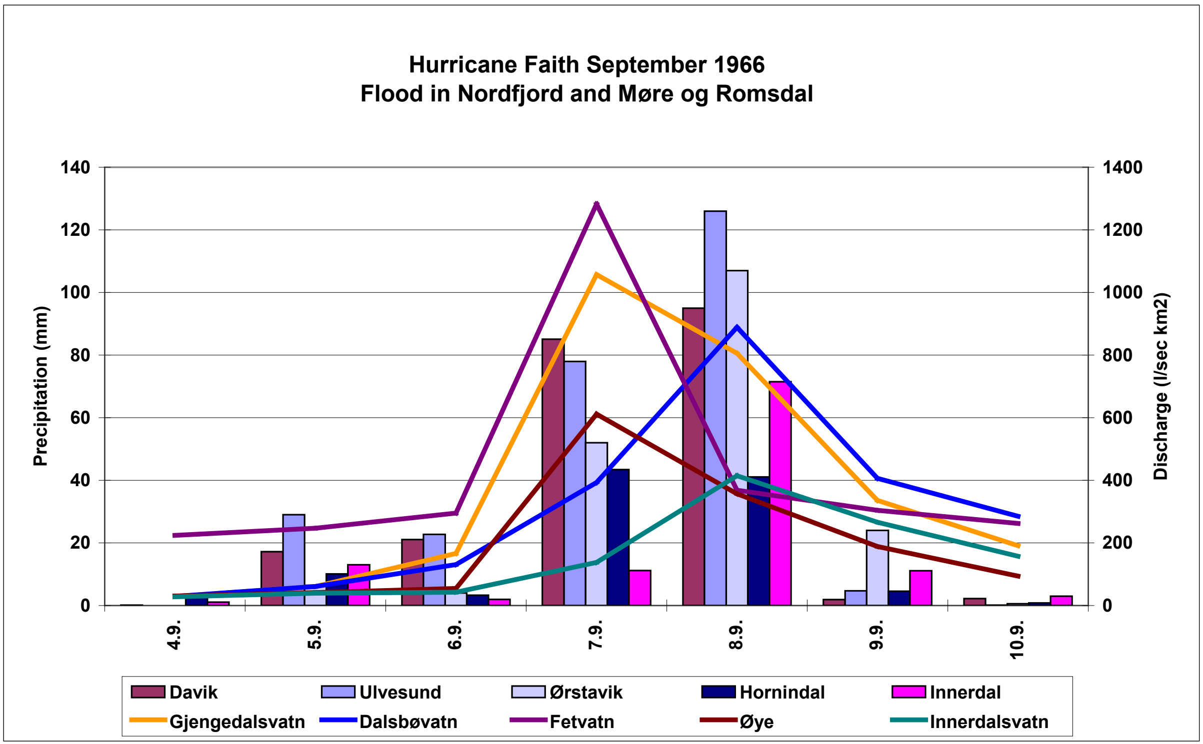


Figure 3.46.4 Observed precipitation and daily discharge in Nordfjord and Møre og Romsdal caused by the remnants of Hurricane Faith.

The floods were large in most rivers with glaciers in parts of the catchment. In River Øyreselv and River Bondhuselv at the west flank of Folgefonni glacier the flood was largest observed since 1922 and 1963 respective. Rivers at the east flank of Folgefonni glacier had also large floods. The flood was third largest in River Jordalselv since 1964. The flood was also largest observed at River Sima west of the Hardangerjøklen glacier 1961-1988. In River Bøyaelv and River Suphellerelv at the southern flank of Jostedalsbreen glacier the flood was by far the largest observed since 1966 and third largest since 1962 in Lake Sogndalsvatn. The flood was only the 11th largest in Lake Nigardsjøen since 1962. The flood was also small in River Årøyelva and in Tunsbergdalen which also were located at the rainshadow east of the large glacier. In catchments facing westwards near Jostefonn and Grovebreen glaciers in the upper River Gaular catchment the flood was largest since 1965. At Lake Grønengstølvatn a specific discharge of 2150 l/s km^2 was observed. The naturalised flood in River Jølstra was den third largest since 1902. River Oselv and River Nordalselv draining the Ålfotbreen glacier towards south and west set new records. Many rivers near the coast without glaciers in the catchment had also large floods. The flood was fourth largest in River Matreelva in Nord-Hordaland since 1917. In River Høyangerelv and River Guddalselv the flood was third largest since 1965 and 1908 respective. Since the flood had short duration, the flood magnitude was much less in catchments comprising large lakes which attenuated the flood. This was the case in River Suldalslågen, River Etneelv at Lake Stordalsvannet, and River Vosso at Bulken. The flood magnitudes less in the rivers in the inner fjords at Vestlandet, the water levels were rising at almost every station even if other floods in 1966 were larger.

Cause of the floods and windstorm - Hurricane Faith

A circular cloudmass appeared on a photo from the satellitte TIROS IX in posisjon 8°N 5°W near the coast of West-Afrika 18 August 1966. The clouds indicated that weak depression was forming. The depression moved westwards at 15- 20 knots the following 8 days. As it moved over varmer water, it started to deepen gradually. The wind velocity increased to 35 knots 22

August, the depression was now a tropical storm.The next day the wind velocity increased above 65 knots, and the cyclone was now a hurricane, which was given the name Faith. Figure 3.46.5 show a satelitte photo of the hurricane.

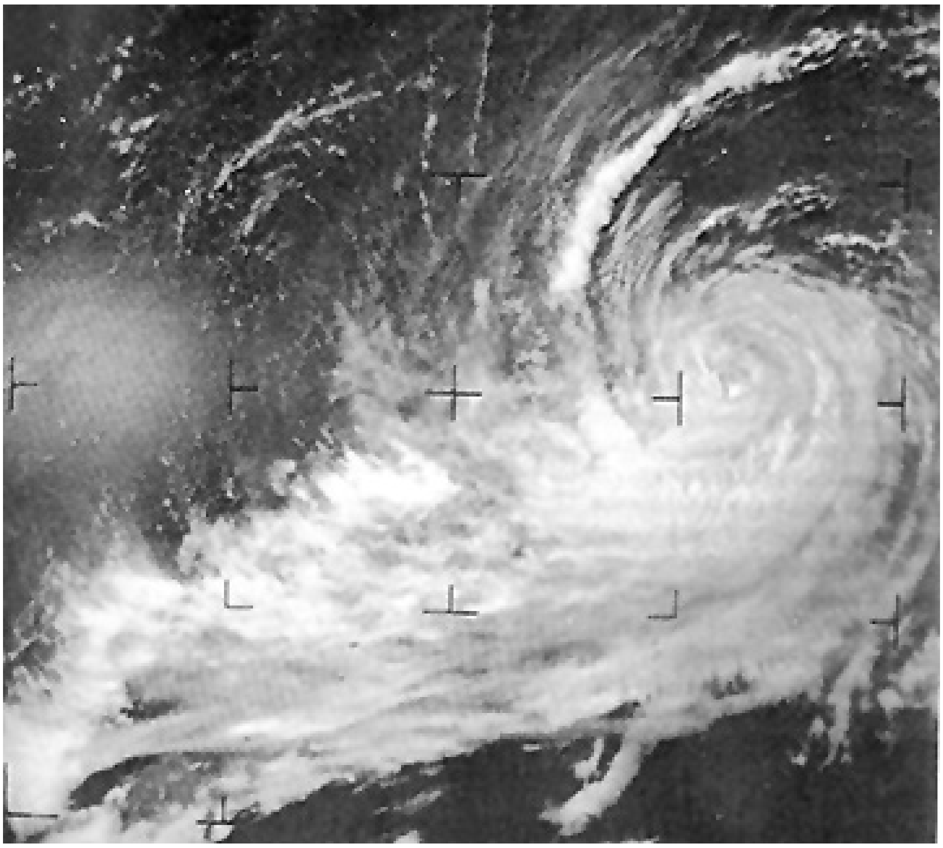


Figure 3.46.5 Satelitte photo of hurricane Faith. (Source: National Hurricane Center).

The maximum wind velocity increased to 75 knots the next days unto the hurricane moved to a position north of the Dominican Republic 27 August. The hurricane turned north-northeastward wile the movement dropped to 5 knots. The strength increased now to a wind velocity of 110 knots and a central pressure of 956 hPA corresponding to a category 3 Major Hurricane on the Safir-Simpsonskalen. It turned towards northeast after three days. The movement increased to 30 and later 40 knots, gradually weakening as it moved over colder water. Faith was downgraded to an extratropical low, passing over the Færøyene 6 6 September. The storm crossed the coast of Norway at Nordsøyan 7 September as a deep depression and moving over Trøndelag, Sweden and Finland before moving northwards to Novaya Zemlya where it finally ended a a stationary depression in 81°N 60°W northeast of Frans Josefs land. The trajectory of the hurricane is shown in Figure 3.46.6.

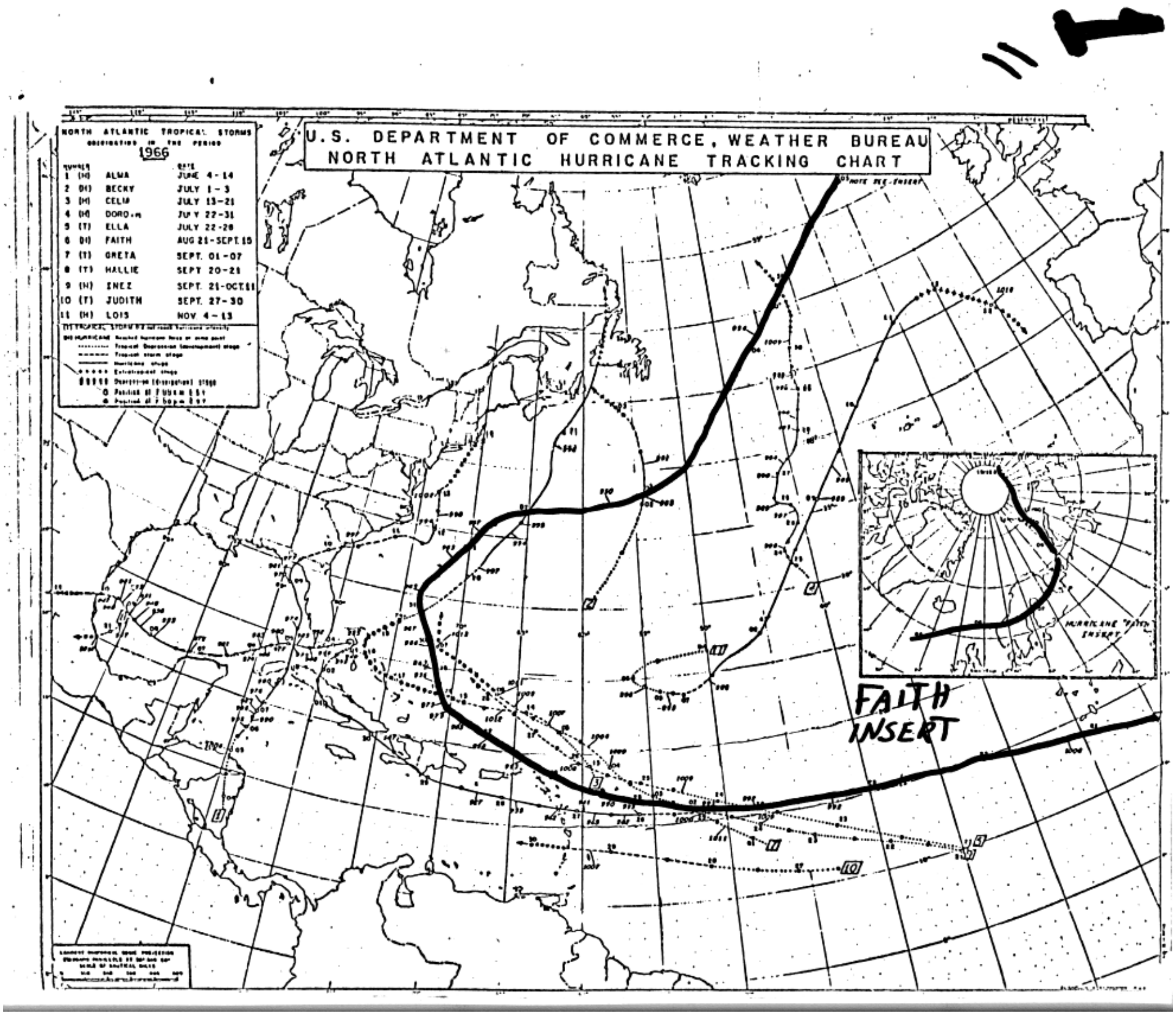


Figure 3.46.6 The trajectory of Hurricane Faith (Source: National Hurricane Center.)

The weather types were **BM** (Grosswetterlagen) and **W/A** (Lamb-Jenkinsson)

Floods and wind damages in Norway.

Although the depression crossed the Norwegian coast as far north as at Nordøyan, the consequenses were felt from Rogaland in the south to Nord-Trøndelag. The radiosonde sent up from Sola airport near Stavanger failed before reaching the 700 hPA level. A car ferry named Skagerak with 160 passengers onboard foundered in Skagerak, fortunately without loss of lives. The entire crop of apples and pears not yet harvested was blow down from the trees in Hardanger. High temperatures and humidity in combination with strong wing gives optimal conditions for extreme melting on the glaciers. The flood was record high in several glacier streams, both from extreme melting and abundant rainfall. Most of the precipitation tend to fall on the outer coast when remnants of tropical cyclones reach the coast of Norway. Faith was unusual in producing heavy rainfall halfway into the fjords as well. The heaviest rainfall fell in ytre Sunnfjord, but an extreme flood was also noted at Fjærland in Sogn. Jostedalen at the east side of the Jostedalsbre glacier was in a rain shadow and the flood in River Jostedøla was quite moderate in 1966.

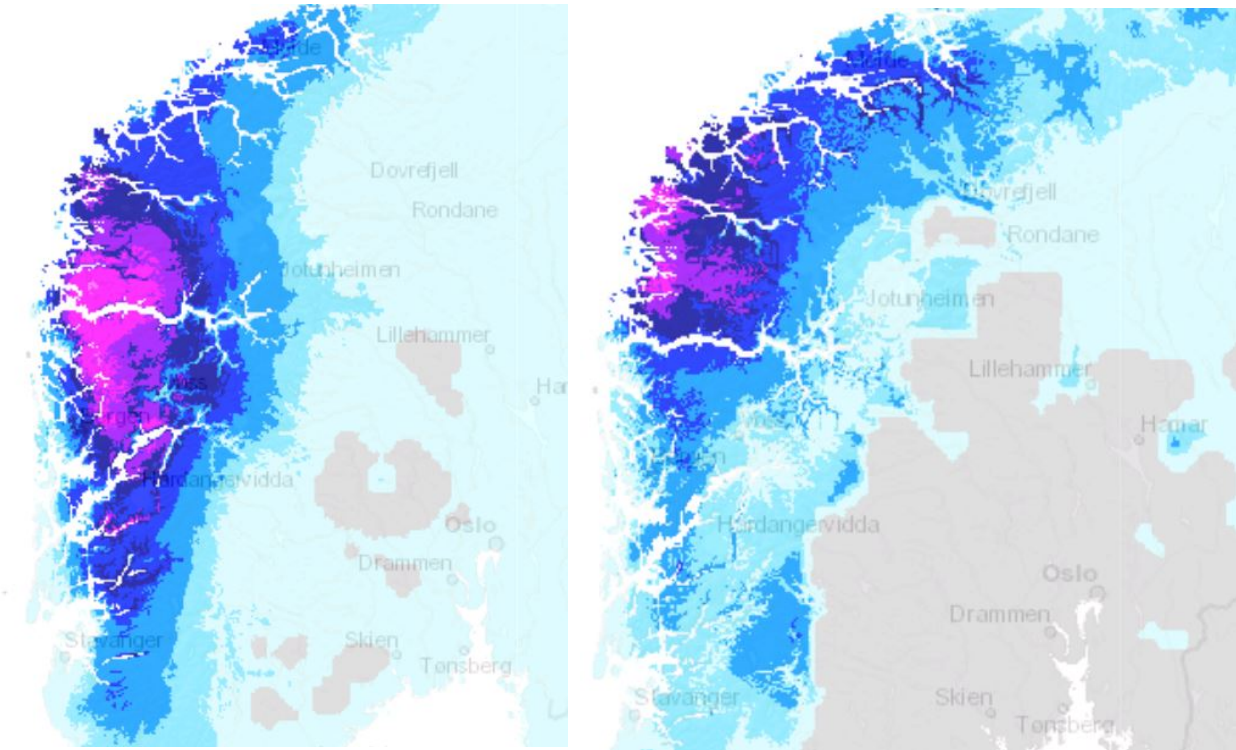


Figure 3.46.7 Distribution of the precipitation from Hurricane Faith in West Norway 7 and 8 September 1966.

3.47 The flood in coastal rivers at Vestlandet 18 December 1966.

Snow fell in many catchments at Vestlandet 29-30 November 1966. The snow reservoir increased at medium and high altitudes until 9 December. After a dry spell unto 16 December more precipitation fell, first as snow, gradually turning into rain as the temperature rose. Heavy precipitation fell in the lowlands as rain 17-18 December, and as snow at high altitudes. Snowmelt and rainfall caused floods in some rivers on the coast. Figure 3.47.1 show observed precipitation and discharge at five precipitation and five gauging stations at Vestlandet.

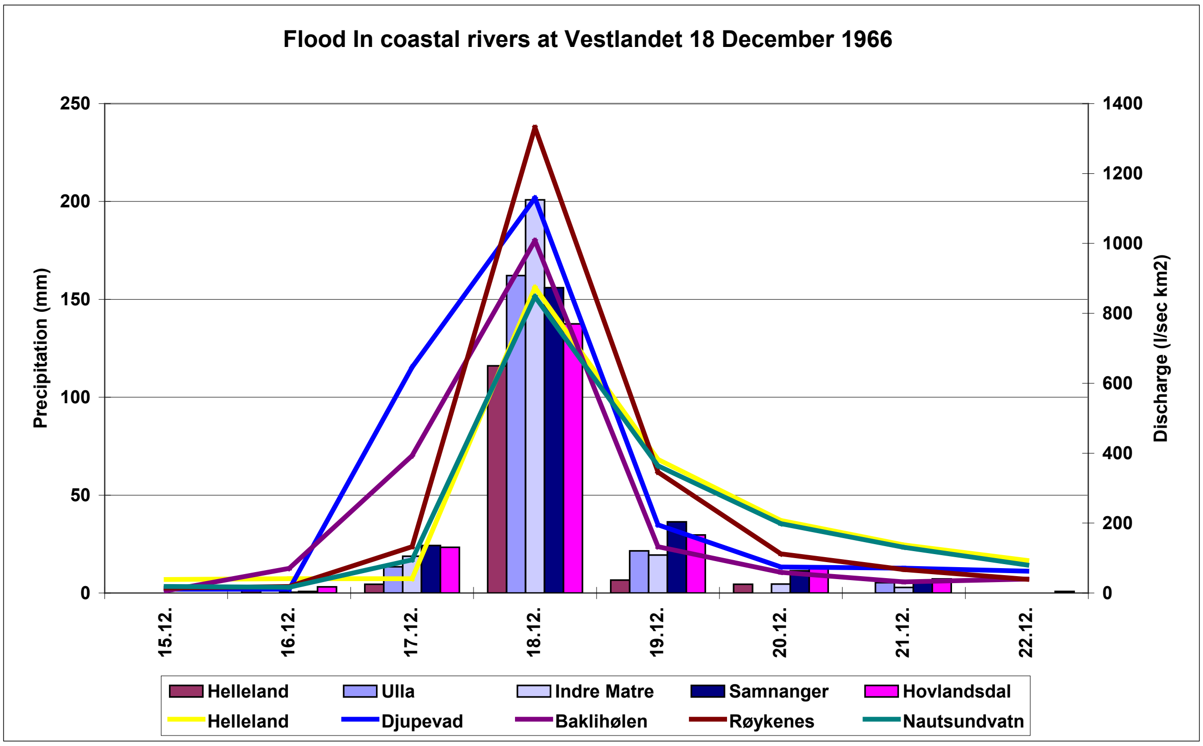


Figure 3.47.1 Observed precipitation and daily discharge in coastal rivers at Vestlandet 18 December 1966.

Causes of the flood:

Initial conditions:

Figure 3.47.2 show the temperatures observed in Bergen in November to December 1966.

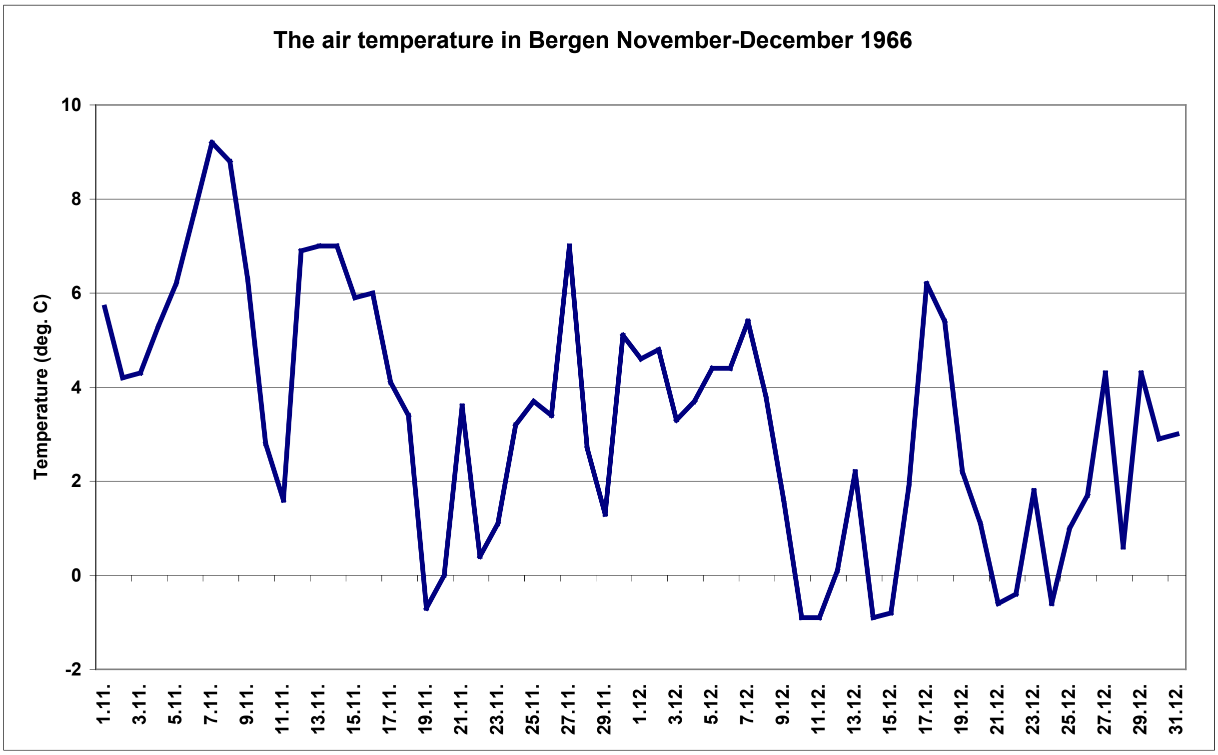


Figure 3.47.2 The air temperature observed in Bergen November to December 1966.

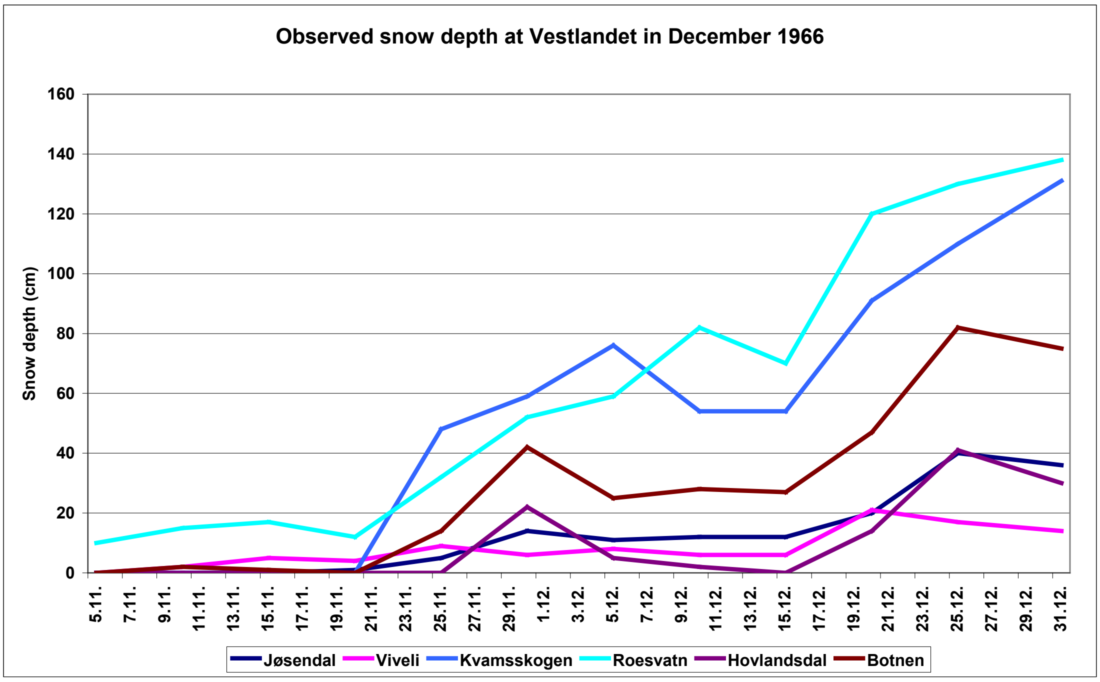


Figure 3.47.3 Observed snow depths at some meteorogical stations in West Norway in December 1966.

The snow started to accumulate at inland stations from 20 November as shown in Figure 3.47.3. By 16 December most of the Vestland was covered by snow as shown in Figure 3.47.4. Mild weather caused the snow to melt in the lowlands by 18 December as shown in the figure.

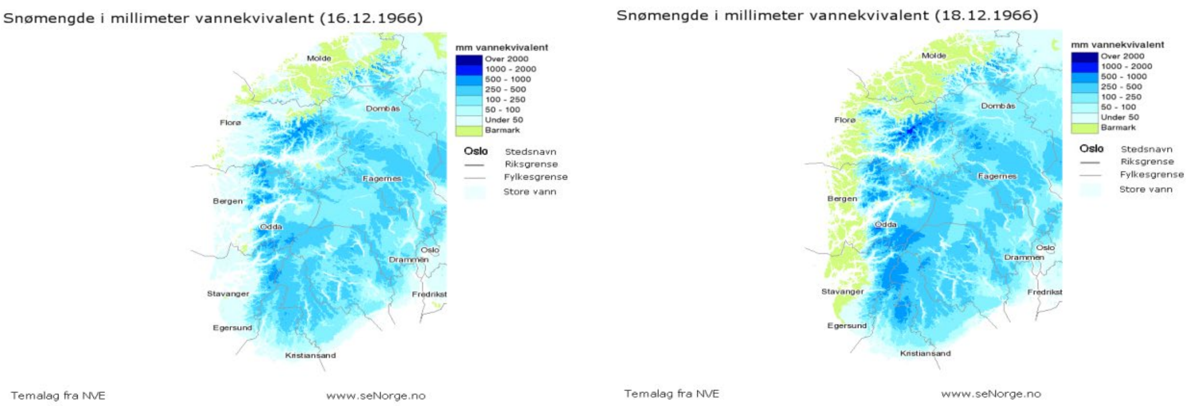


Figure 3.47.4 show the spatial distribution of the water equvivalent of the snow (mm) 16 and 18 December.

The weather causing the floods:
The flood was caused by heavy precipitation combined with some snowmelt as shown in Figure 3.47.5.

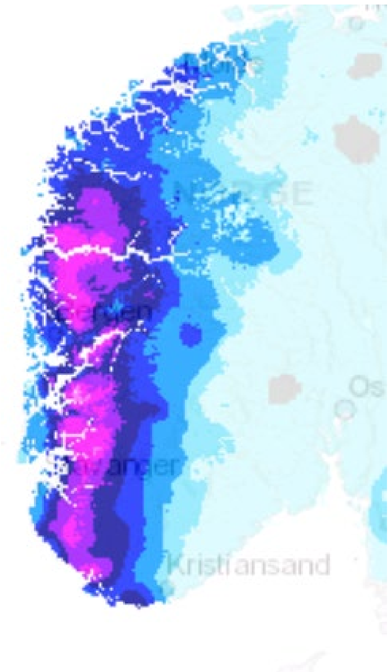


Figure 3.47.5 Spatial distribution of the precipitation and the snow melt 18 December 1966.

A cold spell between 9 and 14 December caused most of the precipitation to fall as snow, but mild weather and rainfall in the low-land 15- 18 December caused the snow melt and the flood to peak before colder weather ended the flood.

An anticyclone had caused the dry and cold spell 9-15 November moved eastwards as a strong depression south of Iceland moved towards the west coast setting up a strong air stream from southwest towards Vestlandet. This was the cause of the extreme precipitation observed den 18 in the morning. Heavy precipitation fell from Mandal in the east to Briksdal and Breim in the north. The precipitation exceeded 100 mm at 29 precipitation stations. Between 90 and 100 mm was observed at additional 10 stations. At Indre Matre in Sunnhordaland it was observed 200,9 mm.

The weather type 18 December was **SEA** (Grosswetterlagen) and **W** (Lamb-Jenkinson).

3.48 A large flood in coastal rivers from Hordaland to Nordfjord in January 1971

Heavy rainfall combined with some snowmelt caused a flood of almost the same magnitude as the severe flood in November 1971 in Høyanger in coastal rivers at Vestlandet. Figure 3.48.1 show observed daily precipitation and discharge in Hordaland and Figure 3.48.2 in Nordhordaland and Nordfjord.

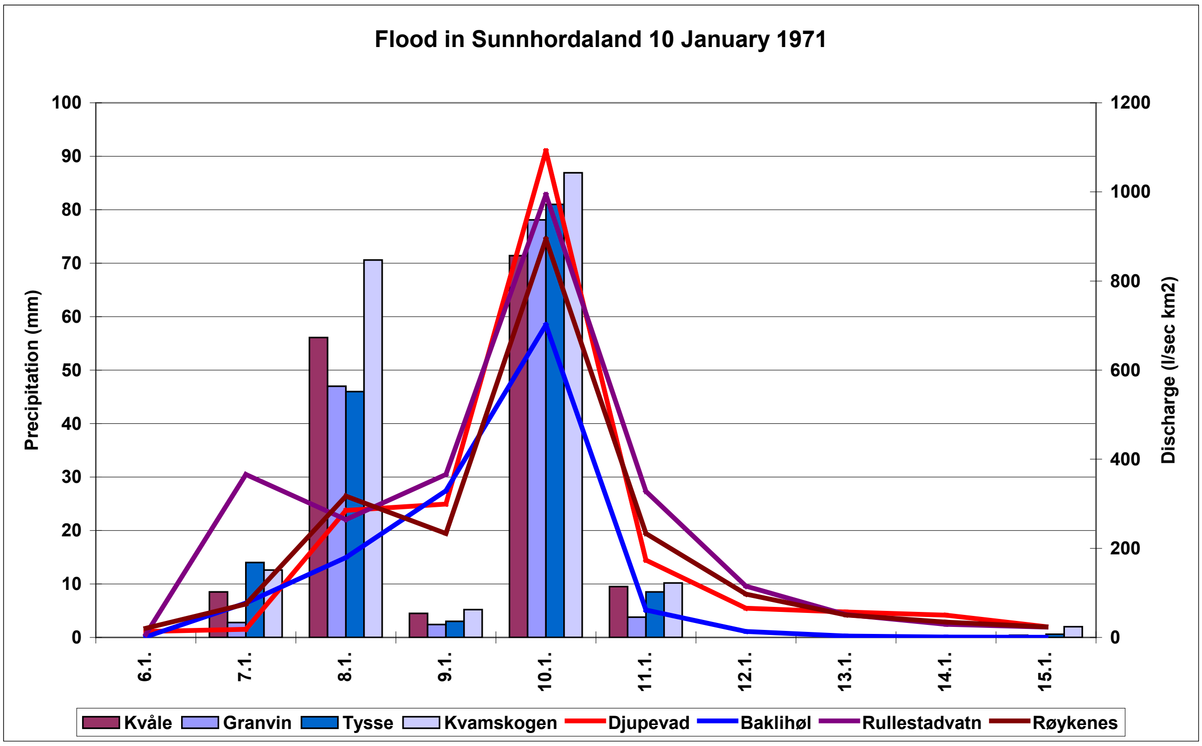


Figure 3.48.1 Observed precipitation and discharge (daily values) during the flood in coastal rivers Sunnhordaland in January1971.

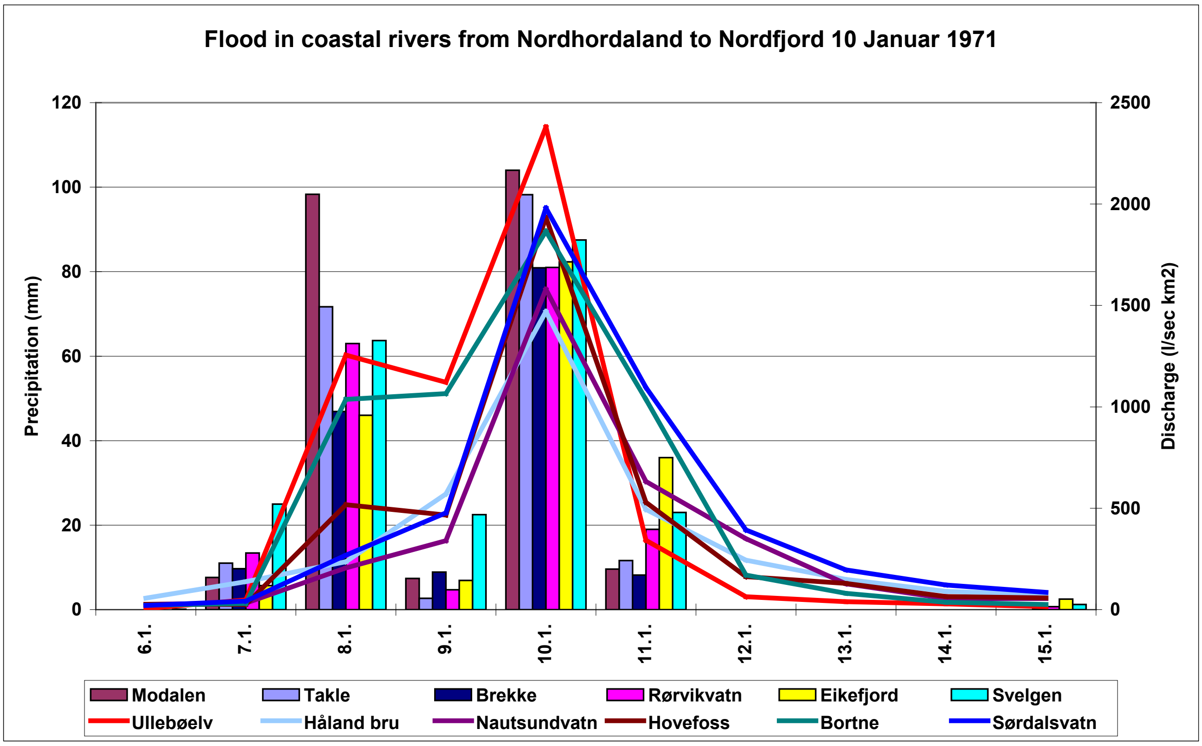


Figure 3.48.2 Observed precipitation and discharge (daily values) during the flood in coastal rivers from Nordhordaland to Nordfjord in January1971.

The flood ranks as the fifth largst at 63.3 Fosse 1935-1979 and seventh largest at 63.2 Brakestad 1935-1979 in River Eksingedalselv, the seventh largest at Skjerping 1908-2014 at Nærøydalen, the sixth largest at 77.3 Sogndalselv 1966-2014 and at 78.8 Bøyumselv 1966-2014, the fourth largest at 82.3 Håland bru 1927-1992, the seventh largest at 82.4

Nautsundvatn 1909-2014 at Guddalselv, the largest at 84.11 Hovefoss (964-2014 and at 85.2 Norddal 1909-1986.

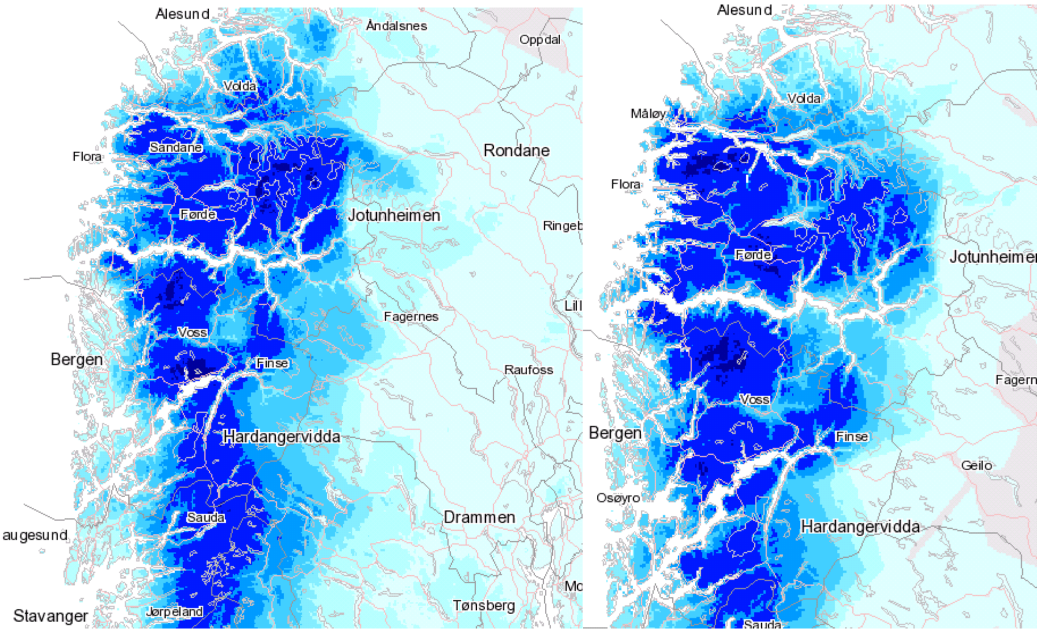


Figure 3.48.3 The precipitation at Vestlandet 8 and 10 January 1971.

Cause of the flood:

An anticyclonic ridge extended from Russia southwestwards across the European mainland to the Iberian penninsula. West of the ridge, a series of intense lows extended from the central Atlantic through the Norwegian Sea, setting up a stream of mild and humid air known as an *Atmospheric River*. This caused locally heavy rainfall on the Norwegian coast.
The weather types were **SWA** (Grosswetterlagen) and **ASW** (Lamb-Jenkinsson)

3.49 The severe flood at Høyanger in November 1971.

A local rainstorm caused a severe flood in the district around Høyanger on the north side of the Sognefjord. The flood caused severe damages at Høyanger.

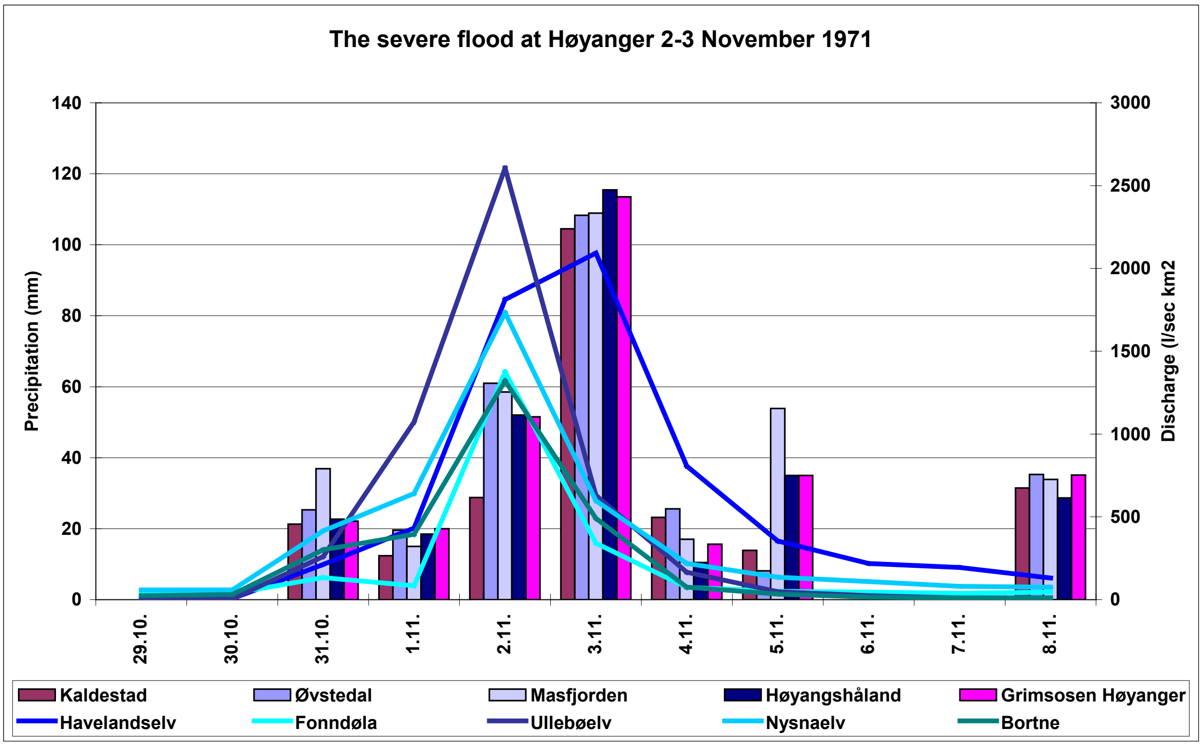


Figure 3.49.1 Observed precipitation and daily discharge during the large flood in outer Sogn in November 1971.

The flood was the largest observed in 80.4 Ullebøelv west of Høyanger 1927-2014, second largest at 70.7 Tistel 1969-1988, third largest at 71.1 Nessedalselv 1965-2014, eight largest at 62.5 Bulken 1892-2914, second largest at 62.6 Austmannshølen, largest at 62.10 Myrdalsvatn 1964-2014, fourth largest at 68.2 Havelandselv 1964-2014 and sixth largest at 84.20 Holsenvatn 1963-2014.

Cause of the flood:

Between an anti-cyclone located over southern part of England, France and Germany and an intense low located at the coast of Nordland, humid and mail air masses were streaming towards the coast of southern Norway causing heavy rainfall in outer Sogn as seen in Figure 3.49.2. The resulting flood was comparable to the flood in January this year.

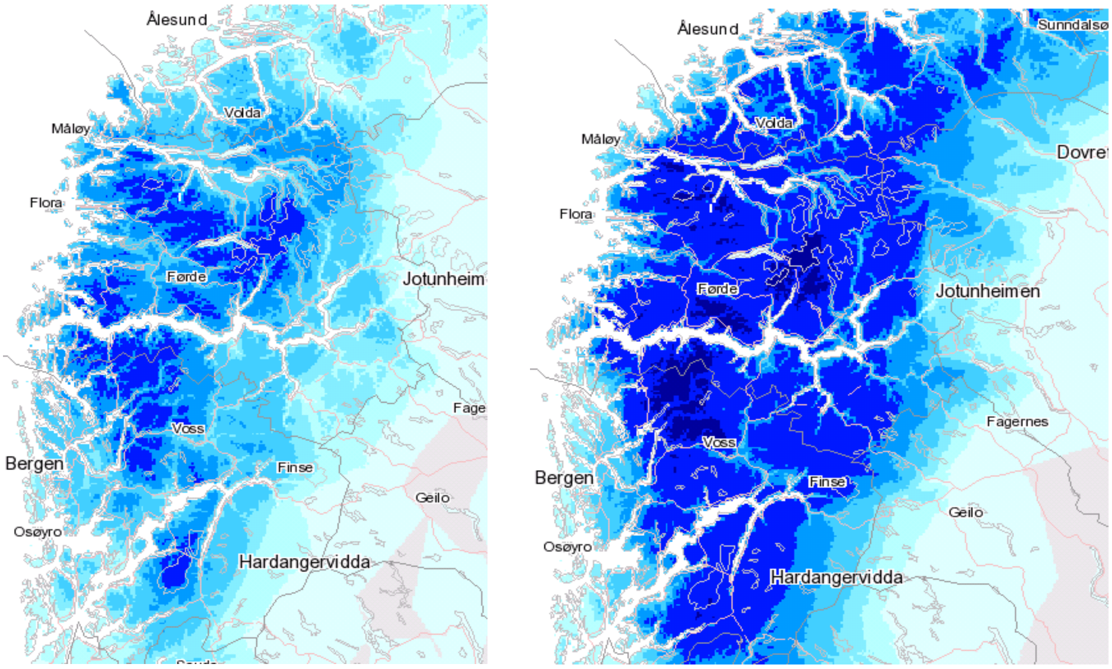


Figure 3.49.2 The spatial distribution of the precipitation 2 and 3 November 1971 in West Norway.

The weather types were **HM** (Grosswetterlagen) and **ASW** / **AW** (Lamb-Jenkinsson)

3.50 The longterm rainfall flood at Vestlandet in September 1973.

Longterm rainfall caused a flood in coastal rivers at Vestlandet in September 1973. Figure 3.50.1 show observed daily rainfall and discharge at selected stations in the region.

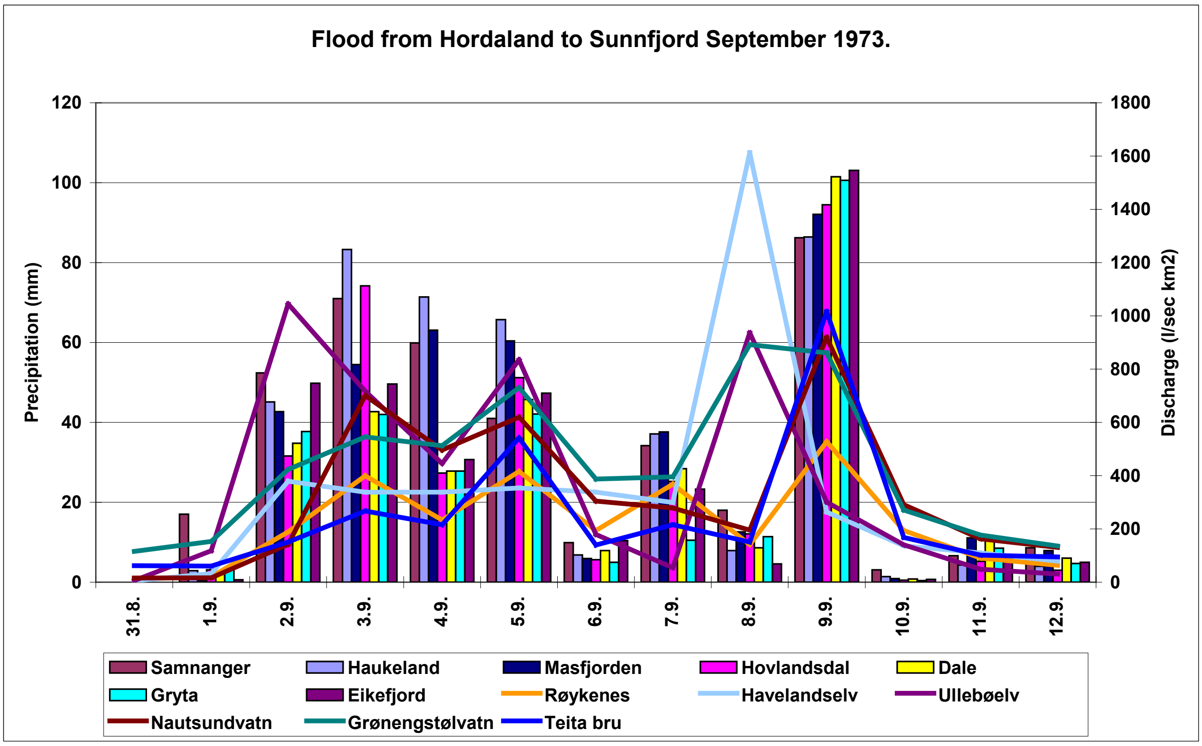


Figure 3.50.1. Observed daily precipitation and discharge in coastal rivers at Vestlandet in September 1973.

The flood was the largest in River Hopra at Tistel 1969-1988, third largest in River Austdøla at 48.5 Reinsnosvatn 1917-2014, fourth largest in River Breimselv at 87.3 Teita bru 1970-2014, sixth largest at 86.1 River Riseelv at Lake Risevatn 1928-2007, 14th largest in 106 years in River Gaular at 83.2 Viksvatn.

Cause of the flood:

Initial conditions:

Longterm rainfall 2-7 September had caused the ground to be saturated before heavy rainfall 8-9 September. The maximum one-day rainfall was observed at Eikefjord in Sunnfjord (103 mm). The highest specific discharge was observed in River Havelandselv (1612 l/sec km^2).

The weather conditions during the flood:

A massive anticyclone was located across Britain and the northern part of the European mainland with a trough extending from the south Atlantic to Iceland. Near the coast of northern Norway polar front depressions were located. The polar front was located from south of Iceland to Trøndelag. Weather types 8-9 September were **WA/U** (Grosswetterlagen) and **A** (Lamb-Jenkinsson).

3.51 Rainfall floods at Vestlandet from September to December 1975.

The autum of 1975 two long-term rainfall events occurred from Sørlandet to Nordmøre. One of the rainfall events caused flood in rivers on the coast of Vestlandet in September 1975. Figure 3.51.1 show observed daily precipitation and discharge at selected stations affected by the flood.

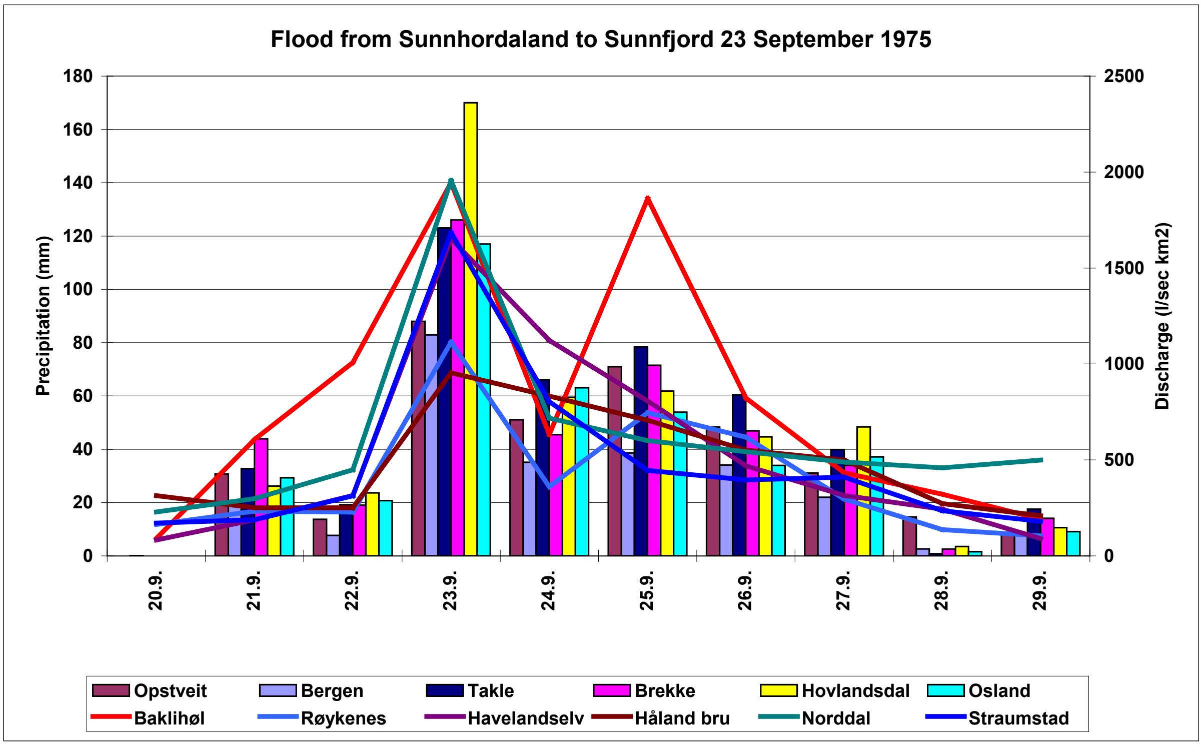


Figure 3.51.1 Observed precipitation and daily discharge from Sunnhordaland to Sunnfjord in September 1975.

The flood was the largest observed in River Hageelv at Lake Hersvikvatn 1934-2013 and in River Norddalselv at Norddal since 1907 in Sunnfjord, in Kvernbekken at Tysvær, in Moelvi at Steinslandsvatn and in Sunndalsvassdraget at Straumstad.

Cause of the first flood:

A large warm anti-cyclone was located at the central Atlantic, with another anti-cyclone extending southwestward from Russia to Iberia. A low was located near Iceland and another in the Norwegian Sea west of Troms in Norway. Warm and humid air masses were streamin eastwards from the North Sea. The weather types were 20-24 September **BM** and 25-27 September: **SWZ** (Grosswetterlagen) and 20-22 September: **AS** / **ASW** 23-24 September: **N** / **C** (Lamb-Jenkinsson).

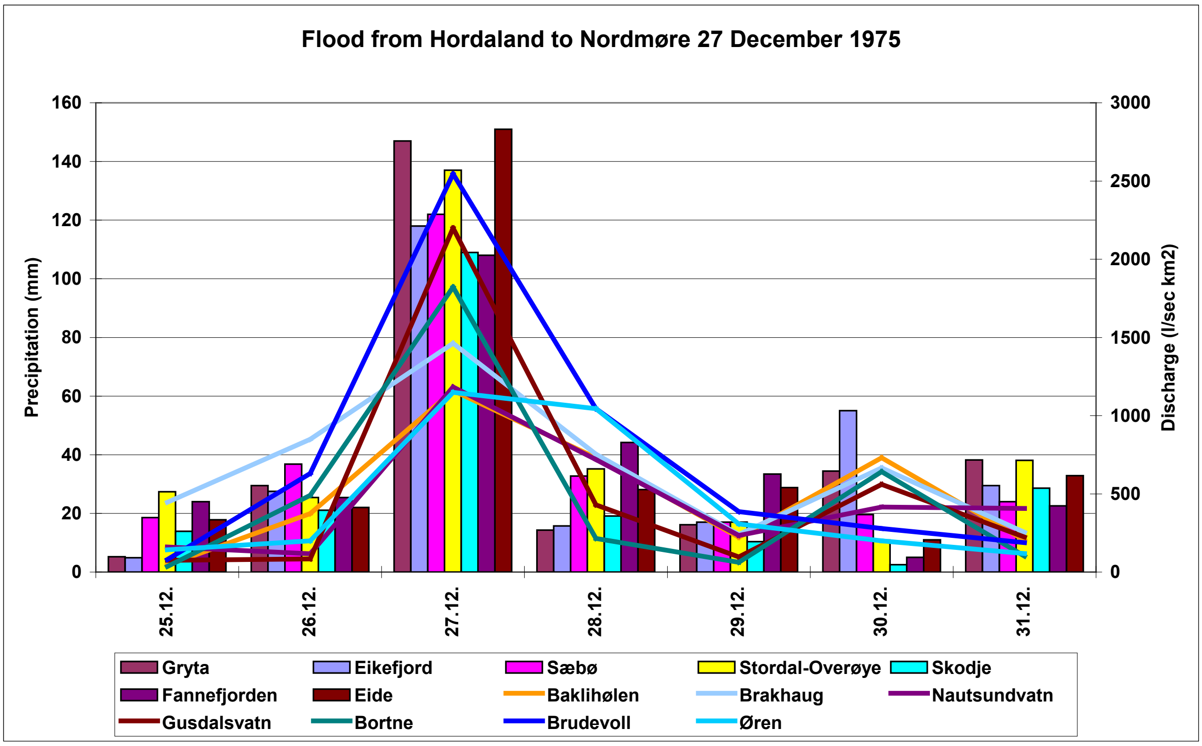
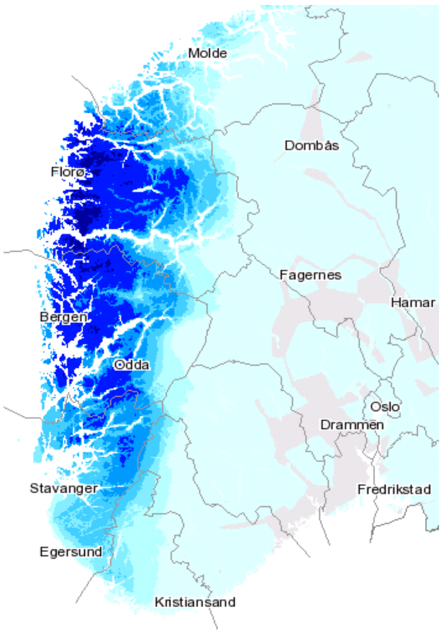


Figure 3.51.2 Observed precipitation and daily discharge from Sunnhordaland to Sunnfjord December 1975.

Cause of the second flood:

A large anti-cyclone was extended from the Atlantic across the Bay of Biskay across France and Spain. A number of depressions in the Norwegian Sea with a through extending from Spitsbergen southwestwards into Eastern Europe. Humid air was streaming eastwards across southern Norway, causing heavy rainfall on the outer west coast. The weather type was stable over a long time and is typical for the phenoma which is known as *Atmospheric rivers.* Weather types were: **WA** (Grosswetterlagen) and **AW** (Lamb-Jenkinsson).



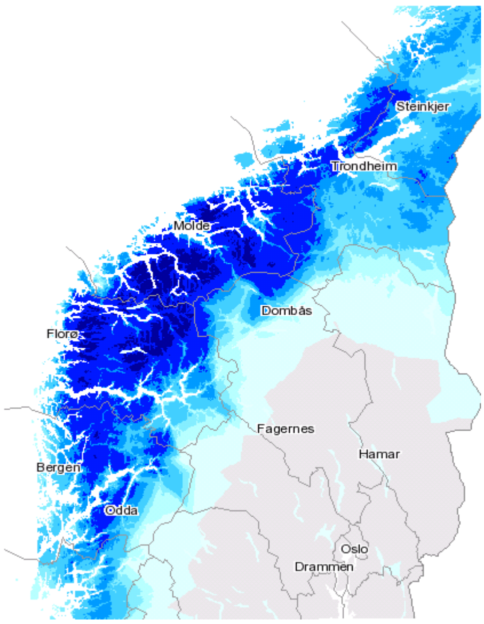


Figure 3.51.3 The spatial distribution of the preciptation 23 September and 27 December 1975.

3.52 A flood in coastal rivers from Sogn to Møre og Romsdal in September 1978.

A severe storm bordering to hurricane force reached West Norway to Møre og Romsdal 17 September 1978. Rainfall ahead of the storm 14-17 September caused a short duration flood in rivers draining to the outer Sognefjord, Sunnfjord, Nordfjord and Møre og Romsdal. Figure 3.52.1 show observed daily rainfall and discharge at selected stations in the region where the flood occurred.

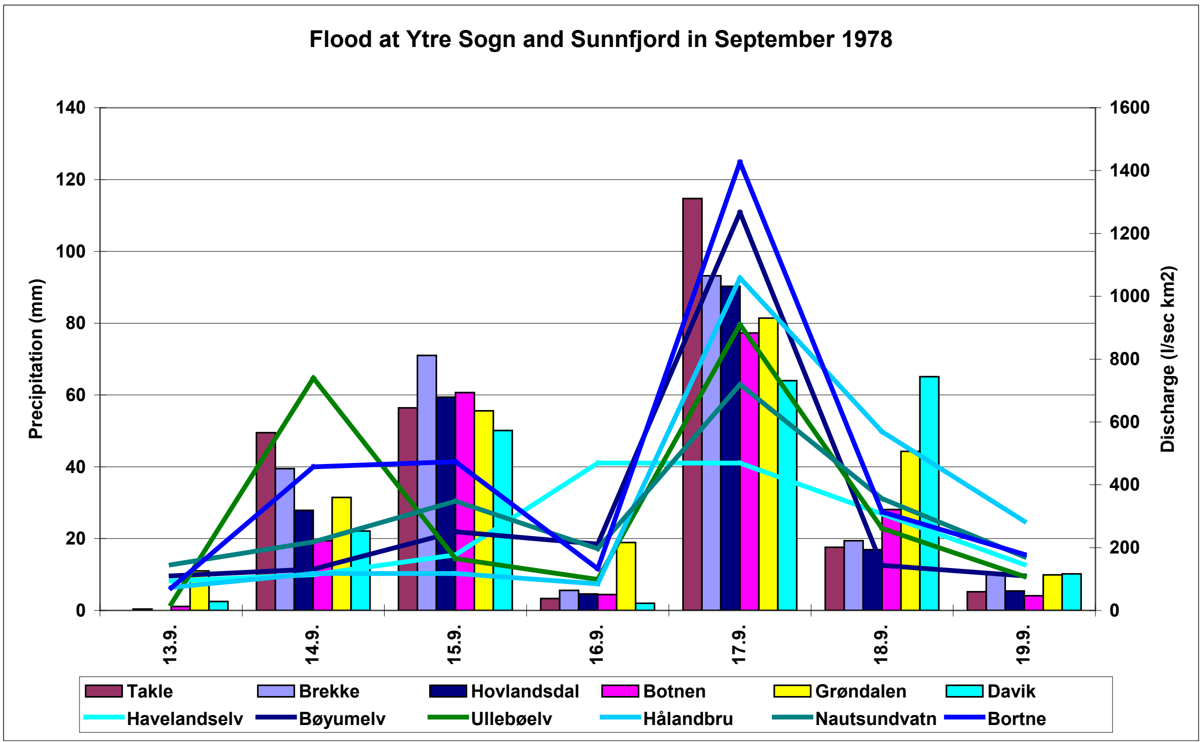


Figure 3.52.1 Observed precipitation and daily discharge from Ytre Sogn to Sunnfjord in September 1978.

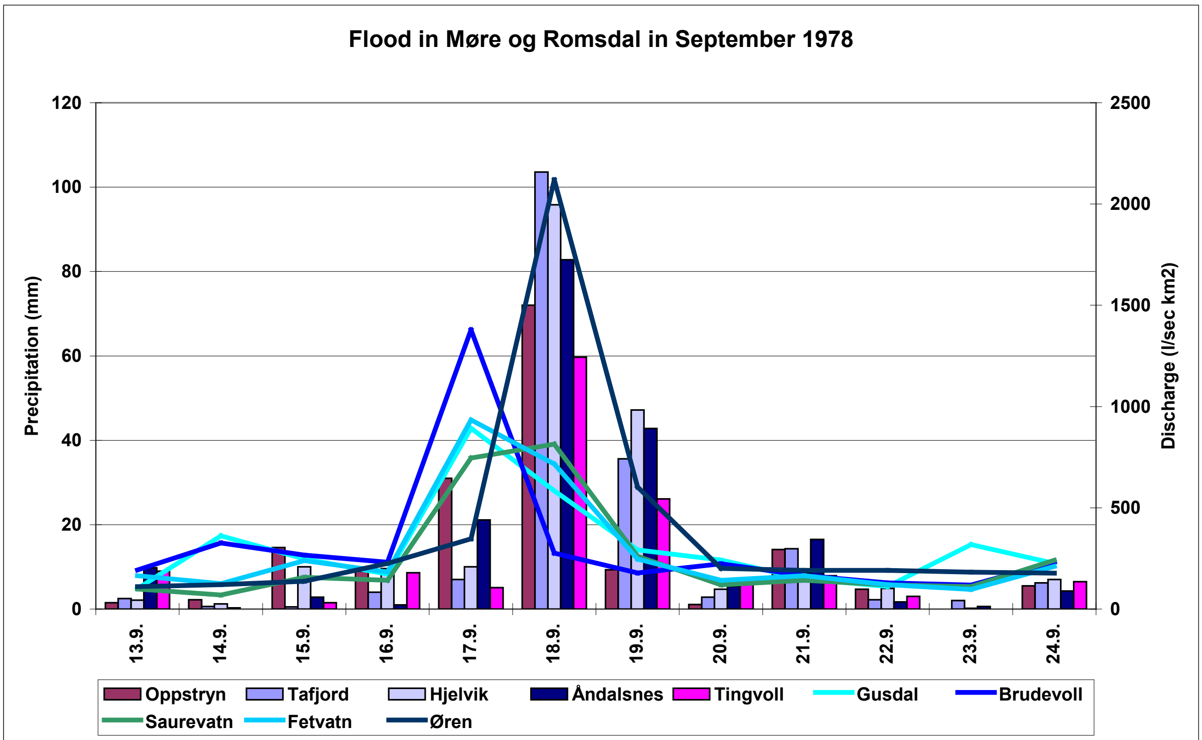


Figure 3.52.2 Observed precipitation and daily discharge from Nordfjord to Sør-Trøndelag in September 1978.

The flood was the third largest observed in River Bøyaelv 1966-2013, the sixth largest in River Bortneelv at Bortne 1970-1983, the fourth largest in River Tennfjordelv at Lake Engesetvatn at Sunnmøre 1923-2014 and the largest in River Gusjåelv at Øren in Romsdal 1923- 2014 .

Cause of the flood:

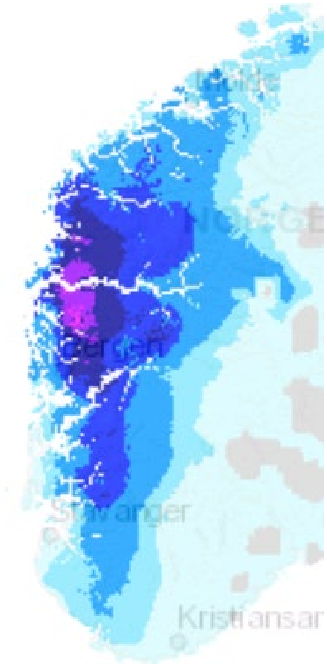


Figure 3.52.3 The spatial distribution of the rainfall 17 September 1978.
The weather types were **WA** (Grosswetterlagen) and **W**/**AW**/**NW** (Lamb/Jenkinsson)

Damages:

The windstorm caused damages of some millions NOK, and took three lives.

3.53 The large flood at Jostedalen in August 1979.

An intense rainfall occurred in Jostedalen 14-15 August 1979 causing a major flood and resulting in severe damages in the valley. The flood was extreme in the main river as well as in the tributaries causing many landslides. The rainstorm occurred further south in West Norway as well, and smaller floods occurred in many rivers in South and West Norway and in some small catchments near the water divide in River Otta. Figure 3.53.1 show observed daily precipitation and dicharge in rivers in Sogn and Figure 3.53.2 at stations from Vest-Agder to Sunnhordaland.

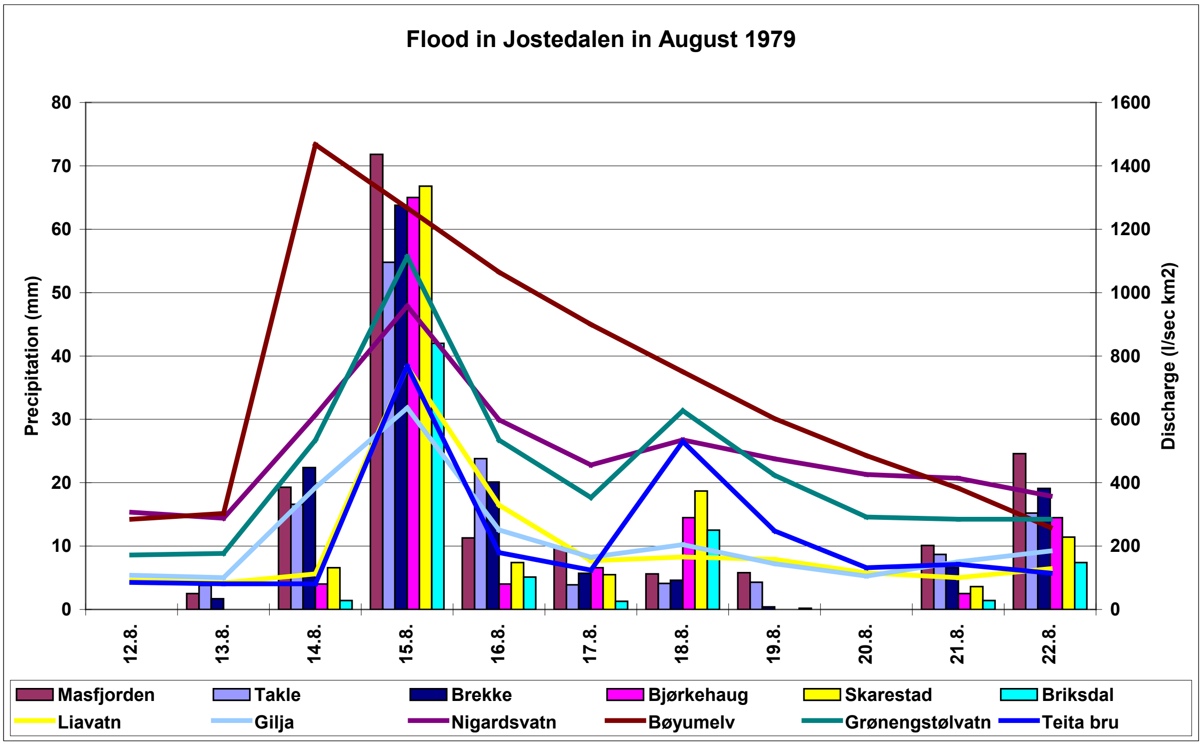


Figure 3.53.1 Observed daily rainfall and discharge during the severe flood in Jostedalen i August 1979.

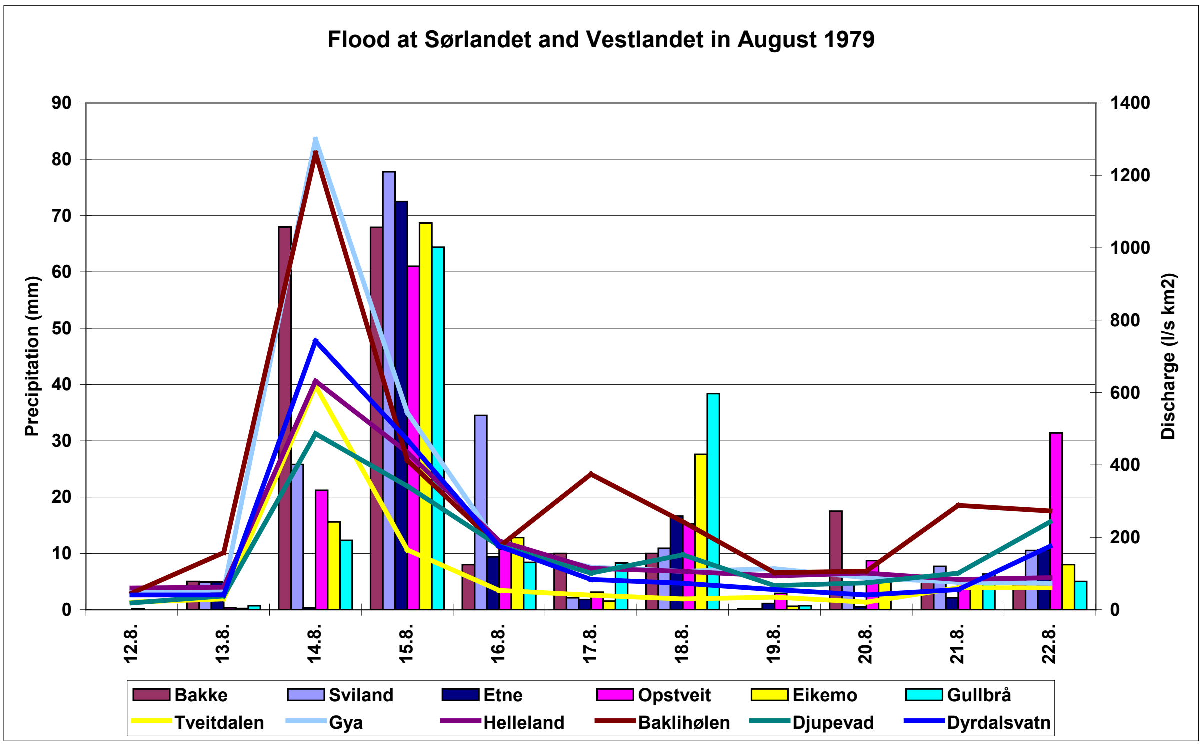


Figure 3.53.2 Observed precipitation and daily discharge in Rogaland and Hordaland in

The flood in Jostedalen was the second largest observed at Lake Nigardsvatn, only exceeded by the flood 30 August 1997 1962-2013. Several large jökullhlaup has occurred in Jostedøla from Tunsbergdalsbreen glacier where the glacierdammed lake Brimkjelen has caused large floods in the lower part of the main river. A flood occurred in Jostedalen in 1966 as a consequence of the tropical hurricane Faith, which ravaged West Norway 7 September 1966. The flood at Jostedalen was smaller, since the rainstorm moved in from southwest. Different exposure caused an extreme flood at Fjærland, which by far exceed the flood in Jostedalen in 1979. The flood at Fjærland in 1979 was the second largest 1966-2010.

It was the largest observed in River Åstri at Lake Liavatn in Skjåk 1964-2013 and third largest in River Tora 1966-2010. The rank ranged from fifth to eight in 40 years in several rivers near Sognefjorden and in Sunnfjord. The flood was fourth or fifth largest in River Hellelandselv and at Bjerkreim at Jæren.

Cause of the flood:

The flood was caused by intense rainfall from south in combination with melting on the glaciers. The largest rainfall was observed at høg-Jæren, but wide-spread heavy rainfall occurred in the mountains at Sørlandet, Ryfylke, Sunnhordaland, Nordhordaland, Sogn og Fjordane to Sunnfjord. The rainfall was moderate on the outer coast. At Fåberg i Jostedalen 78 millimeter rainfall fell and at the front of Nigardsbreen more than 100 millimeter rainfall was observed 14 August. The distribution of the rainfall 14 and 15 August 1979 in West Norway is shown in Figure 3.53.3 and 3.53.4.

Varm and humid air was streaming northwards from the Meditteranian over France towards West Norway. The air stream was caused by a blocking anticyclone east in Fennoskandia and a trough further west. High temperatures caused intense melting on the glaciers. The temperatures may have been strengthened locally by foehn on the lee side of some mountains. The weather types were **HFA** (Grosswetterlagen) and **C/W** (Lamb-Jenkinsson).

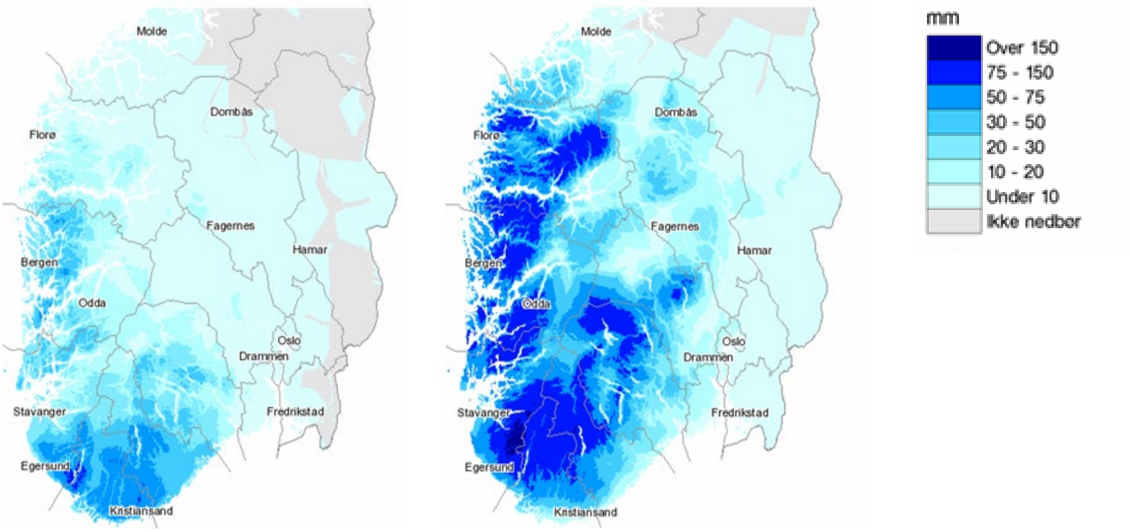


Figure 3.53.3. Observed 1-day rainfall observed 14 (left) and 15 August (right).

The flood:

The water level of River Jostedøla started to increase Tuesday 14 August 15:00 and peaked in the morning of Wednesday 15 August 06:00. The water level was around three meter above the ground. At Myklemyr the water level was two meters higher than during "the hundred year flood" of 1898.

Flood damages:

The water level rose five to six meter in some reaches of River Jostedøla. Many tributaries shifted into new beds. The tributary Sagøyelvi shifted to run through the old rådhus, which was used by the bank and village library. Erosion and deposition of the eroded sand, gravel and rocks caused extensive damages to farmland. 150 daa farmland was damaged, and the entire crop of hay was lost. One farm at Elvøy was totally destroyed

Approx. 100 homes and 30–40 farm buildings were damaged. The damages were most severe at the farms at Fossøy and Myklemyr. The basement and ground floor were inundated in many homes, and both buildings and furniture were damaged. At Myklemyr most of the innbo at the ground floor was destroyed in 30-40 homes and at Fossøy between 20 and 30 homes. The entire stock of three shops was destroyed by the flood water.

The main road through Jostedal was severely damaged, as well as most of the smaller roads. Six large and eight small bridges were destroyed or damaged by the flood. The valley was insulated, and the only form of transport was by helicopter until the road was temporary repaired after 14 days. The flood protection works were also partly destroyed by the flood.

No lives were lost, and nobody was hurt, but many inhabitants, living at exposed locations were evacuated.

Jostedalen was declared as a disaster area. The damages were assessed two days after the flood and the losses were estimated to around 35 million kroner, later reduced to 32 millions.

3.54 The flood at Vartdal at Sunnmøre caused by remnants of Hurricane Bonnie 21-22 August 1980.

A severe flood occurred in rivers from outer Nordfjord to Romsdal. The flood was most intense in the rivers facing the Vartdalsfjord, where the flood was similar to the extreme floods in the same rivers 16 July 1873 and 3 October 1878. Figure 3.54.1 show observed rainfall and discharge at selected stations.

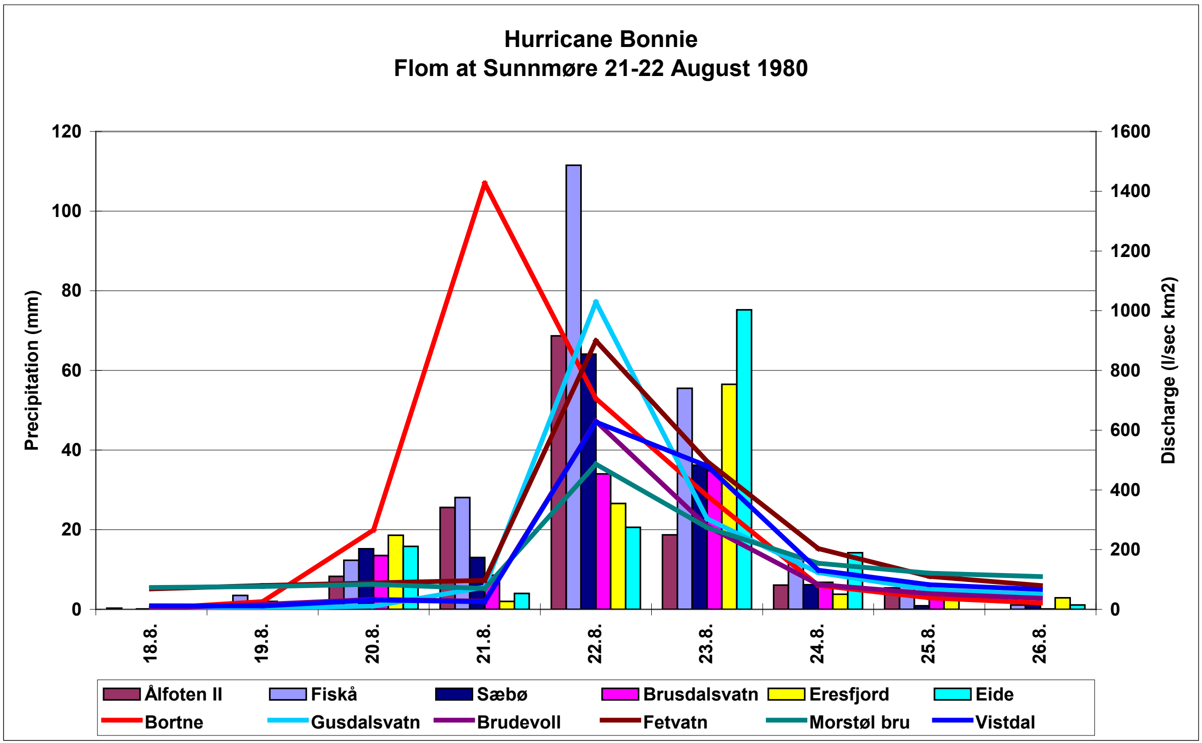


Figure 3.54.1 Observed precipitation and daily discharge at Sunnmøre caused by remnants of Hurricane Bonnie 21-22 August 1980.

A cyclone appeared 17 August south of Nova Scotia. This cyclone was the remnant of the tropical hurricane Bonnie, which turned into an extratropical cyclone on 19 August moving towards northeast. Bonnie made its first appearance near the Kapp Verde islands 13 August. Most of the hurricanes, which turned towards Northwest Europe, start in this area. The extratropical depression crossed inland at the coast of Nord-Trøndelag and Nordland, moving eastwards over Sweden and Finland.

This year no less than six hurricanes went into trajectories towards northwest Europe, see Figure 3.54.2. When a stream from the tropical North Atlantic is esteblished, there is a high risk on torrential rainfall and floods somewhere in Western Europe. The phenomena is known as "Atmospheric rivers" and is also known to cause large floods on the west coast of North America.

The rainfall started at Vestlandet from Jæren to Stadt 21 August and moved north of Stadt on the subsequent day. The rainfall distribution is shown in figure 3 for the two days.

Flood damages:

The largest damages occurred at the two rivers at Vartdal and along River Barstadelva. Bridges were damaged both on state roads and county roads. Farmland was eroded and covered by sand and gravel. Houses were damaged. The landowners obtained compensations from the Natural Peril Fund. Flood protection work after the flood amounted to 6,75 mill.NOK.

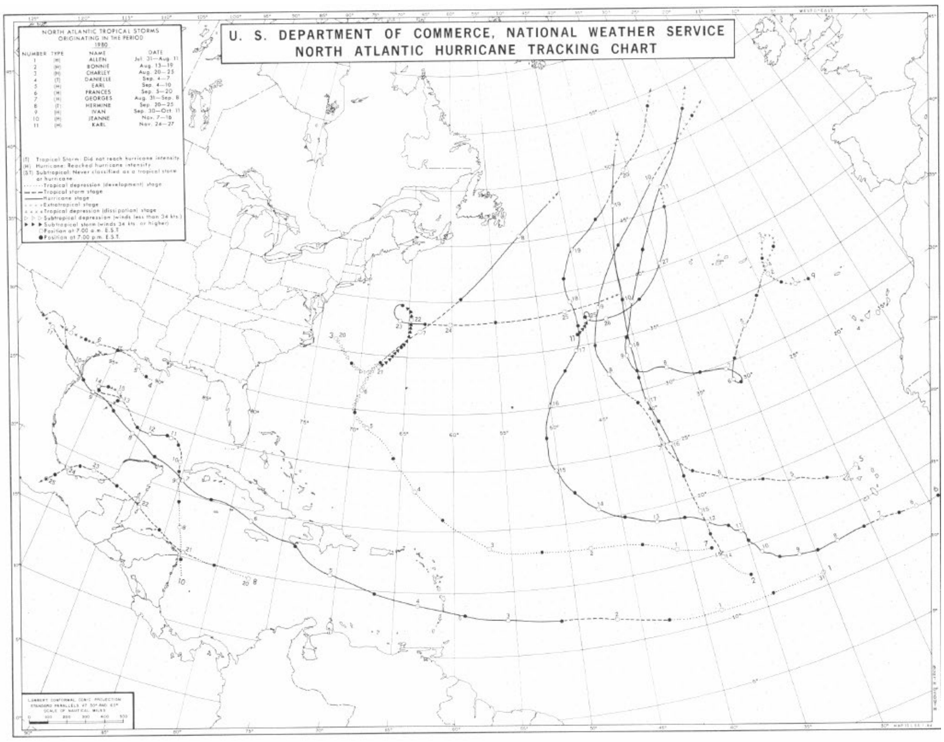


Figure 3.54.2 The trajectories of tropical cyclones in 1980 in the North-Atlantic. Six named storms moved towards Northwest Europe this year. Cyclone 1980-2 Bonnie did probably contribute to the flood at Sunnmøre in August.

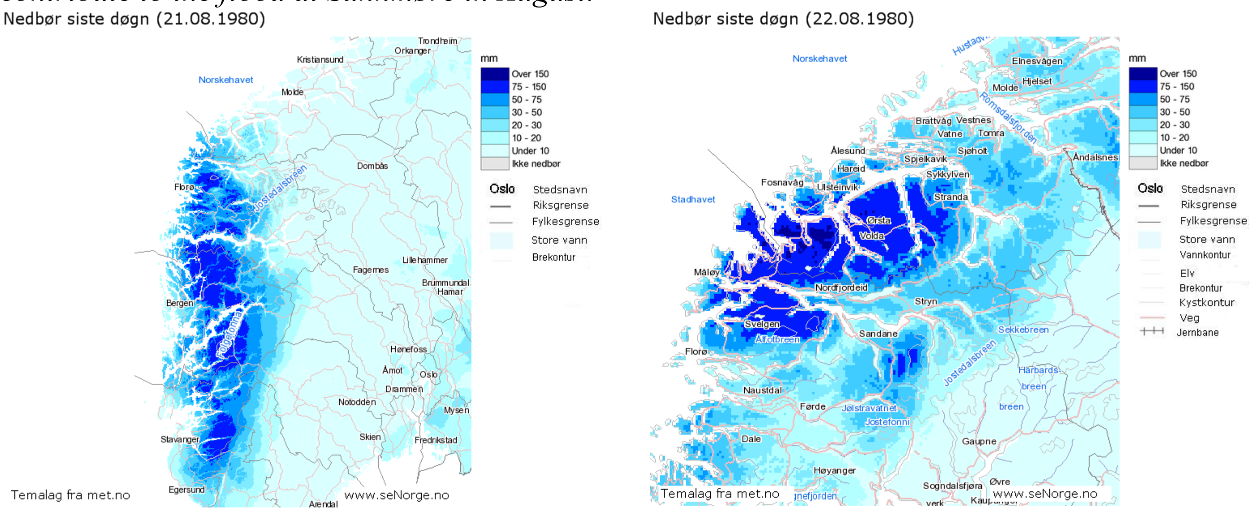


Figure 3.54.3 The rainfall distribution on 21 and 22 August 1980.

3.55 The flood in Hordaland and Sogn og Fjordane 21 November 1980.
A large flood occurred in many coastal rivers at Vestlandet 21 November. Observed daily precipitation and discharge observed in rivers in Rogaland and Hordaland is shown in Figure 3.55.1 and in rivers in Sogn and Fjordane in Figure 3.55.2.

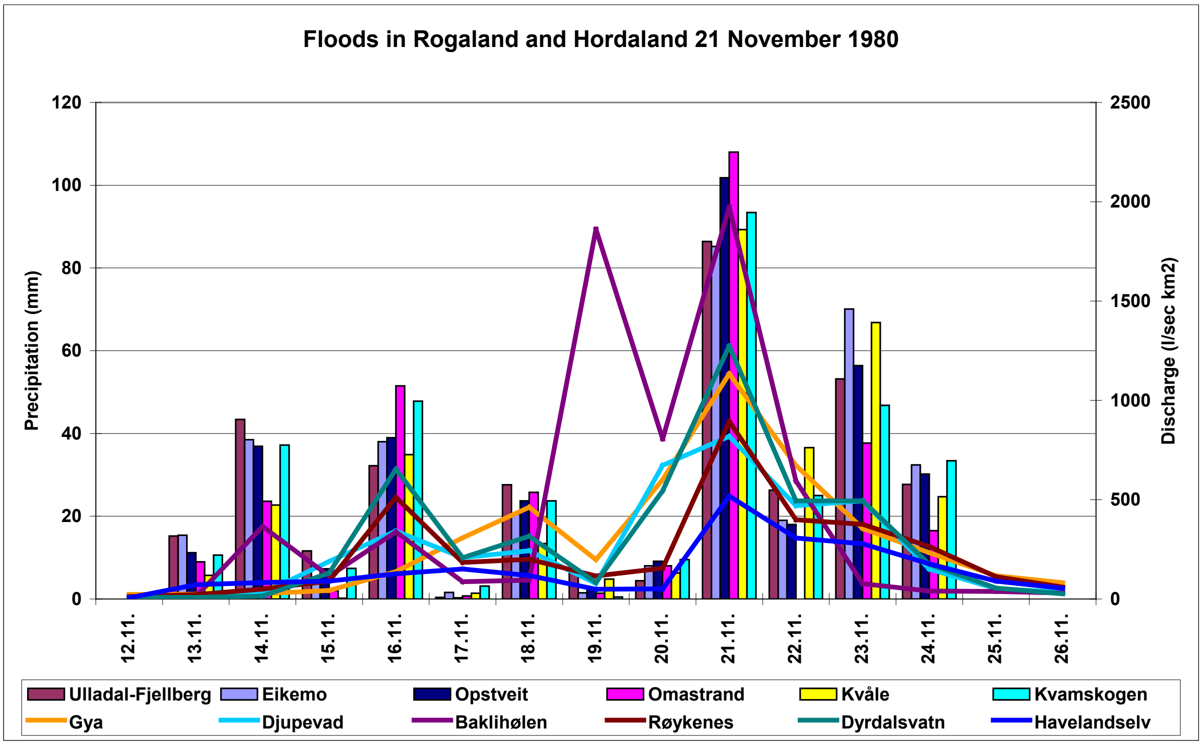


Figure 3.55.1 Observed precipitation and daily discharge in Rogaland and Hordaland in November 1980.

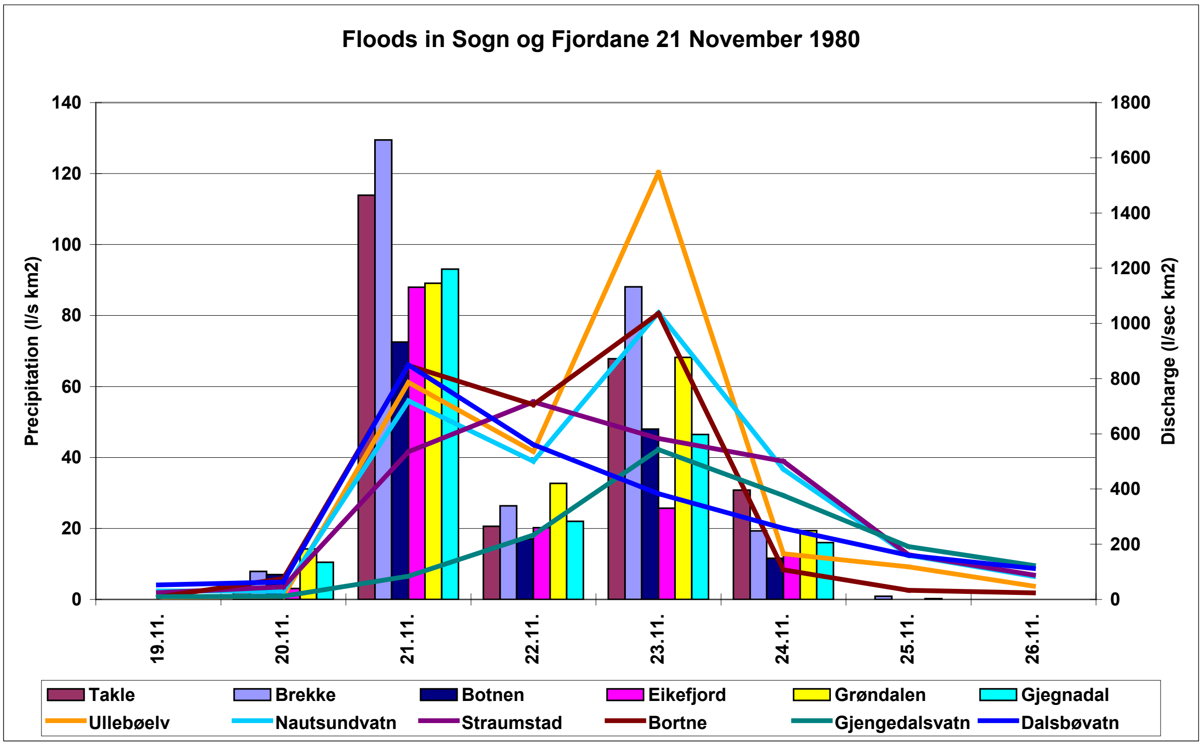


Figure 3.55.2 Observed precipitation and daily discharge in Sogn and Fjordane in November 1980.

The flood was third largest in River Skredalselv at Baklihøl since 1965, in River Nærøyelv at Feios since 1972 and in Lake Dalsbøvatn at Stadt since 1934. The flood was the largest naturalised flood at River Steinslandselv 1930- 2000.

Cause of the flood:

Some snow was present in the inner and upper regions of west Norway prior to the flood. The catchments where the flood occurred had however little or no snow. Figure 3.55.3 show the distribution of the snow water equivalent in South-Norway 21 November.

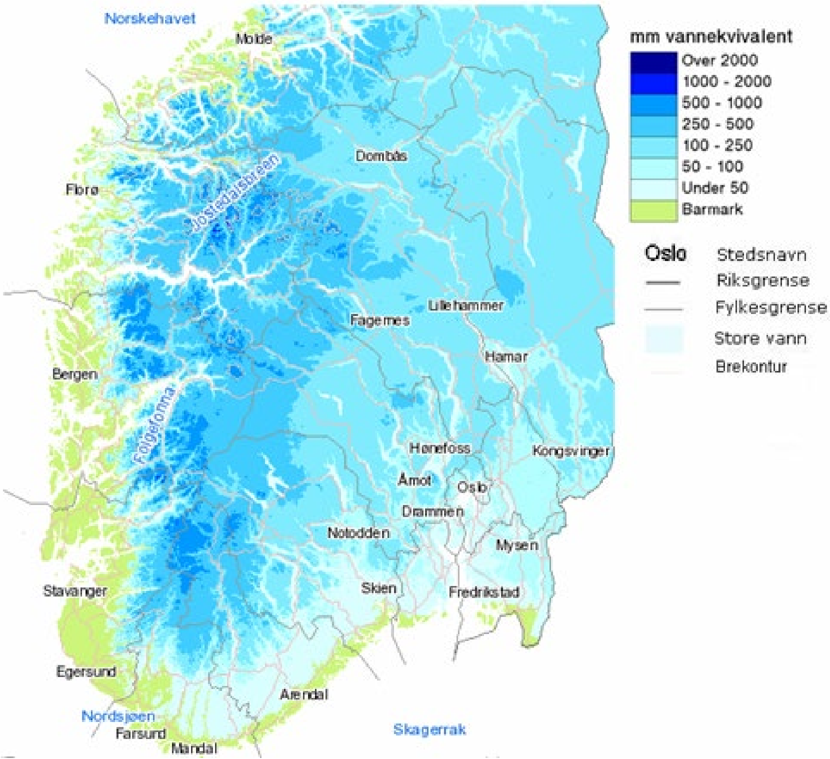


Figure 3.55.3 Spatial distribution of the weater equivalent of the snow in southern Norway 21 November 1980.

Snowmelt contributed to the flood in the inner districts at Vestlandet as shown in Figure 3.55.4, but in coastal rivers heavy rainfall was the only cause of the flood as shown in Figure 3.55.5.

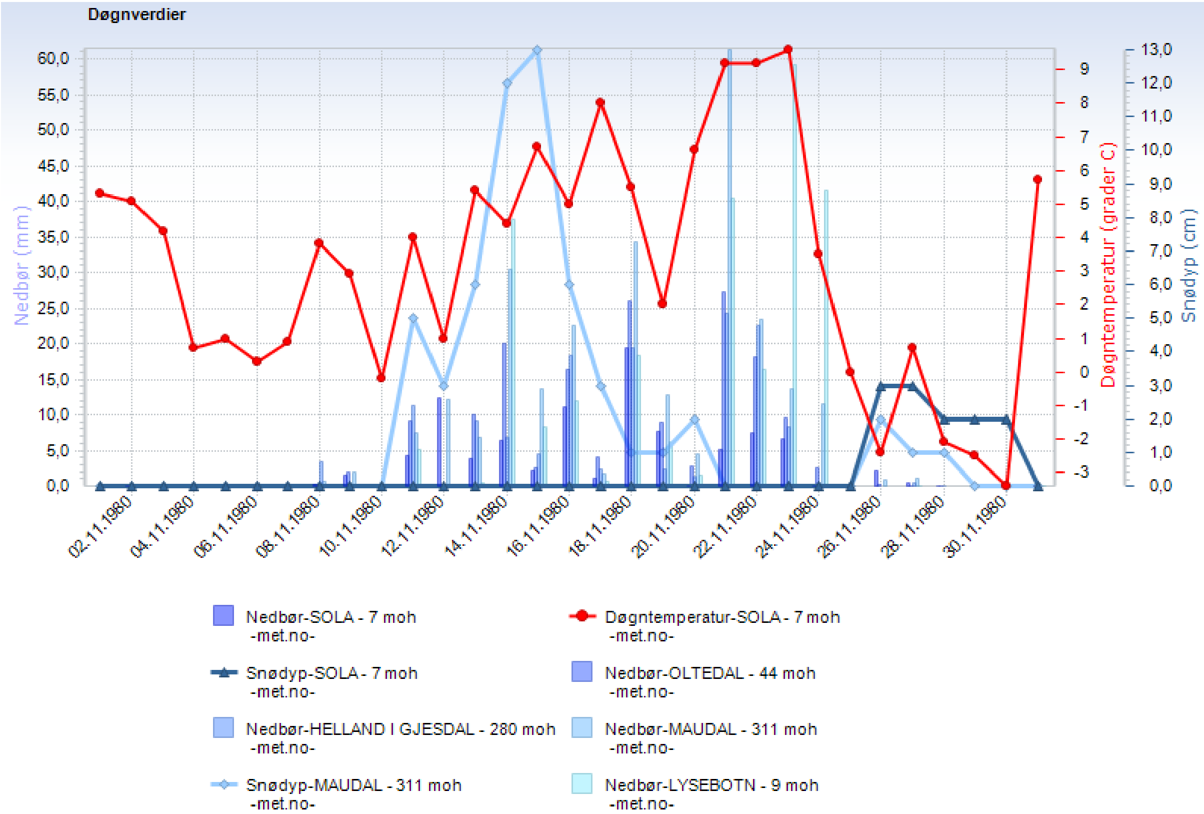


Figure 3.55.4 Observed air temperature at Sola, daily precipitation at stations at Jæren and observed snødepth at Maudal in River Bjerkreimselv (311 m.a.s.l). Some snow was present at Maudal, but this had melted when the rainfall started since the flood coincided with a warm spell.

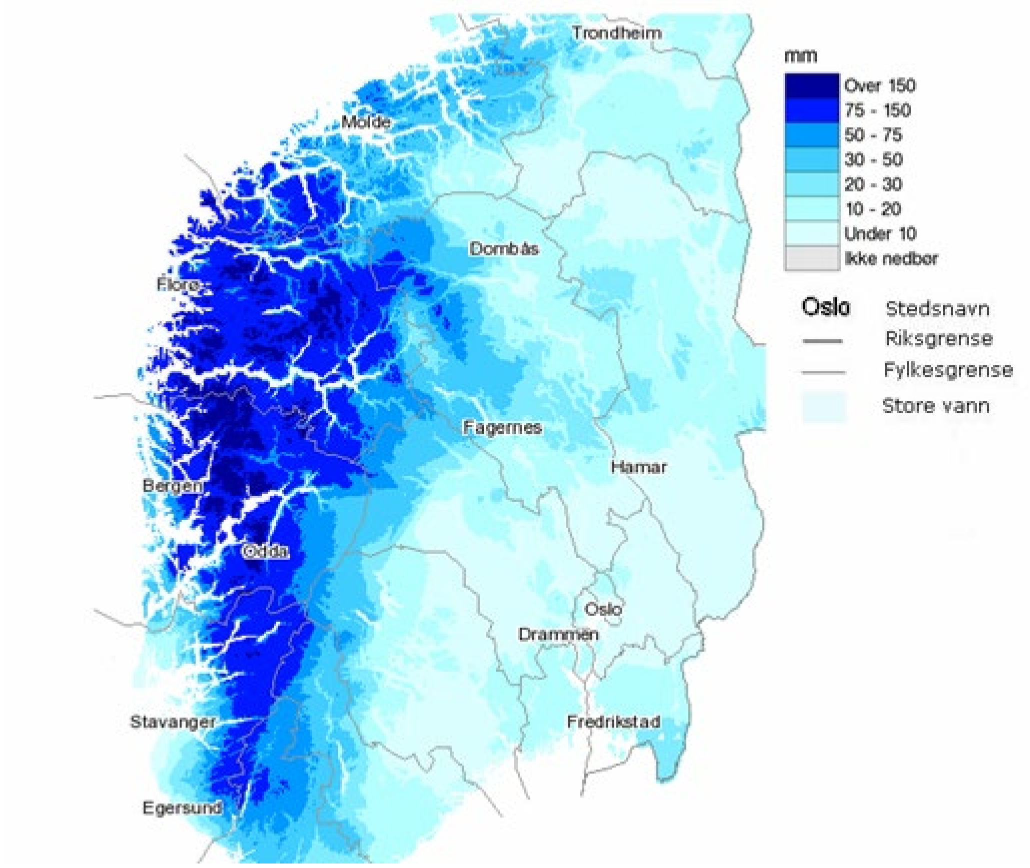


Figure 3.55.5 Precipitation observed 21 November 1980 in the morning. The next day very little precipitation was observed. More precipitation fell 23 November, but far less than on 21 November.

A polar front depression was located at the Atlantic south of Iceland. A trough was extending from the depression towards the coast of west Norway. The flood was caused by a frontal passage causing heavy precipitation over most of South Europe and the northern Mediterainian a ridge from the Iberian penninsula was extending towards north east.

Weather types 21-23 November were **SWA** (Grosswetterlagen) and **W/CSW** (Lamb-Jenkinsson).

3.56 An atmospheric river caused multiple floods in the autumn 1983 at Vestlandet.

An atmospheric river caused almost continous rainfall at Vestlandet in October 1983. A total of 1180 mm was observed at Brekke in Sogn. The rainfall peaked 5 October in Hardanger and at other stations in Rogaland and Hordaland, and some rainfall fell also in Agder. Figure 3.56.1 show observed rainfall and discharge at Jæren. Further north, the most intense rainfall fell between 24 October and 1 November peaking 26-27 and 30 October. Figure 3.56.2, 3.56.3 and 3.56.4 show observed rainfall and discharge at stations in Sunnhordaland and in Sogn and Sunnfjord.

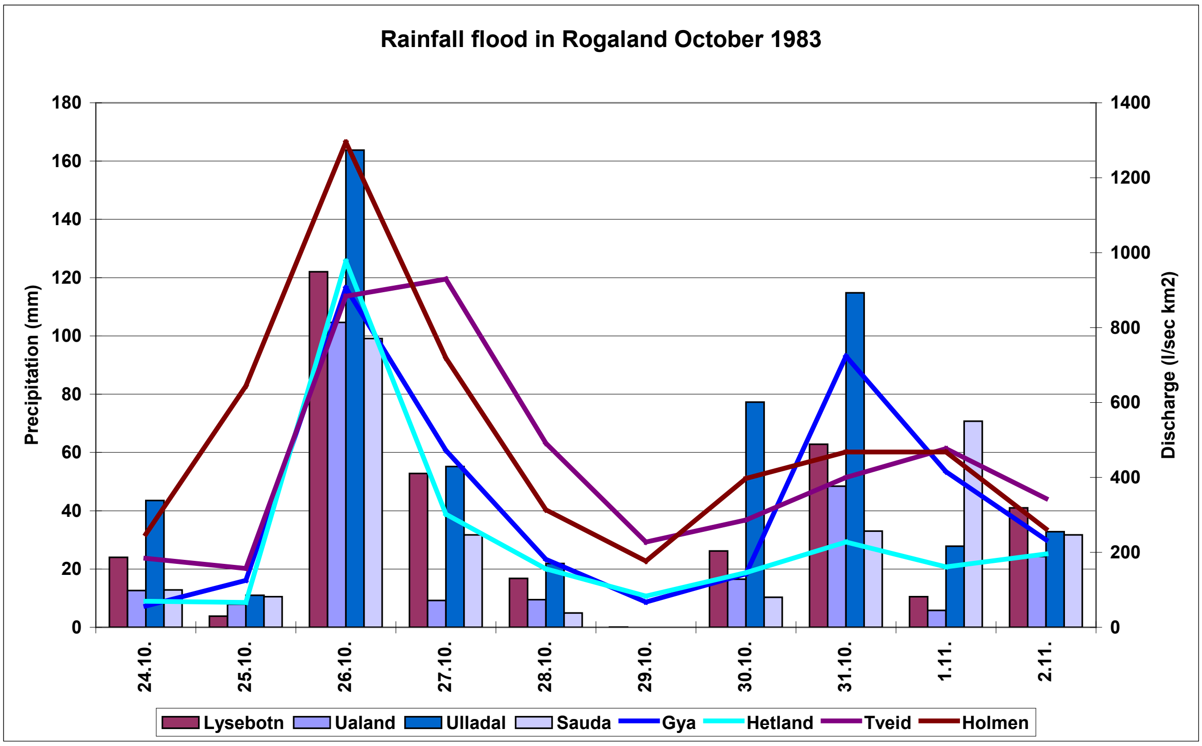


Figure 3.56.1 Observed rainfall and daily discharge during the flood peaks 25 and 30-31 October in Rogaland.

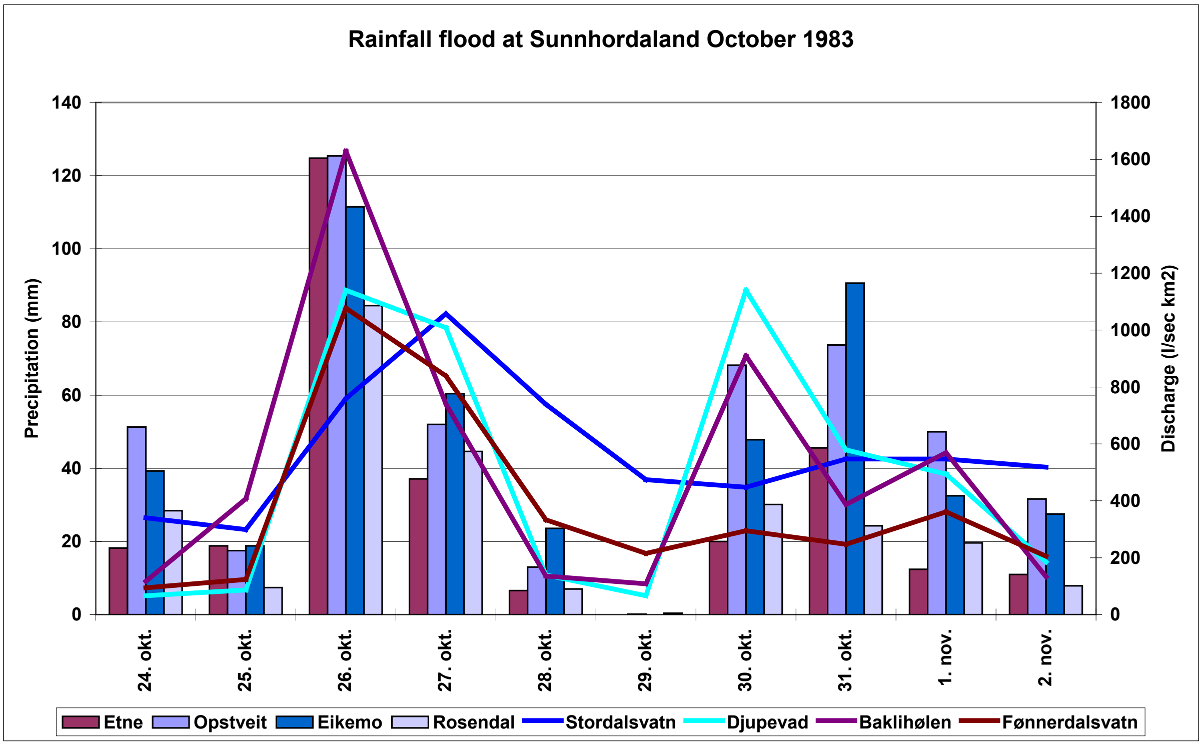


Figure 3.56.2. Observed rainfall and daily discharge during the flood peaks 25 and 30-31 October in Sunnhordaland.

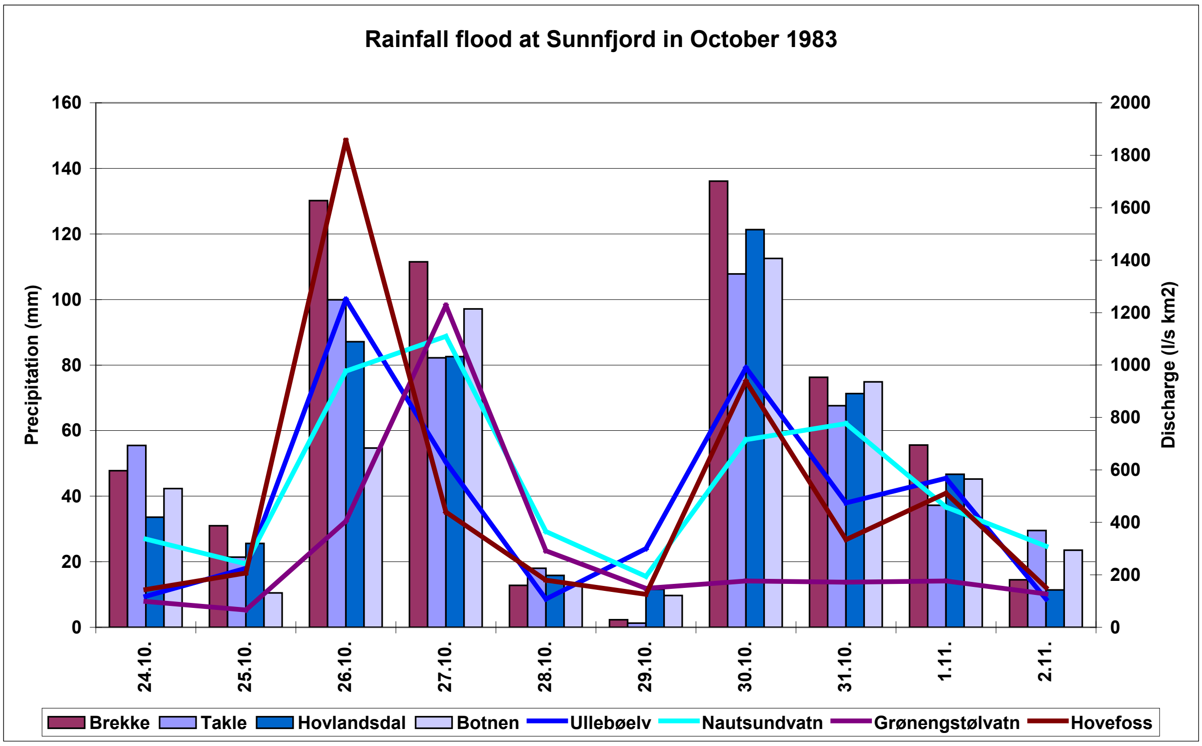


Figure 3.56.3 Observed daily rainfall and discharge during the two flood peaks 26-27 and 30-31 October 1983.

3.57 The rain flood in mountain basins at Vestlandet 1-2 October 1985.

Many rivers from Sogn to Sunnmøre and in western Jotunheimen flooded because of a rainstorm 1- 2 October 1985. Figure 3.57.1 show observed daily precipitation and discharge in felt of the water divide.

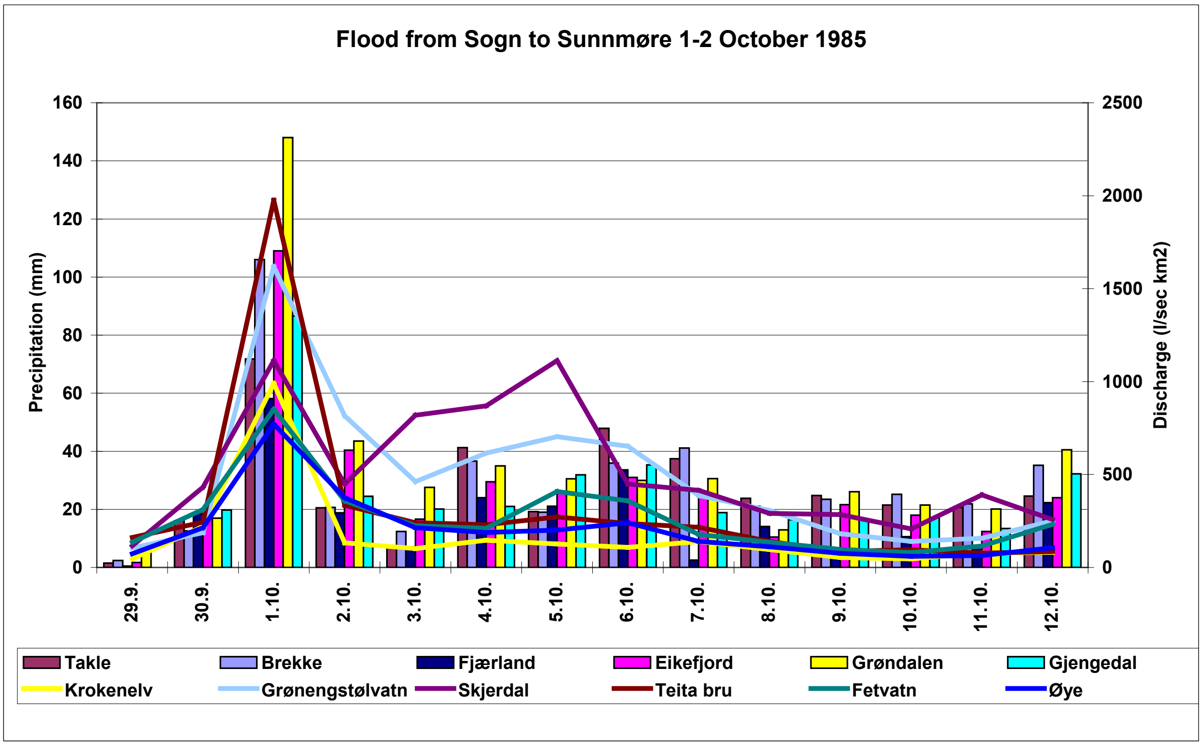


Figure 3.57.1 Observed precipitation and daily discharge during the flood at Vestlandet

1 October 1985.

The flood was largest observed in River Flåmselva at Brekke bru since start of the observations in 1939, in Lake Årdalsvatnet since 1908, in River Langedalselv in Årdal since 1971, in River Gjengedalselv since 1964 and in Breimselv at Teita bru since 1971. It was second largest in River Krokenelv since 1965, in River Sogndalselv since 1962, in River Gaular at Lake Grønengstølvatn since 1965. The flood was third to sixth largest observed at another eight gauging stations in Sogn and Fjordane.

The flood was less unusual in Jotunheimen with the exception of the flood in River Høya at Lake Høydalsvatnet where the flood was largest since the start of observations in 1966.

Cause of the flood:

Figure 3.57.2 show the water equivalent of the snow by 1 October and snow melt in the last 24 hours. Some snow was present in the mountains prior to the flood, and the moderate floods discharge in Ottadalen was caused as much from snowmelt than from precipitation in form of rain.

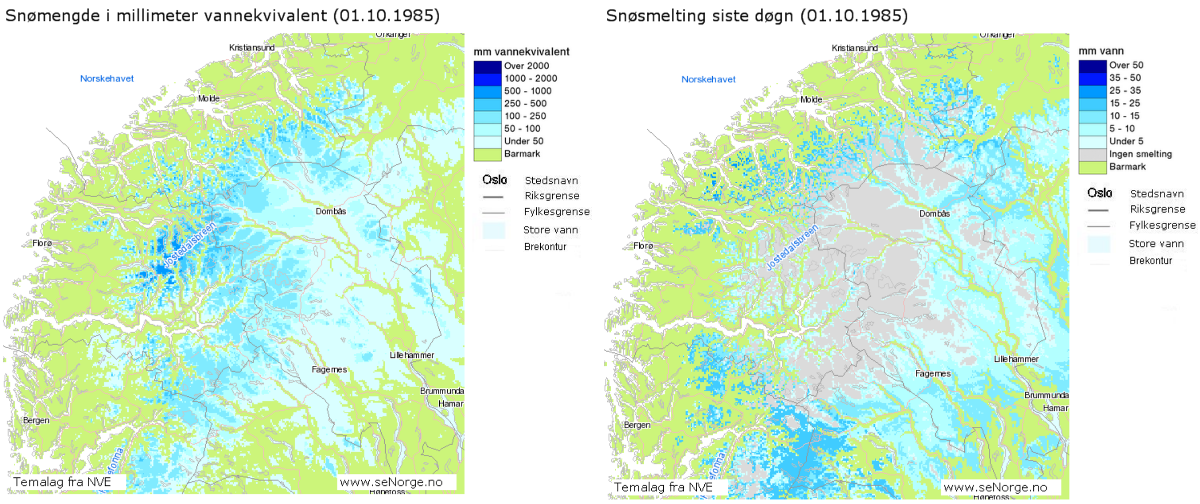


Figure 3.57.2 The spatial distribution of the water equivalent of snow cover and the snowmelt the last 24 hours in region affected by the flood.

The flood west of the water divide was mainly caused by heavy rainfall. Figure 3.57.3 show spatial distribution of the rainfall observed 1 October.

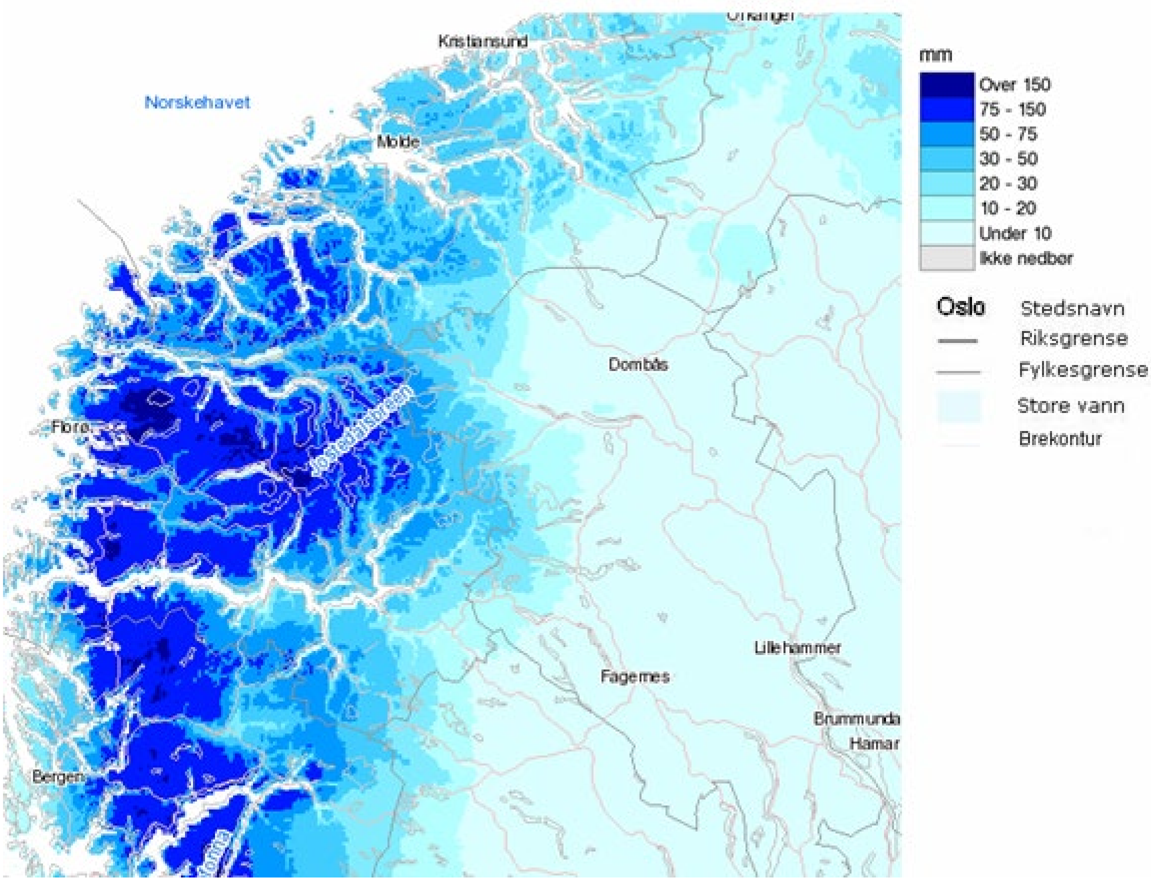


Figure 3.57.3 The spatial distribution of the precipitation 1 October 1985.

The map show that the heaviest rainfall fell from Nord-Hordaland to Sunnfjord. Some precipitation fell east of the water divide towards Ottadalen, but did not penetrate further eastwards.

Cool air from northwest was streaming from the Norwegian Sea towards the northern part of Vestlandet and North Norway. The ridge maintaining the air from northwest moves eastwards 30 September, opening for mild and humid air masses from southwest from the Atlantic. This caused the temperature to rise and the heavy rainfall west of the water divide, causing the flood. The weather types were classified as **SWA** (Grosswetterlagen) and **SE** (Lamb/Jenkinsson).

3.58 The winter floods at Vestlandet in January and February 1989.

A polar-front hurricane struck from Møre og Romsdal to Nord-Trøndelag 15 January 1989. A local flood occurred at Jæren especially in River Bjerkreimselv. Figure 3.58.1 show observed daily precipitation at Sunnhordaland and Figure 3.58.2 at Fjordane and Figure 3.58.3 at Møre and Romsdal. Several winter floods occured later in January and in February.

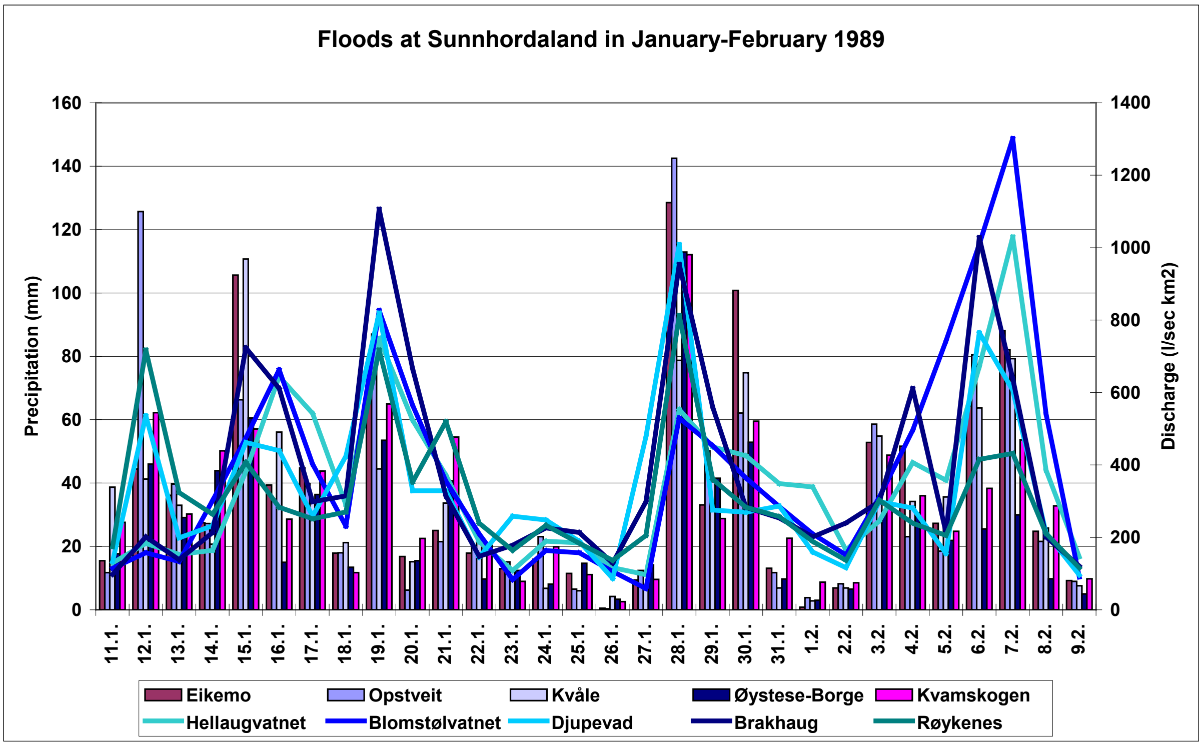


Figure 3.58.1 Observed precipitation and daily discharge during the floods at Sunnhordaland in January-February 1989.

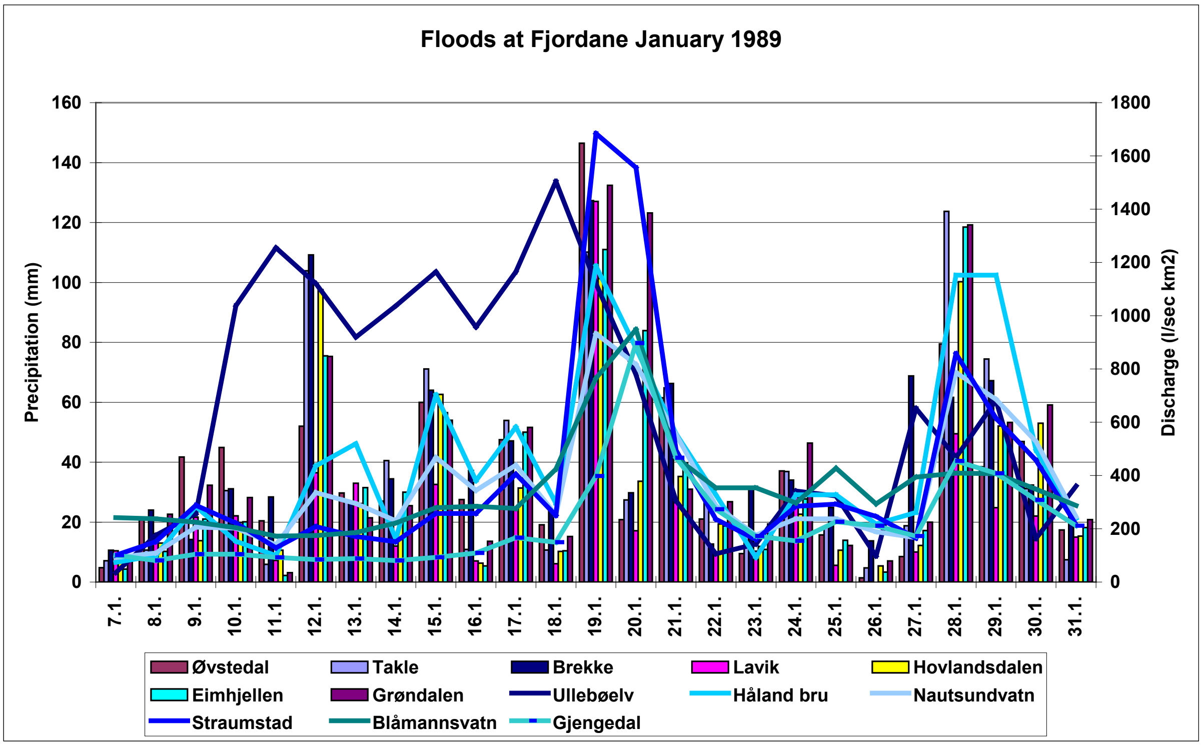


Figure 3.58.2 Observed precipitation and daily discharge during the floods at Fjordane in January 1989.

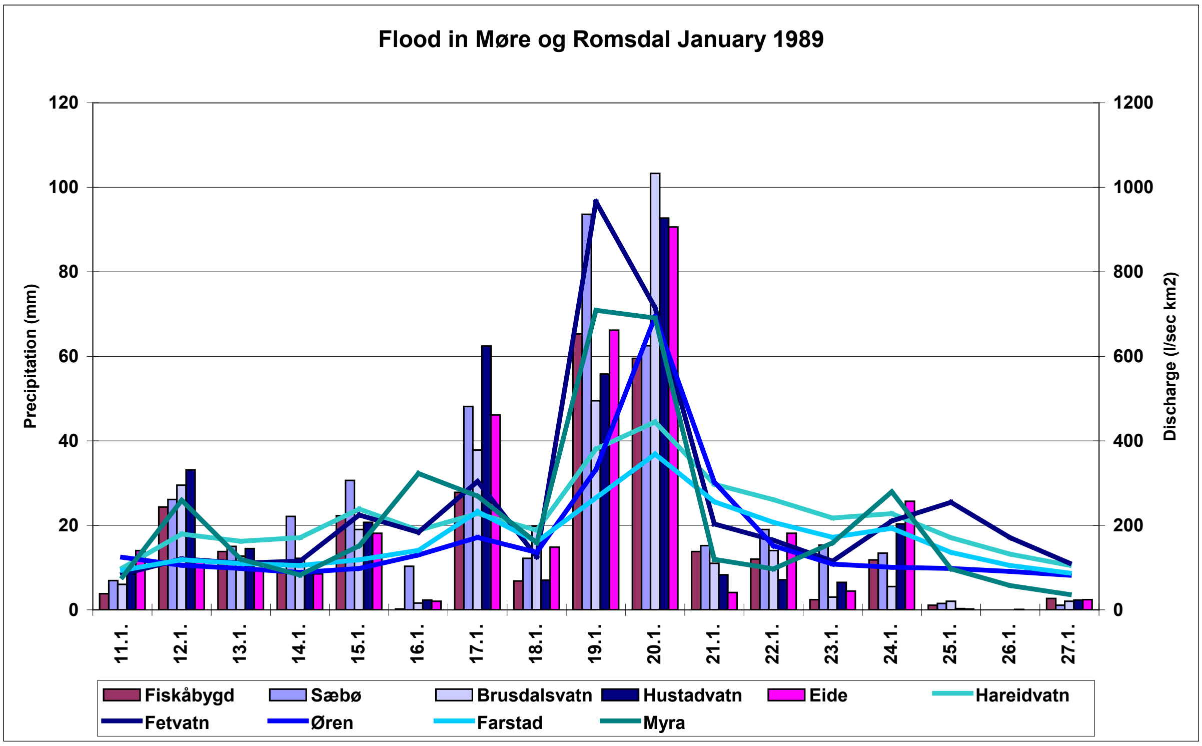


*Figure 3.58.3 Observed precipitation and daily discharge during the floods at Møre and Romsdal in January 19-20 January.*3.59 Floods in West Norway in the aftermath of the extreme "New Year Hurricane" in January 1992.

New Year Ewe 1991 a warning of expected extreme weather was issued from the Meteorological institute. A polarfront hurricane was expected to strike the northern part of Vestlandet. Heavy rainfall had fallen over Vestlandet from Ryfylke to Nordmøre in December 1991. At Opstveit in Sunnhordaland were 84,5 and 162 mm precipitation observed 13-14 December. An anticyclone extended from Central Europe to Great Britain with transport of mild and humid air from the Atlantic further north during the first part of December. Strong westerlies dominated over Northwest Europe in the rest of the month. The hurricane struck from Nordfjord to Nord-Trøndelag. The wind force was later estimated to have a return period of 200 years, causing damages of 2 Billion NOK. As the hurricane moved northestwards warm air caused a large rise in the temperature in the southern part of Vestlandet 1 January, causing much of the snow, which had fallen earlier at lower and intermediate levels to melt. After the hurricane another front caused heavy precipitation from Jæren to Hardanger 3 January, causing floods in several coastal rivers from Sira to Sunnhordaland, as shown in Figure 3.59.1. The precipitation was lower further north where the hurricane had been strongest, and these districts avoided a flood in addition to the wind damages.

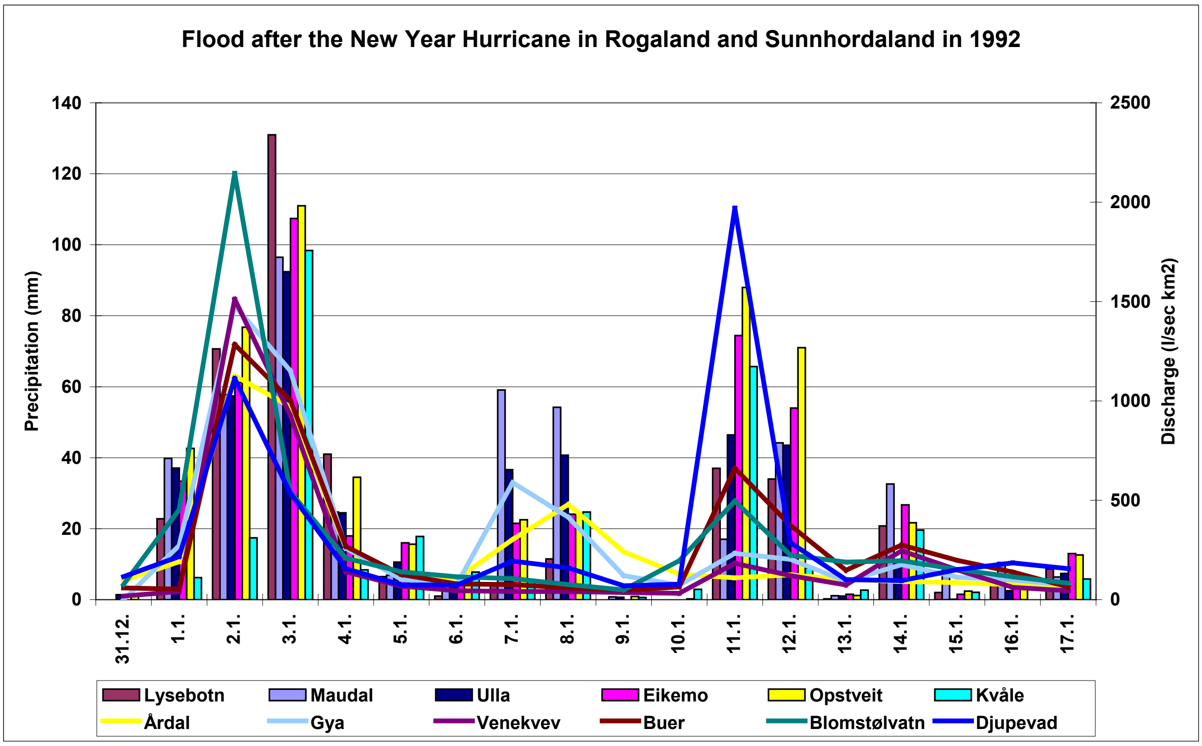


Figure 3.59.1 While the New Year Hurricanes caused most wind damages from Nordfjord to Trøndelag, coastal rivers further south in West Norway had floods, caused mainly by rainfall, but in combination of some snow melt.

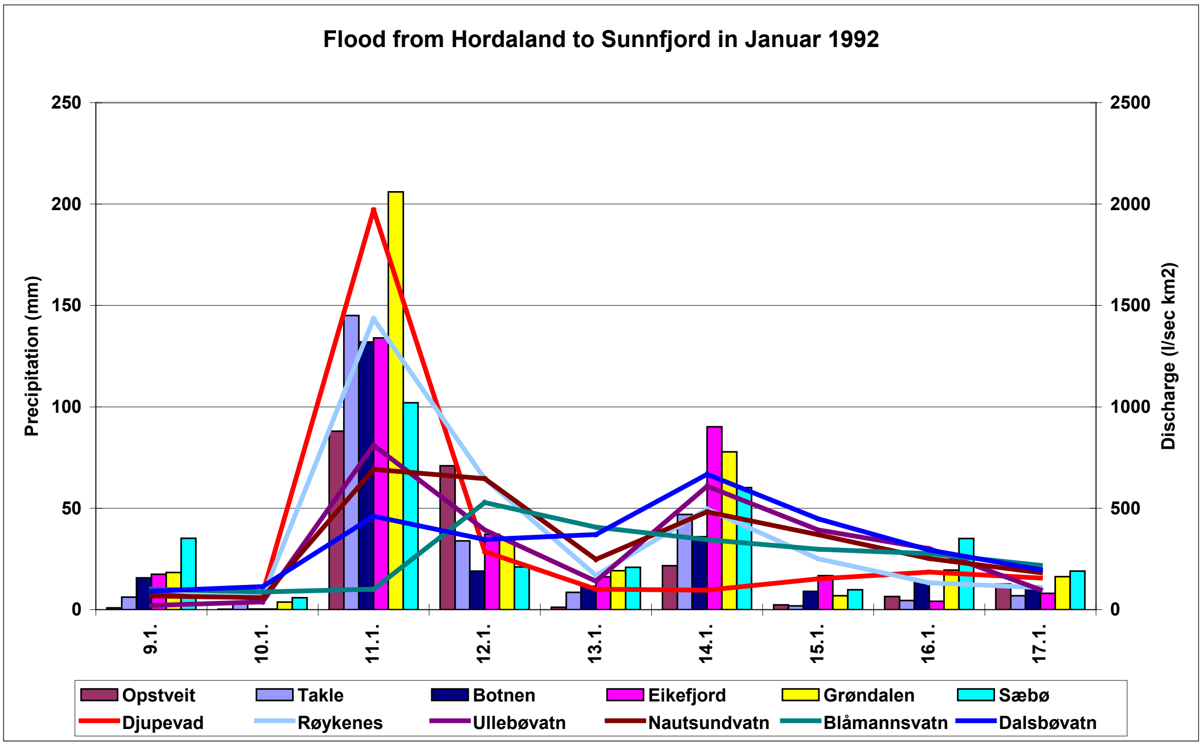


Figure 3.59.2 Observed daily precipitation and discharge resulting from the second frontal passage after the New Year Hurricane at the southern part of Vestlandet. The second flood in January 1992 was partly caused by extreme rainfall as observed at Grøndalen in Sunnfjord.

The flood was the largest observed in Sira in Årdal and in Sandvatn since the observations started in 1970-71. It was fourth largest observed in River Gya siden 1933, second largest at Austrumdal since 1980 and fifth largest at Bjordal since 1984 in Bjerkreim. The flood was in

Sauda at Buer and in Vikedal at Holmen. It was the largest observed in Lake Blomstølvatn in River Etneelv since 1981 and twelfth largest in Lake Stordalsvatn in Etne since 1916. The weather types were **WA** (Grosswetterlagen) and **W** (Lamb/Jenkinsson).

Another front reached Vestlandet 11 January. Most precipitation was observed in Sunnfjord, causing another flood. Figure 3.59.2 show observed daily precipitation and discharge during this flood. The weather types were **HB** (Grosswetterlagen) and **A** (Lamb/Jenkinsson).

Cause of the flood:

Initial conditions:

In spite of a long period with mild weather from southwest, a lot of snow had accumulated in the mountains at Vestlandet by 1 January, when the temperature rose fast as shown in som Figure 3.59.3. Temperatures rising to +10 °C in the lowland caused the snow to melt where snow was present as shown in the Figure.

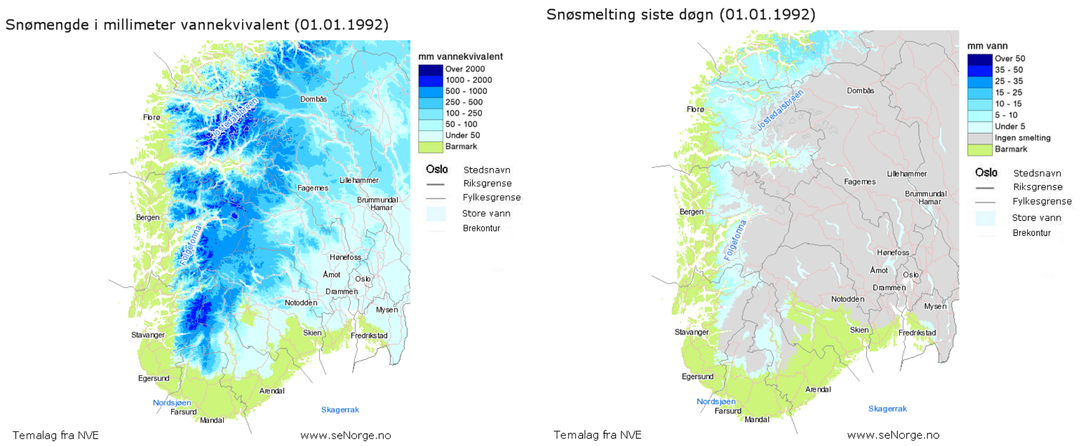


Figure 3.59.3 The spatial distribution of the water equivalent of the snow cover and the snowmelt 1 January 1992.

Figure 3.59.4 show the temperature and the soil moisture deficit 1 January. The temperature was still below 0 in the mountains and in some valleys at Sørlandet, where the warm air did not penetrate.

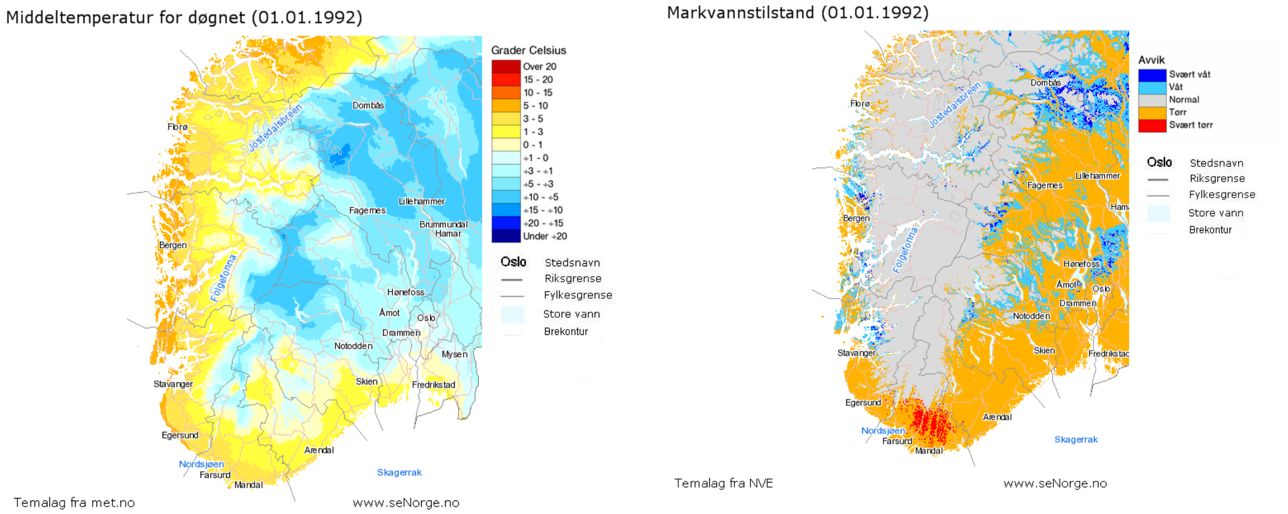


Figure 3.59.4 The spatial distribution of the temperature and the soil moisture deficit 1 January 1992.

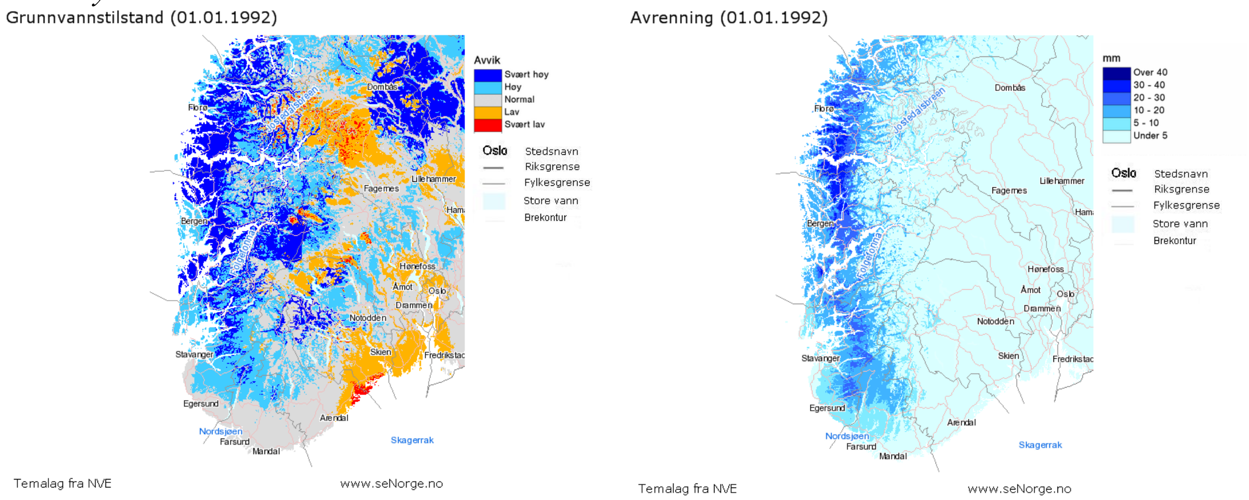
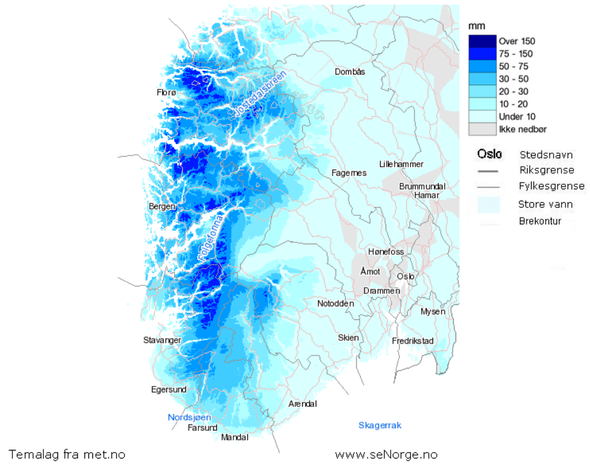


Figure 3.59.5 State of the groundwater storage and discharge 1 January 1992.

The groundwater reservoir was close to normal at Sørlandet and Jæren, but in the Dalane and Ryfylke district the groundwater reservoir was above normal as shown in Figure 5. Det var noe avrenning in midtre strøk at Vestlandet, in hovedsak forårsaket of snøsmelting. The spatial distribution of the precipitation 1-2 January is shown in Figure 3.59.6.
Some precipitation fell during the passage of the storm from Hardanger to Nordfjord 1 January. The precipitation fell partly as snow and did not cause high discharges in the rivers in the district. Some precipitation fell in the inner part of Ryfylke 2 January, but most of the precipitation fell during the night and was observed in the morning 3 January. This precipitation fell mostly as rain, causing the flood shown in Figure 3.59.7. More precipitation fell further north 11 January, causing a flood from Hordaland to Sunnfjord as shown in Figure 3.59.8.

Nedbør siste døgn (01.01.1992)



Nedbør siste døgn (02.01.1992)

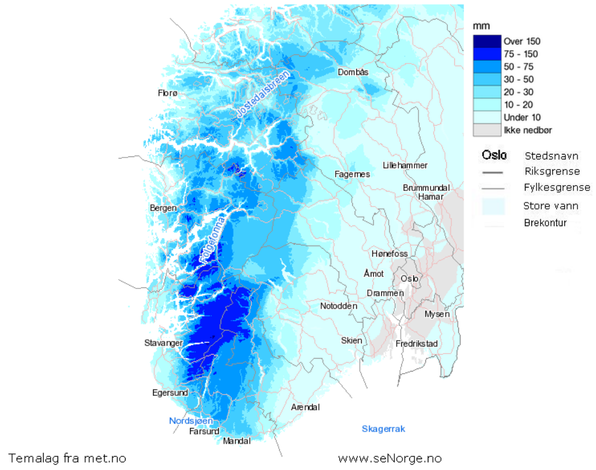
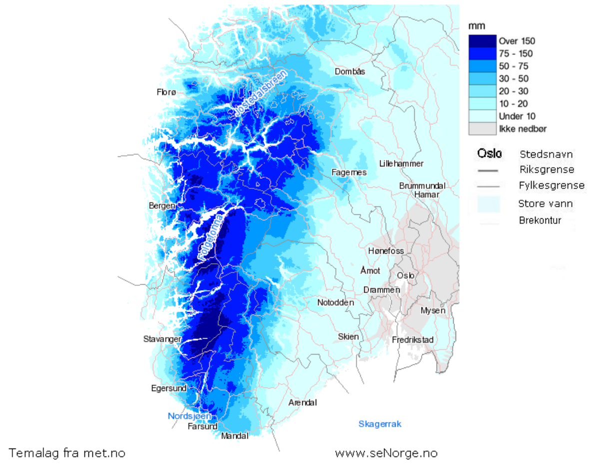


Figure 3.59.6 The distribution of the precipitation 1-2 January 1992.

Nedbør siste døgn (03.01.1992)



Avrenning (03.01.1992)

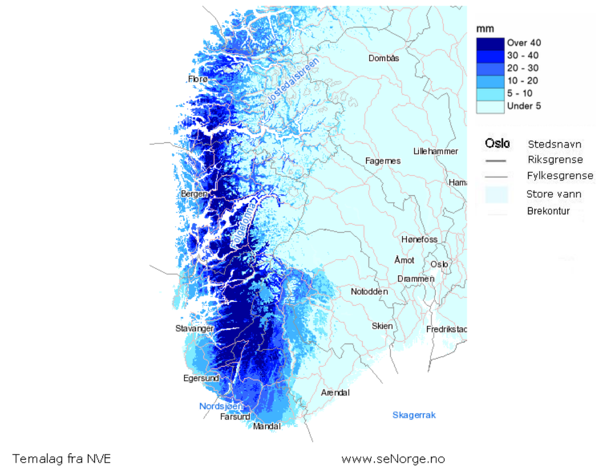
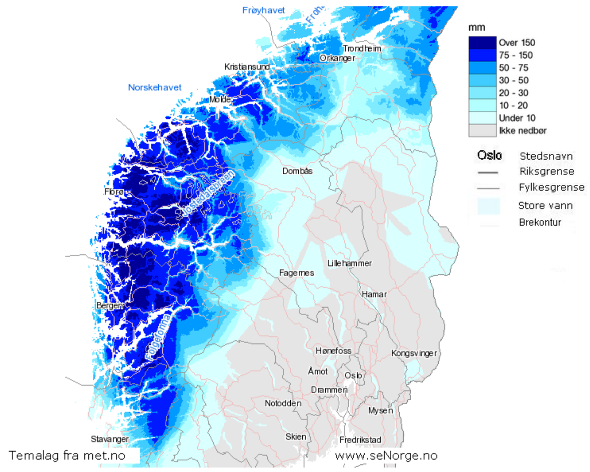


Figure 3.59.7 The distribution of the precipitation and discharge during the flood at South Vestlandet 3 January.

Nedbør siste døgn (11.01.1992)



Avrenning (11.01.1992)

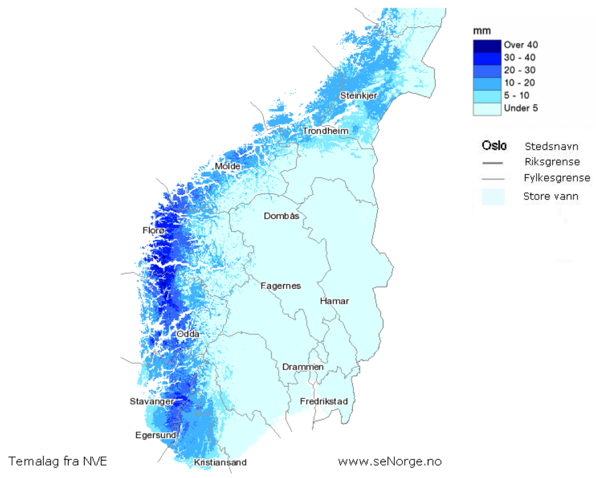


Figure 3.59.8 The distribution of the precipitation and discharge during the flood 11 January 1992 from Hordaland to Sunnfjord.

3.60 The flood at Vestlandet 15 December 1992.

In mid December 1992 a large flood struck in coastal rivers in Ryfylke and Hordaland. The flood in coastal rivers in Sunn- and Nordfjord were smaller than further south. Figure 3.60.1 show daily precipitation and discharge at stations from Ryfylke to Nordhordaland.

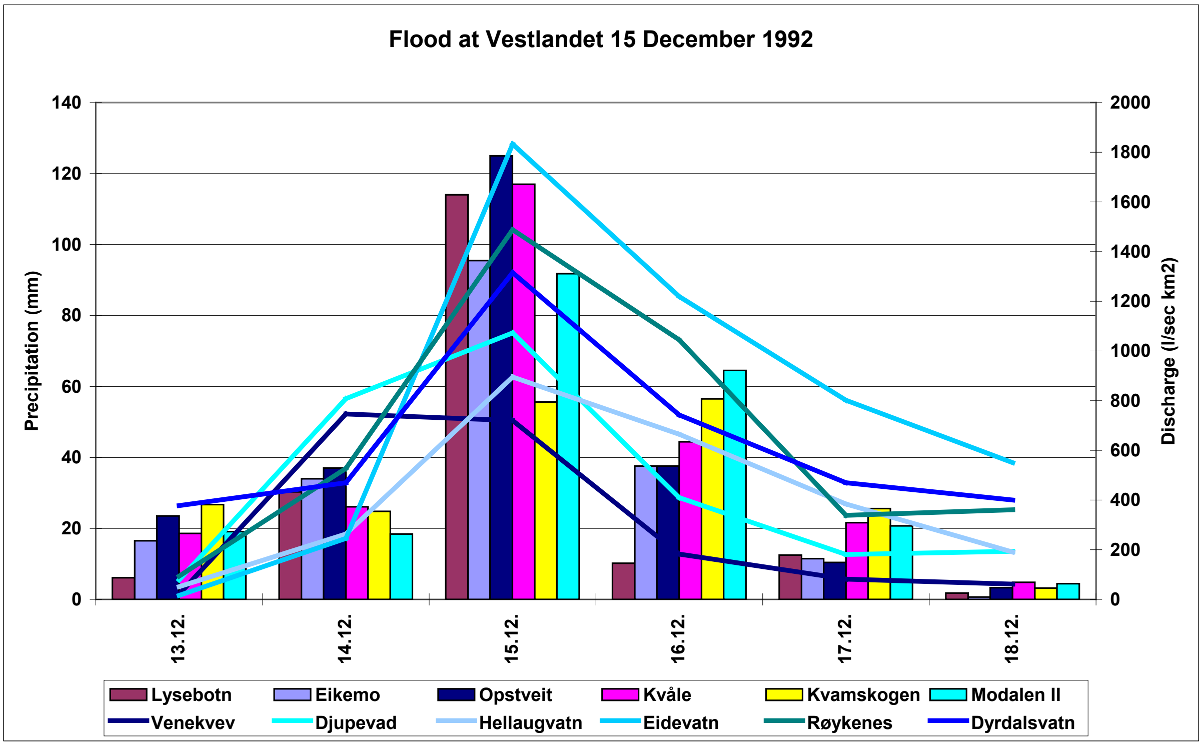


Figure 3.60.1 Observed precipitation and daily discharge at Vestlandet 15 December 1992.

The flood was the largest observed in River Jondalselv at Lake Eidevatn 1908-2001 and the fifth largest at River Oselv ar Røykenes 1934-2008 and at River Åskrelv at Ålfotbreen 1985-2005.

Cause of the flood:

The flood was the result of rainfall combined with some melting: The distribution of the snow water equivalent and the precipitation is shown in Figure 3.60.2.

Between an anticyclonic ridge over the European Mainland and a depression in the Norwegian Sea mild and humid air was streaming from southwest towards the coast of Norway. Weather types 15 December were: **WA** (Grosswetterlagen) and **W** (Lamb-Jenkinsson).

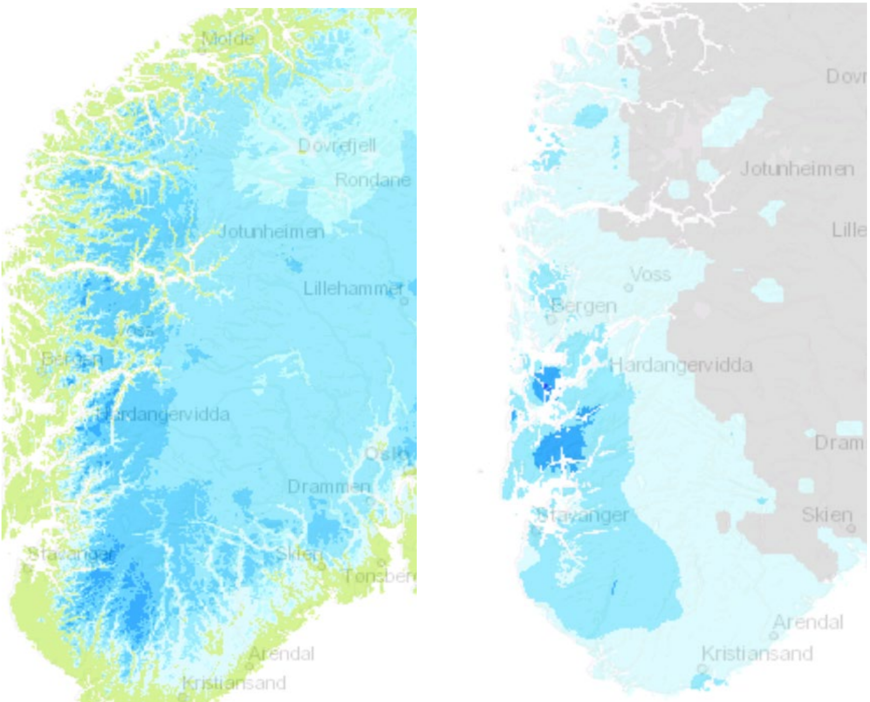


Figure 3.60.2 The distribution of the snow water equivalent and the precipitation 15 December 1992.

3.61 Autumn floods in Hordaland and Sogn in 1995.

A major flood occurred in West Norway in October 1995. Several frontal passages occurred through the month. A rainstorm from 18 to 20 October caused floods in several coastal rivers at Nord-Hordaland and Sunnfjord. The next rainstorm 23-24 October and a more intense rainstorm 27 October resulted in somewhat larger floods in the same rivers from the Bergen peninsula and further north. The rainstorm 23 October was more intense from Vestagder to Åkrafjorden in Sunnhordaland than further north. That day 127 mm rain was observed at Ulla in Ryfylke. Figure 3.61.1 show observed daily precipitation and discharge in Hordaland and n Sogn og in Sunn- og Nordfjord in Figure 3.62.2.

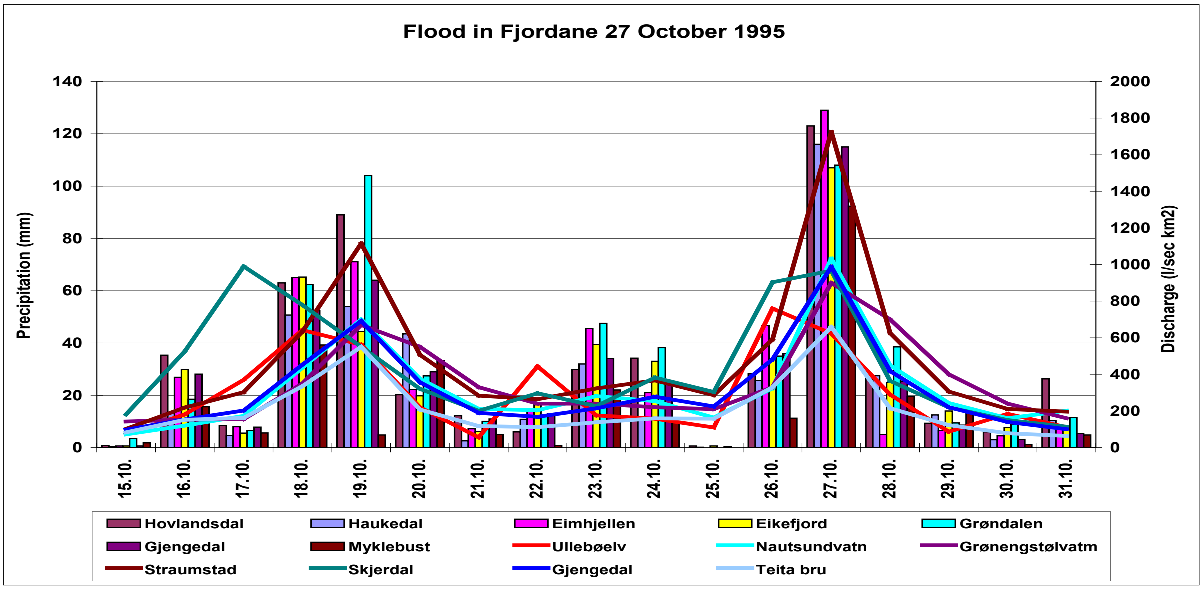


Figure 3.61.1 Observed precipitation and daily discharge in Hordaland and Sogn in October*1995.*

The flood 26-28 October was fourth largest in River Vosso at 62.5 Bulken 1892-2014, third largest in River Kløvtveitelv at 68.1 Kløvtveitvatn 1916-2006, fourth largest in River Flåmselv at 72.5 Brekke bru 1939-2014 and fifth largest in River Sogndalselv at 77.3 Sogndalsvatn 1962-2014 and in River Hageelva at 81.1 Hersvikvatn 1934-2014, fourth largest in River Gaular at 83.2 Viksvatn 1902-2013, and largest in Sunndalsvassdraget at Straumstad 1974-2014 and in Ommedal at Åvatn 1974-2014.

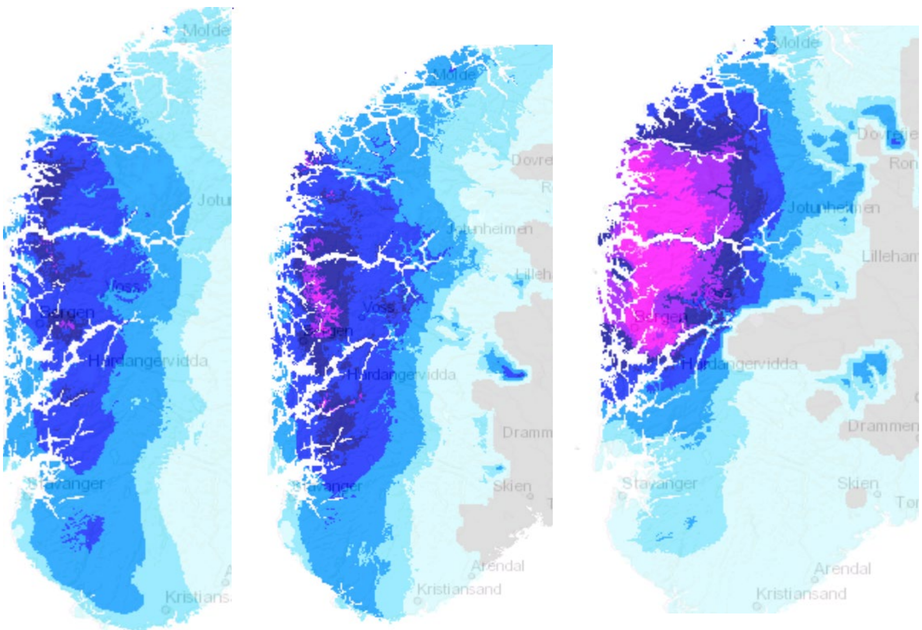


Figure 3.61.2 The distribution of the precipitation 18, 19 and 27 October 1995 at Vestlandet.

3.62 Winter floods at Vestlandet in 1998.

Three heavy rainfall events occurred in coastal basins of West Norway causing winter floods 11 January, 9 February and 22 November in 1998. Observed precipitation and discharge during the January flood in Hordaland is shown in Figure 3.62.1 and the distribution of the water equivalent and the precipitation 11 January 1998 in Figure 3.62.2.

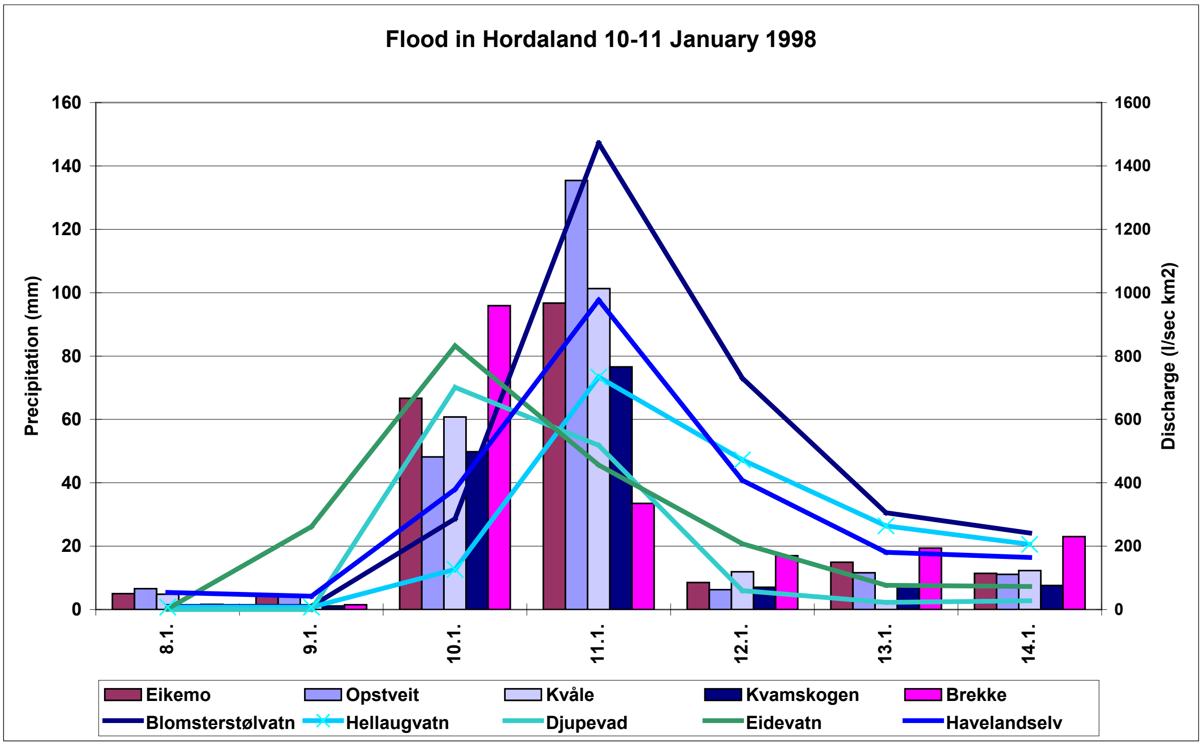


Figure 3.62.1 Observed precipitation and daily discharge in Hordaland in January 1998.

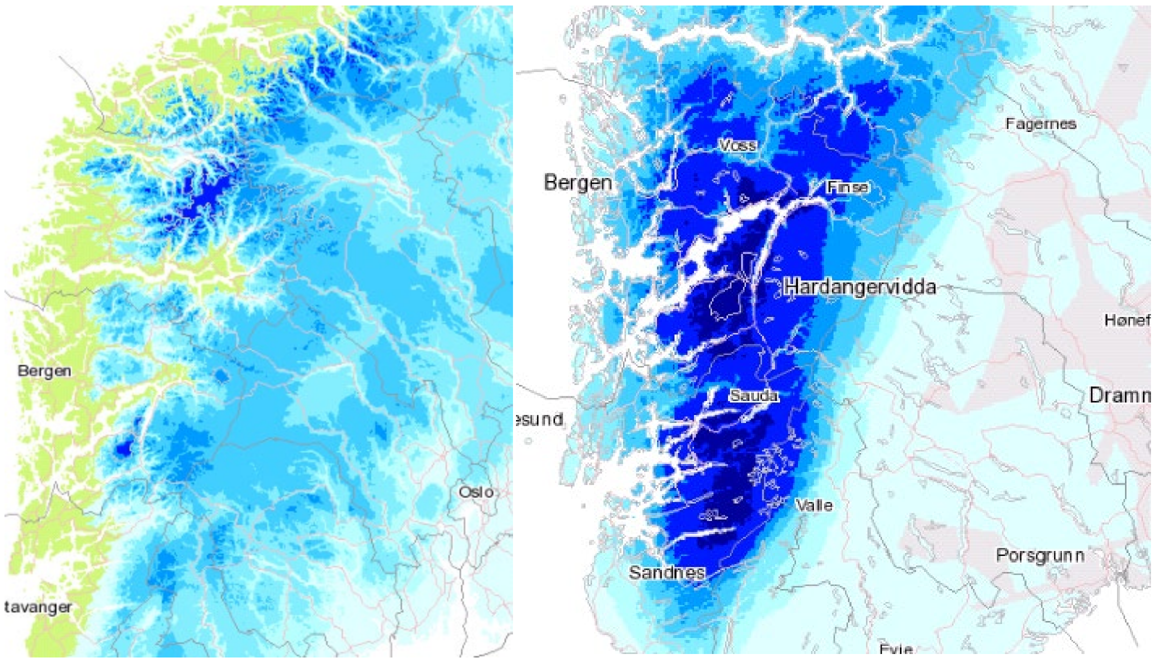


Figure 3.62.2 The distribution of the water equivalent of the snow cover (left) and of the precipitation (right) 11 January 1998 in West Norway.

Most one-day rainfall was observed at Opstveit in Sunnhordaland. Weather types 10-11 January were: **SWA** (Grosswetterlagen) and **SW/ S** (Lamb-Jenkinsson).

The second flood occurred in February. Observed precipitation and discharge during the February flood in Hordaland is shown in Figure 3.62.3 and the distribution of the snow water equivalent and the precipitation 9 February 1998 in Figure 3.62.4.

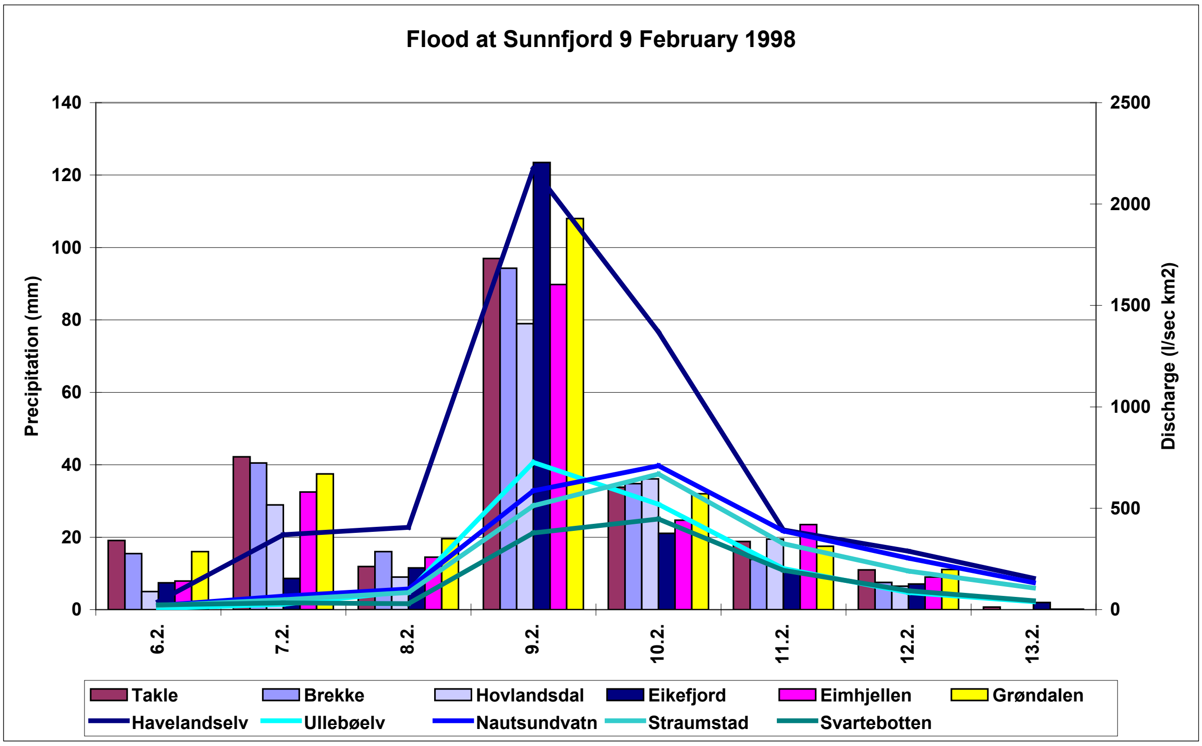


Figure 3.62.3 Observed precipitation and daily discharge at Sunnfjord February 1998

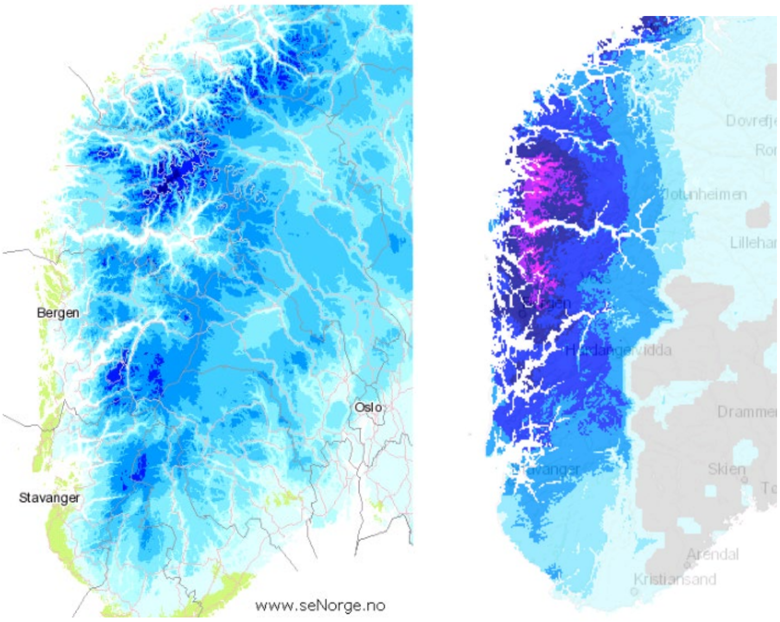


Figure 3.62.4 The distribution of the water equivalent of the snow cover (left) and of the precipitation (right) 9 February 1998 in West Norway.

Most one-day rainfall was observed at Eikefjord (124 mm) and Grøndalen (108 mm) at Sunnfjord. Weather types 9 February were **BM** (Grosswetterlagen) and **SW** (Lamb-Jenkinsson).

The third flood occurred 22 Novenber. Observed precipitation and discharge during the November flood from Nordhordaland to Sunnfjord is shown in Figure 3.62.5 and the distribution of the snow water equivalent and the precipitation 22 November 1998 in Figure 3.62.6.

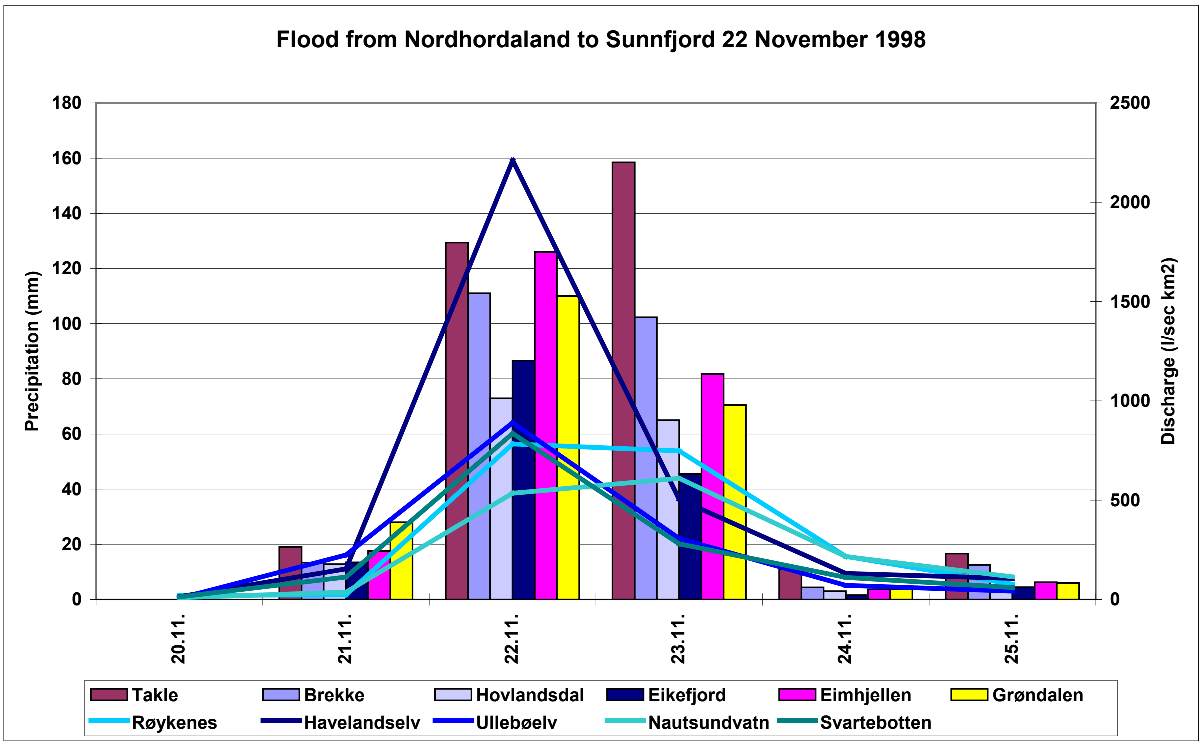
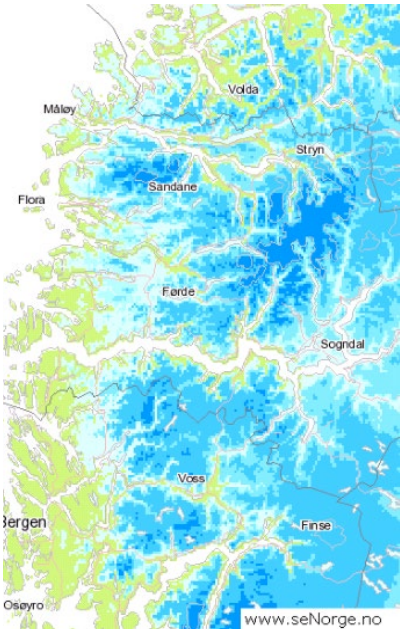


Figure 3.62.5 Observed precipitation and daily discharge from Nordhordaland to Sunnfjord in November 1998



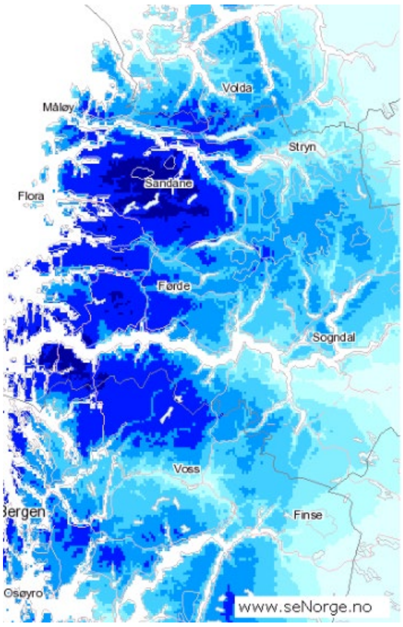


Figure 3.62.6 The distribution of the water equivalent of the snow cover (left) and of the precipitation (right) 22 Nowember 1998 in West Norway.

Most one- and two-day rainfall was observed at Takle in Sogn (159 mm/288 mm).

Weather types 22-23 November were **BM** (Grosswetterlagen) and **SW/A** (Lamb-Jenkinsson).

3.63 The rainfall flood at Vestlandet in September 2003.

A rainfall flood occurred at Vestlandet 25 September 2003. The flood was largest in coastal rivers, especially in Hordaland. Local floods occurred also in rivers further north ie to Sunnfjord. Figure 3.63.1 show observed daily rainfall and discharge at selected stations where the flood was largest.

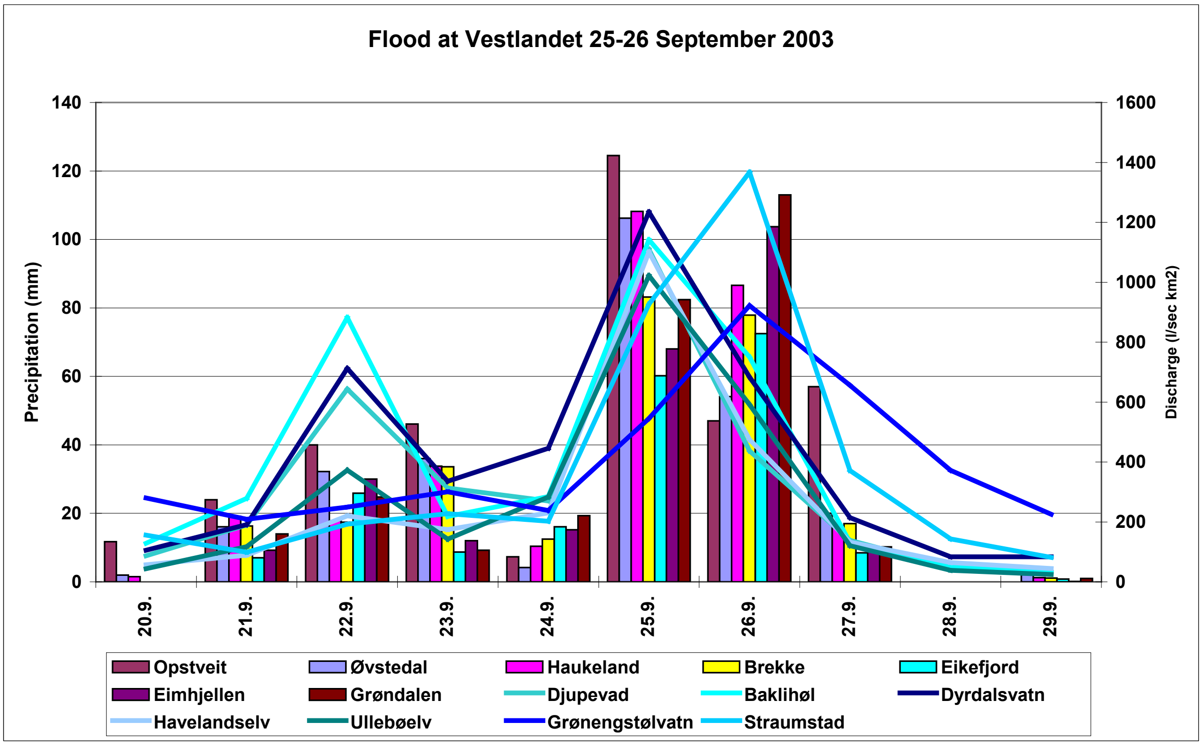
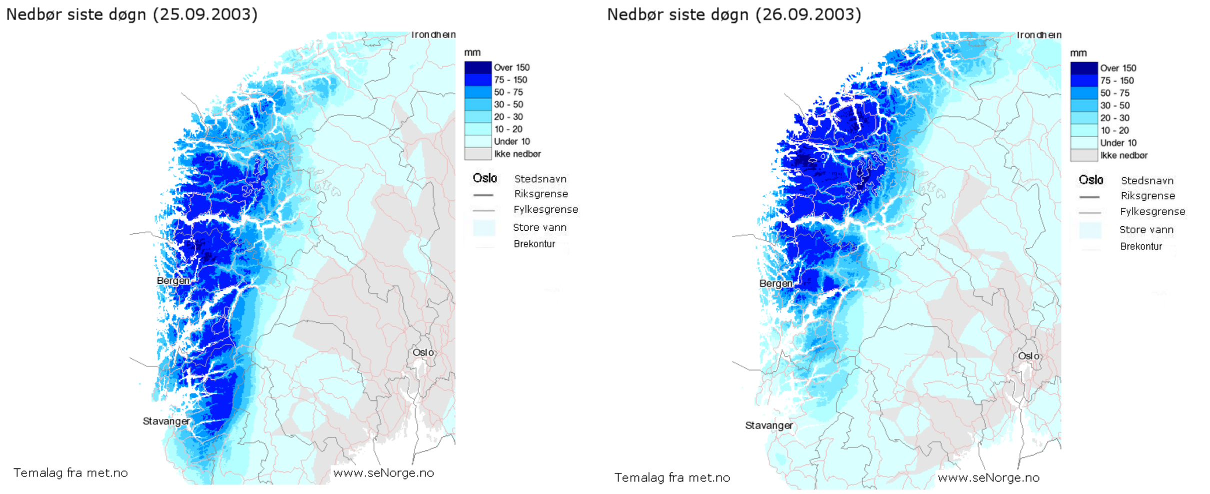


Figure 3.63.1 Observed precipitation and daily discharge during rainfall floods at Vestlandet in September 2003.

The flood was the third largest observed in River Sægrova at Jølster 1996-2005 and in River Skjerdalselv at Hyen 1982-2010 and the fourth largest in River Hareidelv 1985-2006. At Lake Dalsbøvatn at Stad the flood was the ninth largest 1934-2010. The flood ranks from no 11 to 25 in other small coastal streams with longer data series.

Cause of the flood:

The flood was caused by rainfall. Figure 3.63.2 show the distribution of the rainfall at Vestlandet 25 and 26 September. The largest one- and two-day rainfall were observed at Grøndalen in Sunnfjord (113 mm/195 mm). Between an anticcyclone over Storbritannia, which moved eastward over the European mainland, and a depression near the coast of Northern Norway at Lofoten and Troms, a front moved in over the coast of Vestlander from southwest. The weather types 25-26 September were: **SWA** (Grosswetterlagen) and **ASW/C** (Lamb-Jenkinsson).



Figur 3.63.2 The distribution of the rainfall at Vestlandet during the flood in September 2003.

3.64 Winter flood at Vestlandet in December 2003.

A short duration flood occurred in coastal rivers from Sogn to the Fosen peninsula 18-19 December 2003. Figure 3.64.1 show observed daily precipitation and discharge in some catchments.

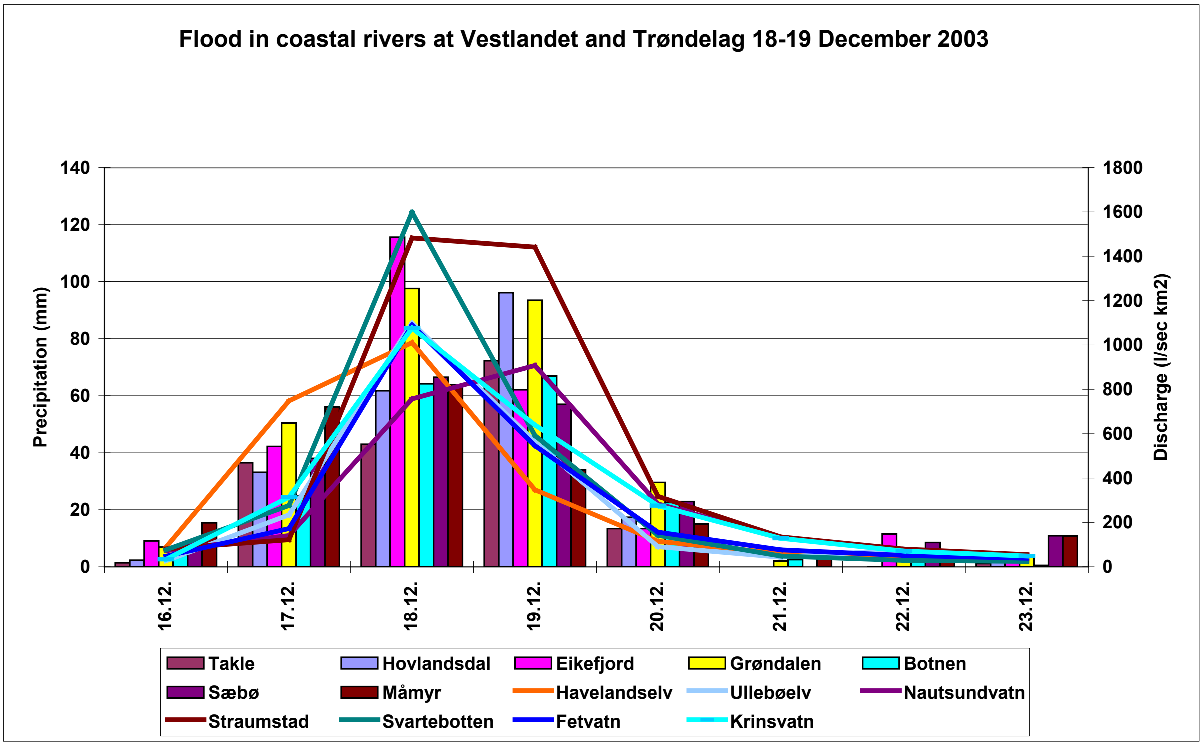


Figure 3.64.1 Observed precipitation and daily discharge from Vestlandet to Trøndelag in December 2003.

The flood was the largest observed at Svartebotten in Sunnfjord 1961-2010 and fifth largest at Krinsvatn at Fosen 1916-2010. The flood does not rank among the largest in other rivers within the region.

The cause of the flood:

Prior to the flood some snow had accumulated except in catchments at the outer coast. Figure 3.64.2 show the distribution of the snow reservoir and the contribution from melting snow to thr flood. Figure 3.64.3 show temperature and the distribution of the precipitation 18 December. High temperatures in early December prevented much snow to accumulate. A drop in the temperature and snowfall from 12 December caused the snow cover to increase to 16 December as shown in Figure 3.64.4. The temperatur increased 17 December, causing snowmelt when the heavy rainfall started.

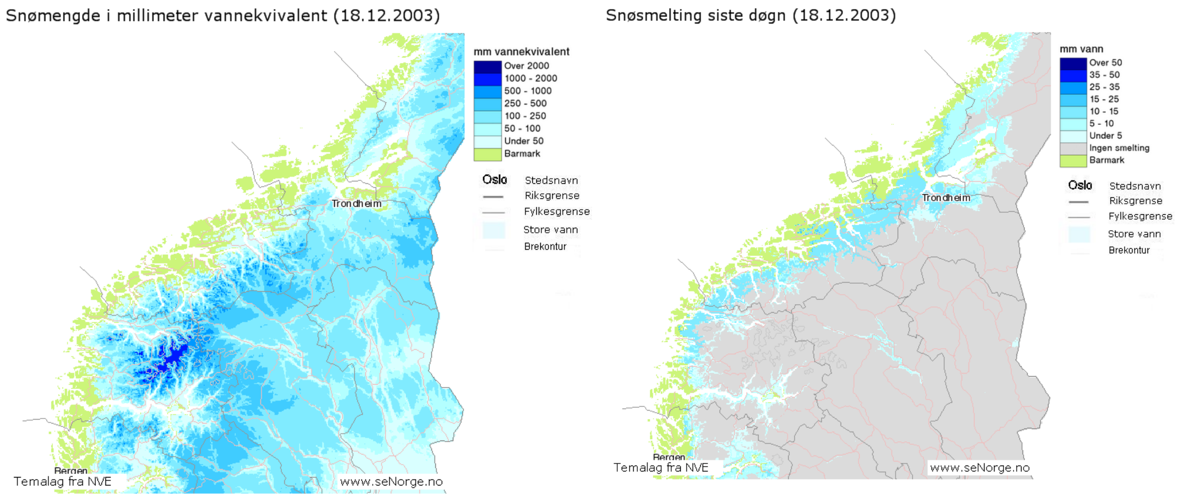
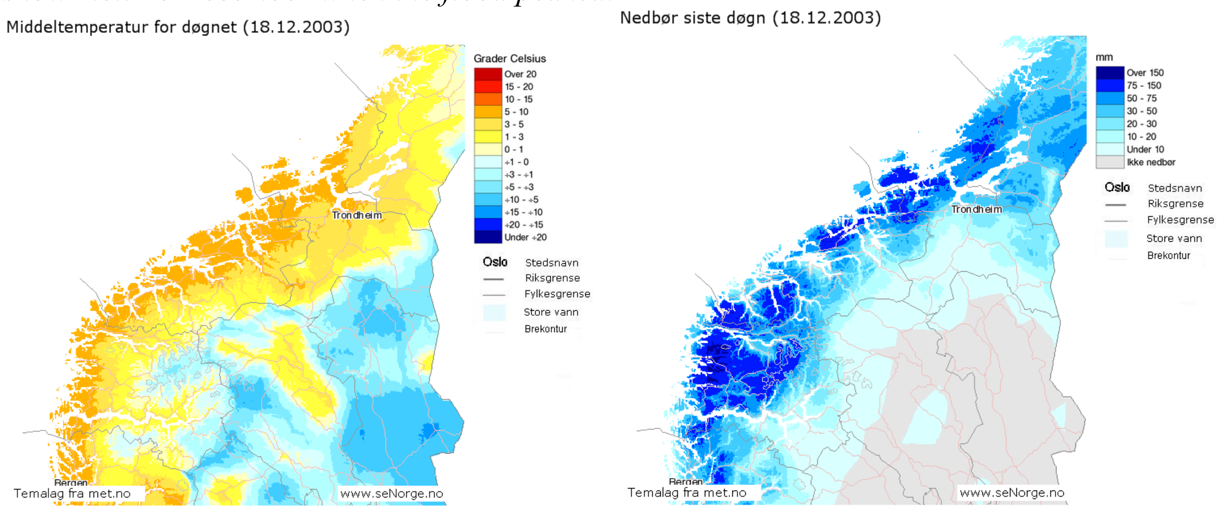


Figure 3.64.2 The distibution of the snow reservoir and the contribution to the flood from snow melt 18 December when the flood peaked.



Figur 3.64.3 Air temperature and the distribution of the precipitation 18 December.

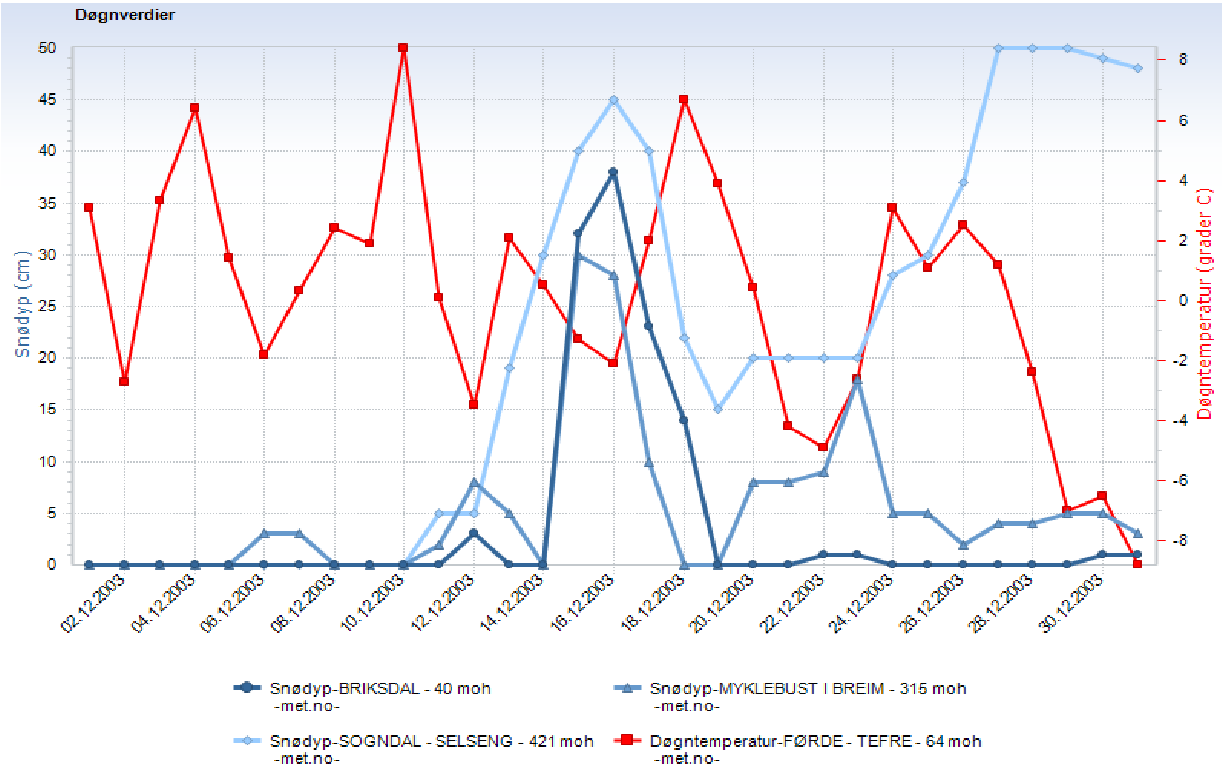


Figure 3.64.4 The air temperature at Tefre at Førde and observed snowdepth at Sogndal, Briksdal and Breim.

An anticyclone with warm core was located over the Europeian mainland extending towards Sørlandet 17-20 December 2003. A depression in the Norwegian Sea moved towards West Norway. The front moved in over the coast of Vestlandet 18 December. The wind shifted to northwest caused showers over the coast in the consequtive days. Weather types were **WZ** (Grosswetterlagen) and **A/ASW/NW** (Lamb-Jenkinsson).

3.65 Flood at Fjærland and slide at Suphellerdalen 7-8 May 2004.

Warm air and rainfall caused melting of remaining snow and glacier ice at Supheller glacier. Meltwater filled a basin next to the glacier. The basin was dammed by moraine masses on the other side and the water broke through this dam, causing mudflow down the Suphellerdal towards the farm Supheller. The mild weather affected smaller catchments with some remaining snow at several locations in inner Sogn. Figure 3.65.1 show observed daily precipitation and discharge in some rivers in the district. There are unfortunately no measurement in Suphellerdalen.

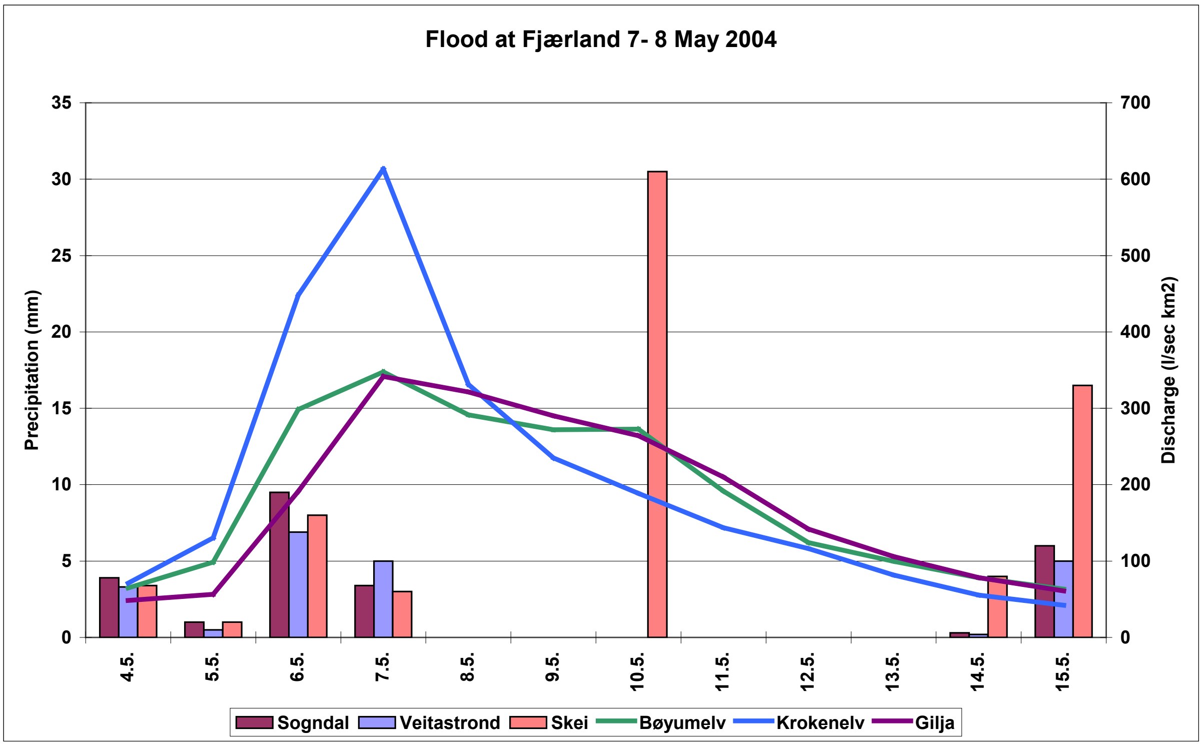


Figure 3.65.1 Observed precipitation and daily discharge in Sogn during the dam burst at Suphellerelva in May 2004.

The cause of the flood:

The event is caused by the same weather as caused the floods in East Norway 6-8 May. Warm air masses originally from southeast penetrated over East Norway with some rainfall in combination with intense melting of the remaining snow. The weather caused foehn wind in the west. The flood at Supheller was caused by melting since the amount of rainfall was low.

Weather types 6-8 May were **TRW/TM/TM** (Grosswetterlagen) and **C/CN/N** (Lamb-Jenkinsson).

3.66 Remnants of Hurricane Karl caused flood at Sunnmøre 27 September 2004.

The number of tropical hurricanes moving towards northwest Europe was exceptionally high in 2004 and 2005. Remnants of two tropical hurricanes and one tropical storm reached the coast of West Norway and Trøndelag. The remnants of Hurricane Frances had caused extensive damages in Florida before the remnants struck til Trondheim district 21 September.

The remnants of Hurricane Karl reached the coast of West Norway at Sunnhordaland causing floods from Sognfjord to Sunnmøre 28 September. Figure 3.66.1 show observed daily rainfall and discharge at stations in West Norway. Observed dicharge and precipitation is shown in Figure 3.66.1. The distribution of the rainfall 7 and 8 Septemver is shown in Figure 3.66.2.

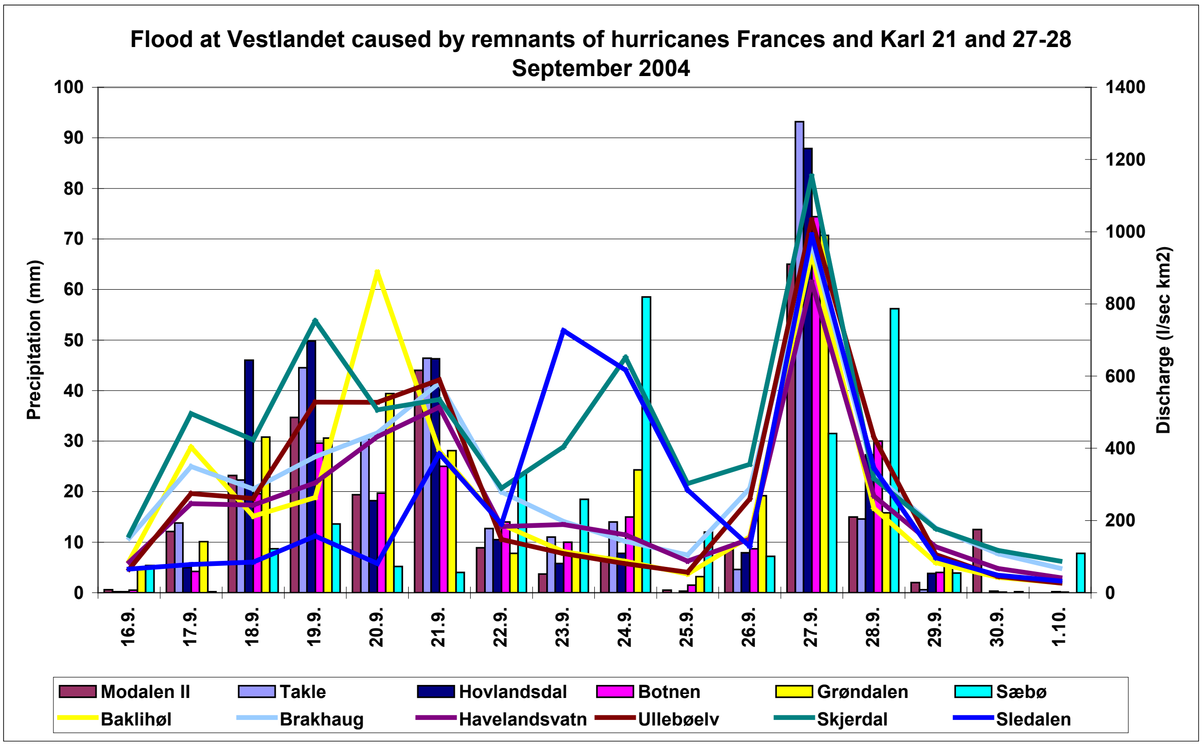


Figure 3.66.1 Observed precipitation and daily runoff at stations in western Norway during the passage of remnants of Hurricanes Frances and Karl in September 2004.

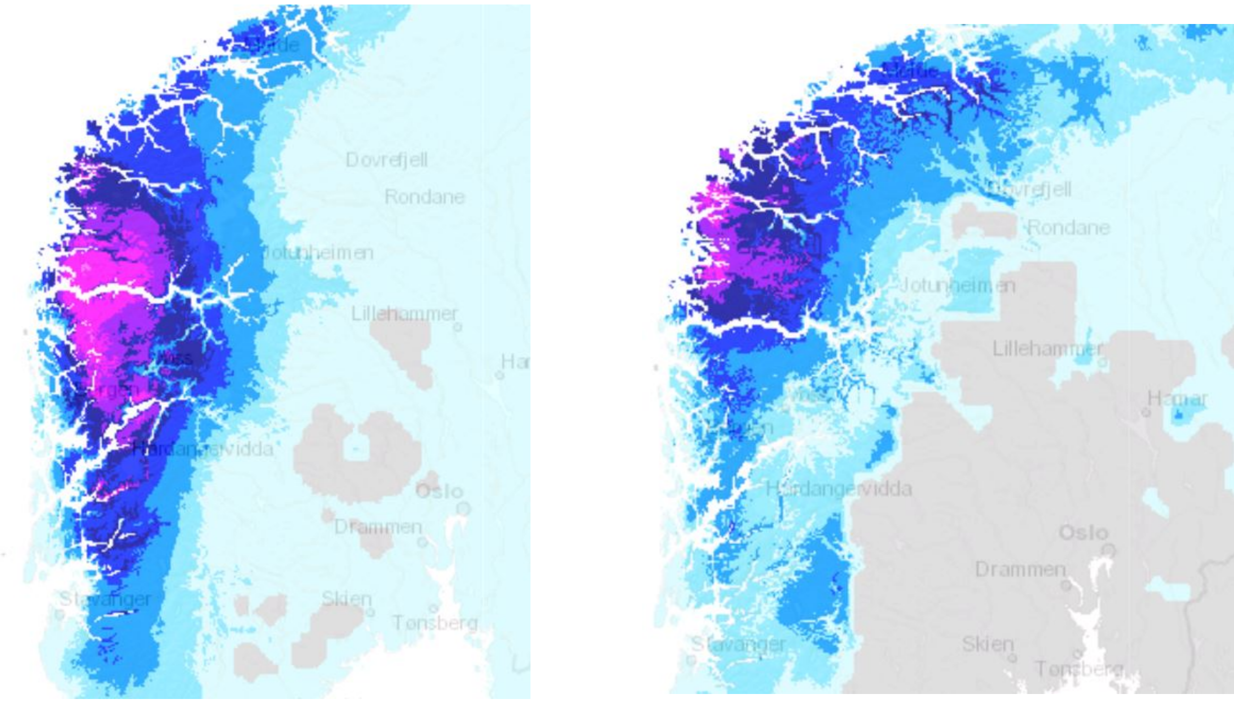


Figure 3.66.2 Distribution of the rainfall 7. - 8. September 1966 from the remnants of Hurricane Karl.

The most severe damages caused by Karl occurred at Ørsta and Vanylven at Sunnmøre. There were, unfortunately, no active gauging stations in this district during the flood. The discharge was also high in several rivers south of the Stad peninsula. It was third largest observed at River Åskora at Ålfoten 1985-2005. The discharge was as high in River Skjerdalselv where it was sixth largest 1982-2010 and in River Sægrova at Jølster. All these stations have some contribution to the discharge from glacial melting. The flood in Sledalen at Volda was largest observed 1996-2010.

The cause of the flood:

Figure 3.66.3 show the trajectories of the tropical cyclones in the North Atlantic in 2004. Tropical Hurricane started as a strong tropical wave, which moved into the Atlantic from the west coast of North-Afrika 13 September 2004. Three days later the wave had developed into a tropical depression southwest of the Kapp Verde islands. Later same day it was upgraded to a tropical storm. The next day (17 September) **Karl** turned northwestwards weering later west-northwest den 18 increasing in strength to tropical hurricane. **Karl** turned northwestward 20 September until turning northeastward 22 September. Karl reached maximum strength 23 September. The maksimum windforce was 125 knots, and the minimum surface pressure was 938 hPA, corresponding to a categori 4 hurricane on the Safir-Simpson scale. Figure 3.66.4 show a satellite photo of Hurricane **Karl** when it was most intense.

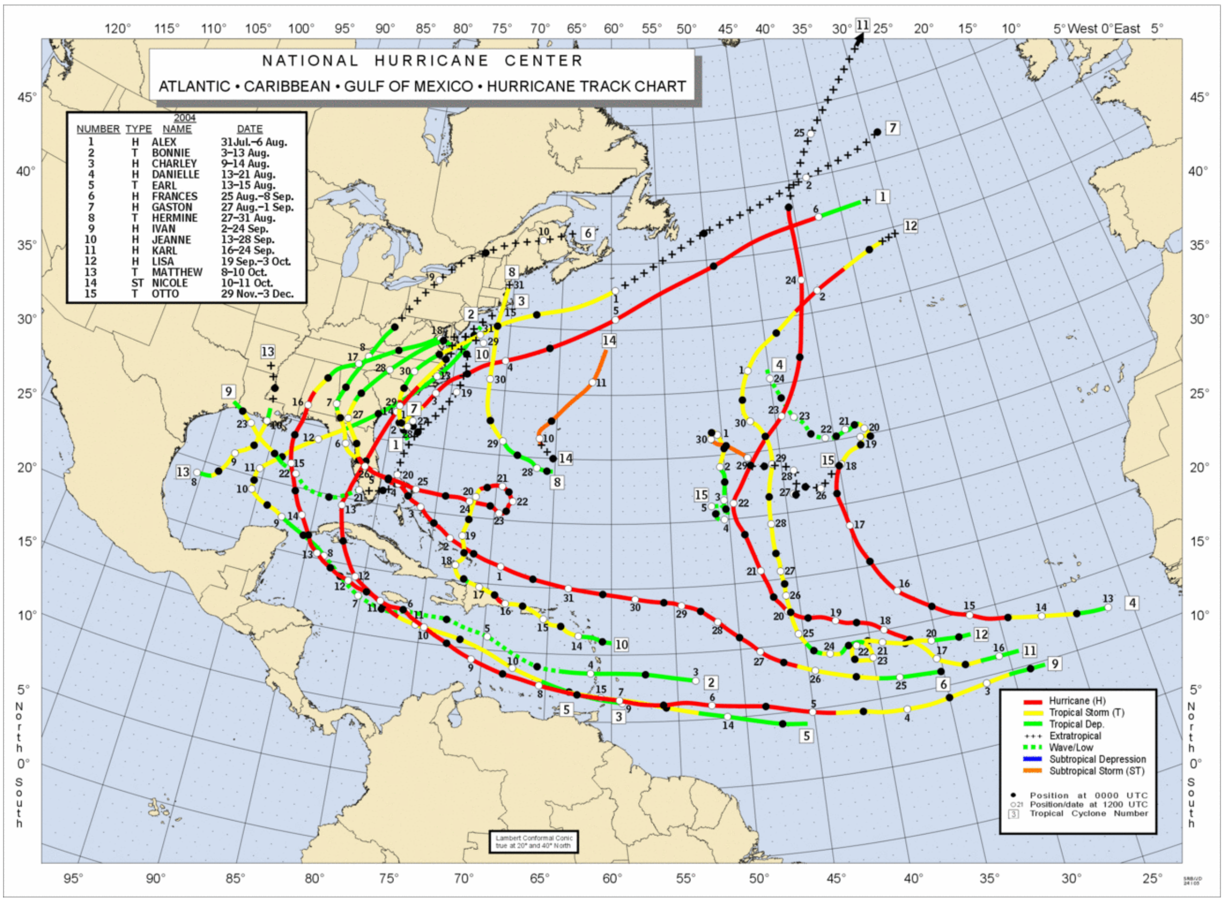


Figure 3.66.3 The trajectories of the tropical hurricanes in the North Atlantic in 2004. (Source: National Hurricane Centre)

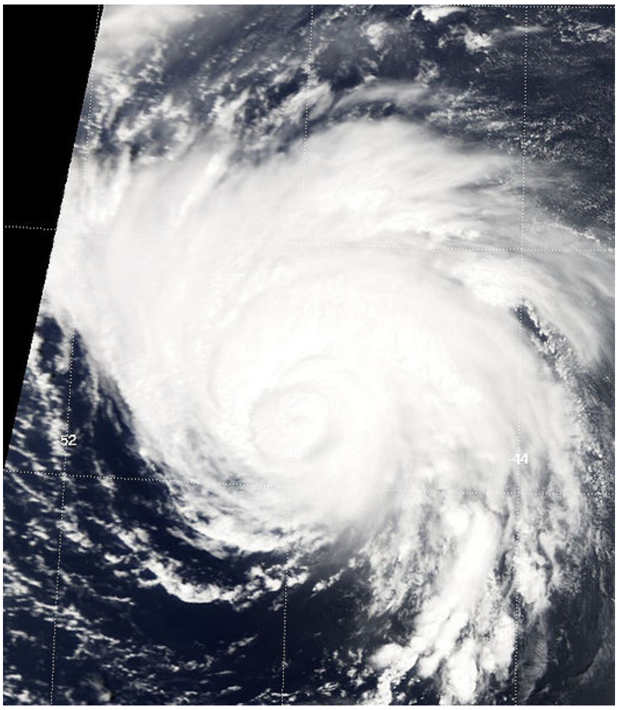


Figure 3.66.4 Hurricane Karl at its maximum strength 23 September 2004. (Source: National Hurricane Centre)

Hurricane Karl was one of several hurricanes and tropical storms in the North Atlantic in 2004. The locations of hurricane Karl and Jeanne and the tropical storm Lisa is shown in Figure 3.66.5.

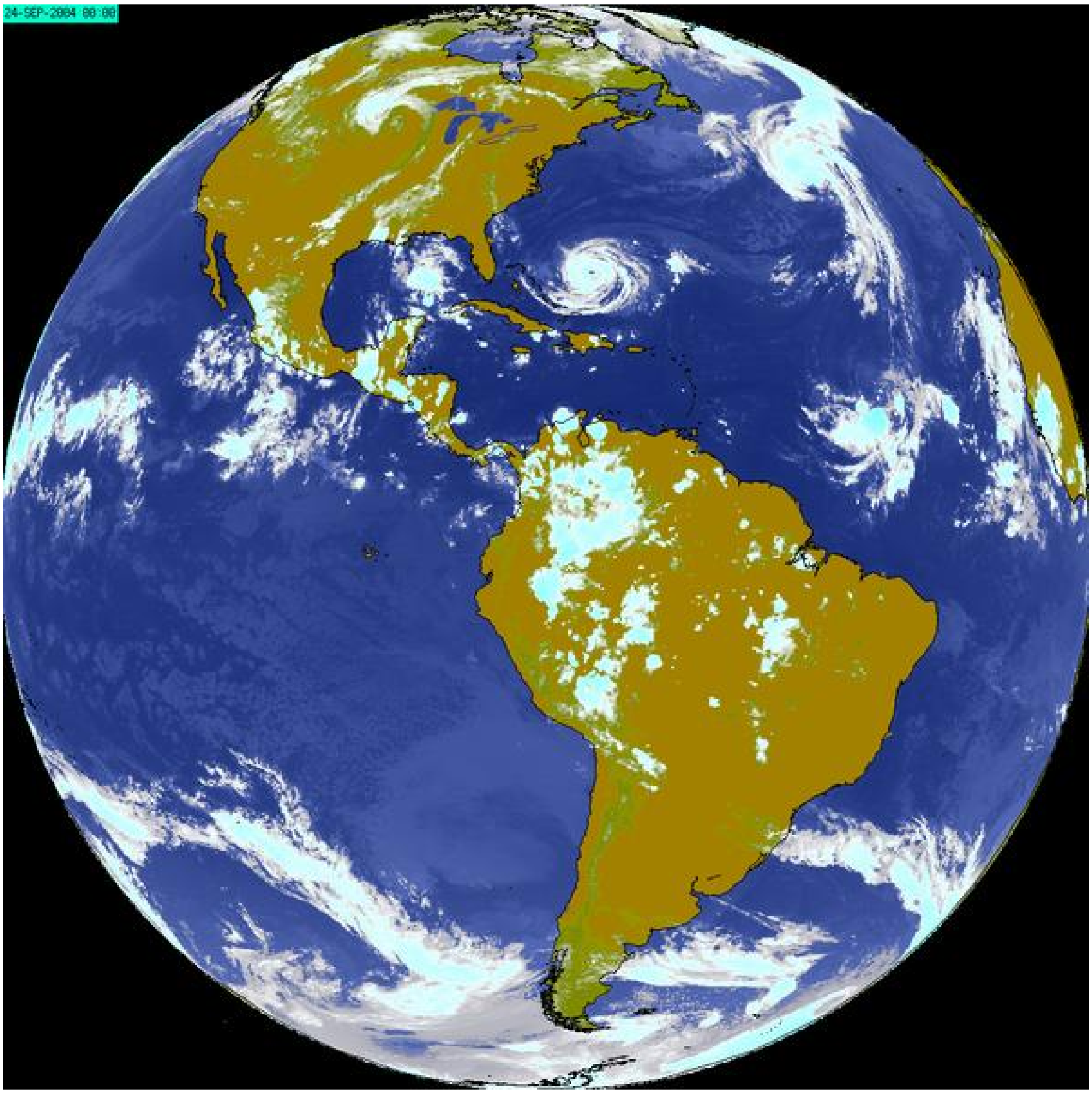


Figure 3.66.5 Satellite photo showing the location of Hurricanes Jeanne and Karl and the tropical storm Lisa.

Flood damages:

Heavy rainfall from midnight Monday 27 to 12 hrs, caused many small rivers to flow over many roads in Ørsta, Volda and Vanylven as the drainage systems overflowed. The banks along River Vikelv were inundated, and a number of shops were flooded. The main road, E-39, was also blocked as well as the road to Sæbø at Hjørungsfjorden. The road on the west side of Hjørungfjord from Standal was blocked as well as the road along the Dalsfjord. Three buildings were evacuated in Vanylven, where the village Sørdalen was insulated. The road to the village Alnes was blocked.

The damages to 70 insured properties was estimated to 10 Mill. NOK, and the damages to the roads and infrastructre to the same amount. The damages were exceeding of the damages at Sunn- and Nordmøre in 2003.

3.67 Floods and slides at Vestlandet 14-15 October 2004.

The subseqent floods occurring at Vestlandet was caused by polar front rainstorms moving in from the Atlantic. Coastal rivers at Sunnhordaland to Sunnfjord had rainfall floods occurring 12 and 14-15 November causing moderate floods. Observed discharge and precipitation is shown in Figure 3.67.1 at stations in Sunnhordaland and at stations further north in Figure 3.67.2.

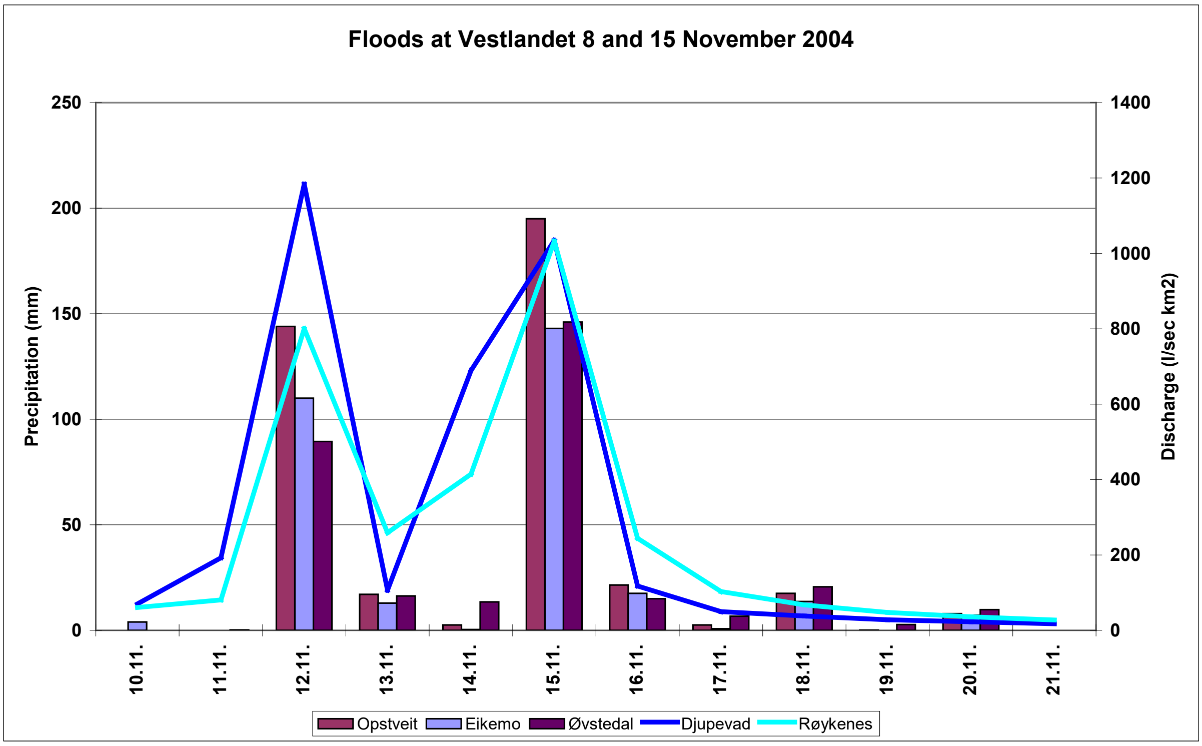


Figure 3.67.1 Observed precipitation and discharge at coastal stations at Vestlandet

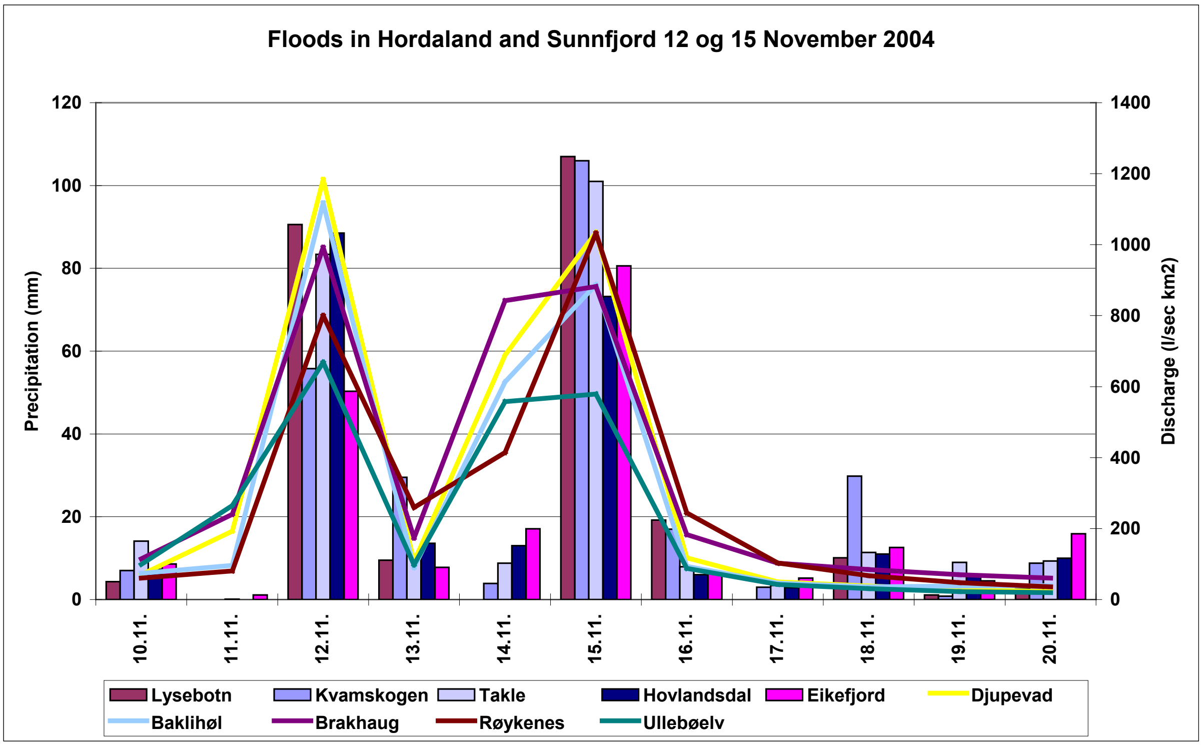


Figure 3.67.2 Observed precipitation and daily discharge in Hordaland and Sunnfjord i November 2004.

The cause of the flood:

During the flood 14-15 November an anticyclone was located at the Atlantic southwest of Ireland. A low was located north of Iceland, setting up transport of humid and mild air towards the coast of western Norway. Another low was located across Novaja Sembla in the Arctic. This low was linked with a through extending to another low located over the Mediteranien north of Tunisia. The air temperature was 8-9° at lowland stations in the district. A cold front caused the temperature to drop 16 November, causing a spell of snowfall 18-27 November. The weather type 12-15 November were **BM** (Grosswetterlagen) and **NW**, **AN**, **AN**, **W** (Lamb-Jenkinsson).

3.68 Floods in coastal basins at Vestlandet 5 December 2004

Another flood occurred 4-5 Decembere 2004 in Hordaland and Sunnfjord. Observed rainfall and discharge is shown in Figure 3.68.1.

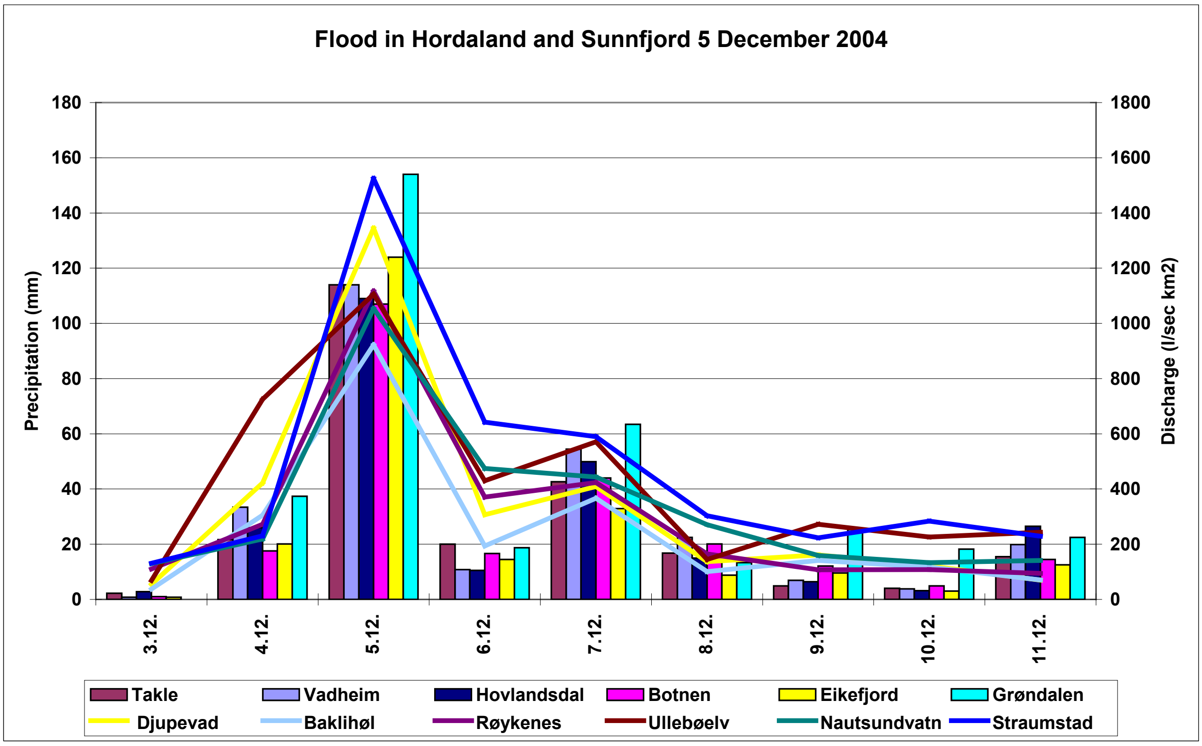


Figure 3.68.1 Observed precipitation and daily discharge in Hordaland and Sunnfjord 5 December 2004.

The cause of the flood:

During the flood 4-5 November an anticyclonic ridge was located at the Biskay south of Ireland and England, extending over France to Poland. A low was located at the Norwegian Sea west of Lofoten, setting up transport of humid and mild air from southwest towards the coast of western Norway. After the colder spell in the second half of Nowember, the temperature again rose to 8-9° at lowland stations in the district, causing the snow to melt. The weather type 4-5 December was: **BM** (Grosswetterlagen) and **AW** (Lamb-Jenkinsson).

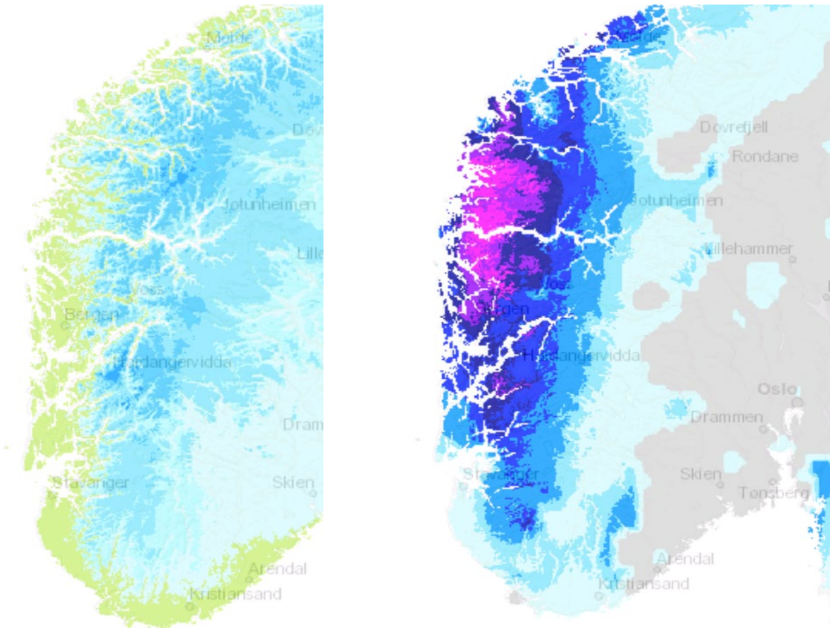


Figure 3.68.2 The distribution of the snow water equivalent and the precipitation on 5 Decenber 2004 at Vestlandet.

3.69 Rainstorms at Vestlandet caused by remnants of Hurricanes Maria and Nate (extreme weather Kristin) 14 September 2005.

Extreme rainfall caused floods at Vestlandet 14 September 2005, especially on the Bergen peninsula. The rainstorm caused several landslides. Figure 3.69.1 show observed daily rainfall and discharge at selcted stations in Ryfylke and Hordaland. Figure 3.69.2 show rainfall and discharge observed with high temporal resolution at the Sandsli catchments in Bergen. Figure 3.69.3 viser daily rainfall and discharge at stations in Sogn og Fjordane.

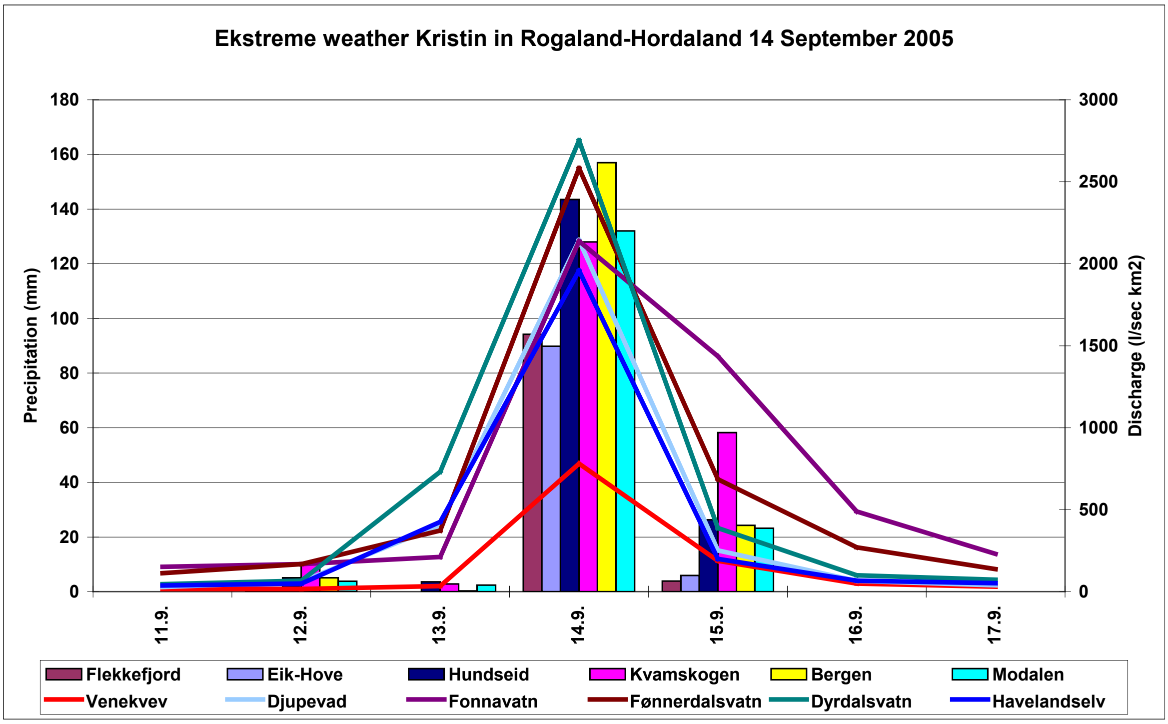


Figure 3.69.1 Observed precipitation and daily discharge in Rogaland and Hordaland 14 September 2005.

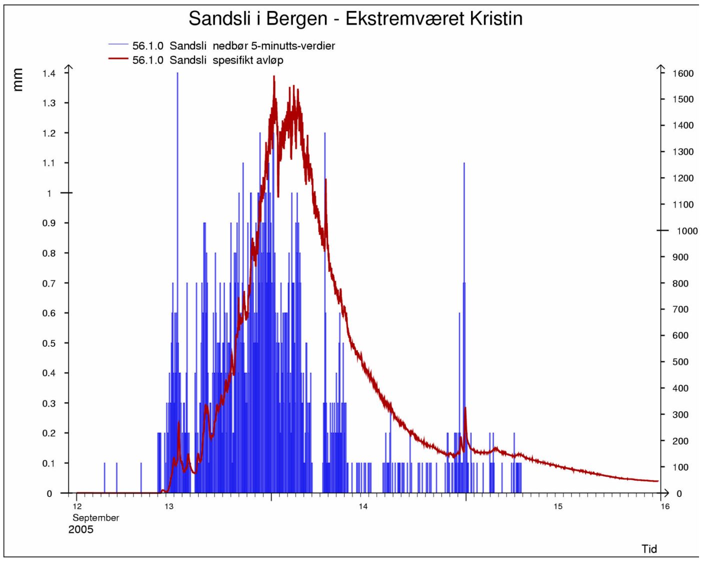


Figure 3.69.2 Observed rainfall and discharge at the Sandsli urban research basin at Bergen 14 September 2005.

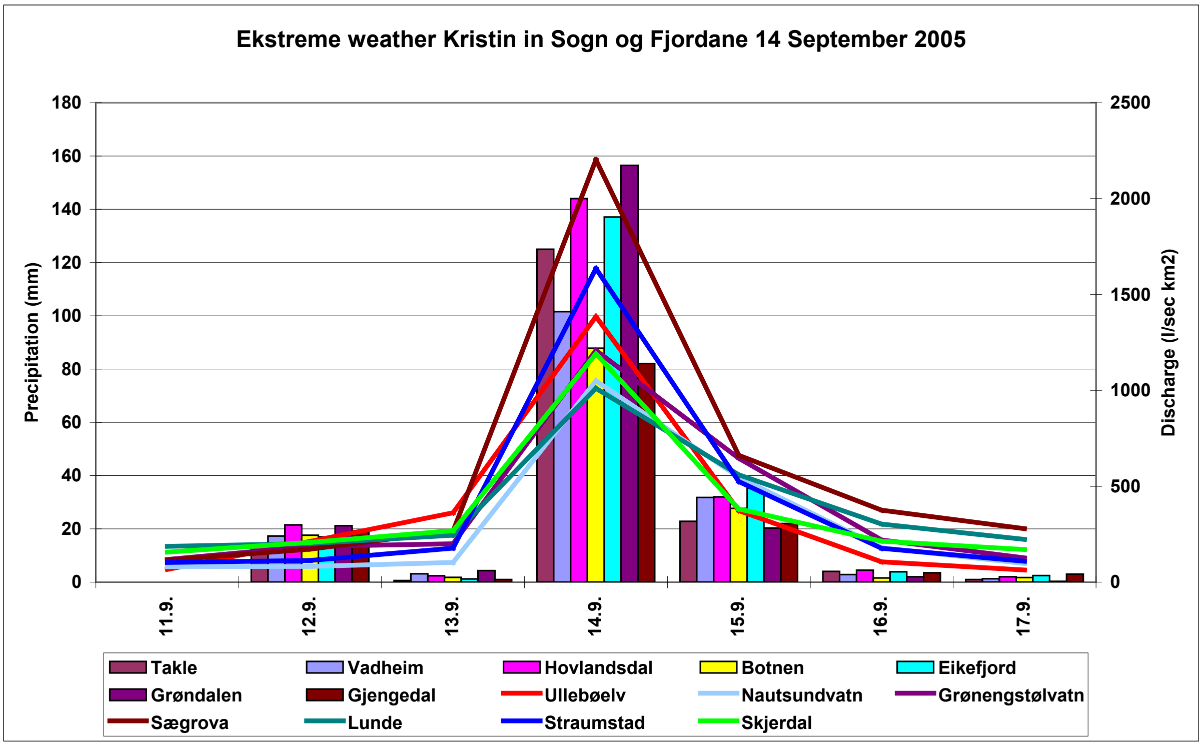


Figure 3.69.3 Observed precipitation and daily discharge in Sogn and Fjordane 14 September 2005.

Figure 3.69.4 show the distribution of the rainfall 14 and 15 September. Maximum one-day rainfall was observed at Opstveit in Kvinnherad of 180 mm den 14 September. At Bergen and at Grøndalen in Nordfjord 156 mm was observed. At least 16 stations exceeded 100 mm this day.

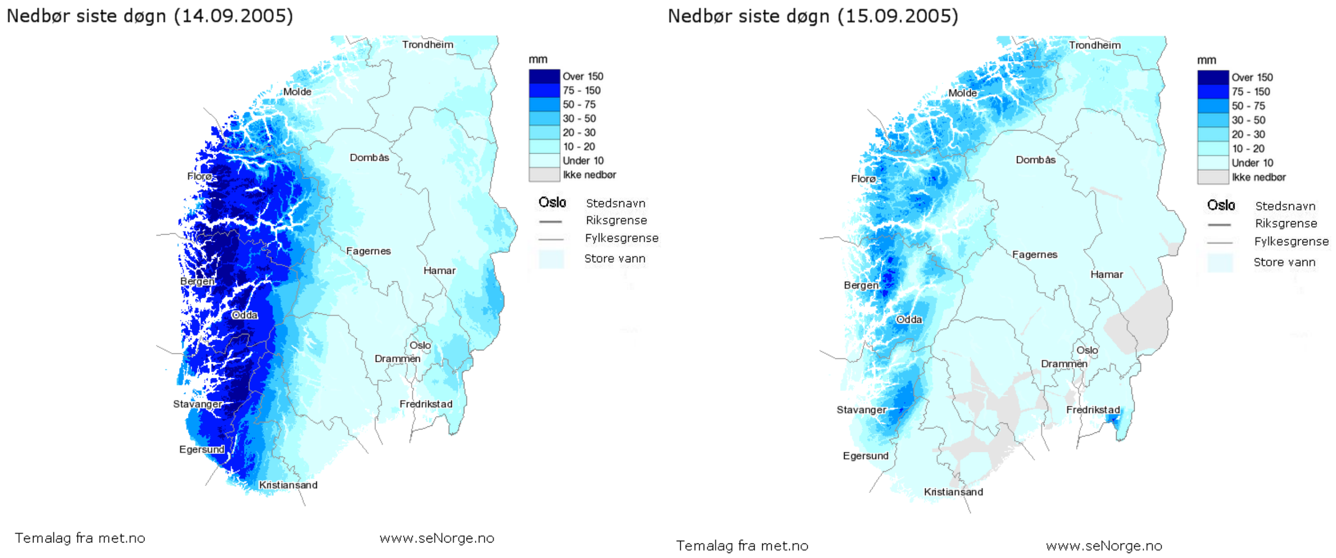


Figure 3.69.4 The distribution of the rainfall during the extreme weather Kristin 14 and 15 September 2005.

Cause of the flood:

A strong tropical wave moved from the west coast of North Africa and into the eastern part of the tropical Atlantic 27 August. The next day two disturbances appeared with strong and deep convection and indications of initial circulation. One of the disturbances moved towards the Kapp Verdeøyene where it disappeared. The other disturbance moved west- and later northwestward and was classified as a tropical depression 1 September. The depression intensified and was reclassified as Hurricane **Maria** 4 September.

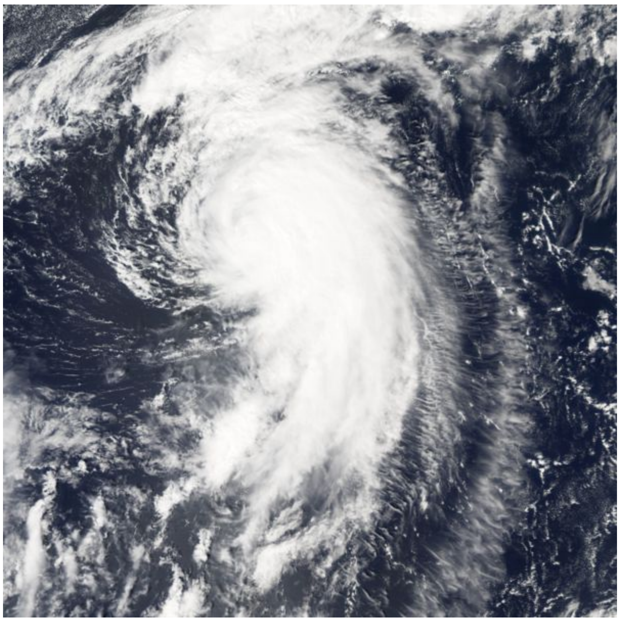


*Figure 3.69.5 Hurricane **Maria**. (Source: National Hurricane Center)*

A tropical wave moved from the west coast of North Afrika into the eastern part of the tropical Atlantic 30 August 2005. The wave moved west-northwestward until it approached the Leeward Islands where it split into two parts. The southern part moved into the Caribian, while the northern part moved between the Leeward Islands and Hurricane **Maria** 3 September. This part developed into a tropical depression southwest of Bermuda 4

September. The cyclone moved northeast towards Bermuda the next two days. **Nate** achieved its maximum force 9 September as a Categori 1 hurricane in the Safir-Simpson scale.

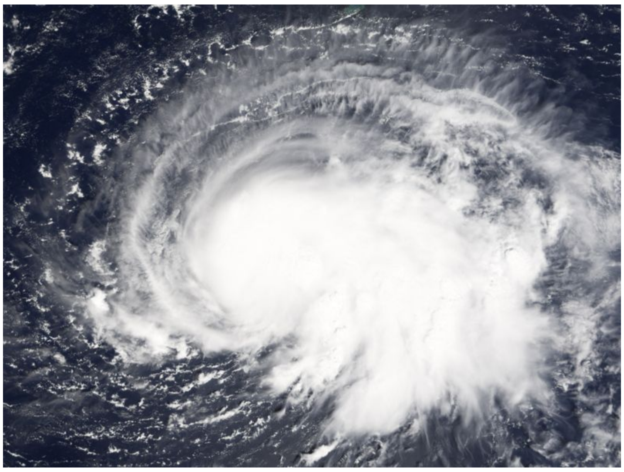


*Figure 3.69.6 Hurricane **Nate**. (Source: National Hurricane Center)*

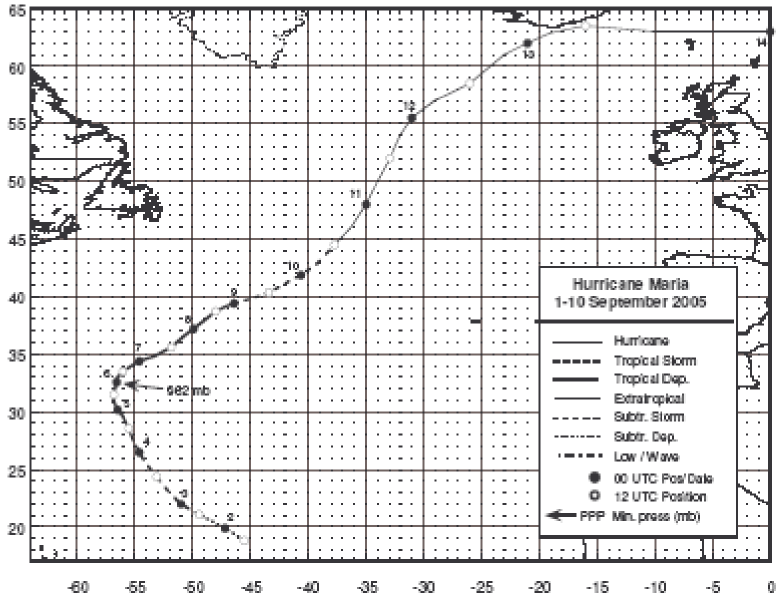


Figure 3.69.7 Location of Hurricane ***Maria*** *1-10 September 2005. (Source: National Hurricane Center. The trajectory in the ekstra-tropical phase is based on analyses of NOAA Ocean Prediction Center).*

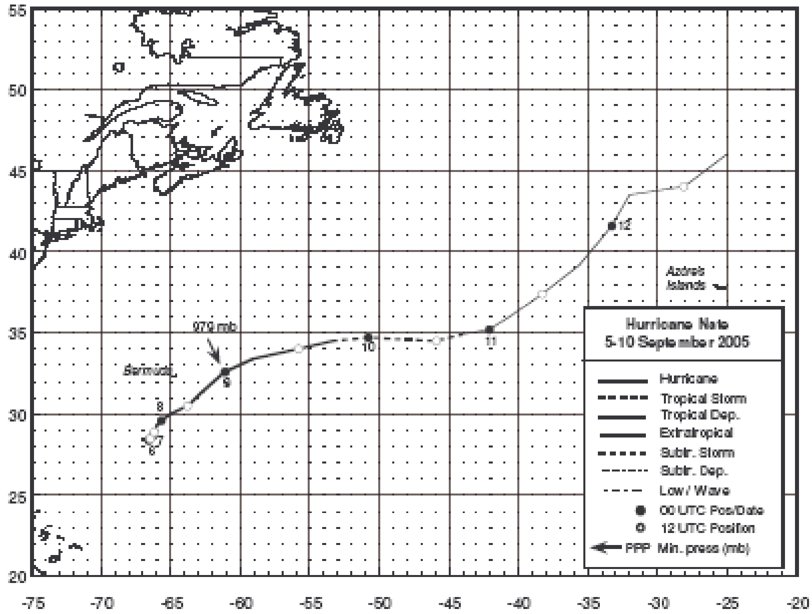


Figure 3.69.8 The location of Hurricane ***Nate*** *5-10 September 2005. (Source: National Hurricane Center. The trajectory of the extra-tropical phase is based on analyses of NOAA Ocean Prediction Center).*

Maria developed a well defined eye 5 September and achieved its largest force as a Categori 3 hurricane 6 September. Maximum wind force was around 100 knots and the minimum pressure 962 hPA. **Maria** was at that time located east of Bermuda. It moved northeastwards gradually weakening. The hurricane increased in strength 7 September to 75 knots, befor it started to weaken. The force was reduced to tropical storm 9 September, but was again reinforced after merging with an extra-tropical cyclone 10 September. It moved close to Iceland 13 and reached the coast of Norway 14 September etter å having merged with another extra-tropical cyclone 14 September.

Nate turned øst-northeastwards 9 September with increasing velocity. The intensitety decreased and in the evening of the same day was **Nate** down classified to tropical storm. It merged with an extra-tropical cyclone north- northeast of Azorene 13 September and moved together with **Maria** in over the coast of Vestlandet 14 September as the extreme weather **Kristin**.

Figure 3.69.9 show a composite satellitte photo for 14 September when the storm reached Norway. Varm and humid air masses were streaming towards Norway from the tropical part of the Atlantic. This weather type has caused many severe floods both in Great Britain an in Norway. Remnants of tropical cyclons can reach Norway from the coast of the North Sea to the Lofoten archipelago in Nordland.

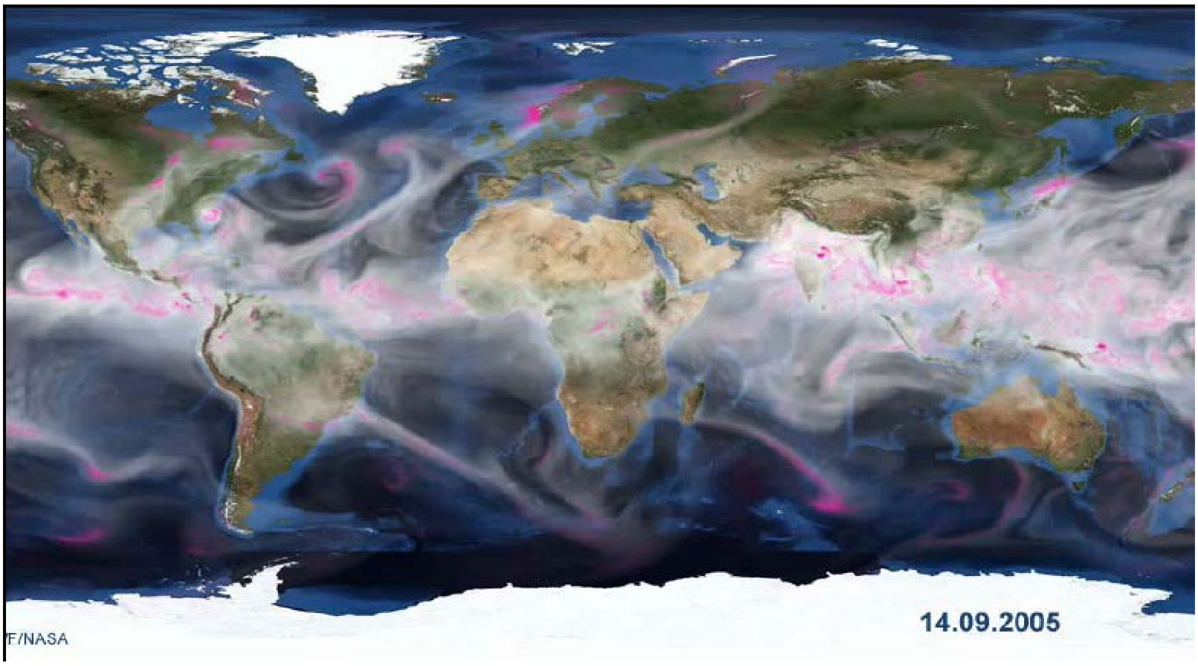
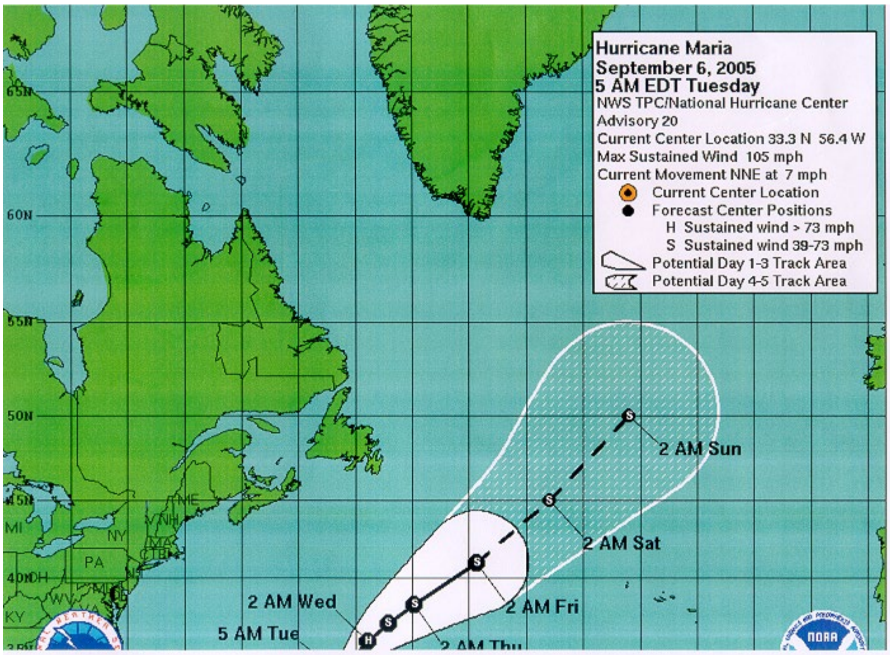


Figure 3.69.9 Composite satellitte photo of the weather 14 September 2005. (Source: NASA)

The weather type was classified as: BM (Grosswetterlagen) and ASW/W (Lamb/Jenkinsson).

Forecasts of the trajectories of the hurricanes:

National Hurricane Center issue forecast of the development and most likely trajectory of tropical storms and hurricanes after at they have developed into tropical depressions. These forecasts are available at NHC’s internett pages. Figur 3.69.10 show the expected trajectories of Hurricane **Maria** og **Nate**.



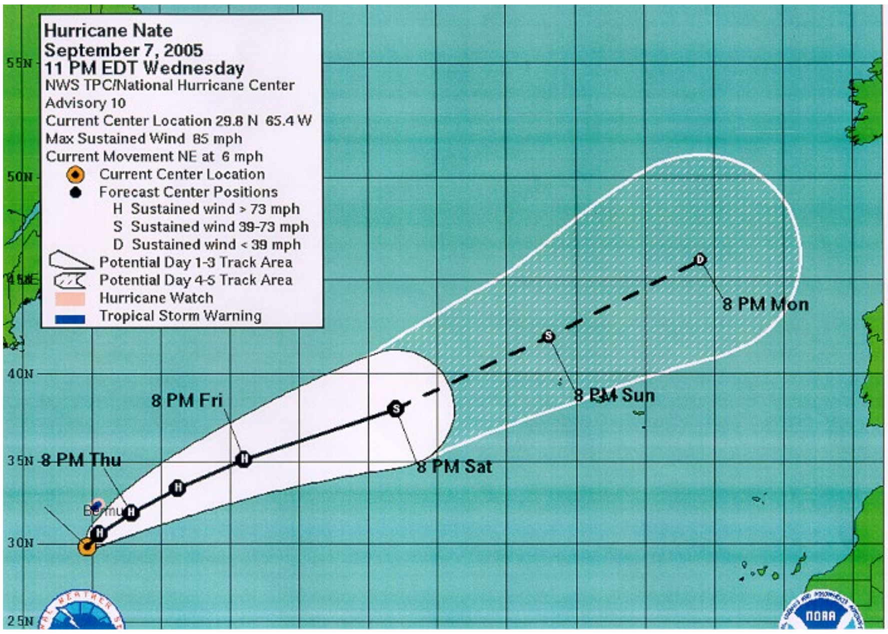


*Figure 3.69.10 Expected trajectory of tropical Hurricane **Maria** (top) and **Nate** (bottom)*

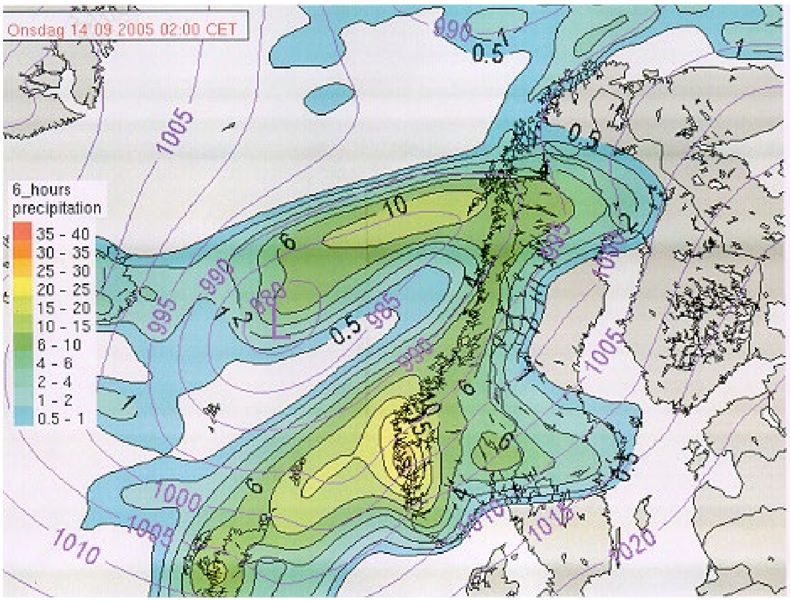


Figure 3.69.11 Forecast of the rainfall expected from extreme weather Kristin. (Source: Kilden)

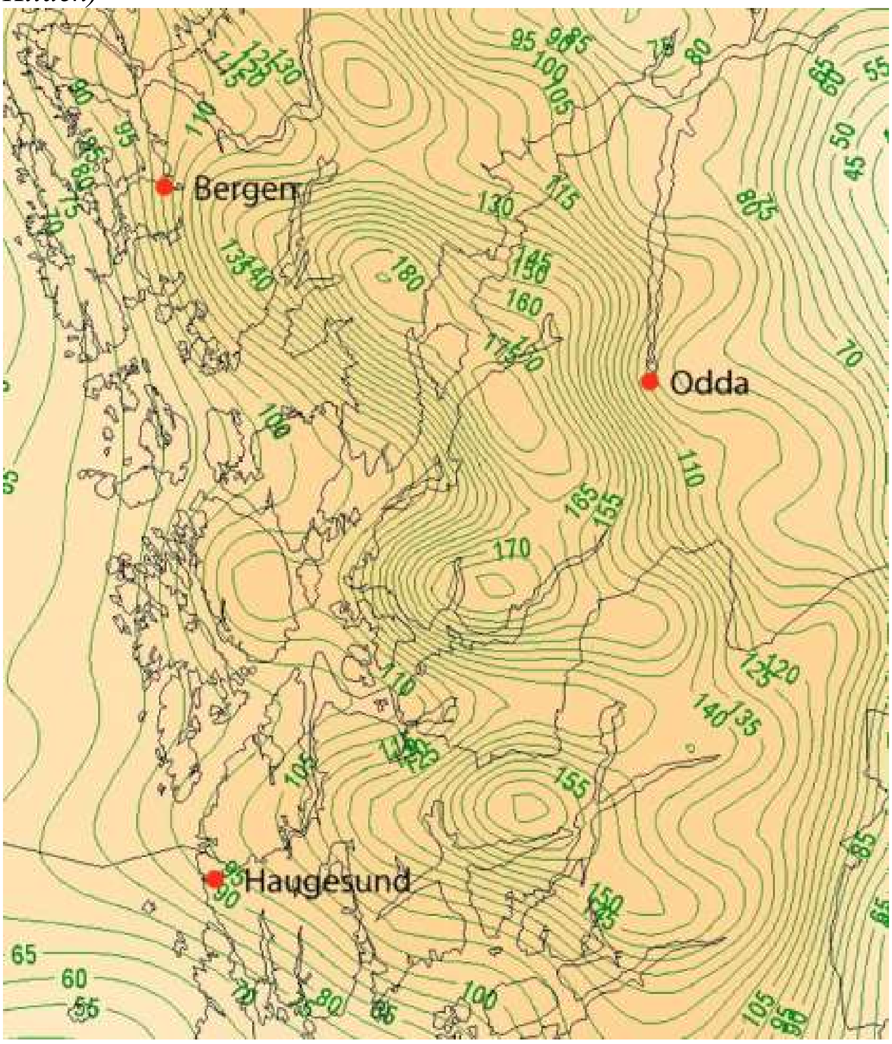


Figure 3.69.12 High resultion forecast of the one-day rainfall from ekstreme weather Kristin. (Source: met.no)

Damages caused by flood and landslides:

Heavy rainfall caused a landslide, which devastated homes in Hatlestad terrasse in Fana in Bergen. Five terrace houses were damaged by the slide, whick occurred half past one in the night. The heavy rainfall increased the pore water pressure between the bedrock and soil in the slopes above the buildings, causing erosjon in the slope. A water pipe collapsed because of the pressure at 17 hrs 13 September, causing additional water to penetrate into the ground, causing the risk of further sides to increase more. Rocks and soil jord penetrated into a number of houses, and ten persons were buried by the slides. One person was killed directly and the other nine were treated at the hospital. One woman and a girl died later. Many inhabitants in the neighbourhood were evakuated. In total 128 people were insolated when the only access road was damaged. The muncipality bought 16 houses, which were later demolished. The State gave 24,7 millions in compensation to five muncipalties affected by **Kristin**. The city Bergen got 18,8 millions of which 12,2 millions was granted for securing Hatlestad terrasse. The other muncipalities which were compensated from the State after **Kristin,** were Voss, Fjell, Vaksdal and Odda. 558 properties obtained compensation from the insurance companies of 78 million kroner.

3.70 Rainstorm at Vestlandet caused by the extreme weather Loke – 14-15 November 2005.

The humid weather with rainfall continued through the first half of November 2005 at Vestlandet. The rainfall peaked 14-15 November when Vestlandet a second extreme weather causing severe flooding in small and medium sized catchments vassdrag in the outher and middle districts from Rogaland to Nordfjord. Warning of the extreme weather was issued in advance by the Meteorological Institute. The extreme weather was named **Loke**. The rainstorm reached first Nordland, but the rainfall was most intense further south at Vestlandet. Figure 3.70.1 show observed rainfall and discharge in rivers in Rogaland and Hordaland. The heaviest rainfall occurred locally in these two counties, but heavy rainfall caused also flood in rivers further north at Vestlandet. Figure 3.70.2 show observed rainfall and discharges in rivers in Sogn og Fjordane.

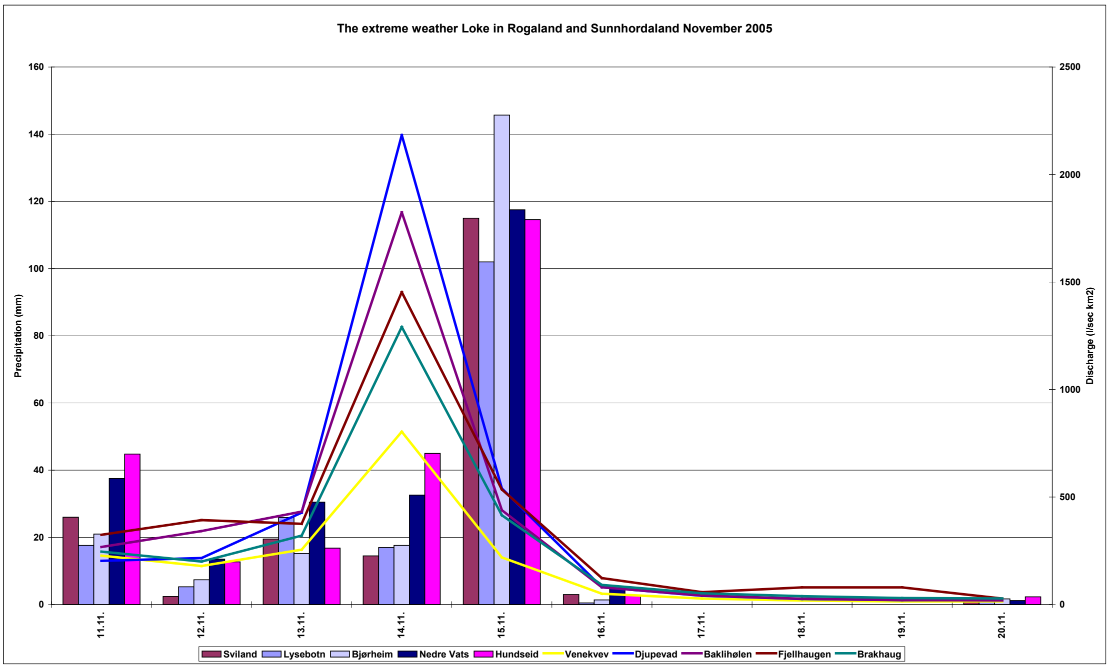


Figure 3.70.1 Observed daily precipitation and discharge at gauging stations in Rogaland and Hordaland.

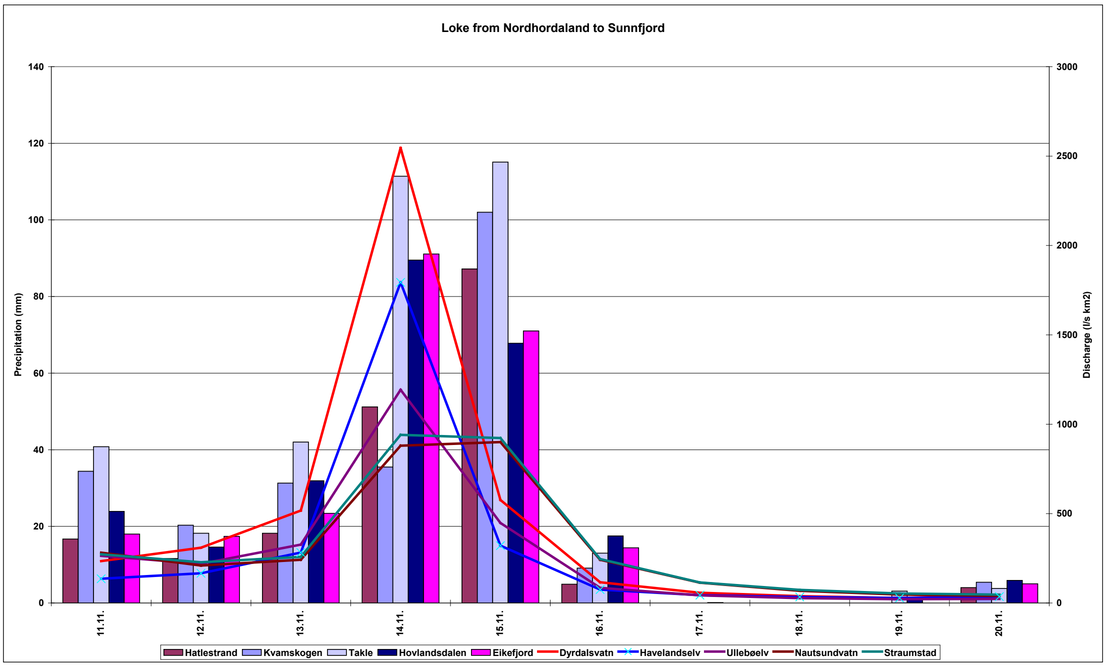


Figure 3.70.2 Observed daily precipitation and discharge at gauging stations in Sogn og Fjordane.

The most severe damages occurred in small watercourses where no discharge observations are available. Moderate floods were observed in the larger watercources at Jæren where the flood in River Bjerkreimselv ranks as the ninth largest since observations started in 1896. The flood was severe in streets at Jørpeland at Strand muncipality, but without discharge observations available. The flood at Lake Stordalsvatn at Etne was the fourth largest since the start of the observations 1912. The flood was the sixth largest since 1965 in River Skredalselv at Bakkelihølen. Severe flooding occurred in River Dalselv at Vaksdal, but observations are lacking. The flood in River Vosso was the fifth largest since the start of observations in 1892. The flood was the largest observed in River Nærøyelv since 1972 and in River Nessedalselv in Sogn since 1962. The return period of the floods in Rivers north of the Sognefjord were generally lower than in rivers further south. Figure 3.70.3 and 3.70.4 show the distribution of the precipitation 9- 12 and 13- 16 November respectively.

Bergen noted a new one-day rainfall record 14 November 2005 of 134.2 mm. The old record was observed at the old met station Bergen I (Pleiestiftelsen) in November 1917. At Takle in Gulen in Sogn og Fjordane 198.5 mm was observed, and at Opstveit i Sunnhordaland was observed a one-day rainfall of 223 mm.

Cause of the flood:

The satellite image in Figure 3.70.5, show that warm and humid air masses is flowing as an atmospheric river towards the west coast of Norway from the tropical part of the North Atlantic similar to what happened in September when West Norway suffered from the ekstreme weather **Kristin**. The extreme weather **Loke** however, did not carry remnant of a tropical cyclone in the airstream from southwest. The amount of rainfall was nevertheless locally as high as that caused by ekstreme Weather **Kristin**.

Figure 6 show daily weather maps 12 – 16 November. A deep low located west of the Norvegian coast produced the heavy rainfall 11- 12 November as shown in Figure 2. A high with a warm kernel west of the low forced the polar front northwards, and the varm air masses reached South-Norway den 13. A polarfront low succeded by a trailing cold front from the

Norwegian Sea caused heavy rainfall 14 November. The weather type was **BM** (Grosswetterlagen) and **AW/NW** (Lamb/Jenkinsson).

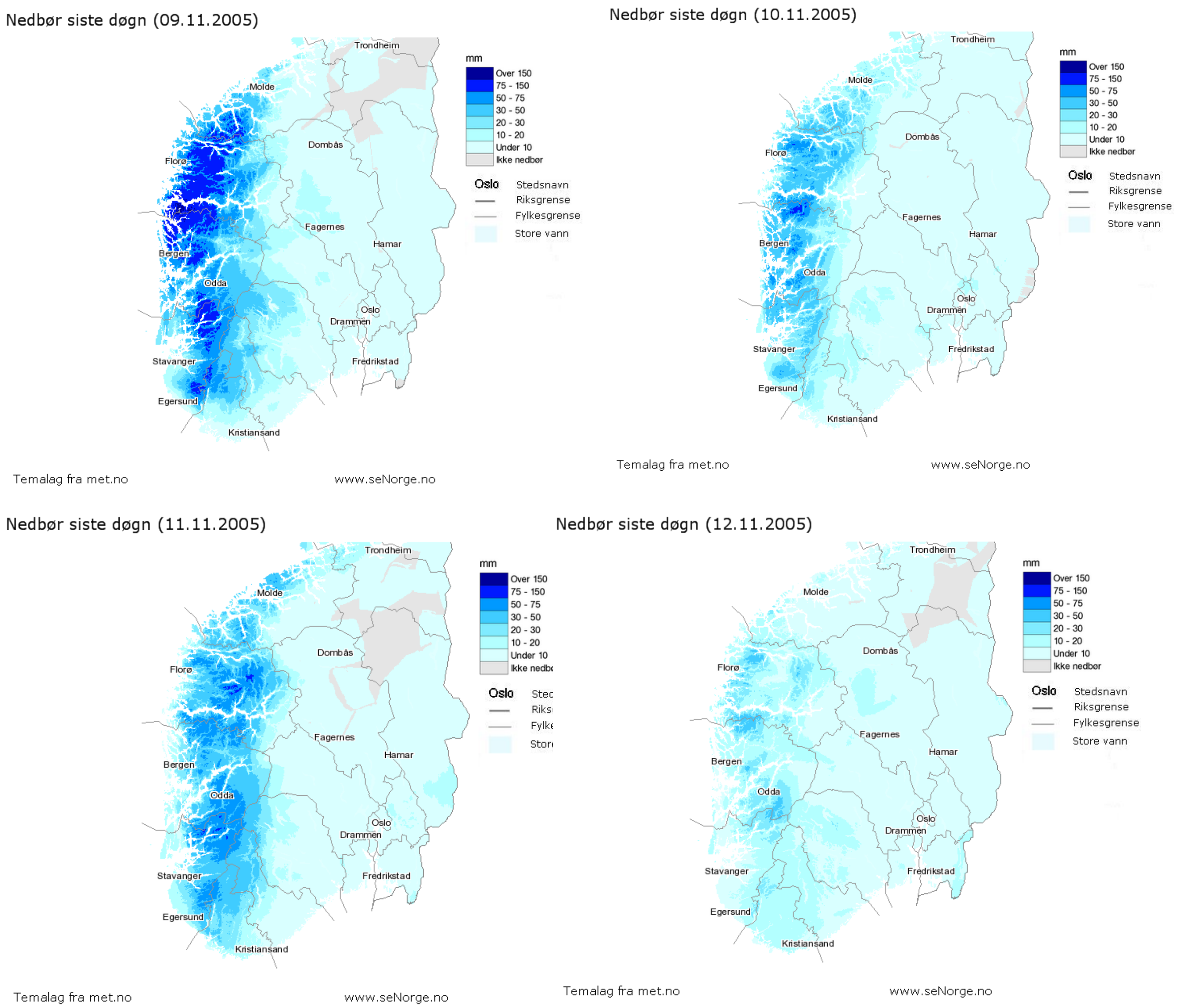


Figure 3.70.3 The spatial distribution of the precipitation in South Norway 9 – 12 November 2005.

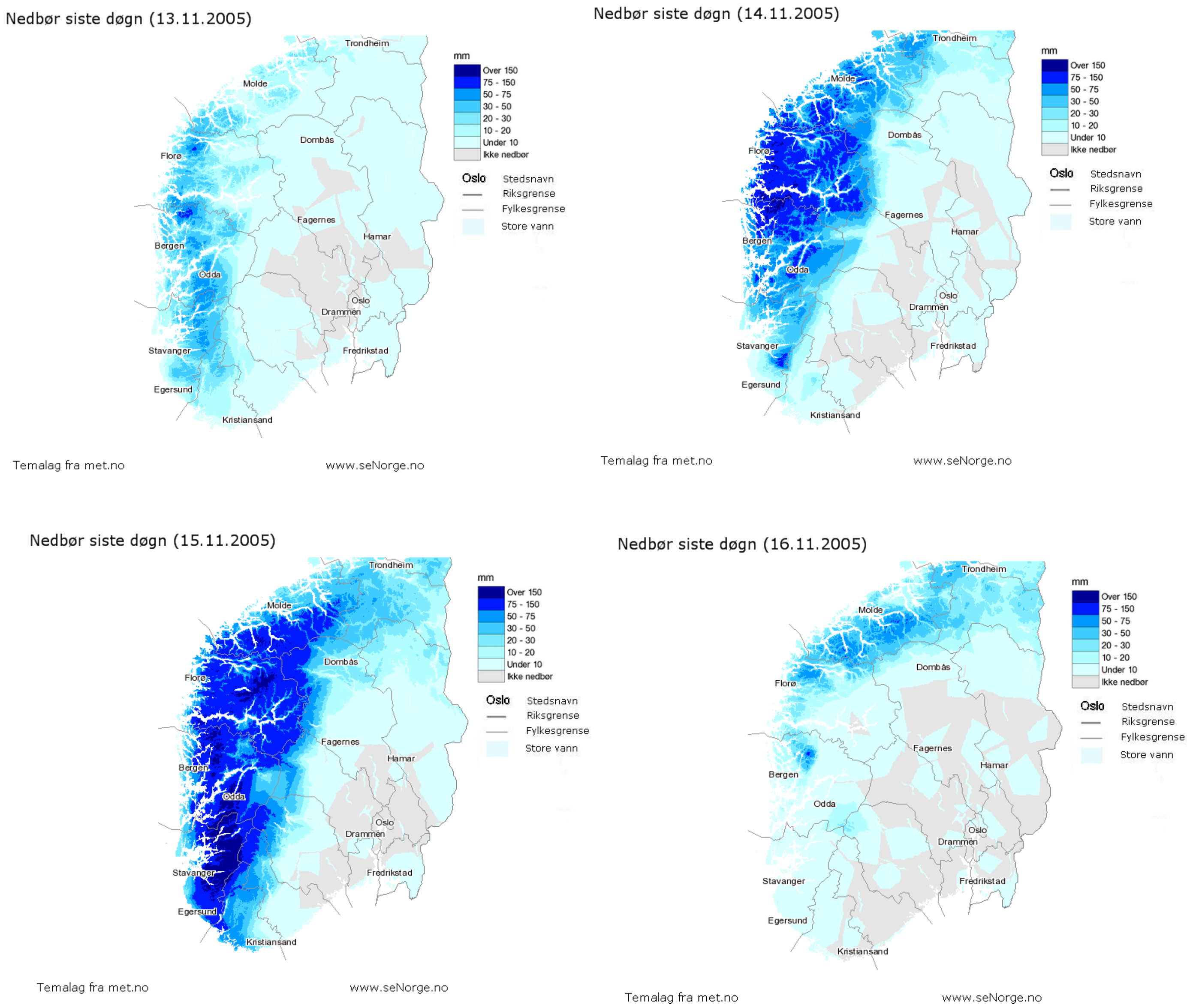


Figure 3.70.4 The distribution of the precipitation in South Norway 13 – 16 November 2005.

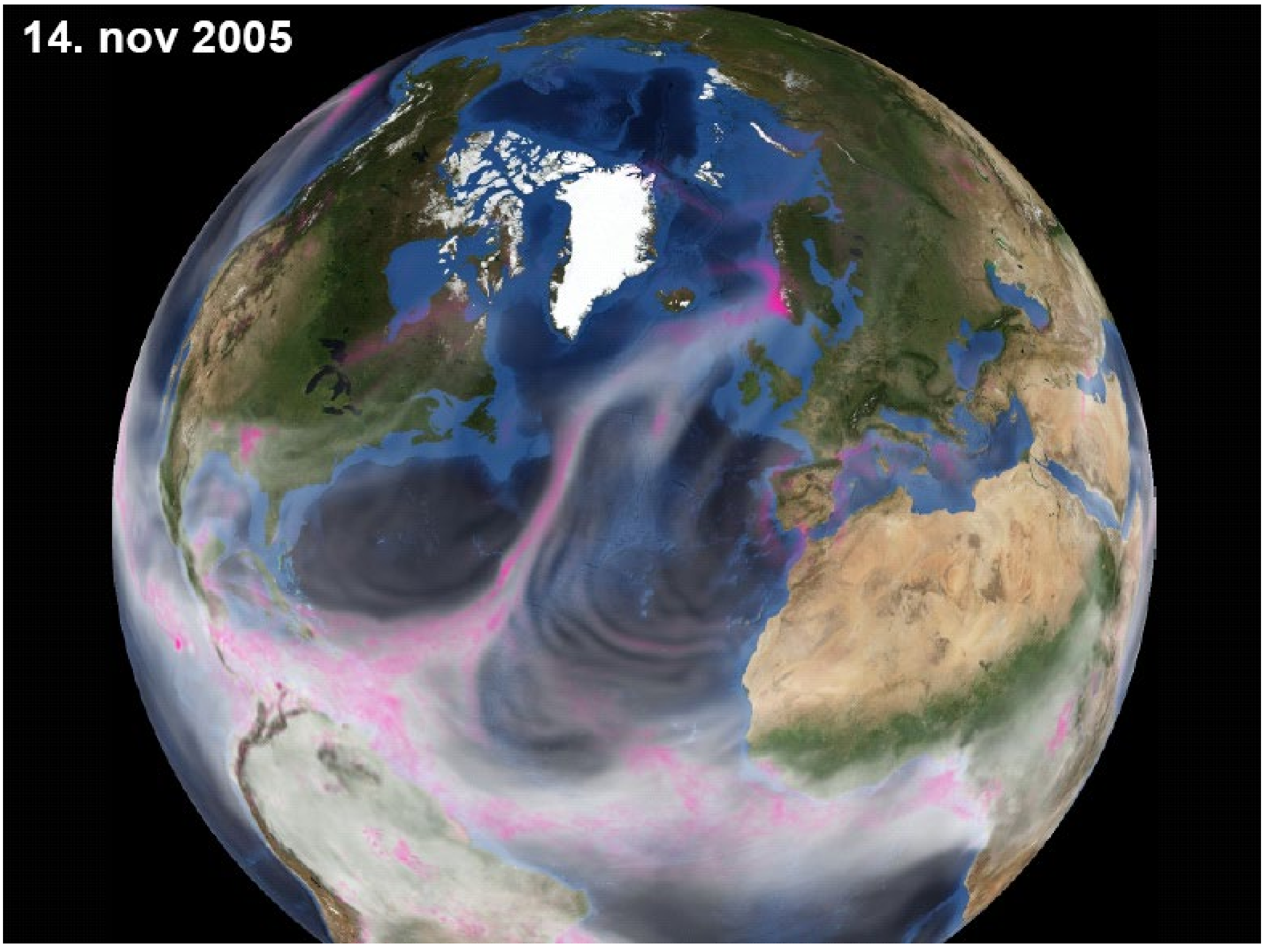


Figure 3.70.5 Satellite photo showing the large scale cirkulation which caused the ekstreme weather Loke. (Source: NASA)

Flood damages:

Number of damages: 786 from flood, 300 from extreme rainfall
Compensations: 61 mill NOK for flood damages
30 mill NOK for rainfall damages

3.71 Rainfall flood at Fjordane in October 2007.

An exceptional flood occurred in River Skjerdalselv 28 October 2007. The river is located at the western side of the Hyen fjord, a branch of Nordfjord running southwards. West of the the fjord are two extremely maritime glaciers, Gjegnalundbre and Ålfotbre located. The catchment of River Skjerdalselv includes parts of the Gjegnalundbre. Figure 3.71.1 show observed daily rainfall and discharge at stations located near the Hyen fjord.

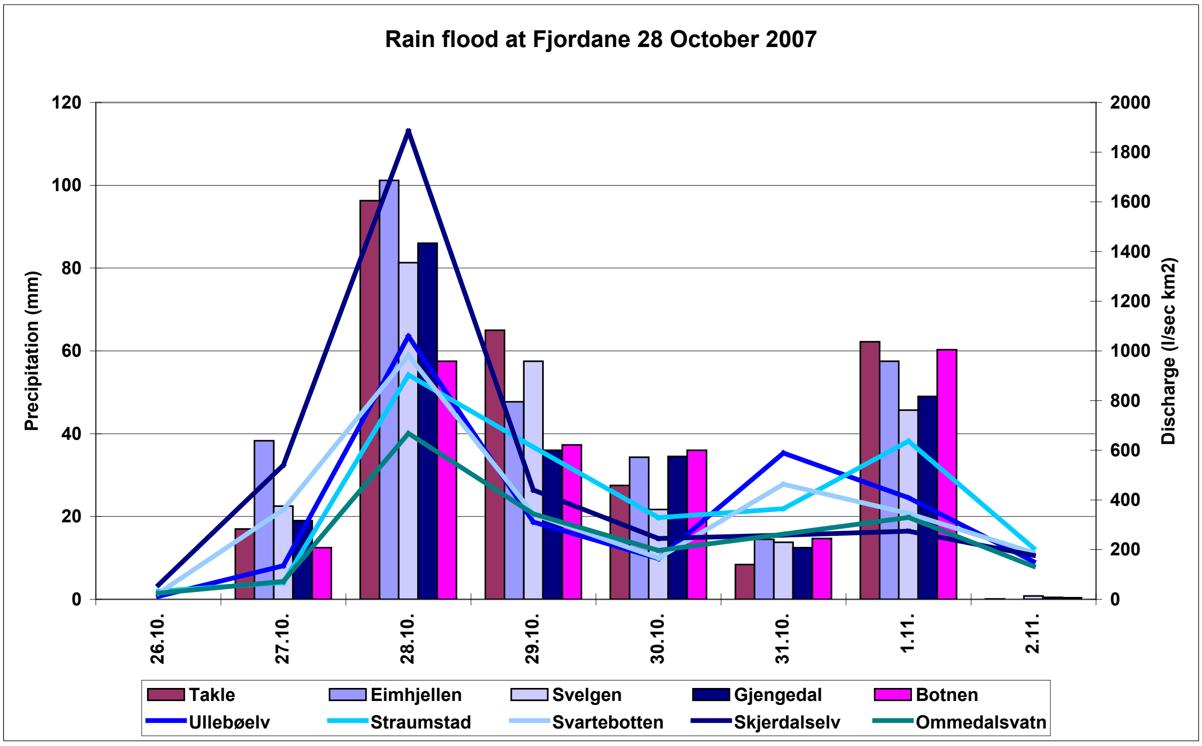


Figure 3.71.1 Observed precipitation and daily discharge during a large rainfall flood at Ytre Nordfjord and Sunnfjord 28 October 2007

Cause of the flood.

The catchment is located on the eastern side of the coastal maximum rainfall zone. Daily rainfall exceeding 100 mm occurs frequently in the district, especially south of the mountain plateau with the two glaciers.

An anticyclonic ridge extended southwestwards from northern Russia across Central Europe, France, Spain and into the Antlantic. A low was located south of Iceland extending into the Norwegian Sea. Mild air masses moved across Norway from southwest as an atmospheric river, causing locally heavy rainfall in west Norway from 27 October to 1 November. The weather type 27-30 October were: **BM** (Grosswetterlagen) and **SW**, **CW**, **W** and **AN** (Lamb Jenkinsson)

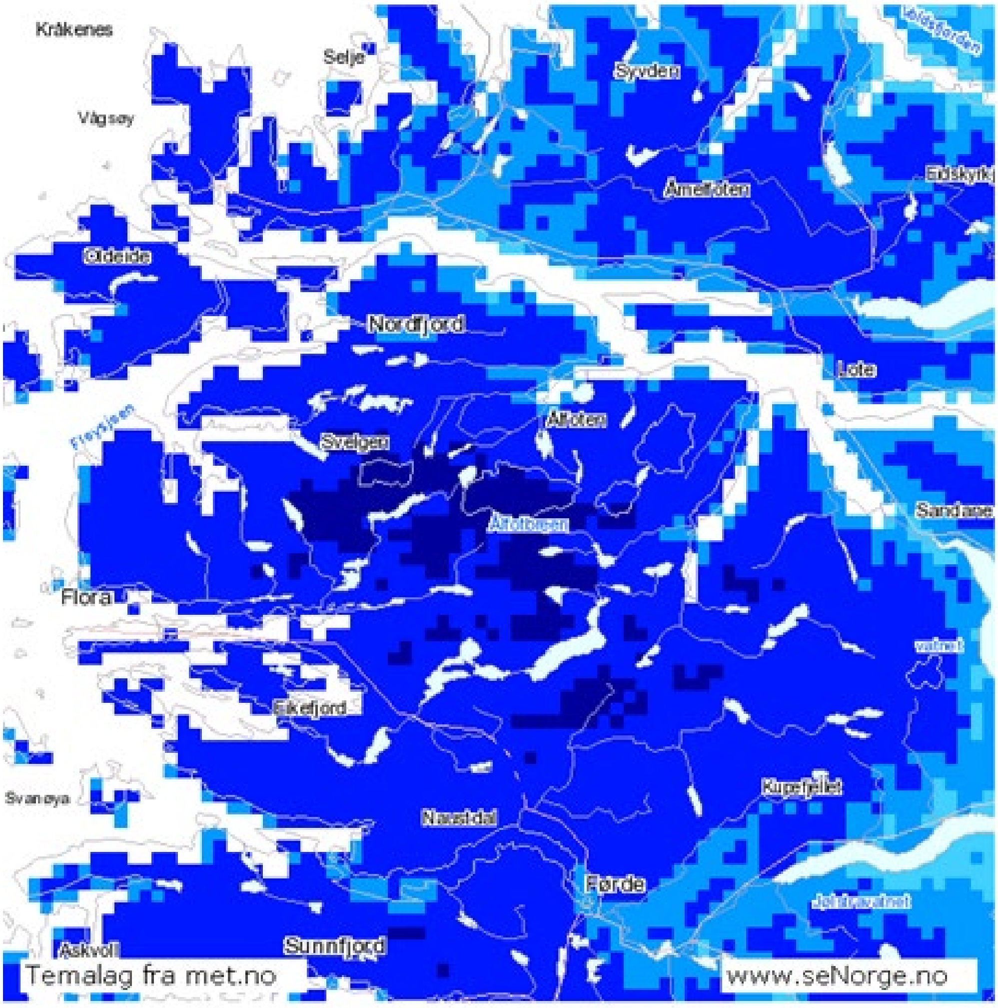


Figure 3.71.2 The distribution of the rainfall and the combined inflow because of rainfall and snowmelt 28 October 2007.

Flood damages.

The riverbed expanded to a width of 340 meter at the farm located near the fjord. The river caused severe damages to the farmland. Two bridges were taken and several water pipes were damaged. One smithy was taken. The total damages was assessed to 3.985.000 NOK. The court decided to grant compensation for the flood damages of 2.259.500 NOK. This amount did not include the cost of additional flood protection works.

3.72 The winter flood at Vestlandet 12 January 2009.

In January 2009 a large flood occurred in coastal rivers from Vest-Agder to Nordfjord. Figure 3.72.1 show observed daily precipitation and discharge in rivers in Rogaland, Figure 3.72.2 in Hordaland and Figure 3.72.3 in Sogn og Fjordane.

Cause of the flood

The flood was caused by heavy rainfall up to 120 mm the 12 January. The weather types 11 – 12 January were: **SWA** (Grosswetterlagen) and **SW**, **SW** and **CW** (Lamb-Jenkinsson).

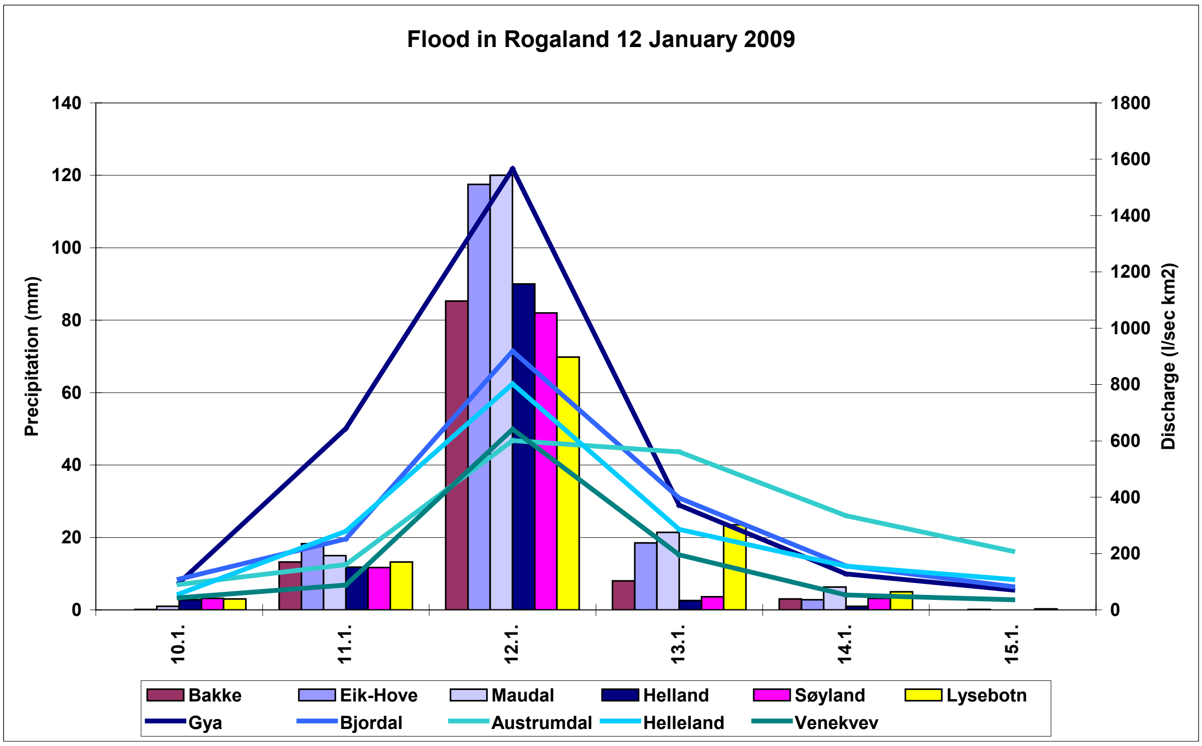


Figure 3.72.1 Observed precipitation and daily discharge during a rainfall flood at Jæren 12 January 2009.

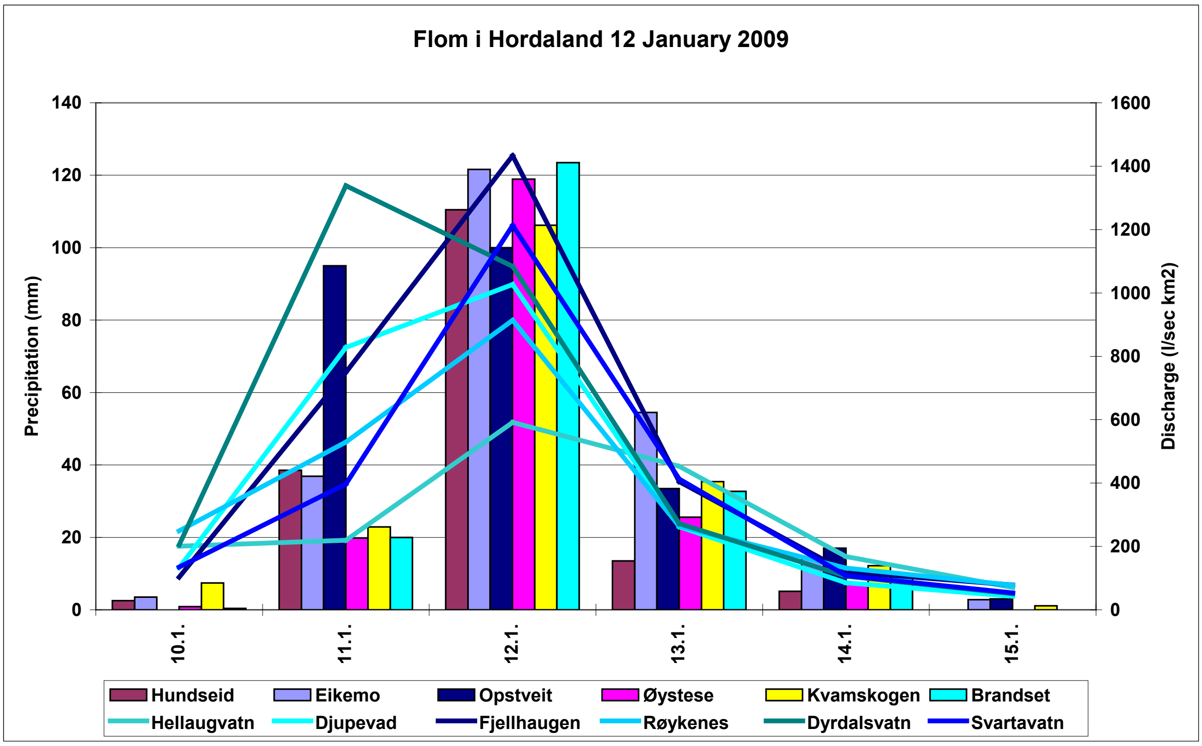


Figure 3.72.2 Observed precipitation and daily discharge during a rainfall flood in Hordaland 12 January 2009.

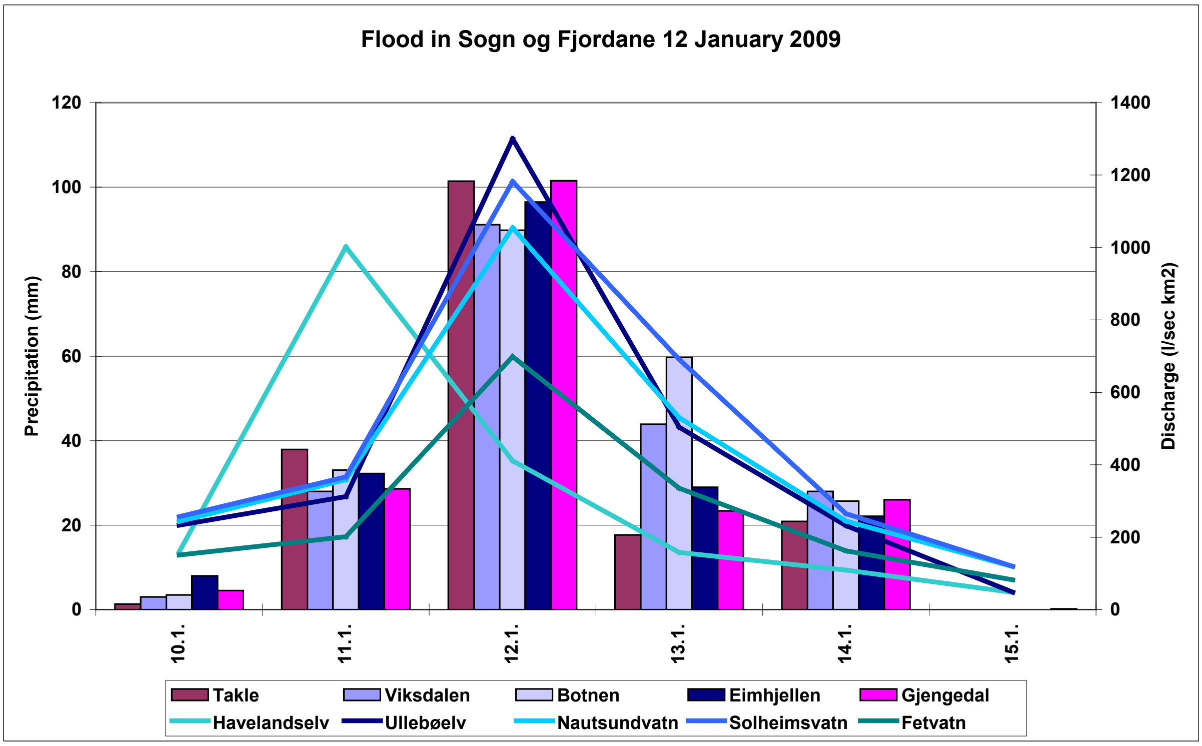
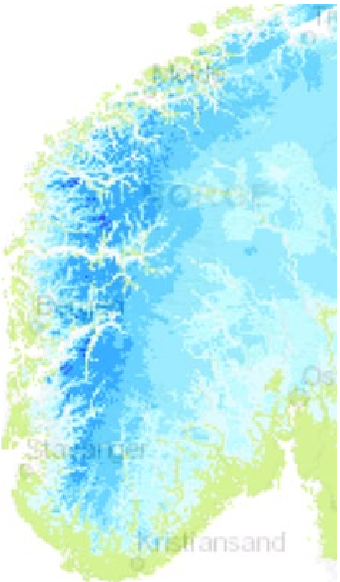


Figure 3.72.3 Observed precipitation and daily discharge during a rainfall flood in Sogn og Fjordane in 12 January 2009.



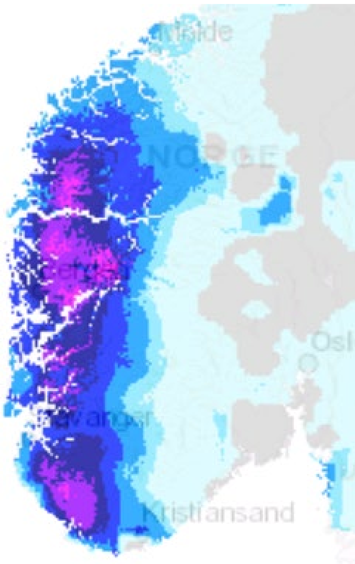


Figure 3.72.4 The spatial distribution of the water equivalent of the snow and the precipitation at Vestlandet 12 January 2009.

3.73 An autumn flood in rivers from Vest-Agder to Nordfjord in November 2009.

An autumn flood occurred in coastal catchments at Vestlandet in late November 2009. Observed preciptation and discharge at gauging stations in Rogaland are shown in Figure 3.73.1. Figure 3.73.2 show precipitation and discharge observed in Hordaland. The spatial distribution of the snow water equivalent and the preciptation is shown in Figure 3.73.3.

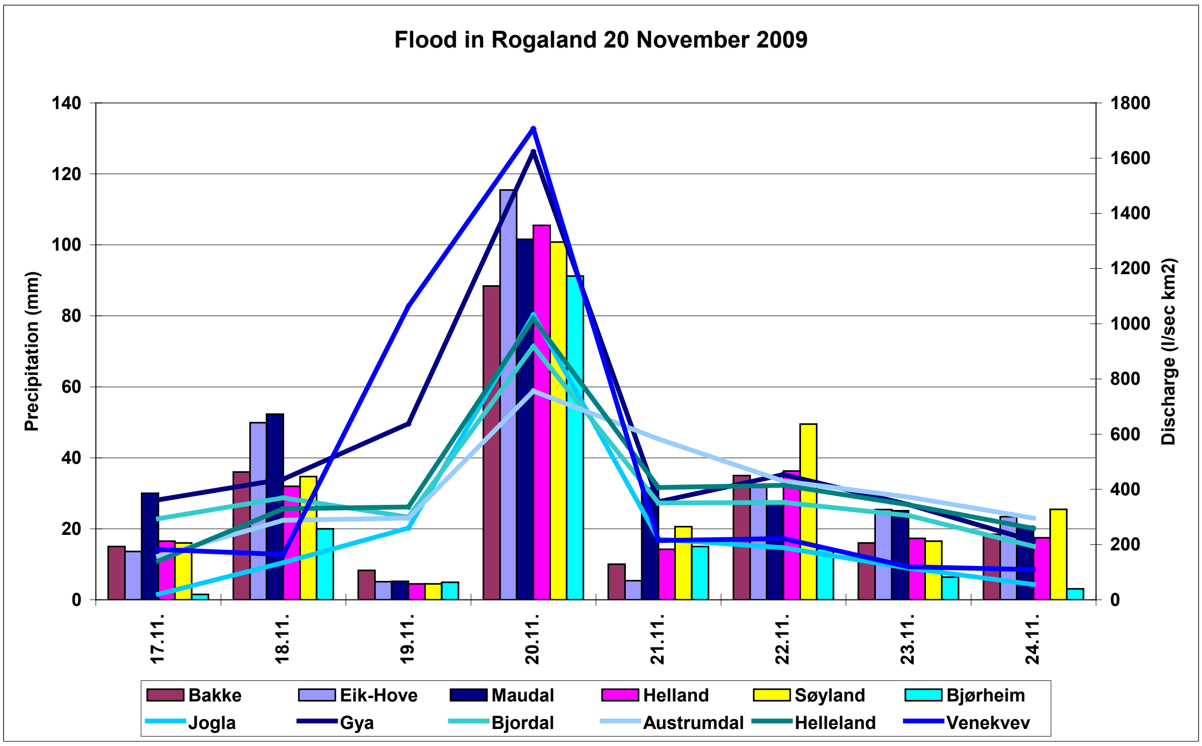


Figure 3.73.1 Observed precipitation and daily discharge during a rainfall flood in Rogaland 20 November 2009.

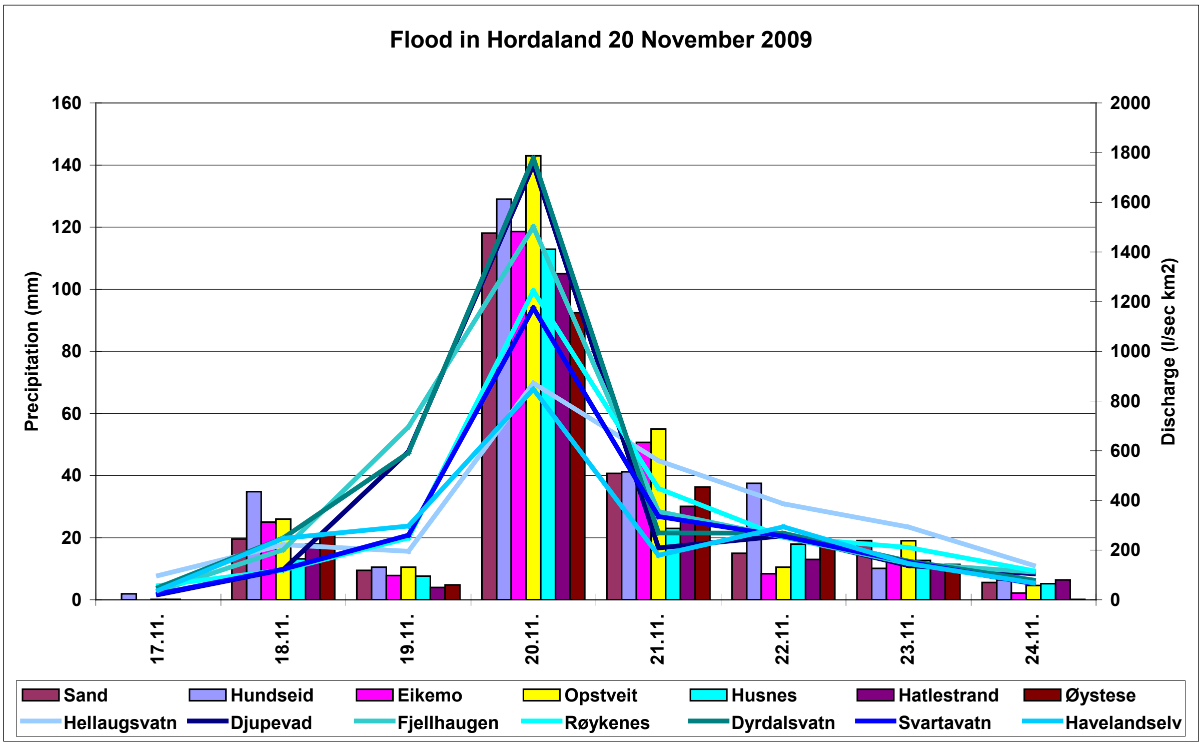


Figure 3.73.2 Observed precipitation and daily discharge during a rainfall flood in Hordaland 20 November 2009.

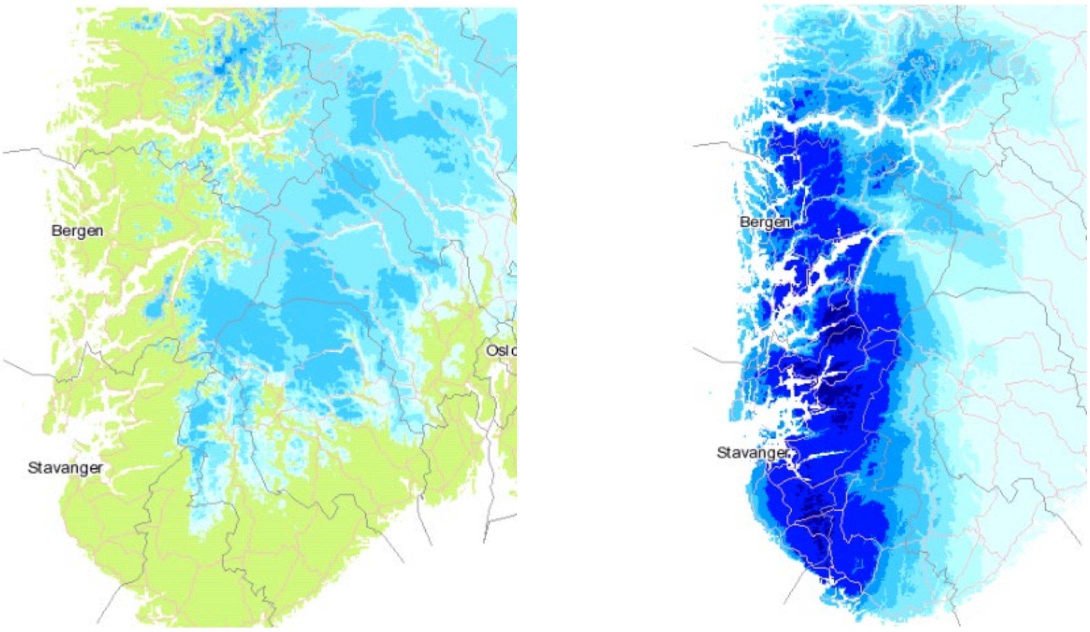


Figure 3.73.3 The distribution of the snow water equivalent and the precipitation in West Norway 20 November 2009.

Cause of the flood

The flood was caused by heavy rainfall in the lower parts of the catchments with contribution from snowmelt from the upper parts of the basins. The weather types 19-22 November were **SWA** (Grosswetterlagen) and **SW**, **SW**, **S** and **CE** (Lamb-Jenkinsson).

3.74 The flood at Vestlandet 20 March 2010.

Heavy snowfall turning into rainfall caused a number of avalanches at the coast from Møre og Romsdal to Helgeland blocking many roads and the railway line between Steinkjer and Mosjøen 10-11 March. Roads at Fosen, Trondheim and in Namdalen were inundated from ice jams. Some coastal basins, especially in Møre and Romsdal suffered from floods as shown in Figure 3.74.1. The weather types 11 -13 March were: **BM**, **NWZ** and **NWZ** (Grosswetterlagen) and **A**, **N**, and **AW** (Lamb-Jenkinsson).

The heavy snowfall continued 15-19 March blocking all major roads out of Møre og Romsdal. The snowfall turned into heavy rainfall 20 March at Vestlandet, causing floods from Hordaland to Nordfjord as shown in Figure 3.74.2. The weather types 19- 21 March were: **SWZ** (Grosswetterlagen) and **W**, **NW** and **SW** (Lamb-Jenkinsson).

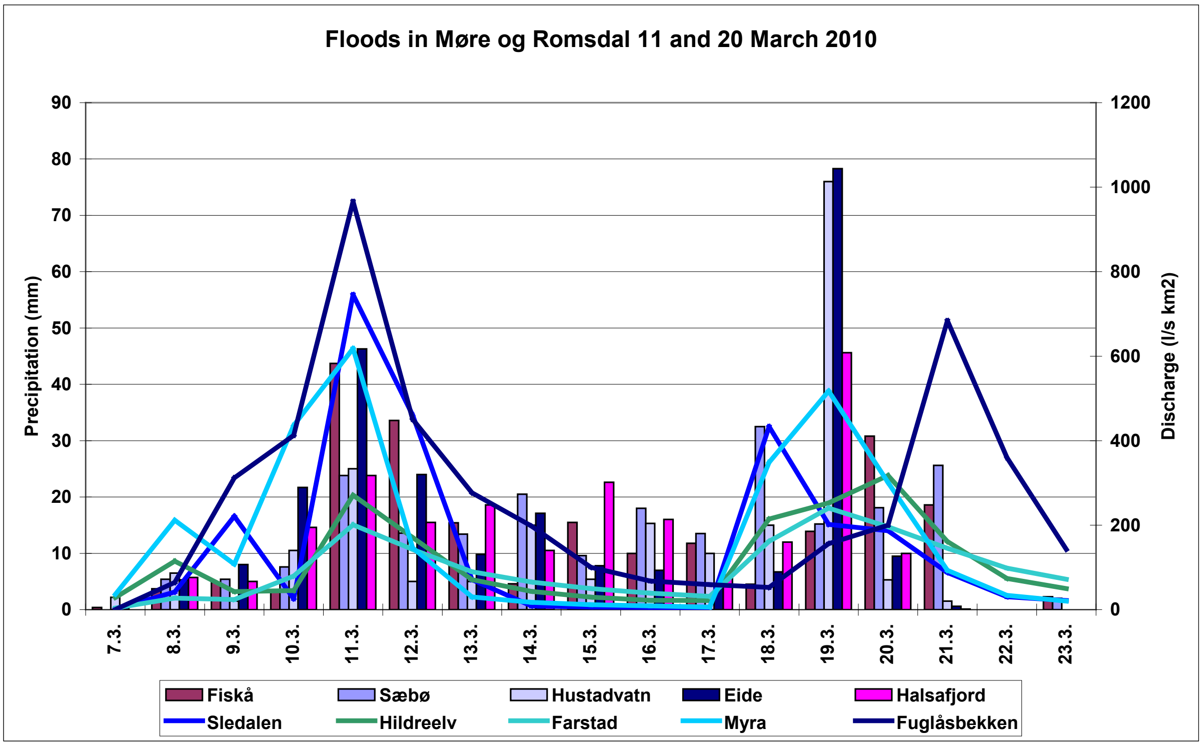


Figure 3.74.1 Observed precipitation and discharge in rivers at Møre og Romsdal 10-11 March 2010

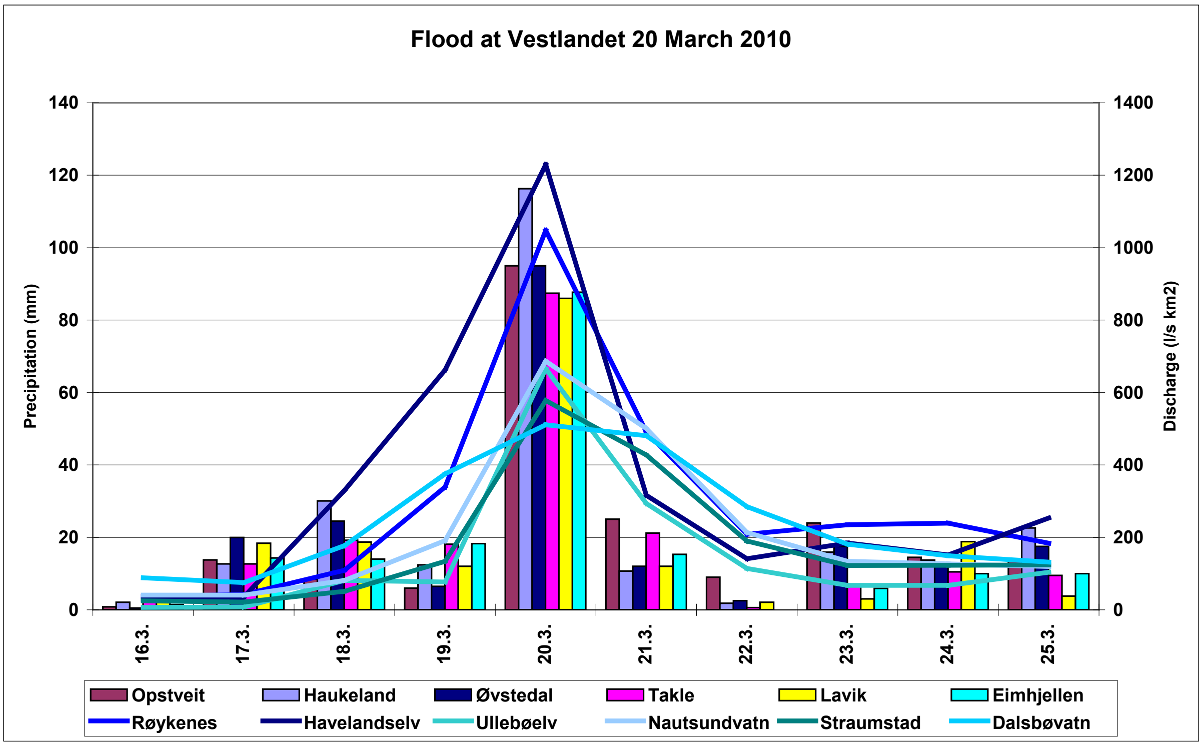


Figure 3.74.2 Observed precipitation and discharge in rivers at Vestlandet 20 March 2010

The flood did not rank among the 10 largest floods at the stations affected by the flood

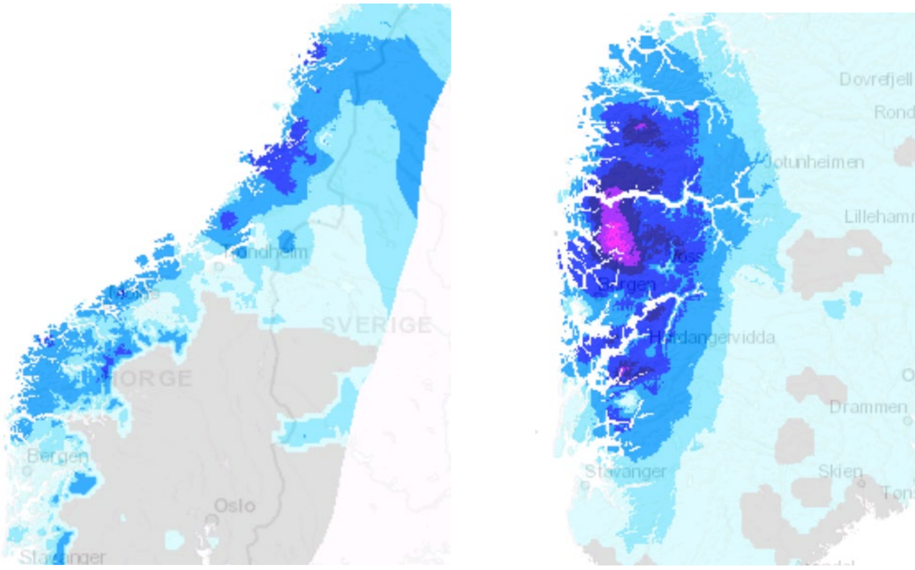


Figure 3.74.3 The spatial distribution of the precipitation 11 March (left) and 20 March 2010 (right).

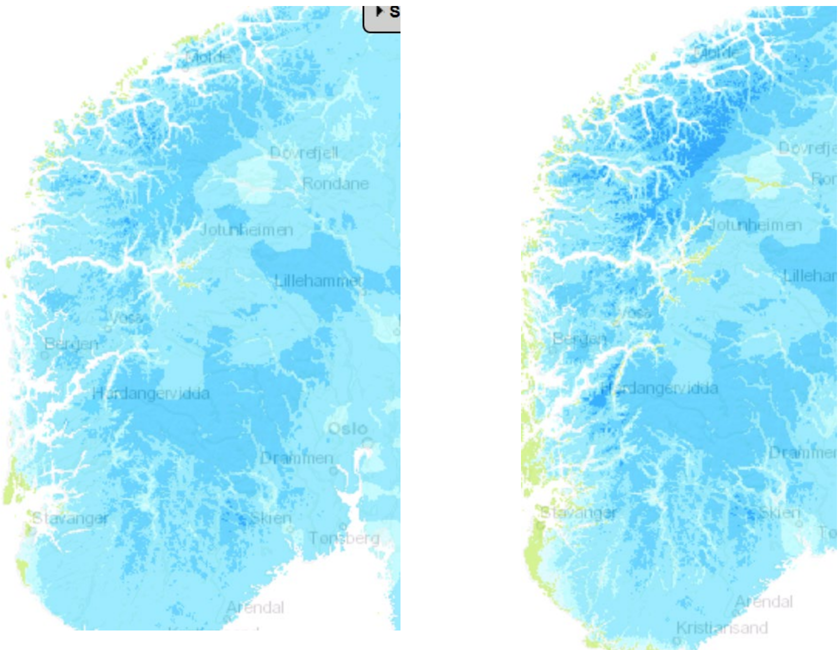


Figure 3.74.4 The spatial distribution of the snow water equivalent 11. March (left) and 20 March 2010 (right).

An anti-cyclone with a warm kernel was located over Great Britain 10-11 March. Further east a low was located over the European mainland with a cold kernel. A large low was located near Spitzbergen with weaker lows further west. Wind was moving from the Norwegian Sea towards the Norwegian coast north of the Sognefjord.

The anti-cyclone over Britain had moved further west into the Atlantic by the 20 March. The polar front extended northeastwards from Spain to the Baltics. A front moved in across the coast of West Norway.

A snowstorm caused further problems to the traffic 24 March at Trøndelag, Strynefjellet and in East Norway at Engerdal.

Damages:
A slush avalanche in River Flesjeelv at Balestrand destroyed a home, killing two people. The slide has a counterpart in the event in a nearby river in 1928. Several homes were flooded at different locations. The number of closed roads caused problems at many locations.

3.75 The rainfall flood at Nordfjord 24-25 July 2011.
An intense thunderstorm caused severe flooding from Faleide to Randabygd in Stryn and at Lote in Eid on the northern side of Nordfjord after midnight 25 July.

Cause of the flood:
The weather type was charcterised with a low extending over Norway from the North Sea and nortwards over the Norwegian mainland with anticyclones over Finland to northeast and another in the Atlantic Ocean southwest of Biskaya. East of the low were warm air masses streaming northwards. The weather was of the Vb-type, although without transport from as far south as the Mediterranian. The rainfall observed 25 July at the rainfall station Kroken was 3,6 mm between 00:00 and 01:00 hrs, 52,6 mm between 01:00 and 02:00 hrs and 5,3 between 02:00 and 03:00 hrs. The total rainfall at Kroken 25 July was 80 mm. The rainfall 25 July at Nordfjordeid-Nymark was 48,2 mm, at Byrkjelo 47,7 mm, at Heggedal at Innvik 49,8 mm and at Myklebust in Olden 47,7 mm. The weather types were **TRM** (Grosswetterlagen) and **N**, **CN** and **AN** (Lamb-Jenkinsson).

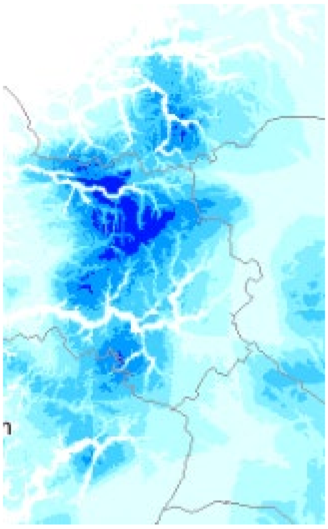


Figure 3.75.1 The distribution of the rainfall 25 July 2011 in Nordfjord and Sogn.

The flood:
There are unfortunately no gauging stations in rivers affected by the rainstorm near the center of the rainfall. River Steindøla and smaller brooks rose quickly and caused damages because of inundations well as erosion.

The event has a counterpart in a flood resulting from a thunderstorm, which occurred from Hennebygda to Hopland at Randabygda in the afternoon 12 July 1941. This rainfall event occurred after a prolonged spell of dry weather.

Flood damages:

The flood came through the forests as well as farmland and brought a lot of trees into the fjord. The most severe damages were caused by River Steindøla at Blakset. The garden was eroded by the river on both sides of a house, and a jacussi, a caravan and damaged the road. Several local roads were taken by the river at Teien. The bridges to Teigen and Dokset were destroyed. Most of the road to Vangen at Fjelli was destroyed. The main road to Blakset suffered severe damages. The Steindøla power station had the engine room filled with large rocks. The damages at the power station was estimated to four-six million Nok. Another bridge was destroyed at Åland in Randabygd, and a property was damaged at Lote at Eid by River Sagelva. The flood caused 43 people to be evacuated.

3.76 The extreme flood at Vestlandet 28-29 October 2014.

Heavy rainfall caused large floods at Vestlandet from Ryfylke to Møre og Romsdal in October 2014. The flood was the highest on record in River Opo, River Vosso and River Gaular. Severe damages occurred at Odda, in Voss and in Flåm in Aurland. The flood is documented in Langsholt et al 2015. Flood damages is documented in Dannevig et al 2016.

Cause of the flood:

Initial conditions:

The rainfall was the result of an atmospheric river, causing rainfall from 10-13 October before the heavy rainfall from 19-29 October. The soil and groundwater reservoirs were therefore filled up prior to the most intense rainstorm 27-28 October. The air temperature was high, and the snow had therefore not accumulated in the catchments prior to the rainstorm.

The rainfall

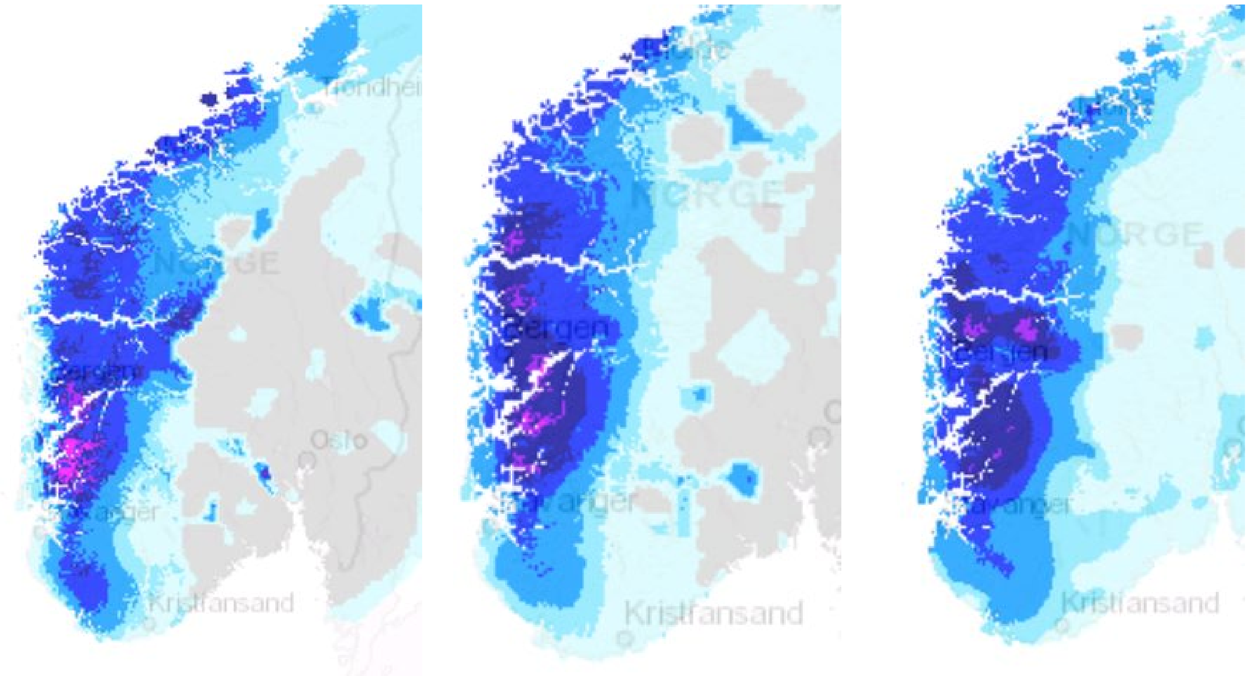


Figure 3.76.1 The spatial distribution of the rainfall at Vestlandet 27 October (left), 28 October (center) and 29 October (right).

The most intensive rainfall occurred in Hordaland, but heavy rainfall occurred also in Sogn og Fjordane. The weather types 27-29 October were: **NWZ**, **NA**, **NA** (Grosswetterlage) and **?**, **SE** and **S** (Lamb-Jenkinsson).

The flood

The intense rainfall caused floods in many rivers from Rogaland to Nordfjord. Figure 3.76.2 show observed daily rainfall and discharges observed at gauging stations in Ryfylke. Observed daily rainfall and discharge at Sunnhordaland is shown in Figure 3.76.3 and 3.76.4 at Hardanger in Figure 3.76.5, in Vosso and adjacent rivers in Figure 3.76.6 and in inner Sogn in Figure 3.76.7 and at Sunnfjord in Figure 3.76.8.

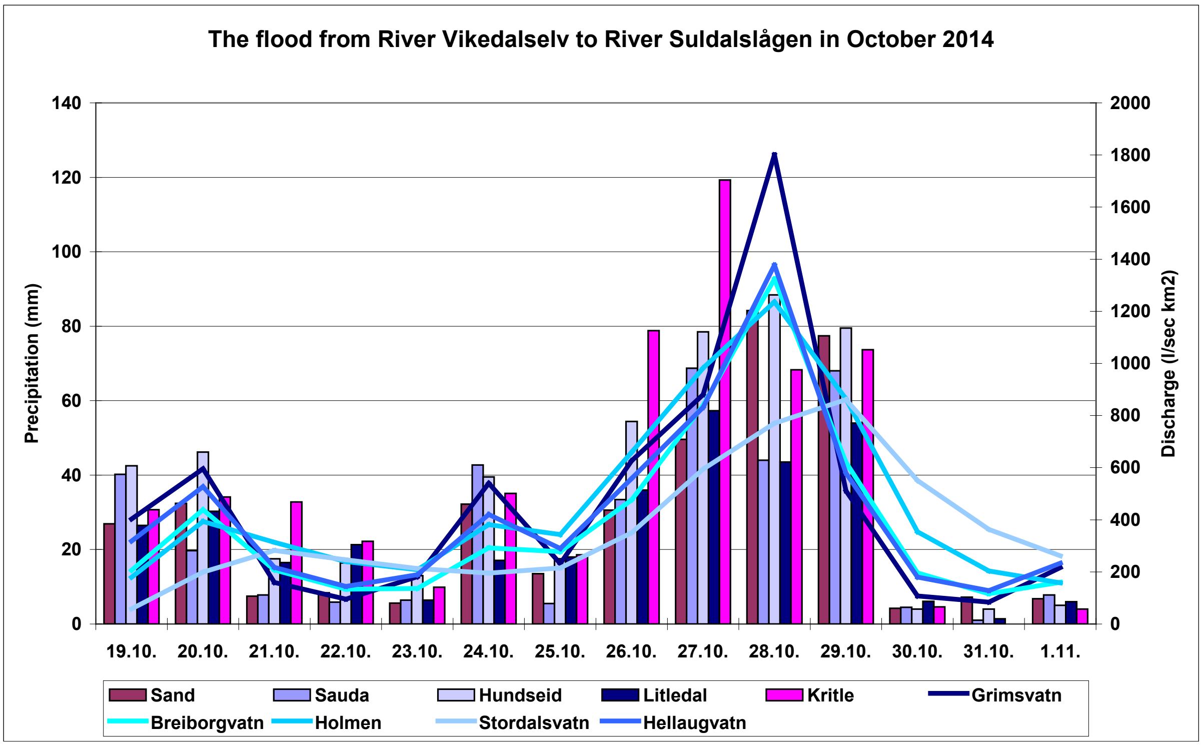


Figure 3.76.2 Daily precipitation and floods in Ryfylke in October 2014.

The flood ranks as the largest on in two smaller catchments in Suldalslågen. The series started in 1974 to 1983. The flood was also large at Sauda, but discharge data are not available there.

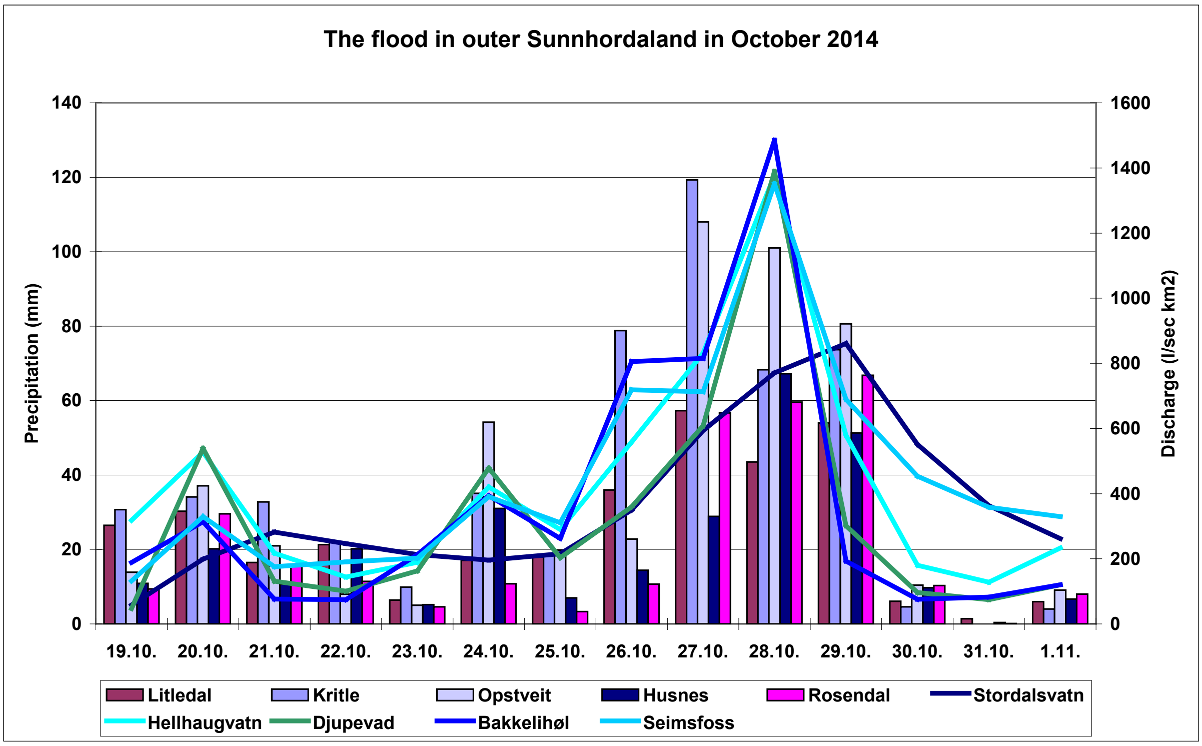


Figure 3.76.3 Daily precipitation and floods in Sunnhordaland in October 2014.

The flood ranks as the sixth largest in River Etneelv at 41.1 Stordalsvatn 1913-2014 and the fifth largest in River Handelandselv at 42.2 Djupevad 1964-2014.

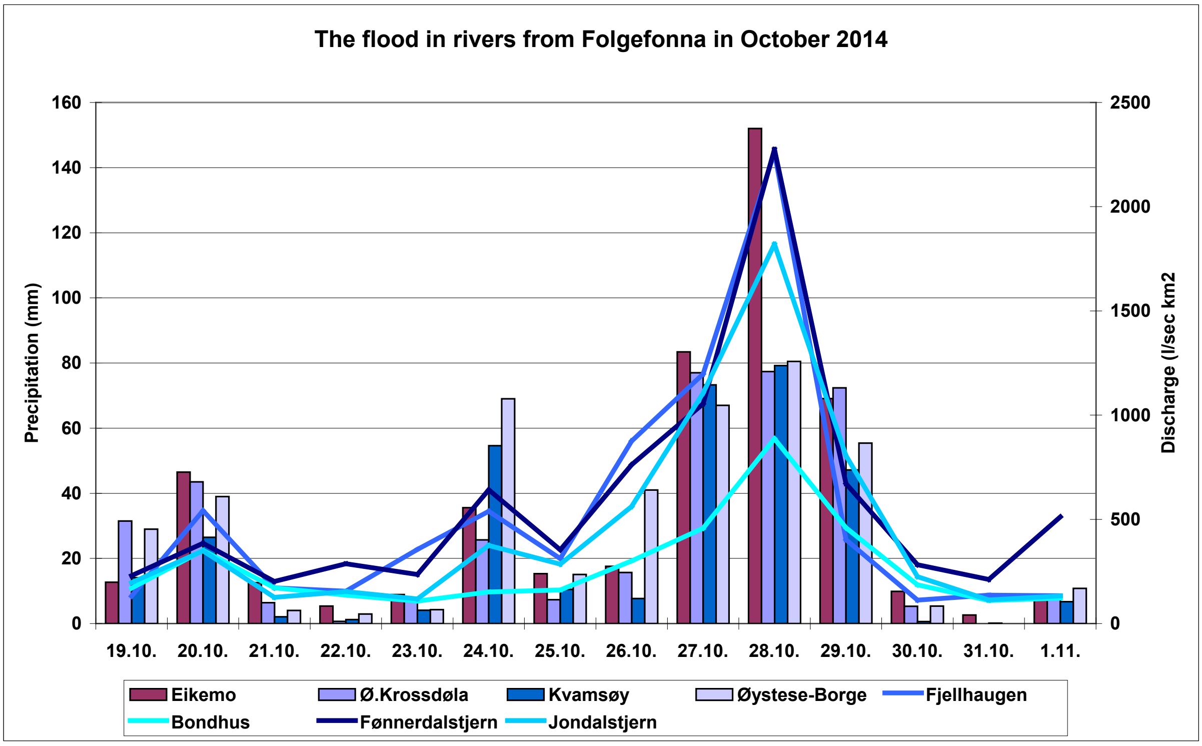


Figure 3.76.4 Daily precipitation and floods in rivers from Folgefonni in October 2014.

The flood ranks as the fourth largest in River Bondhuselv at 46.4 Bondhus 1964-2014 and the second largest at River Pyttelva at 46.9 Fønnerdalsvatn.

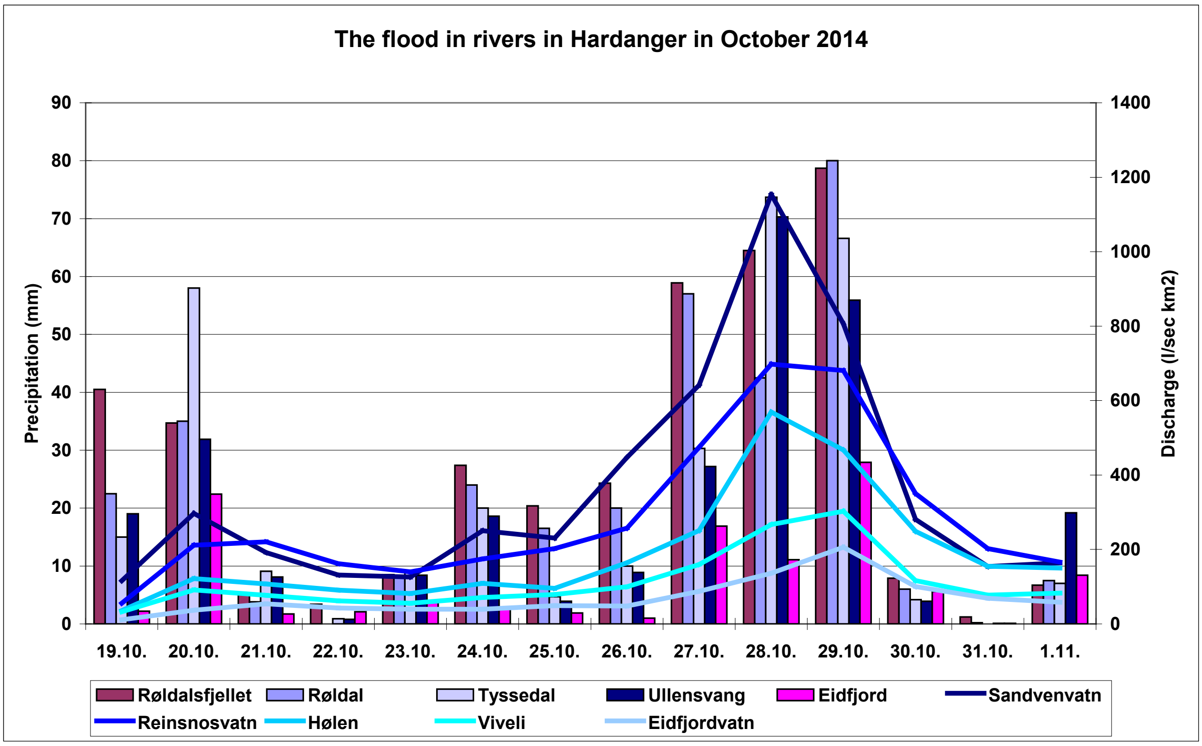


Figure 3.76.5 Daily precipitation and floods in Hardanger in October 2014.

The flood ranks as the largest in River Opo at 48.1 Sandvenvatn 1909-2014 and at 48.5 Reinsnosvatn 1917-2014. It was second largest in River Kinso at 50.1 Hølen 1923-2014.

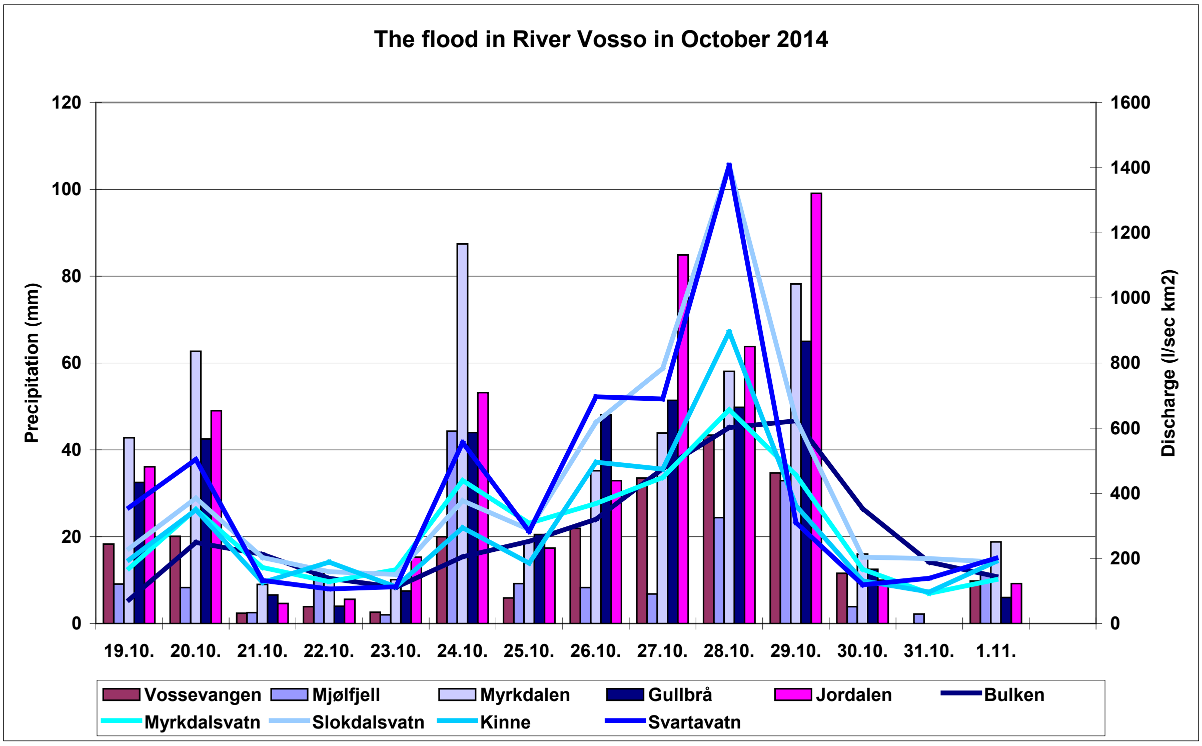


Figure 3.76.6 Daily precipitation and floods in Vosso and adjacent rivers in October 2014.

The flood in River Vosso at 62.5 Bulken is the largest on record since the observations started in 1892. The largest flood on record was the flood 10 October 1918 with a discharge of 598 m3/sec. A large flood 9 December 1873 is said to have been 12,5 in higher than the peak in 1918. The corresponding discharge is 617 m3/sec, which is less than the peak of 2014.

Another flood reaching to level of 1873 occurred 2 November 1888. A third flood occurred simultaneously 1 November 1884 in River Vosso and in River Granvinelv. The flood in River Granvinelv is said to be the largest flood there in the 19th Century. It is possible that the 2014 flood is the largest since the flood in Vosso in 1790. The level of this flood has been compared to the level of the extreme floods in 1719 and 1743.

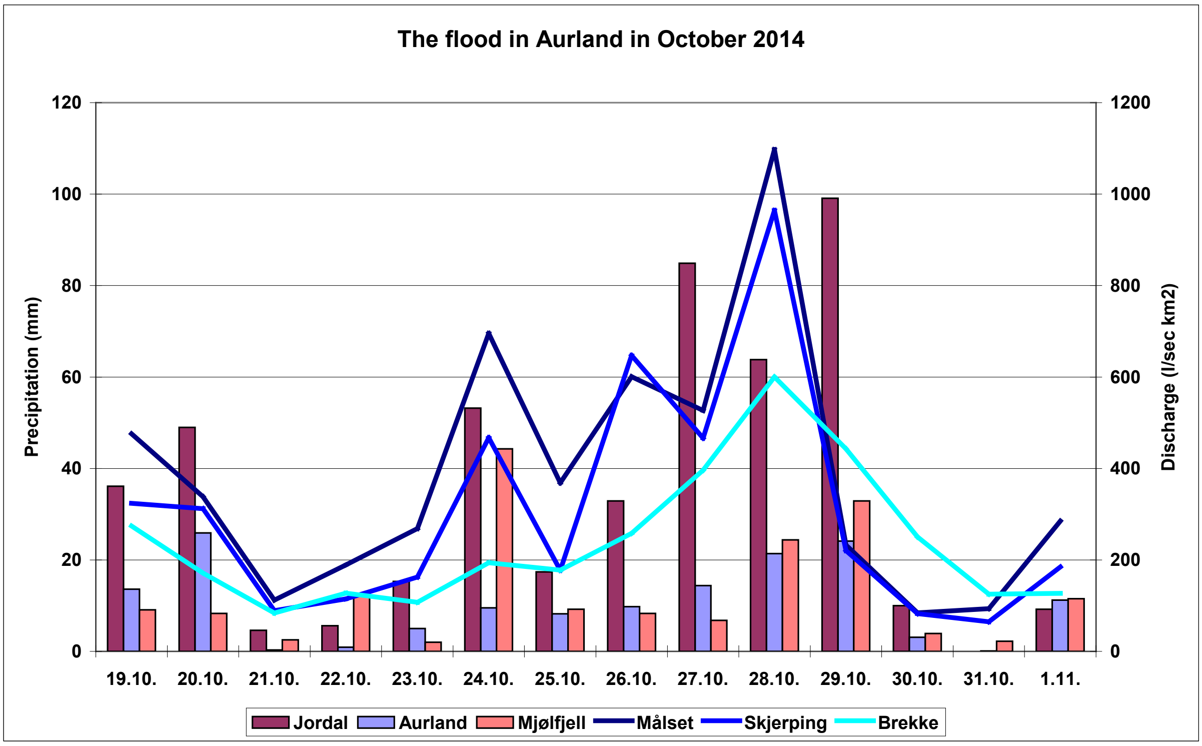


Figure 3.76.7 Daily precipitation and floods in Aurland in October 2014.

The flood ranks as the third largest in River Flåmselv at 72.5 Brekke bru 1915-2014, provided that the estimates of the discharges can be relied on prior to 1939. The flood was the third largest in River Nærøydalselv 1919-2014. The flood was the ninth largest in River Itla at 74.15 Utla 1972-2014 and second largest at 74.16 Langedalen 1973-2014 both in River Årdalselv. It was the third largest in 75.22 Gilja 1964-2014, the seventh largest in River Jostedøla at 76.10 Myklemyr 1979-2014, the second largest in River Sogndalselv at 77.3 Sogndalsvatn 1966-2014 and the fourth largest at River Bøyaelv 1966-2014.

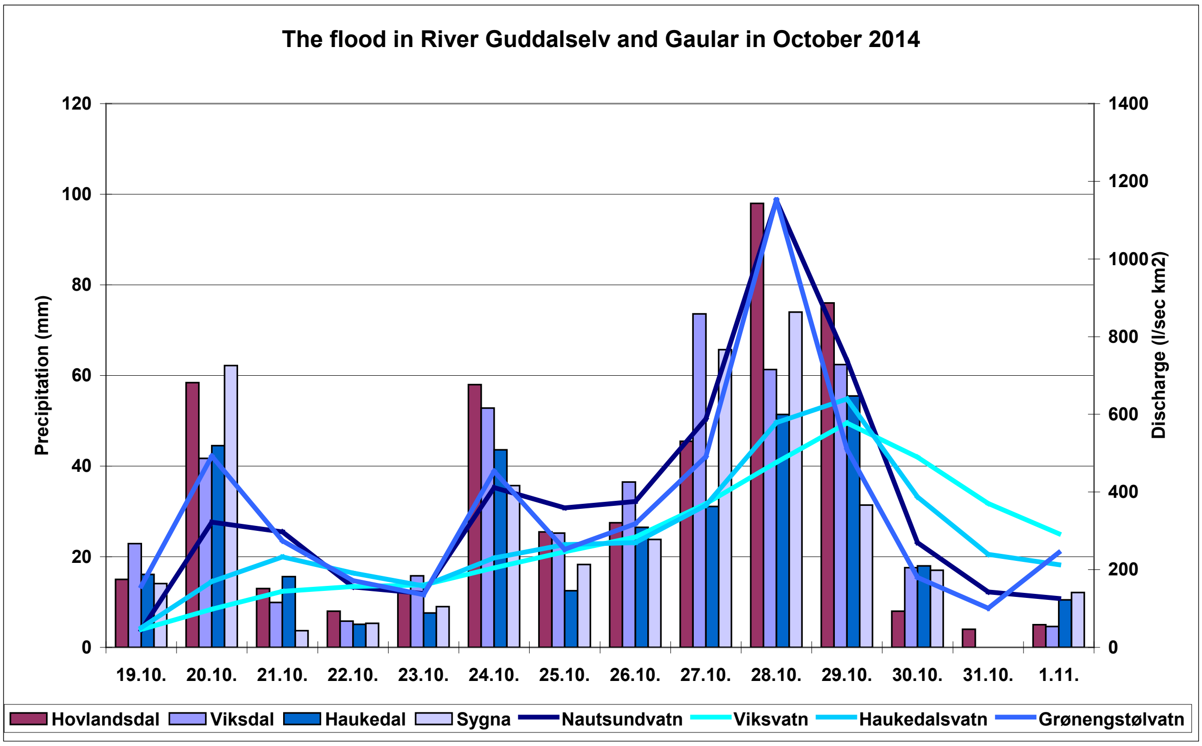


Figure 3.76.8 Daily precipitation and floods at Sunnfjord in October 2014.

Flood occurred in several rivers in outer Sunnfjord, but these floods have been exceeded by several larger floods in the past. The flood observed at River Gaular at 83.2 Viksvatn was the largest on record 1903-2014. The flood was the third largest at 83.12 Haukedalsvatn 1936-2014 and the fourth largest at 83.7 Grønengstølvatn 1966-2014. It was the fifth largest at River Jølstra at 84.14 Jølstervatn ndf 1903-2014 and the eight largest at 84.20 Holsenvatn 1964-2014.

The flood penetrated also into Nordfjord in some smaller rivers. It was the third larges at 86.12 Skjerdal 1983-2014 and the second largest at 86.10 Åvatn 1974-2014, both draining to the Hyenfjord. The flood ranks as the third largest at 83.3/10 Teita bru/Bergheim.

Flood damages:

Sauda

The main road, FV 520, was closed on both sides of the village. Water from Svandalsfossen poured over the road.

Norheimssund

A house was taken by the flood. Some neighbour houses were evacuated.

Odda

The discharge in River Opo was the highest since the start of observations in 1917. The flood between Lake Sandvenvatn flows through the town, which also suffered badly in the town and at the factories badly from flooding in 1962. This rainstorm was local and did not cause damages in the upper part of the catchment. The river undermined several buildings in 2014, and five houses were taken by the river.

2014. The bridge across Opo to the village at Hjølmo was taken by the flood, where 17 people were evacuated.

Evanger and Voss

The railway line to Bergen was closed because of inundation. The road to Ronga at Bolstad was damaged. The Nortura food factory at Evanger was inundated, resulting in damages at buldings and machinery. More than 5 tons of mutton was discarded. Many private houses and forretningsbygg was damaged at Evanger. The E 16 was constricted downstream Flagefossen.

The newspaper Hordaland suffered damages from water in the newspaper building in the town center of Voss. Eighten flats belonging to Fleischers hotel, The Culture bulding at Voss and the Park hotel suffered also damages from the flood. Minigolf course was destroyed. There was water in the basement of the Court house and the Voss sport hall. Several classrooms in the secondary School at Voss were damaged, and the camping site at Voss was inundated. All buildings next to River Vosso have suffered damages from water. Several municipal roads were damaged. The Tinta bridge over Vosso was taken by the flood.

Flåm at Aurland

Thirten private houses suffered total damages at Flåm in Aurland. Five buildings were taken by the river, while eight other suffered total damages. A farmhouse and several smaller farm buildings suffered total damages. The road through the valley in Flåm was cut at several locations. Local roads were taken. The bridge next to the school at Flåm was taken, the bridge at Haugen suffered total damages while the road at the bridge at the church at Flåm was damaged. It was expected that two weeks were required before the traffic could be resumed at the railway line. The church at Flåm was at risk of further landslides. The school at Flåm was also at risk since a flood protection wall was eroded.

Undredal

The main road to Undredal and further to Gudvangen runs through two long tunnels with a side road through the valley to the fiord. The side road road was destroyed by the flood, causing Undredal to be inacessible by cars. Most of the village is, however, located next to the Aurlandfjord. It was therefore feasible to travel out of the village by boat.

Nærøydalen

The flood in River Nærøydalselv caused also damages.

Lærdal

Erosion from River Lærdøla caused riverbank failure, and several buildings with 29 inhabitants were evacuated. The discharge and precipitation were moderate in the main valley, but heavy rainfall the inside valleys caused damages on the road to Vindedal, in Erdalen Kuvelda, Tinjadalen and Råsdalen. The damages were partly caused by erosion and and deposition of debris in the rivers, causing riverbank failures. The access road to several buildings were damaged, farmland suffered and several bridges were taken. The powerline was also damaged

Årdal

People living next to River Utla were evacuated, because of rising water levels and exposure to slides.

Førde

River Jølstra grew quickly and caused inundations at the town Førde. The access road to Stardalen was cut.

Olderdalen

The access road to Olderdalen was broken.

Lars Andreas Roald

Floods in Norway

Appendix D

Mid- and North Norway

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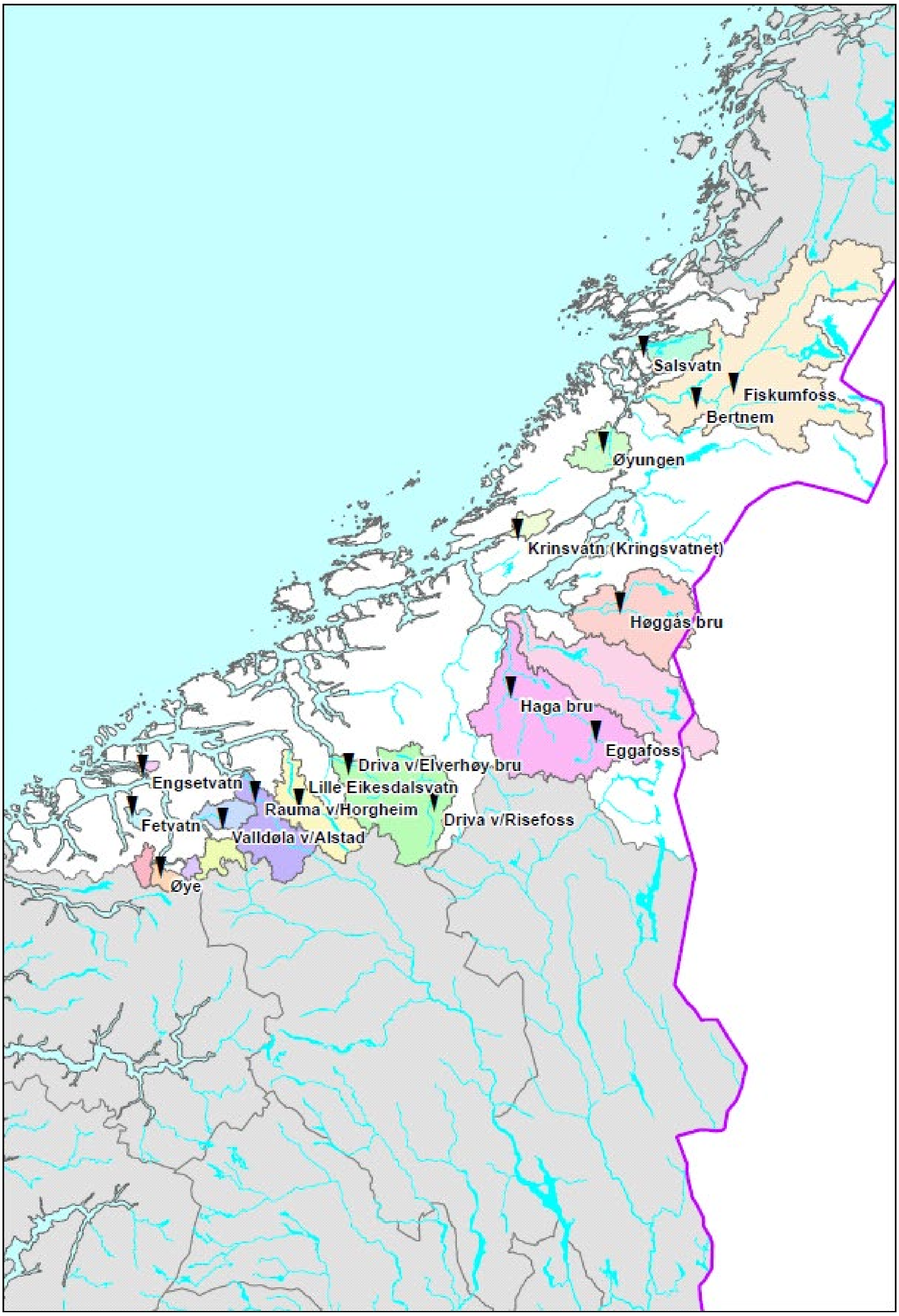


Figure 1. Station map of Mid-Norway. (Source: Søren Kristensen).

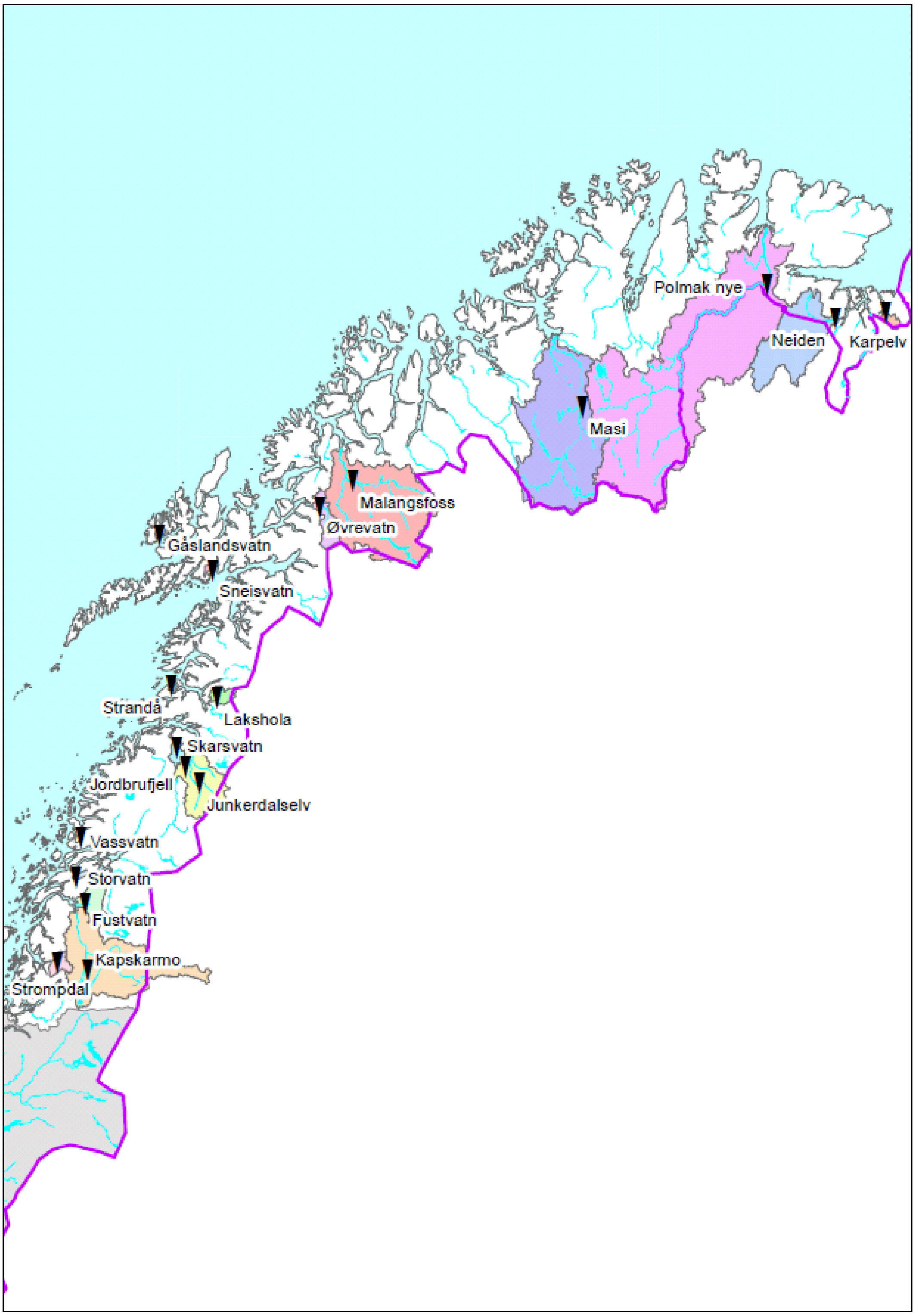


Figure 2. Station map of North Norway. (Source: Søren Kristensen).

1. Introduction to Appendix D

Appendix 4 describes large floods in Mid- and North Norway. The text comprises three parts. The first part lists the number of data series used in the study at gauging stations in the rivers from Møre og Romsdal to Finnmark counties in Norway. The rivers are ordered from Sunnmøre to the border to Russia. The region comprises a few large water courses, such as River Målselv, River Alta, River Tana, River Neiden and River Pasvikelv. These rivers are mostly crossing into Norway from neighbour countries.

Information about historical floods prior to the start of the systematic gauging are unfortunately not available from the three northernmost counties, reflecting that farming was less important than the fisheries and the reindeer farming. Large storms and avalanches were the dominant cause of natural damages. These events are abundant in the records.

The appendix comprises three parts. The first part describes the number of data series used in the study based on annual floods known from historical sources and later observed floods at gauging stations in the rivers from Sunnmøre to Finnmark counties in Norway. The rivers are ordered from Hjørundfjord to Karpelv. The region described in the report includes most of the larger watercourses in Mid and North - Norway where data or information about historical floods prior to the observations are available. Many series are regulated, especially in Nordland. The series in Troms are generally shorter than series further south.

Table 1. Number of data series used in Mid Norway.

District	Number of stations	Number shown in Figure	Additional shorter series
Sunnmøre	9	3	6
Romsdal	9	2	7
Nordmøre	11	2	9
Trøndelag	14	3	11
Fosen/Namsen	9	5	4

Table 2. Number of data series used in North Norway

Counties	Number of stations	Number shown in Figure 1	Additional shorter series
Swedish border	4	0	4
Nordland	39	13	26
Troms	19	2	17
Finnmark	15	4	11

The study used 52 stations in Mid Norway and 77 stations from Nordland to Finnmark.in North Norway

The second part includes the catchment characteristics for each station and gives in tabular form the date and rank of the ten largest floods observed at each station. Most of the long-term series have been affected by hydropower regulations. The effect of regulations is that the flood magnitudes are reduced from the start of the operation of the hydropower scheme. The rank given in the tables refer to the observed data. The flood magnitudes have not been corrected to naturalized discharges from the start of the regulation. This is the reason why fewer large floods occur in recent years in many flood series. The flood series are also shown as graphs for most of the long-term series in the region. Actual discharges are not listed in the tables, but the discharge is given for the largest flood in each series in the unit m^3/sec, l/sec km^2 and mm/day. These values may change when the rating curve is updated.

The third part describes selected historical floods. Most large floods extend over more than one river and can also extend across the boundary between the regions described in each ppendix. Some old floods prior to the start of observations are given, based on other historical sources. Most of the descriptions cover floods based on observations. The description of each flood includes graphs of observed specific discharge and daily rainfall from selected stations. The cause of the floods is given with a description of the initial conditions and the weather type causing the flood. Some information of flood damages is also given where this information is available.

2. Part 1 – Overview by districs or counties

The Appendix covers the counties Møre og Romsdal, SørTrøndelag, Nord Trøndelag, Nordland, Troms and Finnmark. Møre og Romsdal is divided into three districts, Sunnmøre, Romsdal and Nordmøre.

2.1 Møre og Romsdal

Sunnmøre

Sunnmøre is located north of Nordfjord. The coastline runs northeastward from the Stadt Penninsula, and the coastal rivers are protected from some of the severe rainstorms from south-southwest compared to the districts south of Stadt. The terrain is quite alpine on both sides of the inner fiords. The coastal catchments in the district are nevertheless located at the coastal maximum precipitation zone and are exposed to fronts moving in from west or northwest from the Norwegian Sea. These rainfall events have caused some severe floods. Some of these floods were caused by remnants of tropical hurricanes.

West of the mainland coast is located a row of islands with lower mountains. The rainfall is significantly less at these islands and large floods are rare. One cause of local flooding is rainfall events on frozen grounds. Some of the lowlying areas can also be exposed to storm surges.

The district has several long fjords with alpine landscapes on the sides. Some rivers flow toward the fjord bottoms from the water divide toward Nordfjord to the south and toward the Otta basin to the east. The precipitation is lower in these watercourses, but many floods are known, often caused by snowmelt co-inciding with heavy rainfall. The Tafjord basin and some rivers flowing toward Hjørundfjord are strongly regulated, and severe floods in these rivers are usually contained by the reservoirs. The late autumn and winter temperatures observed in Tafjord are occasionally close to 20° resulting from foehn winds, caused by heavy precipitation in East Norway. This is also the case at Sunndalsøra in Nordmøre.

The population at Sunnmøre has suffered from distastrous avalanches causing large loss of lives, rockfalls, landslides, severe storms with occasional storm surges: Floods has also caused damages, especially where rivers flows through villages at the bottom of the fjords. Table 2.1.1.1 lists some historical events occuring prior to the establishment of monitoring stations.

2.1.1.1 RIVERS IN THE ØRSTA/VARTDAL REGION

Three rivers flow northwestward to the Vartdalsfjord from the alpine mountains north of Ørsta. These rivers, Barstadelv, Nøre and Søre Vartdalselv have suffered from some severe floods causing large if local damages (Andersen, 1981). Unfortunately, there have been no gauging stations in either of these rivers. River Ørstaelva has frequently floods at the same time as these three rivers.

2.1.1.2 FLOODS IN RIVERS TOWARD HJØRUNDFJORD

Hjørundfjord is a branch of the Storfjord, which runs to the water divide to Hornindal. Some short rivers are flowing toward the fjord. River Urkeelv flows from east at Urke and River Norangselv flows from southeast to the bottom of the Norangfjord. River Viddalselv flows from east into the main fjord further south. River Sætreelv flows to the fjord from west and River Vikselv flows from southwest to the bottom at the fjord at Øye. River Bondalselv flows from southwest to Sæbø at the western side of the main fjord east of the Norangfjord. Several historical floods are known in these rivers as shown in Table 2.1.1.1.

Some of these rivers have been gauged for shorter periods in connection with the development of the Tussa power scheme. Upstream Øye the gauging station 97.2 Saurevatn was operating 1966-2001. Further upstreams in Skjåkstaddalen a gauging station 97.4 Skjåkstad was operating 1966-1997. The station was closed in 1997, when the river was regulated, but a new station 97.5 Sledalen has been in operation from 1997 observing the discharge upstream the river reach affected by the regulation. Basin characteristics for Saureelv, Sjåkstad and Sledalen are given in Table 2.1.1.2. The ranks of the ten largest annual floods (daily values) are given in Table 2.1.1.3. The date and discharge of the largest annual flood is given in Table 2.1.1.4.

Table 2.1.1.1 Floods at Sunnmøre known from historical sources.

Year	Date	Remarks
1609		Severe flood in River Tennfjordelv (deforestation).
1627		Severe flood in River Tennfjordelv (deforestation).
1656		Flood in Lake Brusdalsvatn.
1675		Flood in River Valldøla.
1683		Storm surge at the coast of Sunnmøre.
1684		Large flood in River Valldøla.
1718		Avalanche, landslide and floods damaged 6 farms in Geiranger and 6 farms in Sunnylven.
1720/21		Flood and bank failure in Ørsta.
1743	4-5/12	Snowmelt and heavy rainfall caused severe flood damages in Volda, Hjørundfjord, Hellesylt and Geiranger.
1764		Rockfall and flood damage at Velle in Sykkylven.
1765		Storm surge at Sunnmøre.
1812		Slides and flood in River Valldøla.
1823	Early October	Landslide dammed River Valldøla.
1842	15-16/10	Snowmelt and heavy rainfall caused large flood in River Valldøla.
1845	31/8	Floodburst at Hollen.
1850	15-20/2	Slush avalanche at Vatne, Røyset, and Hellesylt. 12 fatalities.
1863	Christmas	Rockfall dammed River Bringeelv at Sunnylven.
1873	16/7	Severe flood at Vartdal and Barstadvika.
1878	3/8	Severe flood at Vartdal and Barstadvika.
1879	May	Large spring flood in Geiranger.
1883	7-10/10	Severe flood in River Valldøla.
1893	Autumn	Large flood in River Valldøla.
1902	24/10	Large flood in River Langedøla at Hellesylt.
1906	22-24/11	Large flood at Sunnylven.
1913	24/10	Large flood at Sunnylven.
1925	19-20/2	Severe flood in River Dyrkornelv

There is a short branch of the Hjørundfjord running eastward towards a valley, Norangsdalen. The river flowing at the bottom of the valley, runs westward from the water divide to the east. River Langedalselv flows westward from the other side of the water divide to the fiord at Hellesylt. The mountain sides at the Norangsdal are very steep, and many rockfalls have dammed the river, resulting in a row of small lakes in the bottom of the valley. Avalanches occur frequently and has taken many lives in the past, especially in 1679 and 1868. Although there are no long-term flood observations in the rivers flowing to the fjord, some floods are documented in damage reports. The extreme flood in December 1743 caused damages at at least 10 farms, which obtained deductions for flood damages. A large rockfall occurred in 1908 next to the bottom of Norangsdalen, damming the river and drowning a chalet into a new lake.

Table 2.1.1.2 Catchment characteristics of the three gauging stations in River Saureelv draining to the bottom of Hjørundfjord.

Station	97.2 Saurevatn	97.4 Skjåkstad	97.5 Sleddalen
	Basin characteristics		
Catchment area (km^2)	45,8	10	9,26
Station altitude (m.a.s.l.)	58	89	326
Mean altitude (m.a.s.l)	710	710	740
Top altitude (m.a.s.l.)	1594	1379	1379
Lake (%)	3,84	0	0
Bog (%)	1,33	3,38	3,46
Forest (%)	27,58	31,44	27,43
Mountain (%)	58,17	58,11	61,66
Glacier (%)	2,25	2,69	2,92

Table 2.1.1.3 Date and ranks of the ten largest floods (daily values) at the three gauging stations in River Saureelv.

97.2 Saureelv			97.4 Skjåkstad			97.5 Sleddalen		
1967-2001			1967-1997			1997-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1967	15/12	9	1970	15/9	8	1999	9/4	10
1970	5/9	5	1971	11/1	5	2000	7/8	4
1971	10/1	3	1975	27/12	3	2002	29/9	3
1973	9/9	10	1976	27/6	8	2003	18/12	6
1975	27/12	1	1978	17/9	10	2004	27/9	2
1978	18/9	4	1981	8/1	6	2005	14/9	5
1983	26/10	5	1983	26/10	4	2007	7/9	9
1990	6/2	2	1994	23/11	7	2011	28/6	7
1994	7/9	7	1995	2/8	2	2013	16/11	1
1997	¼	8	1997	2/3	1	2014	28/10	8

Table 2.1.1.4 The largest observed discharge (daily values) at the three gauging stations in River Saureelv.

Station	97.2 Saurevatn	97.4 Skjåkstad	97.5 Sleddalen
Year	1975	1995	2013
Date	27/12	2/8	16/11
q (m^3/sec)	54,39	5,52	10,41
Qsp (l/sec km^2)	1188	552	1125
Qsp (mm/day)	102,6	47,7	97,1

2.1.1.3 RIVER VELLEDALSELV AT LAKE FETVATN IN SYKKYLVEN

River Velledalselv flows from the water divide to Norangsdalen northward to the lake Fetvatn near the bottom of the Sykkylvsfjord at Sunnmøre. Gauging station 97.1 Fetvatn at the outlet of the lake has been operating since 1947. The catchment characteristics are given in Table

2.1.1.5. Several small glaciers in the mountains are fed by wind transport of snow. otherwise the ablation in the summer would make the glaciers disappear because of insufficient accumulation in the winter. These glaciers have been reduced in recent years. The annual floods occur usually in the autumn, most frequently in 22 percent of all years in September and in 23 percent in October, but winter floods occur from November to January. Some of the largest floods are winter floods.

The ranks of the ten largest annual floods (daily values) are given in Table 2.1.1.6. The dates and discharge of the largest floods are given in Table 2.1.1.7. The quality of the rating curve is suspected early in the period. The abundance of floods in the early years is likely to be a result of some undectected change in the controlling profile. No historical floods are known prior to the observations starting in 1945. The Norwegian Geological Survey has however observed several remnants of large prehistorical mountain slides on the bottom of the Sykkylvsfjord.

2.1.1.4 RIVER LANGEDALSELV AND RIVER BYGDAELVA

River Langedalselv flows northward from the water divide to Hornindal to the bottom of Synnylvsfjord at Hellesylt. There are no gauging stations in the river. There is a long-term rainfall station at the top of the catchment, 58960 Rafshol/Hornindal, which has been operating since 1895. The riverbed at the outlet to the fjord shifted during the extreme flood in December 1743.

River Bygdaelv flows westward from the water divide of River Strynselv upstream Flo at Oppstryn toward the bottom of the Synnylvsfjord at Hellesylt at Sunnmøre. There is a gauging station 98.4 Øye with data from 1924. The observed floods (daily values) are shown in Figure 2.1.1. The river is not regulated, but there are plans for future developments. The catchment characteristics are given in Table 2.1.1.5, the dates and ranks of the ten largest annual floods in Table 2.1.1.6 and the date and discharge of the largest flood in Table 2.1.1.7.

Historical floods are known 5 December 1743, May 1879, 24 October 1902, 24 November 1906 and 24 October 1913 (Lillebø, 1993). Several severe floods have resulted in deductions of the taxes from the affected farms. The two catchments have been ravaged by many avalanches, claiming many lives. Rockfalls and landslides have also caused damages in the two catchments (Furseth, 2002).

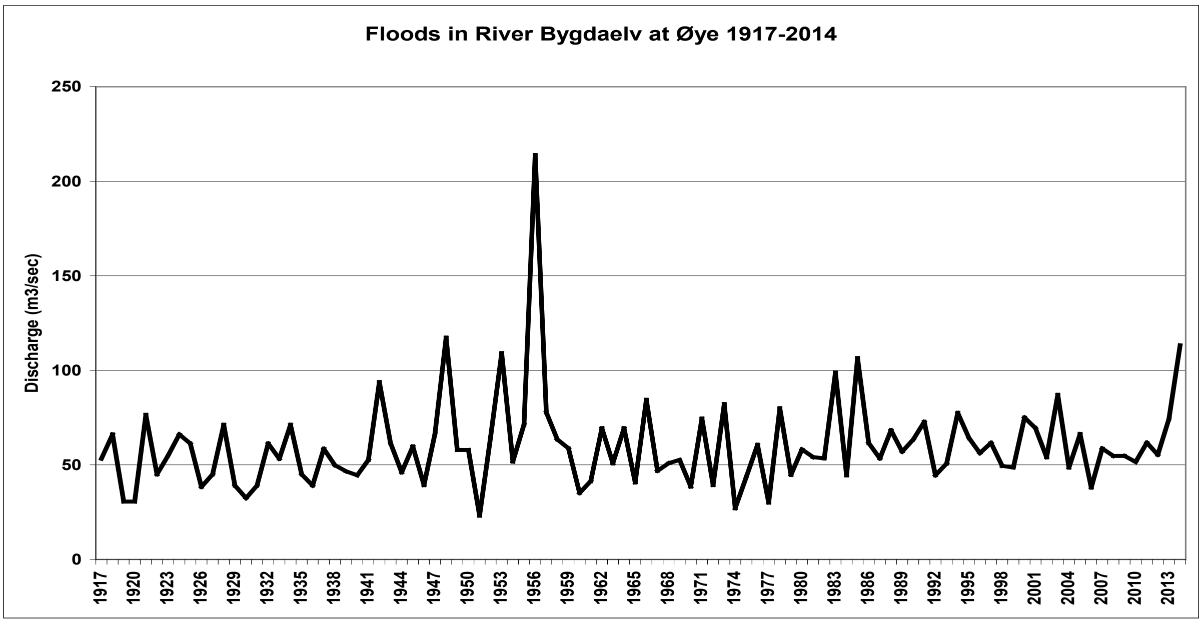


Figure 2.1.1 Annual floods in River Bygdaelv at Øye 1917-2014.

Table 2.1.1.5 Catchment characteristics of the three gauging stations in Sykkylven and Sunnylven.

Station	97.1 Fetvatn	98.1 Fause bru	98.4 Øye
	Basin characteristics		
Catchment area (km^2)	88,95	40,55	138,41
Station altitude (m.a.s.l.)	4	258	147
Mean altitude (m.a.s.l)	591	515	984
Top altitude (m.a.s.l.)	1581	864	1485
Lake (%)	2,12	7,3	4,23
Bog (%)	0,61	2,74	0,36
Forest (%)	36,95	45,48	17,44
Mountain (%)	47,07	36,61	65,2
Glacier (%)	4,32	0	3,74

Table 2.1.1.6 Dates and ranks of the ten largest floods (daily values) at the three gauging stations in Sykkylven and Sunnylven.

97.1 Fetvatn			98.1 Fause bru			98.4 Øye		
1947-2014			1921-1924,1946-1955			1924-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1948	18/9	2	1921	1/11	8	1942	11/9	7
1949	3/10	8	1922	23/5	9	1948	18/9	2
1952	7/1	4	1946	¾	6	1953	10/10	3
1953	4/10	8	1947	4/10	2	1956	22/10	1
1954	18/12	6	1948	18/9	1	1966	7/9	9
1956	22/10	3	1949	3/10	5	1973	9/9	10
1957	8/1	1	1950	20/10	2	1983	27/10	6
1962	9/8	5	1952	20/10	4	1985	1/10	4
1964	30/8	7	1955	20/12	6	2003	25/9	8
1966	7/9	10				2014	28/10	5

Table 2.1.1.7 The largest observed discharge (daily values) at the three gauging stations in Sykkylven and Sunnylven.

Station	97.1 Fetvatn	98.1 Fause bru	98.4 Øye
Year	1957	1948	1956
Date	8/1	18/9	22/10
q (m^3/sec)	195,3	33,19	213,87
Qsp (l/sec km^2)	2195	818	1545
Qsp (mm/day)	190	70,7	133,5

2.1.1.5 RIVER GEIRANGERELV

River Geirangerelv flows toward the bottom of Geirangerfjord from the east. Farms near the river has suffered damages from the same historical floods as Hellesylt. Farms at Geiranger has also suffered from avalanches and rockfalls. Both Hellesylt and Geiranger are expected to suffer severe damages from a future tsunami caused by the large rockfall developing at

Åkerneset further north into the fjord. There is a long-term rainfall station at 60300 Ørjaseter/Geiranger.

2.1.1.6 TAFJORD

The flood regime in River Tafjordelv is strongly affected by regulations. River Muldalselv flowing to the fjord from the north through the waterfall Muldalsfossen had a number of jøkullhlaup in the spring from Lake Illstigvatn in the 1930's. The retreat of the glacier caused these floods to cease. The discharge has been observed at the gauging station 99.3 Øyen 1912-1964. Catchment characteristics are given in Table 2.1.1.9, the dates and ranks of the ten largest annual floods in Table 2.1.1.10 and the date and discharge of the largest flood in Table 2.1.1.11. There is a long-term climate station 60500 Tafjord, which observes high winter temperatures linked to foehn winds. A long-term rainfall station 60400 Nordal has been operating since 1895 at Engeset in the valley west of the Tafjord watercourse. Tafjord suffered from a large rockfall in the Easter 1934 into the fjord, causing a tsunami, which killed 40 people.

2.1.1.7 RIVER VALLDØLA

Valldøla flows southwestward from the water divide towards Romsdal in northeast and Tafjord in south. There is a gauging station at 100.1 Alstad, which has operated from 1983. Catchment characteristics are given in Table 2.1.1.9. The discharge is moderately affected by an upstream diversion to River Verma from Lake Langvatn. Descriptions of several large floods in Valldøla can be found in a farm diary (Grønningseter, 1840-1893), see Table 2.1.1.8. The large floods in the autumn usually occur after snow had accumulated in the mountains, succeeded by a rise in temperature to at least 10° combined with heavy rainfall. Several of these floods have co-incided with floods in Øksendalen at Nordmøre. The dates and ranks of the ten largest annual floods at Alstad are given in Table 2.1.1.10 and the date and discharge of the largest flood is given in Table 2.1.1.11. The district has also suffered from avalanches and rockfalls.

Table 2.1.1.8 Large historical floods in Valldøla

Year	Date	Remarks
1675		Severe flood in Valldøla (co-inciding with floods in Glomma and Gaula)?
1684		
1812	Autumn	
1823	Early October	Landslide dammed the river
1842	15-16 October	Snow melt and heavy rainfall
1850	Early February	Ice run floods. 2 fatalities in Valldal. Co-incided with the disaster at Krogseter at Vatne at Sunnmøre
1850	December	Two large floods
1893	Autumn	Large flood

2.1.1.8 RIVER TENNFJORDELV AT LAKE ENGSETVATN

River Tennfjordelv is located at Haram municipality at the bottom of Grytefjord north of Ålesund. The catchment characteristics of station 101.1 Engesetvatn are given in Table 2.1.1.9. The river is not regulated, but drainage of wetland can have caused some changes in the discharge. The district was mostly forested until the early 1600s. The coast of western Norway was then almost denuded because of large export of timber to England and the

Netherlands. The main farm at the outlet of the river was badly damaged by two severe floods in 1609 and 1627. The gauging station 101.1 Engesetvatn has been operating since 1923. Figure 2.1.1.10 show the annual floods (daily values) 1923-2014. The dates and ranks of the ten largest floods are given in Table 2.1.1.11.

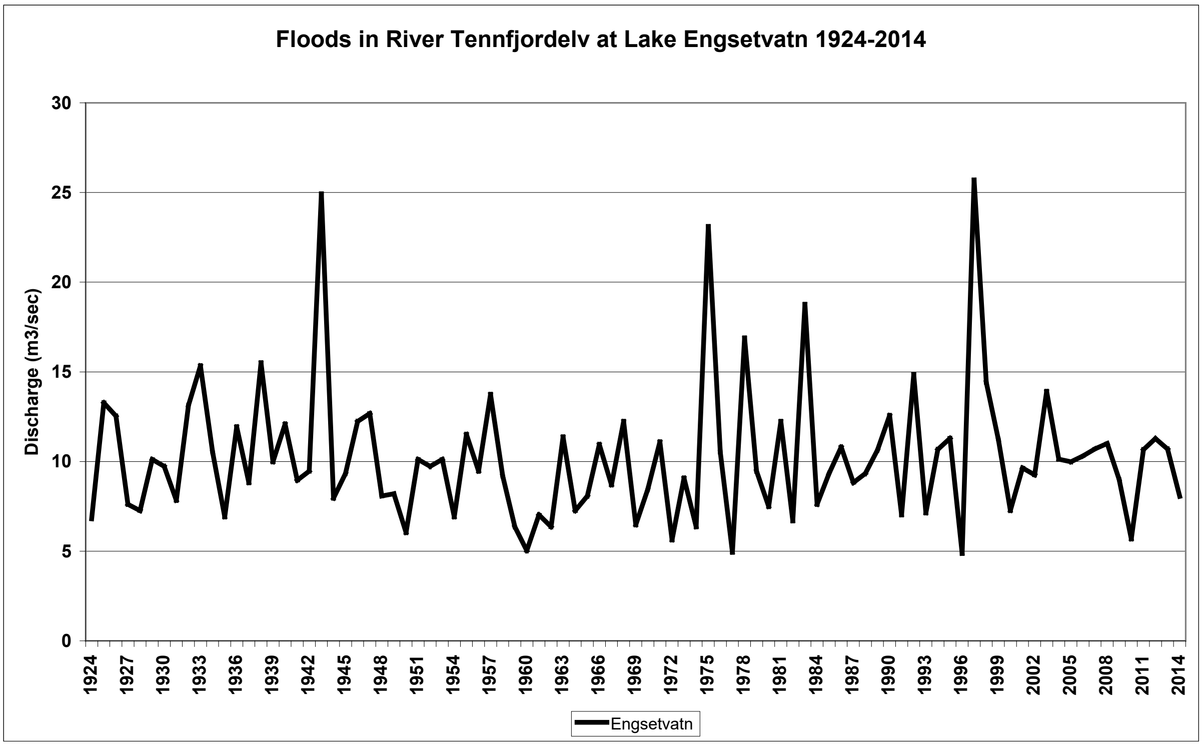


Figure 2.1.2   Annual floods (daily values) in River Tennfjordelv at Lake Engsetvatn 1912-2014.

Table 2.1.1.9   Catchment characteristics for three stations at Tafjord, Valldal and Tennfjord.

Station	99.3 Øyen	100.1 Alstad	101.1 Engsetvatn
	Basin characteristics		
Catchment area (km^2)	183,87	32,49	39,93
Station altitude (m.a.s.l.)	290	269	45
Mean altitude (m.a.s.l)	1328	1120	159
Top altitude (m.a.s.l.)	1994	1735	741
Lake (%)	8,86	5,26	11,14
Bog (%)	0,47	0,46	1,85
Forest (%)	6,35	9,78	60,41
Mountain (%)	76,31	77,74	11,22
Glacier (%)	4,74	4,22	0

Table 2.1.1.10 Dates and ranks of the ten largest floods (daily values) at the three gauging stations at Tafjord, Valldal and Tennfjord.

99.3 Øyen			100.1 Alstad			101.1 Engsetvatn		
1912-1964			1984-2014			1924-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1913	15/10	8	1984	2/6	4	1933	25/12	6
1914	6/7	1	1985	1/10	3	1943	28/12	2
1923	12/7	2	1986	1/10	9	1957	7/10	10
1924	17/8	4	1997	2/7	5	1975	27/12	3
1927	7/7	8	2000	17/5	10	1978	15/9	5
1945	25/6	5	2003	15/8	1	1983	27/10	4
1953	8/9	3	2004	7/5	2	1992	16/1	7
1956	12/6	7	2005	5/7	7	1997	¼	1
1958	30/6	6	2006	13/6	8	1998	20/2	8
1964	15/6	10	2007	7/9	6	2003	19/12	9

Table 2.1.1.11 The largest observed discharge (daily values) at the three gauging stations at Tafjord, Valldal and Tennfjord.

Station	99.3 Øyen	100.1 Alstad	101.1 Engsetvatn
Year	1914	2003	1997
Date	6/7	15/8	¼
q (m3/sec)	126,20	182,0	25,7
Qsp (l/sec km2)	686	804	643
Qsp (mm/day)	59.3	69,5	55,6

Romsdal

The Romsdal district is located northeast of Sunnmøre. The large Romsdalsfjord extends eastward from a row of islands facing the Norwegian Sea. River Rauma flow into the fjord at Åndalsnes from the south and the heavily regulated River Eira into the bottom of Langfjorden further towards northeast. The precipitation decreases from the islands to the west and eastward to the fjord bottoms. The largest floods occur as spring snowmelt floods, but autumn rainfall events have also caused a series of floods in shorter rivers located closer to the coast. Table 2.1.2.1 summarises historical floods, which has occurred in Romsdal. The list is quite short compared to the lists from Sunnmøre and Driva at Nordmøre. Most damages in Romsdal have been caused by avalanches rather than floods. There is however information of several landslides in the records where rainfall and floods may have been the cause. These events have not been included in Table 2.1.2.1 since information of the meteorological conditions are missing.

The largest known rockfall into the sea occurred at Tjelle into Langfjorden 22/2 1756 during an eight days intensive rainfall events. Possible rockfalls are also monitored in the Romsdal valley at Mannen and Børa and a possible rockfall from Opstadhornet at Otterøya into the fjord west of Molde. Some events of storm surges or surges caused by subsurface slides are also known at the lowlying islands further west.

Table 2.1.2.1 Historical floods in Romsdal

Year	Date	Remarks
1650		Large flood in rivers near Langfjorden after long-term rainfall. Landslides destroyed 15 buildings at Mittet.
1743	4-5/12	Snowmelt and long-term heavy rainfall caused floods
1744		Landslide at Mittet caused by the 1743 flood
1750		Deduction at 11 farms in Romsdal, Sunnmøre and Sunnfjord
1756	22/2	Major mountain slide into Langfjorden at Tjelle after 8 days heavy rainfall. 32 fatalities.

2.1.2.1 RIVER RAUMA AT HORGHEIM

River Rauma flows northward from Lake Lesjaskogsvatn at the top of Gudbrandsdalen, ending in the Romsdalsfjord at Åndalsnes. The catchment area is 1.202 square kilometer. The main gauging station 103.40 Horgheim has data from 1912. The gauging station 103.3 Stuguflåten is located upstream the main valley on the plateau downstream the lake. River Ulvå is a tributary from the water divide towards the Tafjord to the west. There is a diversion from this river to the Verma catchment further north. The catchment characteristics at Horgheim, Storhølen and Stuguflåten are given in Table 2.1.2.2. The river was regulated in 1971. River Rauma has a typical spring flood regime. The annual flood occurs most frequently in June (56 percent), in May (22 percent) and in July (17 percent). A large rainfall flood occurred in River Ulvåa near the water divide to Tafjord 26 June 1960, which caused numerous landslides from Kabben.

Horgheim is located just upstreams the point of Mannen where a piece of rock is expected to fall into the valley where a possible damming of River Rauma may take place. There have been many landslides and rockfalls into the valley upstreams Horgheim.

Table 2.1.2.2 Catchment characteristics of three gauging stations in River Rauma.

Station	103.40 Horgheim	101.1 Storhølen	103.3 Stuguflåten
	Basin characteristics		
Catchment area (km^2)	1099	435,5	377,0
Station altitude (m.a.s.l.)	61	489	520
Mean altitude (m.a.s.l)	1241	1301	1322
Top altitude (m.a.s.l.)	2012	1990	2012
Lake (%)	3,81	3,92	3,22
Bog (%)	1,09	1	0,72
Forest (%)	16,97	10,5	19,22
Mountain (%)	72,76	80,1	70,71
Glacier (%)	2,19	3,1	2,44

There is no information about historical floods in River Rauma prior to the start of the observations. The annual floods (daily values) at Horgheim is shown in Figure 2.1.3. The lack of large floods after 1971 is a result of diversions of water past the gauging station at Horgheim. The dates and ranks of the ten largest annual floods at stations in River Rauma are given in Table 2.1.2.3 and the date and discharge of the largest flood in Table 2.1.2.4.

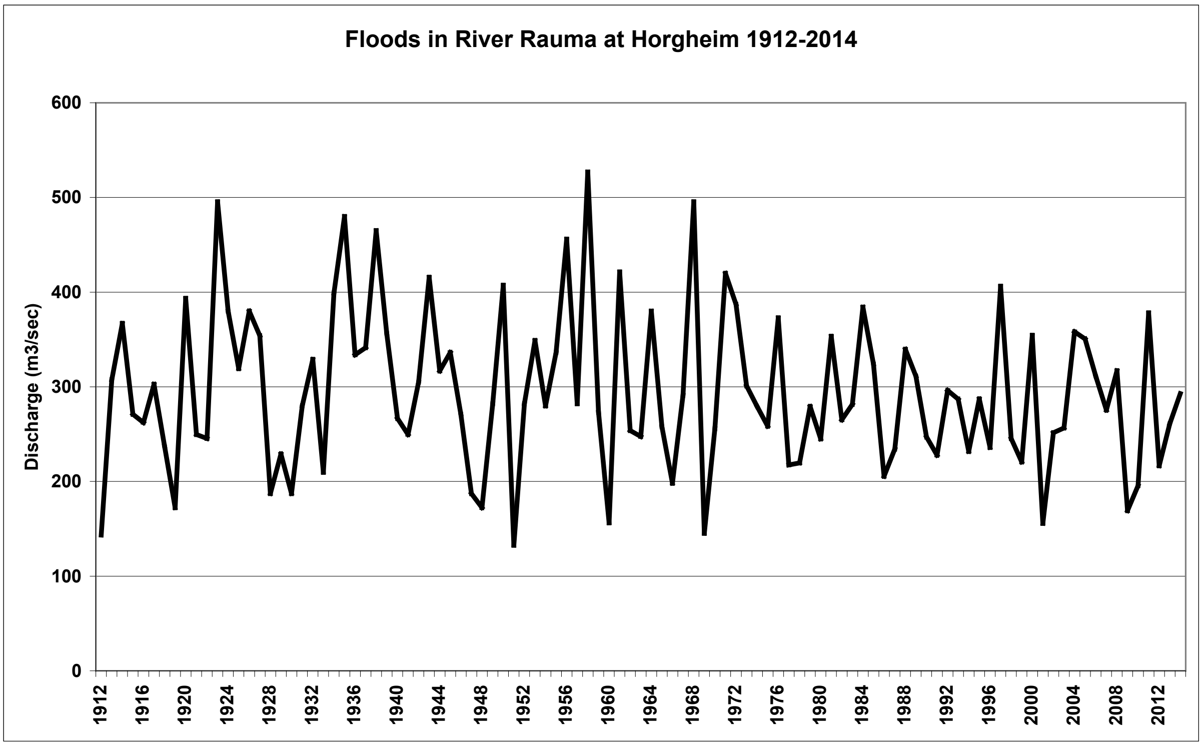


Figure 2.1.3 Annual floods (daily values) in River Rauma at Horgheim 1912-2014.

Table 2.1.2.3 Date and ranks of the ten largest floods (daily values) at the three gauging stations

103.40 Horgheim			101.1 Storhølen			103.3 Stuguflåten		
1912-2014			1971-2014			1971-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1923	13/7	2	1971	30/5	1	1971	1/6	2
1935	23/6	4	1972	7/6	9	1972	7/6	1
1938	1/9	5	1976	27/6	5	1976	27/6	6
1943	22/6	9	1983	20/6	7	1981	25/5	10
1950	8/6	10	1984	2/6	3	1984	3/6	4
1956	12/6	6	1997	2/7	4	1985	29/5	8
1958	1/7	1	2000	18/5	6	1988	30/5	5
1961	2/6	7	2004	7/5	2	2005	6/7	7
1968	4/7	2	2005	21/6	10	2008	3/6	9
1971	31/5	8	2011	10/6	8	2011	10/6	3

Table 2.1.2.4 The largest observed discharge (daily values) at the three gauging stations in River Rauma.

Station	103.40 Horgheim	101.1 Storhølen	103.3 Stuguflåten
Year	1958	1971	1971
Date	1/7	30/5	7/6
q (m^3/sec)	527,0	179,2	162,7
qsp (l/sec km^2)	479	411	432
qsp (mm/day)	41,4	35,6	37,3

2.1.2.2 FLOODS IN COASTAL RIVERS BETWEEN RIVER RAUMA AND RIVER EIRA IN ROMSDAL

River Isa flows westward to the bottom of Isfjorden east of Åndalsnes. The catchment area is 175 square kilometers. There is a gauging station in the catchment, 103.20 Morstøl bru. Rivers Herjeelv and Mittetelv flows northwestward toward the outer part of Langfjorden. There are no gauging stations in these rivers, but there are documentations of severe flood damages from the large floods in 1650 and 1743.

River Visa flows northward through Vistdal to the south side of Langfjorden west of River Eira. The catchment area is 126 square kilometers. The watercourse has one gauging station, 104.23 Vistdal, which has been operating since 1972. The outlet of River Visa into the fjord was ravaged by the tsunami resulting from the large mountain rockfall, Tjellefonna, from the opposite side of the fjord 22 February 1756.

Catchment characteristics of Morstøl bru, Vistdal and a station at Lille Eikesdalsvatn in Eira are given in Table 2.1.2.5. The dates and ranks of the ten largest annual floods are given in Table 2.1.2.6 and the date and discharge of the largest flood in Table 2.1.2.7.

Table 2.1.2.5 Catchment characteristics of three gauging stations in rivers between Rivers Rauma and Eira.

Station	103.20 Morstøl bru	104.23 Vistdal	104.1 Lille Eikesdalsvatn
	Basin characteristics		
Catchment area (km^2)	44,40	66,52	801,44
Station altitude (m.a.s.l.)	110	46	139
Mean altitude (m.a.s.l)	912	737	1267
Top altitude (m.a.s.l.)	1724	1516	1960
Lake (%)	2	2,27	7,51
Bog (%)	0,38	4,12	0,52
Forest (%)	18,18	31,93	3,31
Mountain (%)	72,75	55,23	79,96
Glacier (%)	5,25	0	0,99

Table 2.1.2.6 Dates and ranks of the ten largest floods (daily values) at the three gauging stations between Rivers Rauma and Eira.

103.20 Morstøl bru			104.23 Vistdal			104.1 Lille Eikesdalsvatn		
1972-2014			1976-2014			1907-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1990	10/7	6	1978	30/8	5	1907	15/6	7
1991	20/6	5	1980	22/8	10	1909	24/6	10
2000	7/8	7	1981	13/5	8	1923	13/7	3
2001	10/9	8	1983	27/10	1	1924	23/9	9
2002	28/6	8	1990	30/4	4	1926	19/6	6
2003	14/8	1	1997	14/9	3	1932	7/7	1
2004	24/9	4	1999	9/4	6	1934	9/5	5
2006	5/9	3	2000	7/8	9	1935	22/6	4
2007	7/9	2	2001	10/9	7	1938	1/9	1
2011	23/1	10	2003	15/8	2	1943	13/6	7

Table 2.1.2.7 The largest observed discharge (daily values) at the three gauging stations between Rivers Rauma and Eira.

Station	103.20 Morstøl bru	104.23 Vistdal	104.1 Lille Eikesdalsvatn
Year	2003	1983	1932,1938
Date	14/8	27/10	7/7,1/9
q (m^3/sec)	78,39	61,63	491,85
qsp (l/sec km^2)	1766	926	614
qsp (mm/day)	152,6	96,5	53,0

The largest one-day flood occurred at Morstøl bru 14 August 2003 with a discharge of 78,62 m^3/sec corresponding to 1765 l/sec km^2 or to a runoff of 153 mm/d. The peak of the flood occurred 17:26 with a discharge of 2528 l/sec km^2. The largest one-day flood occurred at Vistdal 27 October 1983 with a discharge of 61,63 m^3/sec corresponding to 926 l/sec km^2 or to a runoff of 80 mm/d. The peak of the flood occurred 05:29 with a discharge of 1450 l/sec km^2. The flood 15 August 2003 was only marginally less with a discharge of 59,29 m^3/sec corresponding to 891 l/sec km^2 or to a runoff of 77 mm/d. The peak occurred at midnight with a discharge of 1496 l/sec km^2.

2.1.2.3 RIVER EIRA

River Eira is the river between Lake Eikesdalsvatn and the bottom of Langfjorden in Romsdal. The upper part of the catchment is River Aura, which was flowing from Lake Aursjøen through Eikesdalen. The original catchment area was 1119 square kilometers. The upper part of the catchment was diverted to Litledalselven at Sunndalsøra via Aura power station with Lake Aursjøen as the reservoir in 1953. Later other smaller parts of the catchment including the Mardalsfoss waterfall were diverted to Romsdalen through the Grytten power station. There are two long-term gauging stations in the catchment, Eikesdalsvatn and Lille Eikesdalsvatn.

The gauging station 104.2 Eikesdalsvatn has been active since 1902. Catchment characteristics are listed in Table 2.1.2.8, the dates and ranks of the ten largest annual floods in Table 2.1.2.9 and the date and the discharge of the largest flood in Table 2.1.2.10.

Lille Eikesdalsvatn is located at Eikesdalen, upstreams Lake Eikesdalsvatn. The gauging station 104.1 Lille Eikesdalsvatn has been active since 1907. Catchment characteristics are listed in Table 2.1.2.5, the dates and ranks of the ten largest annual floods in Table 2.1.2.6 and the discharge of the largest flood in Table 2.1.2.7.

The mountain slopes are steep on both sides of the lake as well in the upstreams valley. Several avalanches in the past has resulted in damages on farms as well as loss of lives.

2.1.2.4 RIVER OSENELV AT BOLSØY

River Osenelv is located at Bolsøy east of Molde and north of Fannefjord, a branch of Romsdalsfjord. The catchment area of the watercourse is 139 square kilometers. The gauging station Øren has been active since 1923. The catchment is not regulated, but drainage of wetland can have caused some changes in the discharge.

Catchment characteristics are listed in Table 2.1.2.8, the dates and ranks of the ten largest annual floods in Table 2.1.2.9 and the discharge of the largest flood in Table 2.1.2.10. Figure 2.1.4 show the annual floods 1924-2014 observed at 105.1 Øren.

Table 2.1.2.8 Catchment characteristics of gauging stations in River Eira, Gusjåelv and Farstadelv in Romsdal.

Station	104.2 Eikesdalsvatnet	105.1 Øren	107.3 Farstad
	Basin characteristics		
Catchment area (km^2)	1093	137,59	24,23
Station altitude (m.a.s.l.)	22	7	11
Mean altitude (m.a.s.l)	1226	235	56
Top altitude (m.a.s.l.)	1961	795	794
Lake (%)	8.66	8,19	4,58
Bog (%)	0,39	15,93	9,99
Forest (%)	5,77	57,4	19,89
Mountain (%)	77,38	9,59	13,87
Glacier (%)	1,42	0	0

Table 2.1.1.9 Dates and ranks of the ten largest floods (daily values) at the three gauging stations in River Eira, Gusjåelv and Farstadelv in Romsdal.

104.2 Eikesdalsvatnet			105.1 Øren			107.3 Farstad		
1902-2014			1924-2014			1966-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1905	22/6	2	1925	17/1	8	1967	15/12	2
1909	27/6	10	1932	29/1	6	1971	25/9	9
1923	13/7	1	1938	4/3	10	1973	10/12	8
1926	11/6	5	1943	28/2	6	1983	11/1	7
1927	8/7	7	1946	3/4	5	1991	24/2	10
1932	8/7	3	1953	25/3	4	1992	18/1	6
1934	11/5	6	1968	27/4	9	1993	21/3	3
1935	25/6	4	1975	27/12	1	1994	21/1	4
1943	14/6	8	1978	18/9	1	1997	14/9	1
1944	12/7	8	1997	31/3	3	1998	9/2	5

Table 2.1.2.10 The largest observed discharge (daily values) at the three gauging stations in River Eira, Gusjåelv and Farstadelv in Romsdal.

Station	104.2 Eikesdalsvatnet	105.1 Øren	107.3 Farstad
Year	1923	1975	1997
Date	13/7	27/12	14/9
q (m^3/sec)	495,16	158,59	11,0
qsp (l/sec km^2)	453	1153	454
qsp (mm/day)	39,1	99,6	39,2

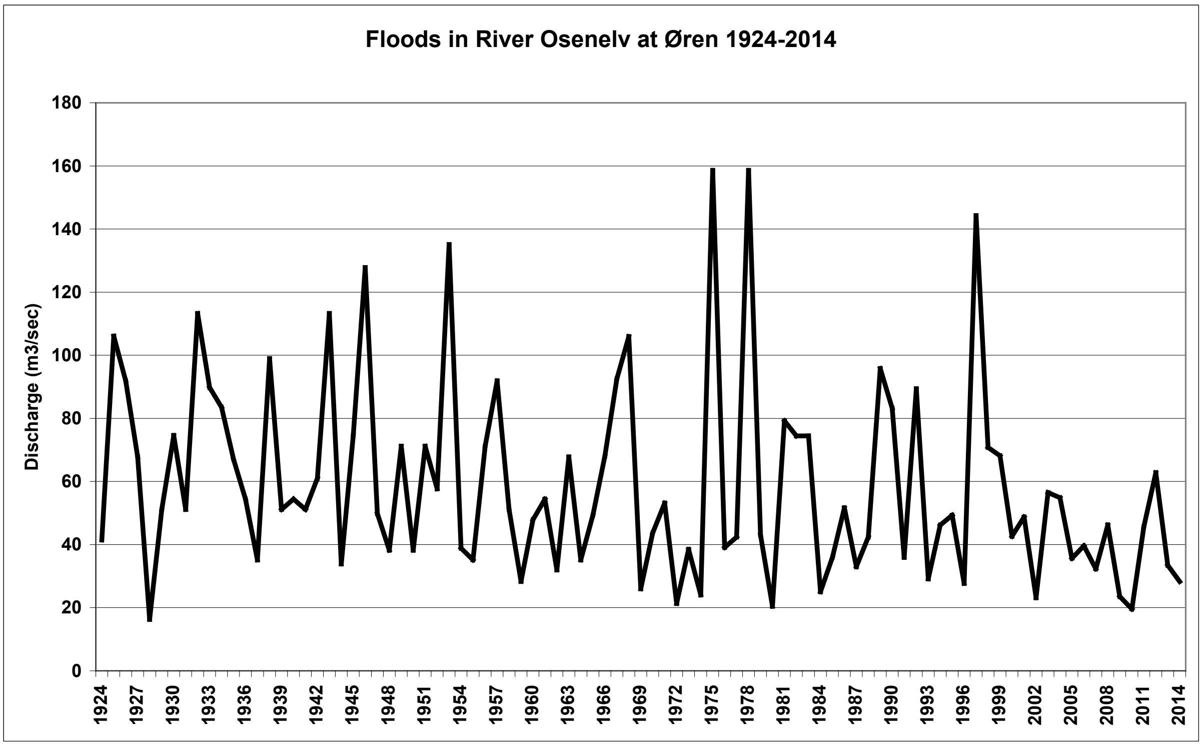


Figure 2.1.4 Annual floods (daily values) in River Osenelv 1924-2014.

2.1.2.4 RIVER FARSTADELV AT FRÆNA

River Farstadelv flows northwestward from a lowlying area northwest of Molde to the Norwegian Sea at Hustavika. The catchment is strongly maritime. The gauging station 107.1 Farstadelv has been active from 1966. Catchment characteristics are listed in Table 2.1.2.8, the dates and ranks of the ten largest annual floods in Table 2.1.2.9 and the discharge of the largest flood in Table 2.1.2.10. Growth of vegetation in the river has affected the data quality.

Nordmøre

Nordmøre is located north of Romsdal. The Tingvoldfjord/Sunndalsfjord runs southeastward to Sunndalsøra where River Driva flows into the bottom of Sunndalsfjorden. The district extends towards Sør-Trøndelag towards north and northeast. The district comprises a number of fiords and islands with valleys goin eastwards to the mountain district known as Trollheimen. The district is less alpine than Sunnmøre.
Several of the rivers within the district are utilised for hydropower production.

2.1.3.1 RIVER USMA

River Usma is a small river draining westward through Øksendalen towards the south side of the Tingvollfjord west of Sunndalsøra. The catchment is exposed to the west, and there have therefore been several of large rainfall floods in the catchment. These rainfall events often co-incide with similar events in River Surna and in River Valldalselv at Sunnmøre.

There is no gauging station in the catchment, but a longterm precipitation station, 63100 Øksendal. Information are available from historical sources of floods, avalanches and landslides, which has caused severe damages as well as loss of lives in Øksendalen.

Table 2.1.3.1 Large floods in Øksendalen from historical sources.

Year	Date	Remarks
1712-13		Avalanches and loss of 5 lives.
1727	March	Avalanche
1727	Before Christmas	Flood
1756	22/2	Flood - 8 days of heavy rainfall
1776	June	Flood
1842	15-16/10	Flood
1848	11/8	Flood
1858	12/4	Avalanche
1868	19/2	Avalanche
1883	Summer	Flood
1883	7-10/10	Large flood

2.1.3.2 RIVER LITLEDALSELV

River Litledalselv drains northwestward to the bottom of the Sunndalsfjord at Sunndalsøra near the outlet of River Driva. The watercourse is regulated with the Aura power station near the outlet of the river. The catchment includes now the entire area diverted from the Eira/Aura catchment to Lake Aursjøen.The valley is steep, and the farms have suffered from multiple avalanches, landslides and rockfalls. The gauging station 109.1 Litledalselv has been operating from 1912 to 1959.

2.1.3.3 RIVER DRIVA

The lower part of River Driva is located at Sunndal municipality at Nordmøre, while the upper part is located at Oppdal in Sør-Trøndelag. The catchment area of River Driva is 2.484 square kilometers. The upper part of the catchment comprises the northern part of Dovrefjell and mountains east of Drivdalen. Driva turns westwards at Oppdal. The river flows towards the Sunndalsfjord at Sunndalsøra at Nordmøre. Some large tributaries have caused severe flood damage, River Tronda joining Driva from west in Drivdalen and River Vinstra flowing in from east at Oppdal. Further west in Oppdal the tributaries Vindøla and Festa join River Driva from north. These tributaries origin in the mountain district Trollheimen.Two long term gauging stations are operating in Driva, 109.42 Elverhøy bru in Sunndalen with data from 1908 and 109.9 Risefoss in Drivdalen with data from 1934. Further upstreams the statio109.2 Kongsvoll was operating from 1922. The severe flood in 1932 destroyed by the station. Another station, 109.21 Svoni, was later established at Dovrefjell in 1970. The data quality is bad prior to 1995.

The discharge in the lower part of the river is affected by the regulation from 1973. There is a long term precipitation station at 63500 Sunndal. The bottom of the valley has suffered from many floods, avalanches, icefalls, landslides and windstorms in Sunndalen, causing loss of lives as well as considerable damages. Some of these events have been documented by Johannessen (1955-1963). The most severe avalanche occurred in February 1868 killing 32 men working on the new road between Oppdal and Sunndalsøra (Furseth (2006). An overview of these historical events is given in Table 2.1.3.2.

Table 2.1.3.2 Historical floods in River Driva.

Year	Date	Remarks
1665		Deduction at Bjørbekk and Ottem in Sunndal.
1666	August	Deduction at 6 farms in Sunndal for flood and bank failure.
1676		Deduction at Furu and Ottem in Sunndal after bank failure and rockfall probably in 1675.
1693	Spring	Deduction at 4 farms in Sunndal after flood and bank failure in 1692.
1698	19/7	Severe rainfall flood in Rivers Vinstra and Tronda.
1789	21-23/7	Storofsen – Severe damages in Oppdal and Sunndal.
1855		Flood in River Driva.
1863		Flood in River Driva at Oppdal.
1873	24/7	Large rainfall flood and landslides in River Driva.
1875	18/8	Flood in River Driva.
1879	June	Spring flood in River Driva.
1880		Ice run flood in River Driva.
1881	25-27/12	Large flood in River Driva after rainstorm and ice run.
1882	18/1, 25/1,16/3	Ice run floods in River Driva.
1896	End of January	Ice run flood in River Driva after rainstorm.

The catchment area at 109.42 Elverhøy bru is 2.437 square kilometers. The station has a typical spring flood regime. The annual flood occurs in 25 percent of all years in June, 57 percent in July and 14 percent in August.

The catchment area of 109.9 Risefoss is 745 square kilometers. The station has a spring flood regime. The annual flood occurs 27 percent in June, 63 percent in July and 7 percent in August of all years. The most severe floods in River Driva occur, however, in the summer, caused by heavy rainfall perhaps combined with some snow melting. The largest observed flood in 2011 and the second largest in July 1932 were caused by rainfall at the peak of snow melting at Dovrefjell.

The gauging station 109.20 Grensehølen is located at River Driva at the county bondary is operating since 1965 The catchment characteristics at Elverhøy bru, Grensehølen and Risefoss are listed in Table 2.1.3.3, the dates and ranks of the ten largest annual floods (daily values) in Table 2.1.3.4 and the largest discharge in Table 2.1.3.5. The annual floods at Elverhøy bru are shown in Figure 2.1.5 and at Risefoss in Figure 2.1.6.

There are some gauging stations in tributaries to the main river. 109.29 Dalavatn is small catchment located at the mountains on the southers side of the main valley. Further upstreams River Grøva flows into the main river from the valley Grøvudalen. This river flows northward from the Snøhetta/Larstindan region. The gauging station 109.12 Bruøy was active in the tributary Grøva 1949-1990. River Festa flows into the main river at Oppdal from the Trollheimen mountains. The gauging station 109.7 Festa was active 1919-1973. The river was regulated in 1951.

The catchment characteristics of the three gauging stations 109.29 Dalavatn, 109.12 Bruøy and 109.7 Festa are listed in Table 2.1.3.6, the dates and ranks ofthe ten largest annual floods in Table 2.1.3.7 and the date and discharges of the largest flood in Table 2.1.3.8.

Table 2.1.3.3 Catchment characteristics of the gauging stations Elverhøy bru, Grensehølen and Risefoss in River Driva.

Station	109.42 Elverhøy bru	109.20 Grensehølen	109.9 Risefoss
	Basin characteristics		
Catchment area (km^2)	2437	1633	745
Station altitude (m.a.s.l.)	34	220	556
Mean altitude (m.a.s.l)	1217	1202	1347
Top altitude (m.a.s.l.)	2283	2283	2283
Lake (%)	2,83	2,82	1,87
Bog (%)	1,78	2,07	1,22
Forest (%)	17,65	17,57	6,79
Mountain (%)	69,56	68,45	83,98
Glacier (%)	0,79	0,5	0,9

Table 2.1.3.4 The dates and rank of the ten largest floods (daily values) observed in River Driva at Elverhøy bru, Grensehølen and Risefoss.

109.42 Elverhøy bru			109.20 Grensehølen			109.9 Risefoss		
1908-2014			1965-2014			1935-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1932	8/6	2	1967	30/5	6	1935	17/6	6
1934	9/5	10	1968	3/7	8	1939	20/6	7
1943	22/6	7	1971	31/5	6	1943	13/6	2
1985	29/5	8	1972	7/6	9	1961		10
1995	2/6	4	1973	1/6	1	1963	28/6	3
1997	9/5	5	1979	2/6	5	1966	19/5	4
2000	18/5	6	1995	2/6	3	1967		9
2003	15/8	3	1997	2/7	10	1973	1/6	1
2004	7/5	9	2003	15/8	4	1995	2/6	8
2011	10/6	1	2011	10/6	2	2011	10/6	5

Table 2.1.3.5 The discharge (daily values) of the largest flood observed at Elverhøy bru, Grensehølen and Risefoss.

Station	109.42 Elverhøy bru	109.20 Grensehølen	109.9 Risefoss
Year	2011	1973	1973
Date	10/6	1/6	1/6
q (m^3/sec)	883,61	679,72	369,73
qsp (l/sec km^2)	363	200	496
qsp (mm/day)	31,3	17,3	43,0

The large flood in 1932 caused the gauging station at 109.2 Kongsvoll to fail 7 July. The discharge was then 115,34 m^3/sec corresponding to 421 l/sec km^2 or 36 mm/d. It was stated that that the flood was the largest since Storofsen and in River Jora at Dombås. A new station was established at Svoni i 1970. The largest flood observed there 1 June 1973 was 71,91 m^3/sec corresponding to 528 l/sec km^2 or 46 mm/d.

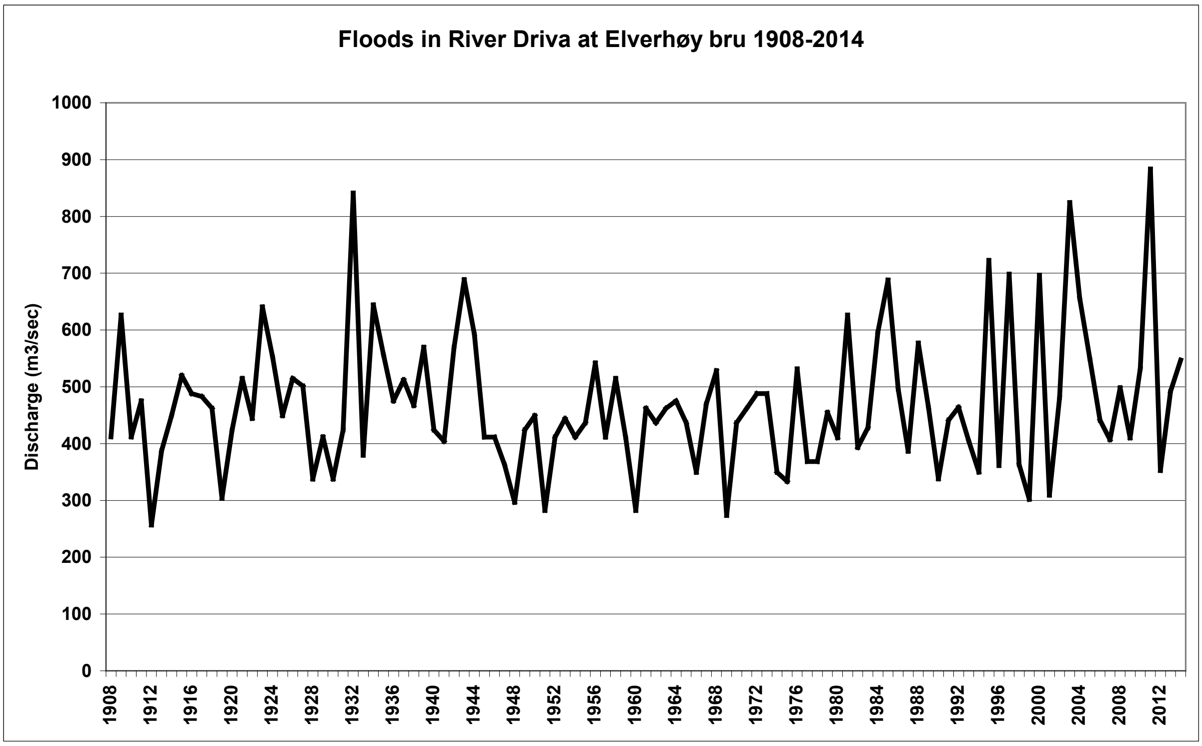


Figure 2.1.5   Annual floods (daily values) in River Driva at Elverhøy bru 1908-2014.

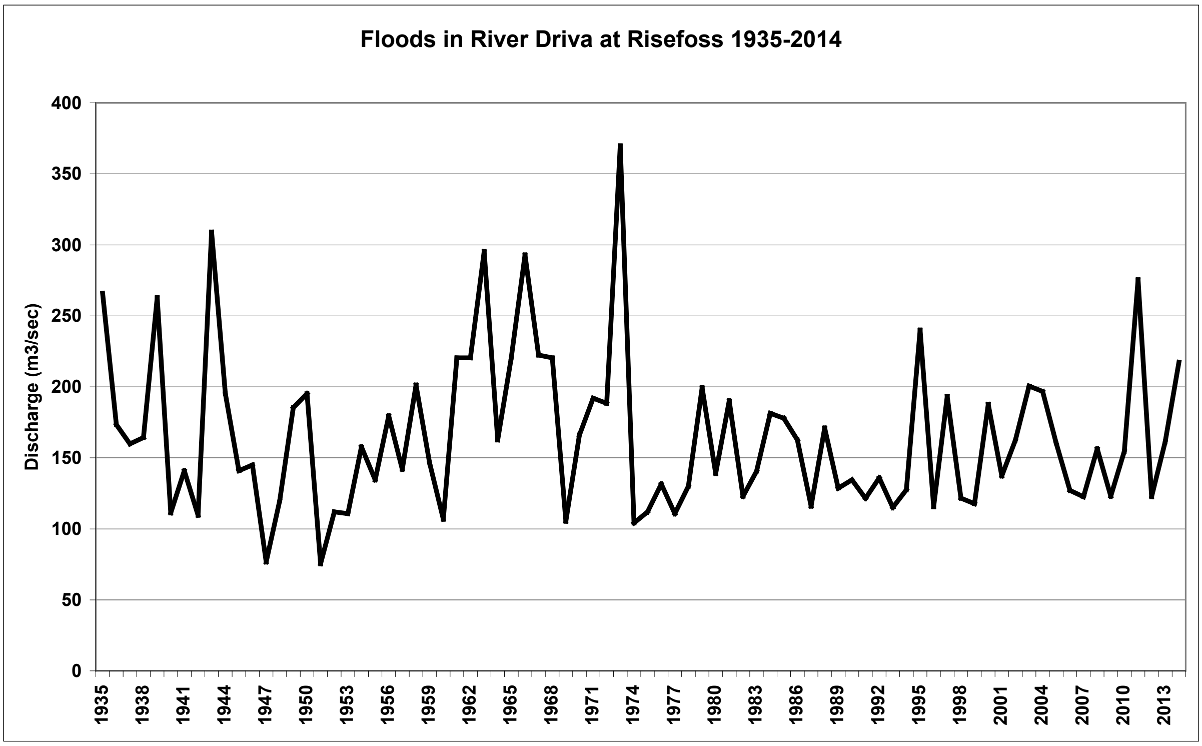


Figure 2.1.6   Annual floods (daily values) in River Driva at Risefoss 1935-2014.

Table 2.1.3.6 Catchment characteristics of gauging stations in tributaries to River Driva.

Station	109.29 Dalavatn	109.12 Bruøy	109.7 Festa
	Basin characteristics		
Catchment area (km^2)	85,45	473,74	173,78
Station altitude (m.a.s.l.)	440	259	639
Mean altitude (m.a.s.l)	1178	1346	972
Top altitude (m.a.s.l.)	1808	1981	1665
Lake (%)	4,73	3,38	13,58
Bog (%)	2,18	1,06	4,15
Forest (%)	12	13,51	22,13
Mountain (%)	73,3	78,95	53,65
Glacier (%)	0,83	0,42	0,42

Table 2.1.3.7 Dates and ranks of the ten largest annual floods (daily values) at the three stations in tributaries to River Driva.

109.29 Dalavatn			109.12 Bruøy			109.7 Festa		
1975-2014			1949-1990			1919-1973		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1976	11/6	8	1950	7/6	7	1923	13/7	1
1981	23/5	4	1952	3/7	10	1932	8/7	6
1985	28/5	10	1955	12/7	6	1934	10/8	2
1988	29/5	6	1956	12/6	3	1935	18/6	7
1991	20/6	5	1958	30/6	2	1938	10/6	9
1995	2/6	7	1961	2/6	9	1943	14/6	5
1997	9/6	3	1963	28/6	7	1944	10/6	4
2000	17/5	2	1964	14-15/6	5	1946	3/6	10
2003	15/8	1	1968	3/7	1	1956	13/6	3
2011	10/6	9	1973	1/6	4	1968	19-20/6	7

Table 2.1.3.8 Dates and discharges of the largest annual flood (daily values) at the three stations in tributaries to River Driva.

Station	109.29 Dalavatn	109.12 Bruøy	109.7 Festa
Year	2003	1968	1923
Date	15/8	3/7	13/7
q (m3/sec)	40,56	201,44	54,22
qsp (l/sec km2)	475	425	312
qsp (mm/day)	41,0	36,7	27,0

2.1.3.3 RIVER ÅLVUNDA AND RIVER TOÅA

River Ålvunda or Ulvunda flows westward from Trollheimen and Innerdalen through Virumdalen to the Ålvundfjord a branch of the Halsafjord. The catchment area is 200 square kilometres. The discharge has been observed at 111.1 Innerdalsvatn 1966-1989 and at 111.8 Nerdal 1967-2002.

River Toåa flows northwestward from Trollheimen to the Todalsfjord, a branch of Halsafjord. The catchment area is 251 square kilometres. The discharge has been observed at

111.3/5 Talgøyfoss 1936-2014 and at Todalselv 1907-1938. Catchment characteristics of the joint series are given in Table 2.1.3.7. The dates and ranks of the ten largest annual floods are given in Table 2.1.3.8 and the date and discharge of the largest flood in Table 2.1.3.9. The discharge was briefly observed at 111.4 Kårvatn 1932-1934 and in the tributary Nauståa at 111.10 Nauståa 1978-2014. The river was regulated in 1973.

2.3.1.4 RIVER SURNA

River Surna flows westward from Rindalsskogen to Surnadalsfjorden at Surnadalsøra. The larger tributaries of River Surna are Rinna, Folla and Vindøla. There are no longterm discharge series in River Surna, but shorter series at some locations. Precipitation has been observed at the station 64800 Surnadal since 1896. Historical floods, causing damages at various farms, have been listed by Hyldbakk (1957). These are shown in Table 2.1.3.6. Large rainfall events and floods tend to co-incide with large events in Øksendal and in Valldal at Sunnmøre.

Table 2.1.3.6 Large floods in River Surna from historical sources.

Year	Date	Remarks
1727	Autumn	Flood damages at 14 farms. Deductions 31/5-1728
1756	22/2	Severe flood after 8 days of rainfall. Co-incides with the landslide at Tjelle into Langfjorden in Romsdal
1774		River bank failures
1789	21-23/7	Storofsen - damages at many farms
1814		River bank failure at Grimsmo. Loss of farmland
1847	Before Christmas	Large flood damaged most of the roads
1854		Large flood
1862		Large flood
1863	After Christmas	Ice run destroyed flood protection works
1879	June	Flood
1880	3-4/12	Ice runs
1881	25-27/12	Large ice run flood
1882	1/1, 25/1, 16/3	Ice runs
1883	8/10	Major rainfall flood
1909	14/8	Severe rainfall flood comparable with 2003
1929	25/6	Large spring flood
1934	6-8/5	Large spring flood

Table 2.1.3.7 Catchment characteristics of gauging stations in in River Toåa and Surna.

Station	111.3/5 Todalselv/Talgøy foss	112.6 Sjursberget	112.8 Rinna
	Basin characteristics		
Catchment area (km^2)	206,83/150,47	168,48	86,23
Station altitude (m.a.s.l.)	18/92	77	467
Mean altitude (m.a.s.l)	883/917	775	814
Top altitude (m.a.s.l.)	1620	1663	1587
Lake (%)	3,75/4,92	2,46	3,05
Bog (%)	0,97/0,86	5,28	6,85
Forest (%)	15,45/11,98	20,02	15,11
Mountain (%)	74,56/79,76	55,79	64,1
Glacier (%)	0	0,11	0,44

Table 2.1.3.8 The dates and ranks of the ten largest floods (daily values) observed i in River Toåa and Surna.

111.3/5 Todalselv/Talgøyfoss			112.6 Sjursberget			112.8 Rinna		
1908-2014			1958-1984			1970-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1909	14/8	3	1958	12/7	4	1971	30/5	5
1918	25/6	5	1959	15/9	9	1973	1/6	5
1929	10/9	4	1960	29/6	5	1978	24/5	10
1932	7/7	5	1964	30/8	7	1981	25/5	9
1936	20/7	9	1966	24/9	9	1983	26/10	3
1940	24/8	8	1967	22/11	7	1986	8/6	8
1953	7/9	1	1968	22/10	2	1990	1/5	2
1956	12/6	7	1971	7/10	6	1997	8/6	7
1957	6/10	10	1983	26/10	1	2002	19/9	1
1964	31/8	2	1984	19/5	2	2010	19/6	4

Table 2.1.3.9 The largest observed discharge (daily values) at the three gauging stations in River Toåa and Surna.

Station	111.3/5 Todalselv/Talgøyfoss	112.6 Sjursberget	112.8 Rinna
Year	1953	1964	2002
Date	7/9	26/10	19/9
Q (m^3/sec)	246,50	166,15	74,25
qsp (l/sec km^2)	1638	986	861
qsp (mm/day)	141,5	85,2	14,4

River Grytåa is located between the reservoir Engelivatn and Valsøyfjorden with a gauging station at 113.3 Sletthølen, which has been active 1943-2013. The series is affected by regulations but have been used extensive in homogeneity testing in double-mass analysis based on estimated inflow series. The gauging station 114.1 Myra is located at a small coastal catchment at the island Ertvågøy. The station has been active since 1988. The gauging station

19.4 Rovatn in River Søa has been active since 1923, but are strongly affectecd by regulations in 1940, 1966 and 1967. The first regulation affected mostly low flow data, but the data quality is generally low. The series have been included in the report because of a lack of better series in the district.

Table 2.1.3.10 The discharge (daily values) of the largest flood observed observed in River Grytåa, at River Myra and at River Søa.

Station	113.3 Sletthølen	114.1 Myra	119.4 Rovatn
	Basin characteristics		
Catchment area (km^2)	22,63	16,46	236,68
Station altitude (m.a.s.l.)	214	30	12
Mean altitude (m.a.s.l)	373	212	383
Top altitude (m.a.s.l.)	964	891	1027
Lake (%)	8,7	0,49	8,35
Bog (%)	10,73	13,52	17,23
Forest (%)	32,11	39,1	38,81
Mountain (%)	34,97	42,08	27,6
Glacier (%)	0	0	0

Table 2.1.3.11 The dates and rank of the ten largest floods (daily values) observed at River Grytåa, at River Myra and River Søa.

113.3 Sletthølen			114.1 Myra			119.4 Rovatn		
1943-2010			1988-2014			1924-2011		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1943	28/2	1	1989	25/10	6	1932	28/1	2
1945	11/3	6	1990	10/7	3	1943	28/2	6
1946	¼	3	1994	23/11	7	1946	4/4	3
1947	21/10	4	1998	25/2	1	1947	22/10	7
1953	24/3	4	1999	9/4	2	1953	25/3	1
1954	5/8	10	2003	17/12	4	1955	23/11	8
1956	17/11	9	2006	6/2	5	1975	9/10	5
1971	6/12	8	2007	16/11	8	1976	8/9	9
1975	27/12	7	2008	27/11	9	1982	27/3	10
1992	15/1	2	2012	29/2	10	1983	27/10	4

Table 2.1.3.12 The largest observed discharge (daily values) at the three gauging stations at River Grytåa, at River Myra and at River Søa

Station	113.3 Sletthølen	114.1 Myra	119.4 Rovatn
Year	1943	1998	1953
Date	28/2	25/2	25/3
q (m3/sec)	28,81	16,90	199,16
qsp (l/sec km2)	1273	1026	841
qsp (mm/day)	110,0	88,7	72,7

The island Hitra is located on the southern side of the inlet to the Trondheim fjord. The climate is highly maritime with most floods occurring in the late autumn or winter. The gauging station 117.1/2/3/4 Valen has been operating from 1934 to 1939. The station was reactivated in 1952 and is still active. Catchment characteristics are listed in Table 2.1.3.13 together with the year, date and ranks of the ten largest annual floods (daily values) at the station. The largest floods occurred in the early 1950s according to the records. There is some reason to suspect the data quality in this period. The year, date and discharge of the largest flood is given in Table 2.1.3.14 below.

Table 2.1.3.13 The catchment characteristics and the dates and the ranks of the ten largest floods observed at 117.4 Valen.

Station 117.4 Valen		The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km2)	12,44	1951	14/12	6
Station altitude (m.a.s.l.)	35	1952	28/3	1
Mean altitude (m.a.s.l)	83	1953	25/3	8
Top altitude (m.a.s.l.)	89	1954	23/10	4
Lake (%)	9,27	1955	26/1	3
Bog (%)	27,18	1956	2/4	9
Forest (%)	56,97	1957	28/2	2
Mountain (%)	0,32	1989	20/1	7
Glacier (%)	0	2002	29/3	10
		2003	19/12	5

Table 2.1.3.14 The date and the discharge of the largest annal flood observed at 117.4 Valen.

Station	117.4 Valen
Year	1952
Date	28/3
q (m3/sec)	27,76
qsp (l/sec km2)	707
qsp (mm/day)	61,0

2.2 Trøndelag

Trøndelag comprises of two former counties, Sør-Trøndelag and Nord-Trøndelag. South of the Trondheimsfjord three large watercourses are flowing northward or westward from the water divide to Østlandet and Sweden to the Trondheimfjord, River Orkla, River Gaula and River Nidelva. Three large watercourses are flowing westward from the border to Sweden to the Trondheimsfjord, River Stjørdalselv, River Verdalselv and River Snåsaelv. The Fosen peninsula is located north of the outer and west of the inner part of the fjord. Further north there is a large water course River Namsen flowing southwestward from the mountain district near the border to Sweden to the west coast at Namsos.

2.2.1 RIVER ORKLA

River Orkla is the westernmost of the three large rivers flowing northward from the water divide toward East Norway to the southern side of the Trondheimfjord. The watercourse has suffered from some severe floods in the past as shown in Table 2.2.1.1

Table 2.2.1.1 Large floods in River Orkla from known from historical sources.

Year		Date	Remarks
1674		Summer	Severe rain- and hail storms
1675			Extreme floods (Co-inciding with floods in Glomma)
1689			Severe floods (Deductions 1690 and 91)
1727		Just before Christmas	Severe flood (Snowmelt and Ice run)
1740		Summer	Hailstorms at Hove, Mosbrynd, Halsgjerdet, Solem and Løkken.
1745			Deductions at Kalstad after floods in 1727 and 1740-45.
1760		Spring	Severe flood in Orkla, worst damage at Grut.
1784			Deductions after several floods since 1719,
1789		20-23/7	Extreme flood (Storofsen)
1798			Flood destroyed bridges
1806		10-11/6	Flood (most severe at Støren)
1815			Landslide caused major bank failure at Søberg farm
1835		9/8	
1844		10/5	Flood took bridge
1844		15/6	Level close to 1789
1844		19-20/8	New rainfall flood – worst at Støren
1849		19-2010	Large flood – worst at Støren
1850		Spring	Flood at Soknes
1867			Flood damages in several rivers in Trøndelag and Hedmark
1879		Spring	Damages at Singsås in Gauldalen
1881		25-27/12	Major Icerun floods in Orkla, Gaula and Driva
1896		31/1-21/2	Several ice runs.
1918			Severe rainfall flood – worst in Gaula
1934			Snowmelt flood
1935		16-20/6	Large mountain flood
1940		24/8	Extreme rainfall flood – worst in Gaula, but also in Orkla and Glomma

The gauging station 121.10 Bjørset dam has been in operation since 1912. Catchment characteristics are given in Table 2.2.1.2.

The date and ranks of the ten largest observed floods (daily values) at Bjørset dam is given in Table 2.2.1.3 below. Figure 2.2.1 show the annual floods observed at Bjørset 1912-2014. The discharge of the largest flood observed at Bjørset is given in Table 2.2.1.4.

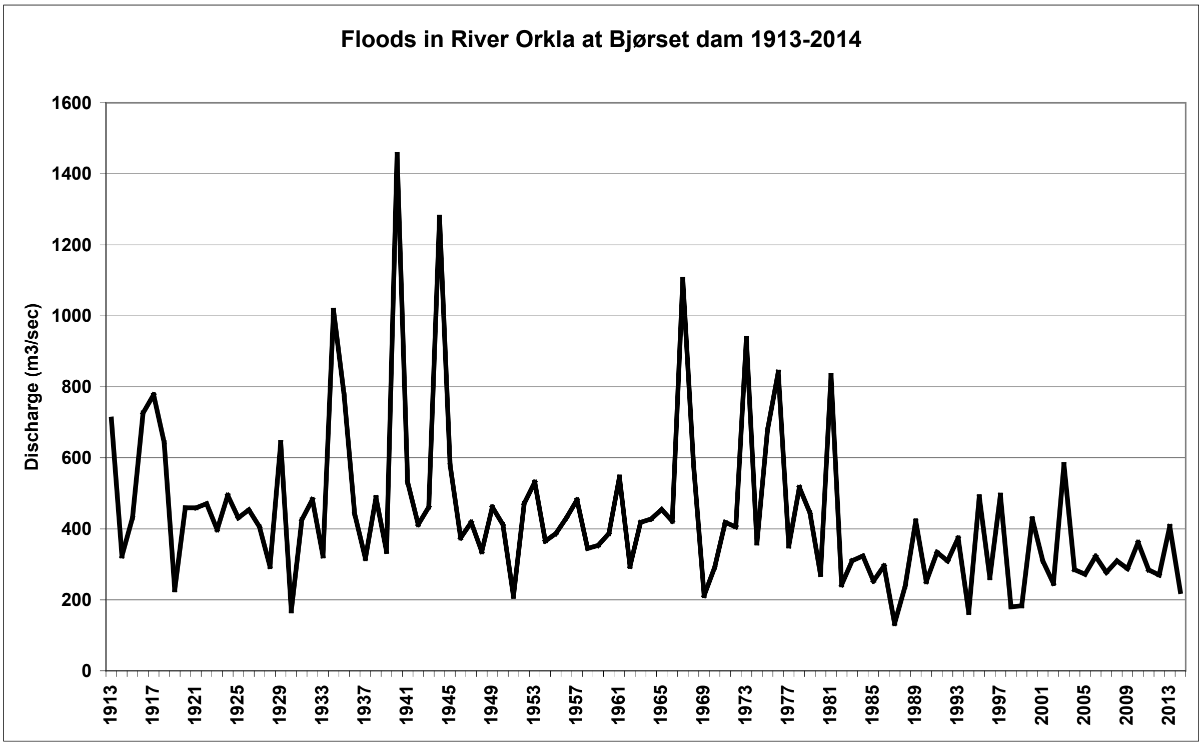


Figure 2.2.1 Annual floods (daily values) in River Orkla at Bjørset 1912-2014.

2.2.2 RIVER GAULA

River Gaula is one of the main watercourses, which flows out into a branch of the Orkdalsfjord; a branch of the Trondheimsfjord at Gaulosen southwest of Trondheim. The catchment area is 3.659 square kilometers and is located east and north of River Orkla. The large tributary, Lundesokna (250 square kilometers), joins River Gaula from east at Lundamo. Sokna joins Gaula from south at Støren (572 square kilometers), Bua from south at Bones (493 square kilometers), Forda from south at Singsås (312 square kilometers), Holta from north at Osan in Gauldalen (141 square kilometers), Lea from south and Holda from northeast in Haltdalen (234 square kilometers) and Hesja from south (252 square kilometers).

The upper part of the catchment is not regulated and has no large lakes, which could attenuate the flood. The rainfall floods have therefore short duration and large magnitudes. The peak discharge is therefore often much larger than the 24-hours mean value at the time of culmination. Many historical floods are known in River Gaula, althougthe levels are not known prior to 1908. Gaula has also been affected by many clay- and landslides. Table 2.2.1.2 lists historical floods in River Gaula prior to the systematic observations.

Table 2.2.1.2 Large floods in River Gaula from known from historical sources.

Year	Date	Remarks
1345	September	Kvasshyllanraset - 500 fatalities
1647		Deduction at farms in Gimse skr – riverbank failure
1671		Deduction at Gravråk farm
1675	28 May	Severe flood - damages at Bogen in Gauldalen
1689/92		Several floods - damaged farms at Orkla and Gaula
1723		Damages after clayslide and flood at Lauvset, Havdal, Kvamen, Stokan, Vollan at Hovin
1734		Flood at the lower Gaula - most severe in Horg
1737	Summer	Rainstorm in Soknedal - bridge destroyed
1771	28-29 May	Severe flood - most severe at Horg
1789	21-23/7	Storofsen - damages from Støren to Melhus
1798		Flood destroyed bridges
1806	10-11/6	Flood - most severe at Støren
1815		Landslide caused major bank failure at Søberg farm
1844	19-20/8	Rainfall flood in Sokna
1849	19-20/10	Large flood at Støren
1850	Spring	Damages at Soknes
1867		Flood damages in several rivers in Trøndelag
1879	Spring	Damages at Singsås in Gauldalen
1881	25-27/12	Major ice-run flood upstrams Holtålen
1896	31/1-21/2	Several ice runs

There are several gauging stations in the river. The gauging station 122.2 Haga bru is located downstream Støren and has been operating since 1908. The controlling section is moderately unstable, and new rating curves were established several times. Data from the gauging station Gaulfoss further downstream were used to fill in data at Haga bru when the station has failed in recent time. Floods in River Gaula are mostly spring floods, but there are also large summer and autumn floods in the watercourse. The annual flood has occurred in 49,5 percent of all years in May and 27,8 percent in June.

High up in Gaula, data are available at 122.11 Eggafoss at Holtålen from 1941. The flood levels are known at several locations during the extreme flood in 1940. The flood level at the confluence with elven Hesja in Holtålen during the ice run flood 25-27 December 1881 was as high as the level in 1940. Heavy rainfall caused the severe flood and severe damages in Ålen 16 August 2011. The largest annual flood at Eggafoss has occurred in 64 percent of all years in May and 27 percent in June. Catchment characteristics of the gauging stations Haga bu and Eggafoss are given in Table 2.2.1.3.

Table 2.2.1.3 Catchment characteristics of gauging stations in River Orkla and Gaula,

Station	121.10 Bjørset dam	122.2 Haga bru	122.11 Eggafoss
	Basin characteristics		
Catchment area (km^2)	2316	3060	653
Station altitude (m.a.s.l.)	130	57	285
Mean altitude (m.a.s.l)	861	738	844
Top altitude (m.a.s.l.)	1641	1325	1284
Lake (%)	2,3	2,06	2,84
Bog (%)	16,14	14,59	12,57
Forest (%)	31,73	36,43	24,55
Mountain (%)	40,34	36,09	43,96
Glacier (%)	0	0	0

The dates and ranks of the ten largest daily floods at the gauging stations Bjørset dam, Haga bru and Eggafoss are given in Table 2.2.1.4. The dates and discharges of the largest daily floods are given in Table 2.1.2.5.

Table 2.2.1.4 The dates and ranks of the ten largest floods (daily values) observed at stations River Orkla and Gaula.

121.10 Bjørset dam			122.2 Haga bru			122.11 Eggafoss		
1912-2014			1908-2014			1941-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1916	10/5	10	1909	14/8	8	1941	27/5	1
1917	31/5	8	1917	31/5	7	1944	10/6	7
1934	6/5	4	1918	25/6	2	1964	31/8	6
1935	17/6	8	1925	18/8	9	1967	29/5	10
1940	24/8	1	1934	4-8/5	4	1973	1/6	3
1944	10/6	2	1940	24/8	1	1978	23/5	4
1967	30/5	3	1944	10/6	3	1995	2/6	5
1973	1/6	5	1967	29/5	10	2011	16/8	2
1976	22/5	6	1973	1/6	6	2013	22/5	8
1981	13/5	7	1995	2/6	5	2014	22/5	9

Table 2.2.1.5 The largest observed discharge (daily values) at the three gauging stations in River Orkla and Gaula.

Station	121.10 Bjørset dam	122.2 Haga bru	122.11 Eggafoss
Year	1940	1940	1941
Date	24/8	24/8	27/5
q (m^3/sec)	1454,64	2150	394,59
qsp (l/sec km^2)	628	702	603
qsp (mm/day)	54	61	52

The largest one-day flood occurred at Haga bru 24 August 1940 with a discharge of 2150 m^3/sec corresponding to 702 l/sec km^2 or to a runoff of 61 mm/d. The value given in the original observations is the peak discharge in excess of 3000 m^3/sec. The daily mean value has been estimated to 2150 m^3/sec.

The largest one-day flood occurred at Eggafoss 27 May 1941 with a discharge of 394,59 m^3/sec corresponding to 603 l/sec km^2 or to a runoff of 52 mm/d. High time resolution data are missing for the earlier floods at Eggafoss. The mean discharge of the extreme flood 16 August 2011 was 374,69 m^3/sec corresponding to 573 l/sec km^2 or to a runoff of 49 mm/d. The peak discharge was however 829,13 m^3/sec corresponding to 1267 l/sec km^2. Direct observations are unfortunately missing at Eggafoss from the extreme flood 1940. The flood level has however been found by surveying and is of the same magnitude as during the large flood in 2011 (Strand, 1941).

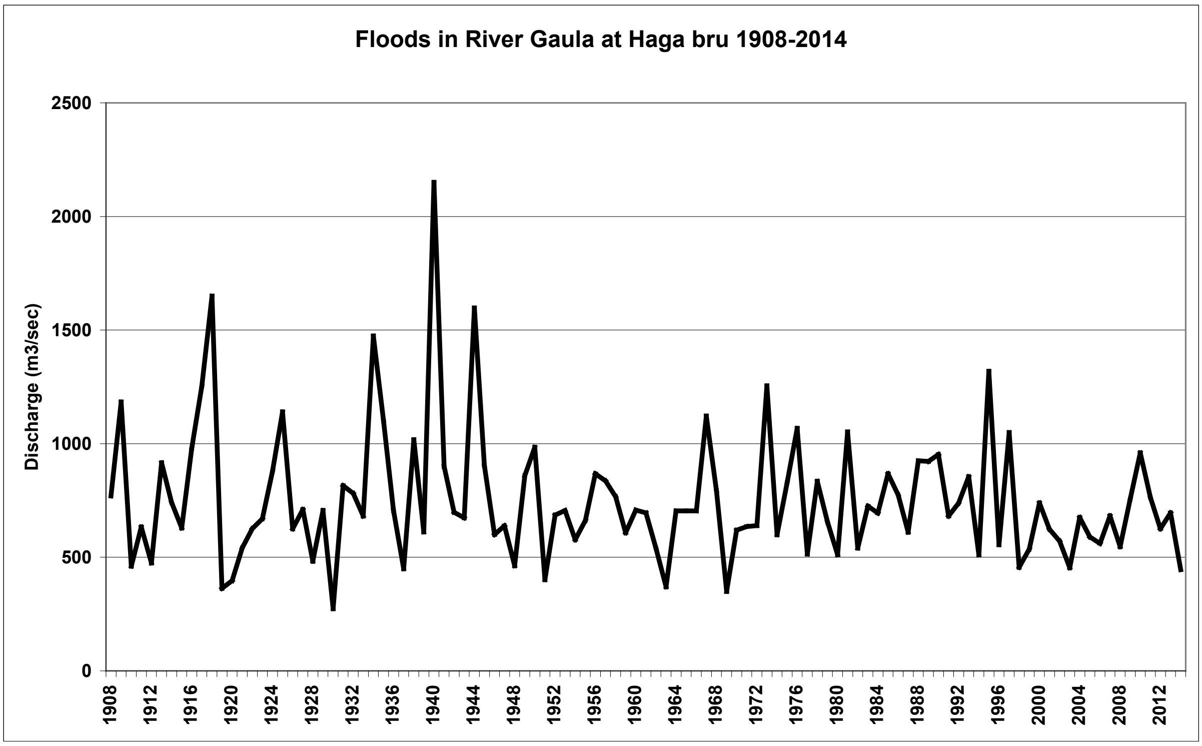


Figure 2.2.2 Annual floods in River Gaula at Haga bru 1908-2014.

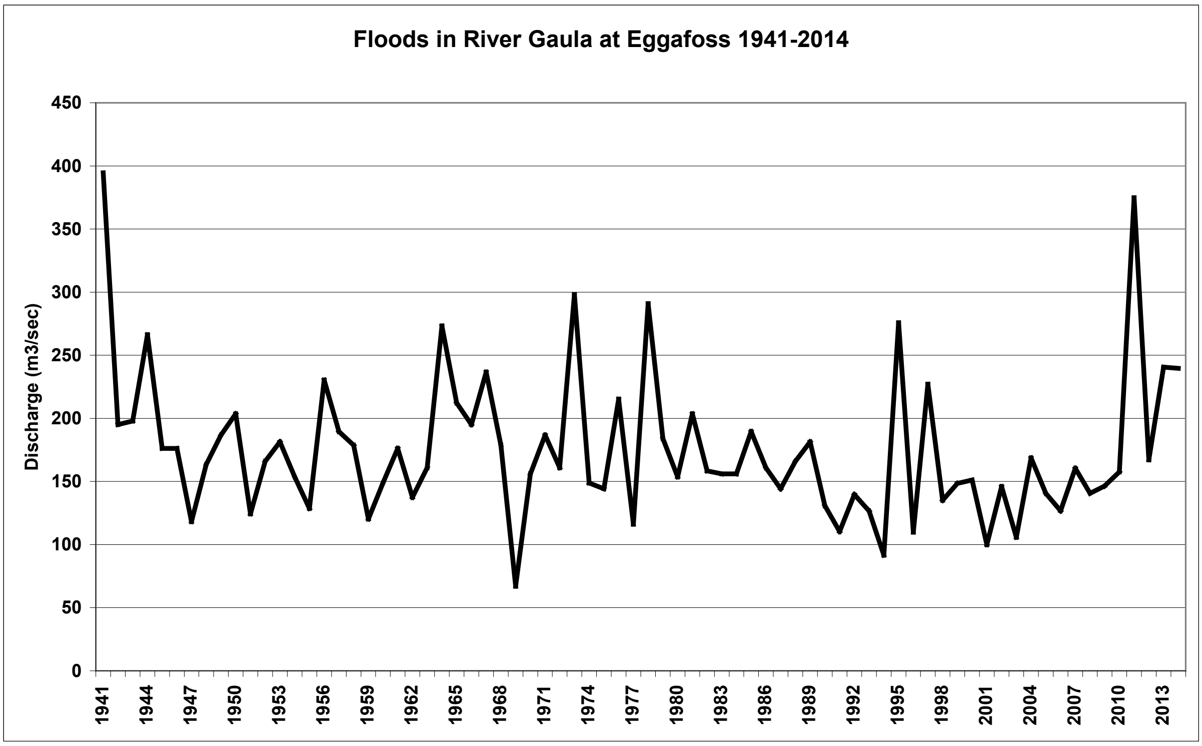


Figure 2.2.3 Annual floods in River Gaula at Eggafoss 1908-2013.

2.2.3 RIVER NIDELV

River Nidelv is the third of the large rivers feeding the southern side of the Trondheimsfjord. The river origins in the mountains Sylane on the Swedish side of the national boundary as well as from the water divide to River Glomma. River Nea flows northwestward through Tydal to Lake Selbusjøen and northward to Trondheim into the Trondheimfjord. The data series at the gauging station 123.20 Rathe started in 1881. The river is strongly regulated. Catchment characteristics are listed in Table 2.2.1.6, the dates and ranks of the ten largest floods in Table 2.2.1.7 and the discharge of the largest flood in Table 2.2.1.8. Figure 2.2.4 skow observed floods at Rathe in River Nidelv.

Table 2.2.1.6 Catchment characteristics of the gauging stations Rathe, Selbusjø and Stokke in River Nidelv

Station	123.20 Rathe	123.4 Selbusjø	123.49 Stokke limn
	Basin characteristics		
Catchment area (km^2)	3058	2876	1990
Station altitude (m.a.s.l.)	14	158	178
Mean altitude (m.a.s.l)	686	714	799
Top altitude (m.a.s.l.)	1772	1772	1772
Lake (%)	7,37	7,73	6,53
Bog (%)	12,81	12,51	12,47
Forest (%)	34,18	32,93	24,02
Mountain (%)	35,92	38,12	49,3
Glacier (%)	0	0	0,01

Table 2.2.1.7 The dates and ranks of the ten largest annual floods (daily values) observed at Rathe, Selbusjø and Stokke in River Nidelv.

123.20 Rathe			123.4 Selbusjø			123.49 Stokke limn		
1881-2014			1901-1957			1915-1991		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1881	28/6	7	1905	21/6	10	1915	10/6	3
1882	5-6/6	6	1907	17/6	7	1916	7/5	4
1889	1/6	4	1913	5/5	9	1917	14/5	7
1899	24/6	8	1917	5/6	4	1918	26/6	1
1917	5/6	5	1929	29/5	7	1925	19/8	10
1934	11/5	1	1934	11/5	1	1934	8/5	2
1938	11/6	3	1938	11/6	2	1938	30/5	5
1941	31/5	9	1941	31/5	5	1941	29/5	9
1944	13/6	2	1944	13/6	2	1944	9/6	6
1949	22/5	9	1949	22/5	5	1945	19/10	8

Table 2.2.1.8 The dates and discharges (daily values) observed at at the Rathe, Selbusjø and Stokke in River Nidelv.

Station	123.20 Rathe	123.4 Selbusjø	123.49 Stokke limn
Year	1934	1934	1918
Date	11/5	11/5	24/6
q (m^3/sec)	802,45	770,85	122,51
qsp (l/sec km^2)	262	268	564
qsp (mm/day)	22,7	23,2	48,7

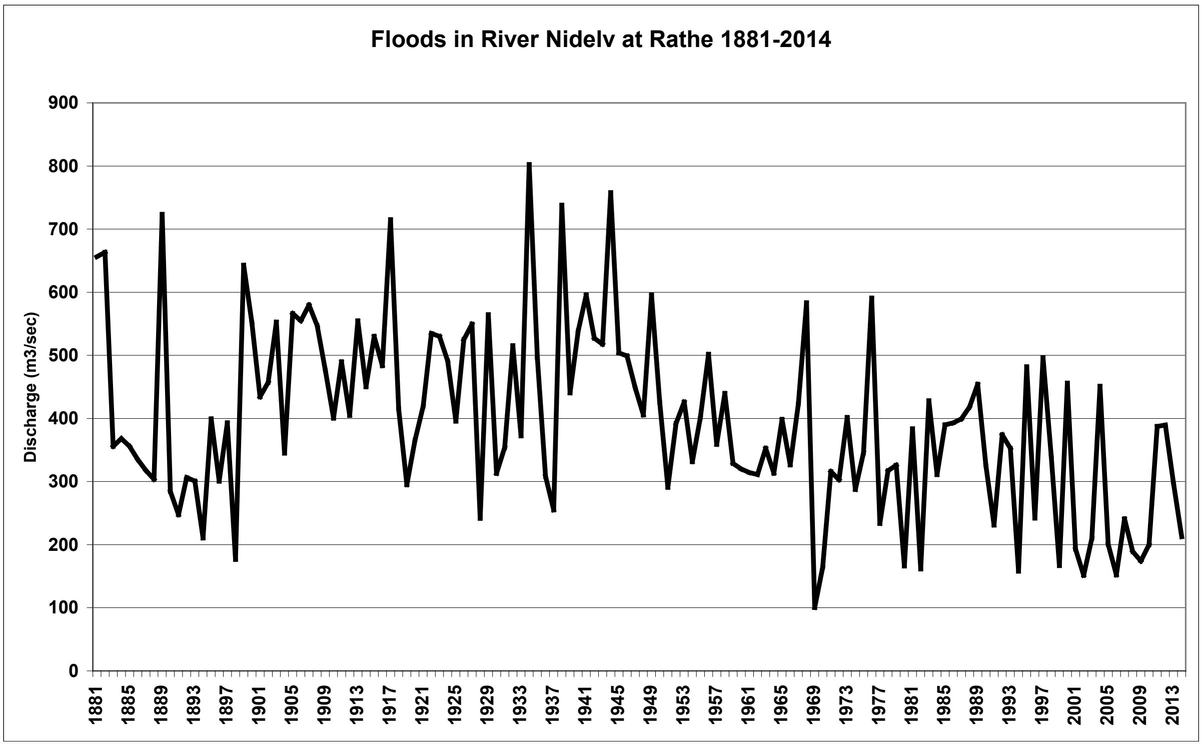


Figure 2.2.4 The annual floods in River Nidelv at Rathe 1881-2014.

2.2.4 RIVER STJØRDALSELV

River Stjørdalselv flows westward from the border to Sweden to the Trondheimsfjord at Værnes. The catchment area is 2.117 square kilometers. The main branch is regulated, but the tributary Forra flowing in from north, has an uregulated gauging station at 124.2 Høggås bru. Table 2.2.1.8 summarises historical floods in River Stjørdalselv. Catchment characteristics are listed in Table 2.2.1.9, the dates and ranks of the ten largest floods in Table 2.2.1.10 and the discharge of the largest flood in Table 2.2.1.11. As in other of the large rivers east and south of the Trondheimsfjord the catchment has a large fraction of bogs in the catchment. Many clay slides have occurred next to the main river as well ar the tributary Forra. Figure 2.2.5 show observed floods at Høggås bru.

Table 2.2.1.9 Catchment characteristics of gauging stations in River Nidelv

Station	124.12 Hegra bru	124.2 Høggås bru	124.3 Tangfoss
	Basin characteristics		
Catchment area (km^2)	1873	494,2	532,5
Station altitude (m.a.s.l.)	10	98	140
Mean altitude (m.a.s.l)	532	505	640
Top altitude (m.a.s.l.)	1246	1246	1245
Lake (%)	4,87	7,38	5,84
Bog (%)	20,67	26,17	19,49
Forest (%)	37,22	28,65	30,36
Mountain (%)	25,69	27,48	27,37
Glacier (%)	0	0	0

Table 2.2.1.10 The year, dates and ranks of the ten largest floods at Hegra bru Høggås bru and Tangfoss in River Stjørdalselv.

124.12 Hegra bru			124.2 Høggås bru			124.3 Tangfoss		
1963-2014			1912-2014			1933-1993		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1966	30/4	9	1925	17/1	8	1934	5/5	6
1967	14/12	9	1932	29/9	2	1940	24/8	2
1981	13/5	8	1936	2/9	10	1947	20/10	3
1982	26/3	3	1940	24/8	6	1948	1/12	4
1990	1/5	6	1947	20/10	1	1950	28/7	1
1992	15/1	4	1949	3/10	7	1953	4/6	9
1998	19/2	7	1953	25/3	3	1975	29/10	5
2000	8/8	5	1961	21/11	5	1983	26/10	10
2006	31/1	1	2006	31/1	7	1987	6/8	7
2012	23/3	2	2012	23/3	9	1988	1/8	8

Table 2.2.1.11 The dates and discharges (daily values) observed at Hegra bru, Høggås bru and Tangfoss in River Stjørdalselv.

Station	124.12 Hegra bru	124.2 Høggås bru	124.3 Tangfoss
Year	2006	1947	1950
Date	31/1	20/10	28/7
q (m^3/sec)	878,13	354,56	436,70
qsp (l/sec km^2)	469	717	820

qsp (mm/day)	40,5	62	70,9

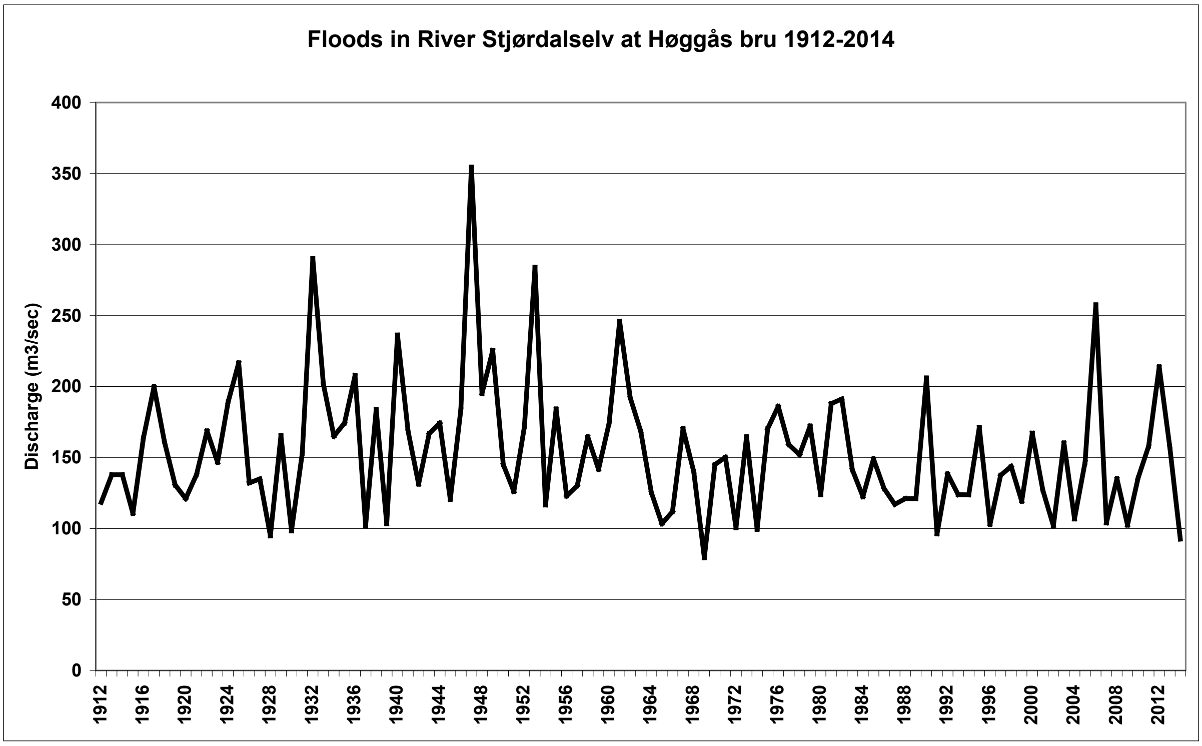


Figure 2.2.6 Annual floods (daily values) in River Stjørdalselv at Høggås bru 1912-2014.

2.2.5 RIVER VERDALSELV

River Verdalselv is located at Verdal municipality in Nord-Trøndelag. The river flows westward from the water divide to Sweden to the east side of the Trondheimsfjord at Verdalsøra. The catchment area of the watercourse is 1471 square kilometers. The gauging station 127.6 Grunnfoss has been active since 1907. The observations were discontinued in the years 1930-1951 but were resumed from 1952. Catchment characteristics are listed in Table 2.2.12, the dates and ranks of the ten largest floods in Table 2.2.1.13 and the discharge of the largest flood in Table 2.2.1.14.

The gauging station 127.11 Veravatn is located close to the border to Sweden in River Helgåa. Catchment characteristics are listed in Table 2.2.1.12, the dates and ranks of the ten largest floods in Table 2.2.1.13 and the discharge of the largest flood in Table 2.2.1.14.

Another branch, River Inna flows to the border further southeast to Lake Innsvatn. The gauging station 127.12 Innsvatn has been active since 1973. There is a longterm precipitation station near by at 70360 Sulstua with data from 1895.

The lower part of the Verdalselv catchment is located at marine clays, and the large clayslide 19/5 1893 caused severe damages at 100 farms and claimed 116 fatalities.

2.2.6 RIVER SNÅSAELV

River Snåsaelv is flowing from Lake Snåsavatn and into the innermost part of Trondheimsfjord, Beitstad-fjorden at Steinkjer. The catchment area of the watercourse is 2122 square kilometers. There is a number of smaller streams flowing into Lake Snåsavatn from Lierne and from the water divide to River Namsen to northwest.

The gauging station Støafoss has been active since 1932. The observations were terminated in 1952 but were resumed in 1958. Catchment characteristics are listed in Table 2.2.1.12, the dates and ranks of the ten largest floods in Table 2.2.1.13 and the discharge of the largest flood in Table 2.2.1.14. The longterm precipitation station 70850 Kjøbli has been active since 1895. Figure 2.2.7 show the annual floods observed at Støafoss.

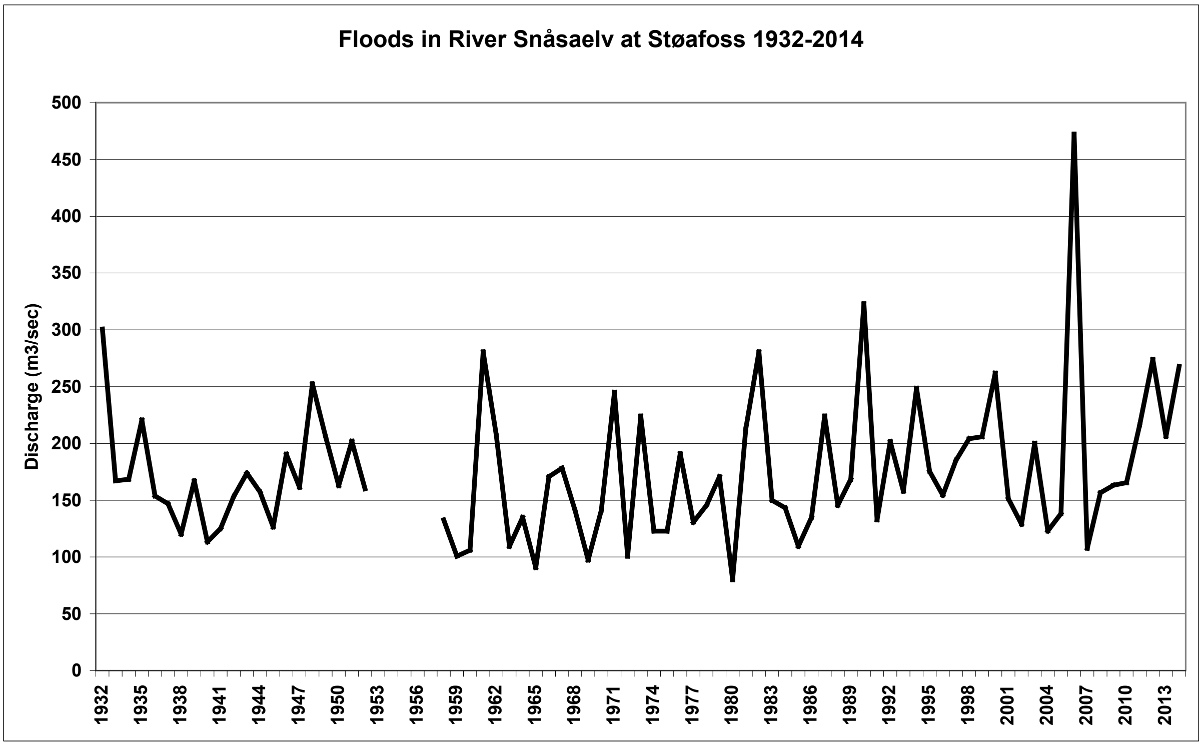


Figure 2.2.7 Annual floods (daily values) in River Snåsaelv at Støafoss 1932-2014.

Table 2.2.1.12 Catchment characteristics of gauging stations in Verdalselv and Snåsaelv.

Station	127. 6 Grunnfoss	127.11 Veravatn	128.5 Støafoss
	Basin characteristics		
Catchment area (km^2)	880,42	176,13	476,58
Station altitude (m.a.s.l.)	38	361	78
Mean altitude (m.a.s.l)	500	518	358
Top altitude (m.a.s.l.)	1215	1215	817
Lake (%)	4,18	4,76	4,79
Bog (%)	12,15	20,68	19,44
Forest (%)	36,47	33,54	53,02
Mountain (%)	37,91	25,09	16,09
Glacier (%)	0	0	0

Table 2.2.1.13 The dates and ranks of the ten largest floods (daily values) observed in Verdalselv and Snåsaelv.

127.6 Grunnfoss			127.11 Veravatn			128.5 Støafoss		
1907-1929,1952-2014			1966-2014			1932-1952,1958-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1953	25/3	3	1967	27/5	3	1932	28/11	3
1961	21/11	4	1973	8/1	5	1948	1/12	9
1962	5/12	2	1976	27/5	9	1961	21/11	4
1966	20/9	7	1978	24/5	6	1982	27/3	4
1967	4/7	9	1984	19/5	10	1990	3/12	2
1971	14/5	5	1990	2/5	7	1994	23/11	10
1994	23/11	8	1995	3/6	2	2000	9/8	8
1995	2/6	6	2006	1/2	1	2006	31/1	1
2000	8/8	7	2008	3/5	8	2012	23/3	6
2006	31/1	1	2010	17/5	4	2014	4/12	7

Table 2.2.1.14 The largest observed discharge (daily values) at the three gauging stations in Verdalselv and Snåsaelv.

Station	127.6 Grunnfoss	127.11 Veravatn	128.5 Støafoss
Year	2006	2006	2006
Date	31/1	½	31/1
q (m^3/sec)	785,54	101,68	472,35
qsp (l/sec km^2)	892	577	991
qsp (mm/day)	77,1	49,9	85,63

Rivers flowing from the Fosen peninsula

The Fosen peninsula is a lowlying area northwest of the Trondheimsfjord. The climate is maritime, and floods can occur at all seasons. The largest floods occurring in the district happened at the end of January in 1932 and 2006. The meteorological station at 71800 Måmyr has recorded many large rainfall events. This is also the case for the former station 71400 Lysvatnet further east at the peninsula.

2.2.7 RIVER NORDELV AT LAKE KRINSVATN

River Nordelv flows southward to the Trondheimsfjord northwest of Rissa at Fosen with a catchment area of 214 square kilometers. The gauging station at 133.7 Lake Krinsvatn has been in operation since 1916. Observed floods are shown in Figure 2.2.8. The flood regime is maritime. The annual flood occurs frequently from October to May. The largest annual floods occur most frequently in December in 16 percent of all years. Catchment characteristics are listed in Table 2.2.1.15, the dates and ranks of the ten largest floods in Table 2.2.1.16 and the discharge of the largest flood in Table 2.2.1.17.

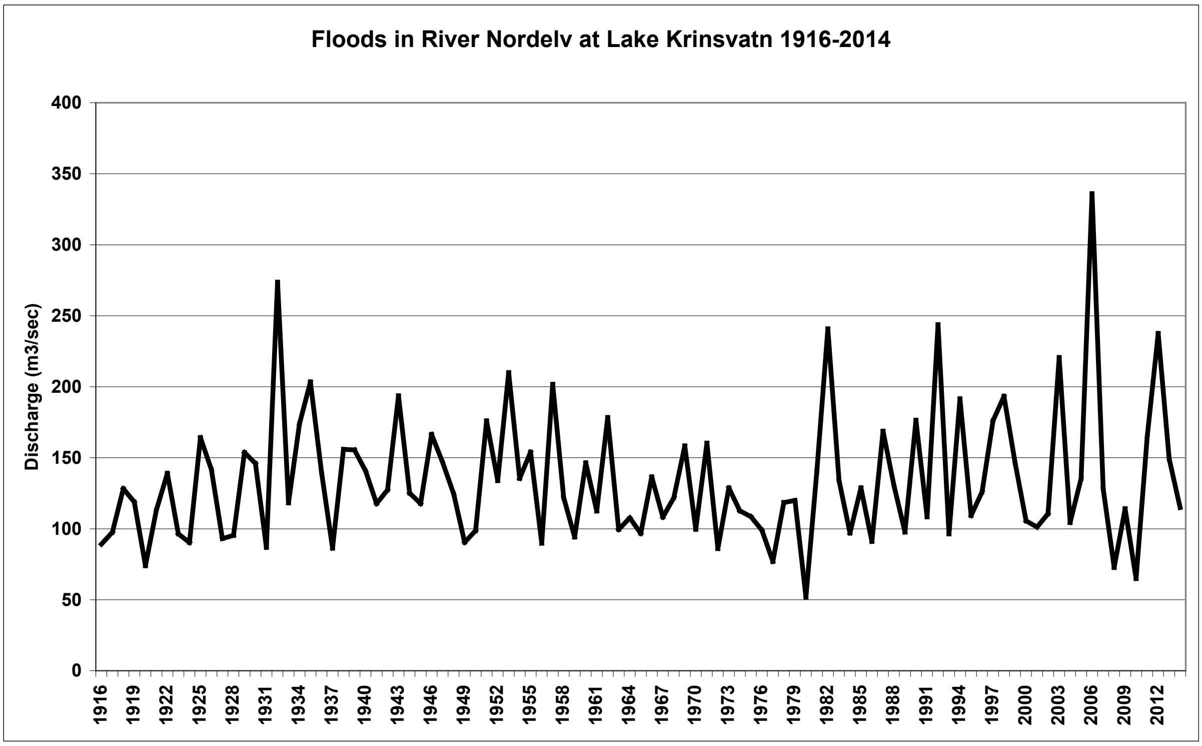


Figure 2.2.8 Annual floods (daily values) in River Nordelv at Lake Krinsvatn 1916-2014.

Table 2.2.1.15 Catchment characteristics of gauging stations at the Fosen Peninsula.

Station	133.7 Krinsvatn	138.1 Øyungen	140.1/2 Salsvatn
	Basin characteristics		
Catchment area (km^2)	205	239	432
Station altitude (m.a.s.l.)	87	103	9
Mean altitude (m.a.s.l)	348	294	270
Top altitude (m.a.s.l.)	627	682	763
Lake (%)	7,5	6	13,9
Bog (%)	9	19	2,8
Forest (%)	20	40	27,6
Mountain (%)	57	26,5	43,8
Glacier (%)	0	0	0

Table 2.2.1.16. The dates and ranks of the ten largest floods (daily values) observed at the Fosen peninsula.

133.7 Krinsvatn			138.1 Øyungen			140.1/2 Salsvatn		
1916-2014			1917-2014			1916-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1932	28/1	2	1930	4/12	8	1929	29/3	7
1935	7/8	8	1932	28/1	2	1932	29/1	5
1953	25/3	7	1938	8/6	9	1953	26/3	2
1957	9/1	9	1947	20/10	7	1959	13/9	10
1982	26/3	4	1953	25/3	4	1961	22/11	8
1992	15/1	3	1957	9/1	6	1962	6/12	4
1998	19/2	10	1982	26/3	5	1992	16/1	9
2003	18/12	6	1990	3/12	10	2006	1/2	1
2006	31/1	1	1998	19/2	3	2009	28/9	6
2012	23/3	5	2006	1/2	1	2013	13/9	3

Table 2.2.1.17 The largest observed discharge (daily values) at the three gauging stations at the Fosen peninsula.

Station	133.7 Krinsvatn	138.1 Øyungen	140.1/2 Salsvatn
Year	2006	2006	2006
Date	31/1	1/2	½
q (m^3/sec)	335,9	377,9	205,9
qsp (l/sec km^2)	1116	1581	303
qsp (mm/day)	140	137	26

2.2.8 RIVER ÅRGÅRDSELV AT LAKE ØYUNGEN

River Årgårdelv is located further north at the Fosen peninsula with a catchment area of 549 square kilometers. The gauging station at 138.1 Øyungen has been operating since 1916. The observed floods are shown in Figure 2.2.9. The flow regime at Øyungen is maritime as at Krinsvatn. The most frequent floods occur from October to May. The annual flood happens most frequently in December in 18 percent of all years, and the two largest floods occurred in January. Catchment characteristics are listed in Table 2.2.1.15, the dates and ranks of the ten largest floods in Table 2.2.1.16 and the discharge of the largest flood in Table 2.2.1.17.

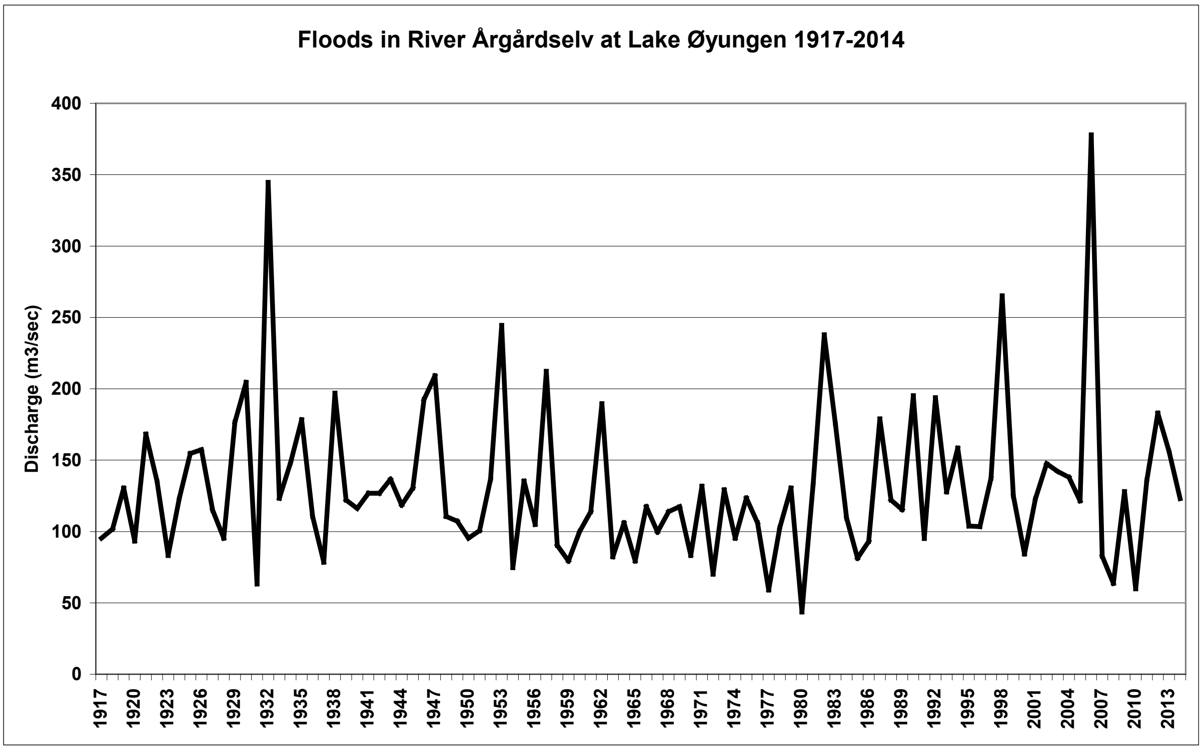


Figure 2.2.9 Annual floods in River Årgårdselv at Lake Øyungen 1917-2014.

2.2.9 RIVER SALSVATNSELV

The river from Lake Salsvatn flows towards west into the Foldafjord in Nord-Trøndelag. Lake Salsvatn is the second deepest lake in Norway (464 m). The gauging station 140.1/2 Salsvatn has been operating since 1916. The annual floods are shown in Figure 2.2.10. The flow regime is maritim and the annual flood occurs in all months of the year except in August. Most of the annual floods have occurred in October (15,6 percent), in May (11,5 percent) and in January and September (10,4 percent) each of all years. The large winter floods co-incide with the floods at the Fosen peninsula further south.

Catchment characteristics are listed in Table 2.2.1.15, the dates and ranks of the ten largest floods in Table 2.2.1.16 and the discharge of the largest flood in Table 2.2.1.17.

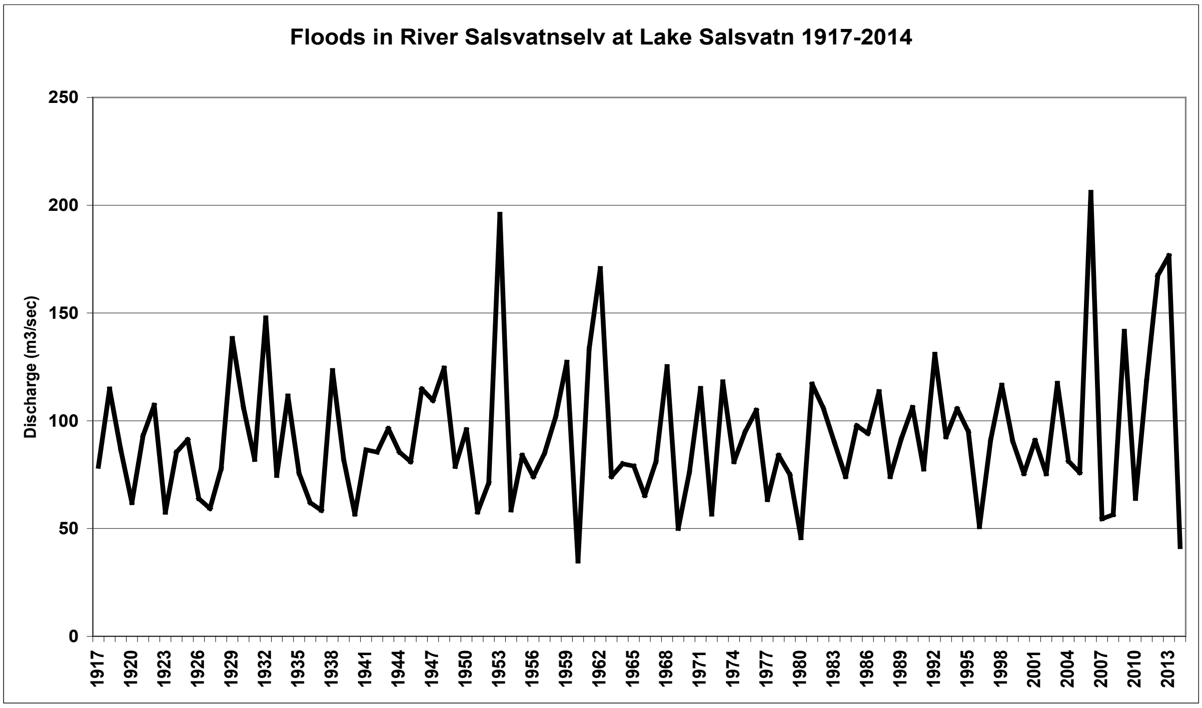


Figure 2.2.10 Annual floods at Lake Salsvatn 1917-2015.

2.2.10 RIVER NAMSEN

River Namsen has a catchment area of 6.273 square kilometers, of which 2,65 square kilometers is located at Sweden. The river flows southwestward from Lake Namsvatn and drains most of Børgefjell National Park. The flow regime is affected by hydropower regulations.

The discharge has been observed at the gauging station 139.8/34 Fiskumfoss from 1908 to 1998. Further downstreams the discharge has been observed at 139.17 Bertnem with data from 1961 to 2011.

The gauging station 139.15 Bjørnstad is located west of Lake Namsvatn close to the water divide to River Svenningsdalselv, the western branch of River Vefsna. Catchment characteristics are listed in Table 2.2.1.18, the dates and ranks of the ten largest floods in Table 2.2.1.19 and the discharge of the largest flood in Table 2.2.1.20.

Table 2.2.1.18 Catchment characteristics of gauging stations in River Namsen.

Station	139.17 Bertnem	139.34 Øvre Fiskumfoss	139.15 Bjørnstad
	Basin characteristics		
Catchment area (km^2)	5.161,5	3.271,9	1.032,6
Station altitude (m.a.s.l.)	7	69	225
Mean altitude (m.a.s.l)	524	539	700
Top altitude (m.a.s.l.)	1675	1675	1675
Lake (%)	7,53	8,64	9,79
Bog (%)	9,02	7,31	5,66
Forest (%)	33,81	29,82	19,25
Mountain (%)	39,76	43,28	55,57
Glacier (%)	0	0,05	0,14

Table 2.2.1.19 The dates and ranks of the ten largest floods (daily values) observed in River Namsen.

139.17 Bertnem			139.34 Øvre Fiskumfoss			139.15 Bjørnstad		
1961-2014			1908-2002			1935-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1961	22/1	2	1932	29/1	7	1935	18/6	9
1962	6/12	1	1943	15/6	6	1938	9/6	7
1971	7/10	3	1948	1/12	4	1943	16/6	3
1973	6/1	9	1950	8/6	9	1946	28/6	8
1976	29/6	7	1953	26/3	3	1947	7/7	3
1982	26/3	6	1959	12/9	8	1949	5/6	2
1990	3/12	10	1961	22/1	1	1961	22/11	1
1994	7/10	8	1962	6/12	2	1995	4/6	10
2001	15/2	4	1971	7/10	5	2009	27/9	6
2006	½	5	1994	7/10	10	2013	12/12	5

Table 2.2.1.20 The largest observed discharge (daily values) at the three gauging stations in River Namsen.

Station	139.17 Bertnem	139.34 Øvre Fiskumfoss	139.15 Bjørnstad
Year	1962	1961	1961
Date	6/12	22/1	22/11
q (m^3/sec)	3.280	2.305	365,9
qsp (l/sec km^2)	636	704	352,6
qsp (mm/day)	54,9	60,9	30,5

Most of the catchment is east of Namdalen. River Tunnsjøelv flows westward from the regulated reservoir Tunnssjøen to Tunnsjødal in Namdalen. Lake Tunnsjøen has diversion to Lake Limingen in Norway and and Lake Kvarnbergvatn. There are four gauging stations located at rivers draining to Sweden, see below.

River Nesåa is flowing into River Namsen at Nes. The gauging station 139.19 in Neselva was active 1966-1999.

Further south River Sandøla flows from Lierne to Formofoss south of Grong. The gauging station 139.16/35 Trangen has been active in Sanddøla since 1934.

River Luru flows into River Sanddøla at Formofoss from Lierne south of Sandøla. The gauging station 139.26 Embretshølen is located on River Luru. The observation started in 1980. Catchment characteristics of these three stations are listed in Table 2.2.1.21, the dates and ranks of the ten largest floods in Table 2.2.1.22 and the discharge of the largest flood in Table 2.2.1.23.

Table 2.2.1.21 Catchment characteristics of stations in tributaries to River Namsen.

Station	139.16 Trangen	139.26 Embretshølen	139.19 Iskvernsfoss
	Basin characteristics		
Catchment area (km^2)	852,5	494,8	249,7
Station altitude (m.a.s.l.)	138	138	100
Mean altitude (m.a.s.l)	558	574	617
Top altitude (m.a.s.l.)	1384	1068	1155
Lake (%)	9,34	3,38	6,62
Bog (%)	13,56	10,57	6,04
Forest (%)	42,11	18,74	17,77
Mountain (%)	29,23	61,73	56,54
Glacier (%)	0	0	0

Table 2.2.1.22 The dates and ranks of the ten largest floods (daily values) observed in tributaries to River Namsen.

139.16 Trangen			139.26 Embretshølen			139.19 Iskvernsfoss		
1935-2014			1980-2014			1966-1999		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1943	15/6	4	1985	30/10	9	1966	20/9	10
1948	1/12	5	1990	3/12	5	1967	5/7	3
1953	26/3	3	1994	7/10	2	1968	22/10	8
1961	21/11	1	1995	2/6	6	1971	7/10	1
1962	6/12	2	2000	17/5	8	1973	6/1	5
1966	20/9	6	2004	1/5	7	1974	8/4	7
1971	8/10	10	2006	1/2	4	1976	28/6	6
1973	6/11	6	2010	17/5	1	1982	26/3	2
1974	26/5	9	2011	7/9	3	1994	14/10	9
1976	28/6	8	2013	22/5	10	1995	2/6	1

Table 2.2.1.23 The largest observed discharge (daily values) at the three gauging stations in tributaries to River Namsen.

Station	139.16 Trangen	139.26 Embretshølen	139.19 Iskvernsfoss
Year	1961	2010	1971
Date	21/11	17/5	7/10
q (m3/sec)	409,7	269,3	165,8
qsp (l/sec km2)	481	544	664
qsp (mm/day)	41,5	47,0	57,4

Several of the largest floods in Rivere Namsen has occurred together with ice runs. The riverbed is vulnerable to erosion, and large clay and land slides occur frequently and can dam the river.

Rivers draining towards Sweden

The national border between Norway and Sweden does not follow the water divide in parts of Trøndelag. Some lakes in Norway drains toward Sweden through tributaries to the major Swedish watercourses Ångermannsälven and Indalsälven. These catchments drain the eastern part of Lierne where the western part drains to River Snåsaelv and River Namsen. There are a few stations in some of these tributaries, which have been operating since the 1930s to 1940s. These rivers have a typical inland flood regime. The annual flood occurs usually in May (62-66) and June (32-36) percent of all years, and melting snow is the main cause of these floods. Several of the larger flood occurs simultaneous with large spring floods in the inland of southern Norway. There have been a few late autumn floods in the region.

2.2.11 RIVER ÅNGERMANNSÄLV

The gauging station 307.7 Landbru is located at Røyrvik municipality in River Huddingselv close to the national border. The river flows westward to Lake Limingen which drains southeastward through River Linvasselv across the national border and into Lake Kvarnbergsvattnet. Catchment characteristics are listed in Table 2.2.1.24, the dates and ranks of the ten largest floods in Table 2.2.1.25 and the discharge of the largest flood in Table 2.2.1.26.

A second gauging station further south 307.5 Murusjøen drains towards Sweden through Muruelven joining the Lake Hetøglen downstream Lake Kvarnbergvattnet. Catchment characteristics are listed in Table 2.2.1.24, the dates and ranks of the ten largest floods in Table 2.2.1.25 and the discharge of the largest flood in Table 2.2.1.26.

A third station 307.14 Saksvatn is located north of Lake Limingen close to the water divide to River Namsen. Catchment characteristics are listed in Table 2.2.1.24, the dates and ranks of the ten largest floods in Table 2.2.1.25 and the discharge of the largest flood in Table 2.2.1.26.

Table 2.2.1.24 Catchment characteristics of three gauging stations in the upper Ångermannsälv in Norway.

Station	307.7 Landbru	307.5 Murusjø	307.14 Saksvatn
	Basin characteristics		
Catchment area (km^2)	58,9	345,6	64,3
Station altitude (m.a.s.l.)	480	310	464
Mean altitude (m.a.s.l)	711	528	610
Top altitude (m.a.s.l.)	1119	1267	1006
Lake (%)	6,8	8,9	5,15
Bog (%)	4,22	13,39	17,8
Forest (%)	31,48	53,7	20,22
Mountain (%)	41,65	17,12	38,67
Glacier (%)	0	0	0

Table 2.2.1.25 Dates and ranks of the ten largest annual floods at stations in the upper Ångermannsälv in Norway.

307.7 Landbru			307.5 Murusjø			307.14 Saksvatn		
1944-2014			1926-2014			1960-1990		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1950	7/6	10	1927	6/6	10	1961	3/11	2
1961	3/6	6	1934	9/5	3	1962	6/12	6
1967	2/6	7	1938	1/6	5	1965	28/6	9
1973	2/6	4	1943	15/6	1	1971	7/10	5
1982	31/5	8	1949	23/5	8	1972	8/6	1
1984	28/5	2	1967	3/6	7	1973	8/6	3
1995	4/6	1	1976	28/5	4	1976	28/6	7
2004	8/5	4	1978	31/5	6	1984	28/5	8
2005	14/6	9	1990	6/5	9	1985	3/6	9
2013	22/5	3	1995	4/6	2	1989	29/6	4

Table 2.2.1.26 The largest observed floods (daily values) at three gauging stations in the upper Ångermannsälv in Norway

Station	307.7 Landbru	307.5 Murusjø	307.14 Saksvatn
Year	1995	1943	1972
Date	4/6	15/6	8/6
q (m^3/sec)	36,92	111,90	41,89
qsp (l/sec km^2)	601	324	654
qsp (mm/day)	52	28	56,5

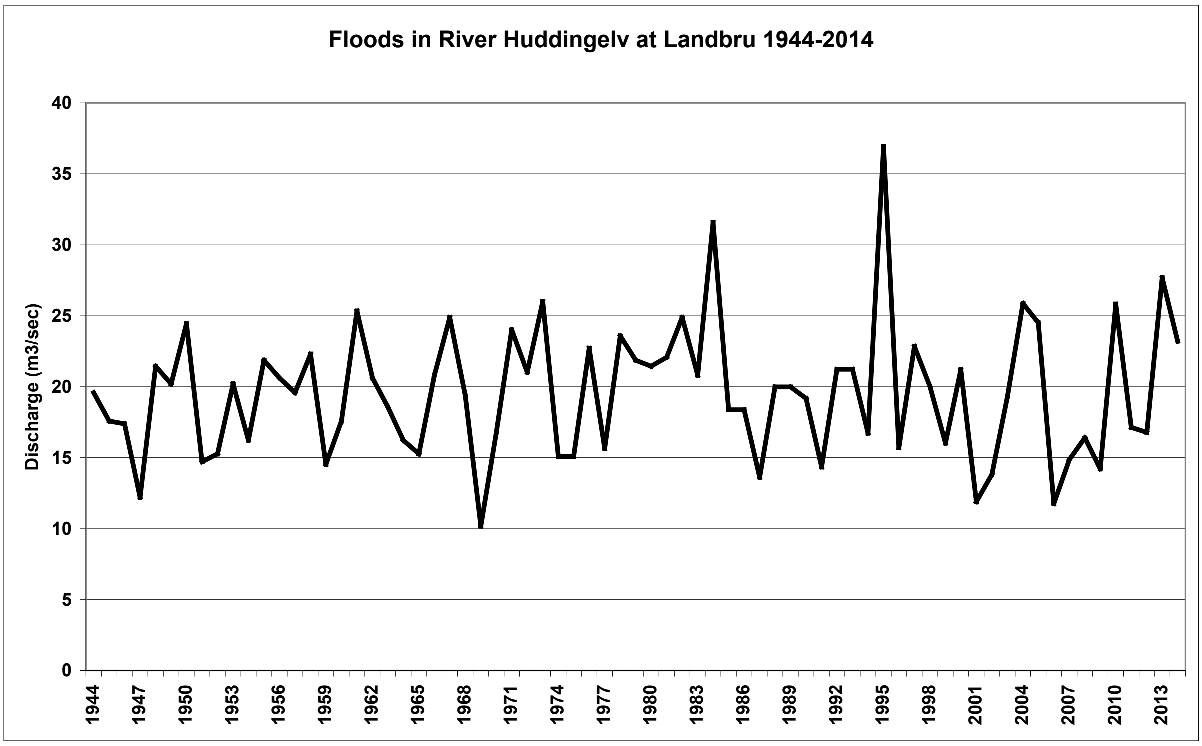
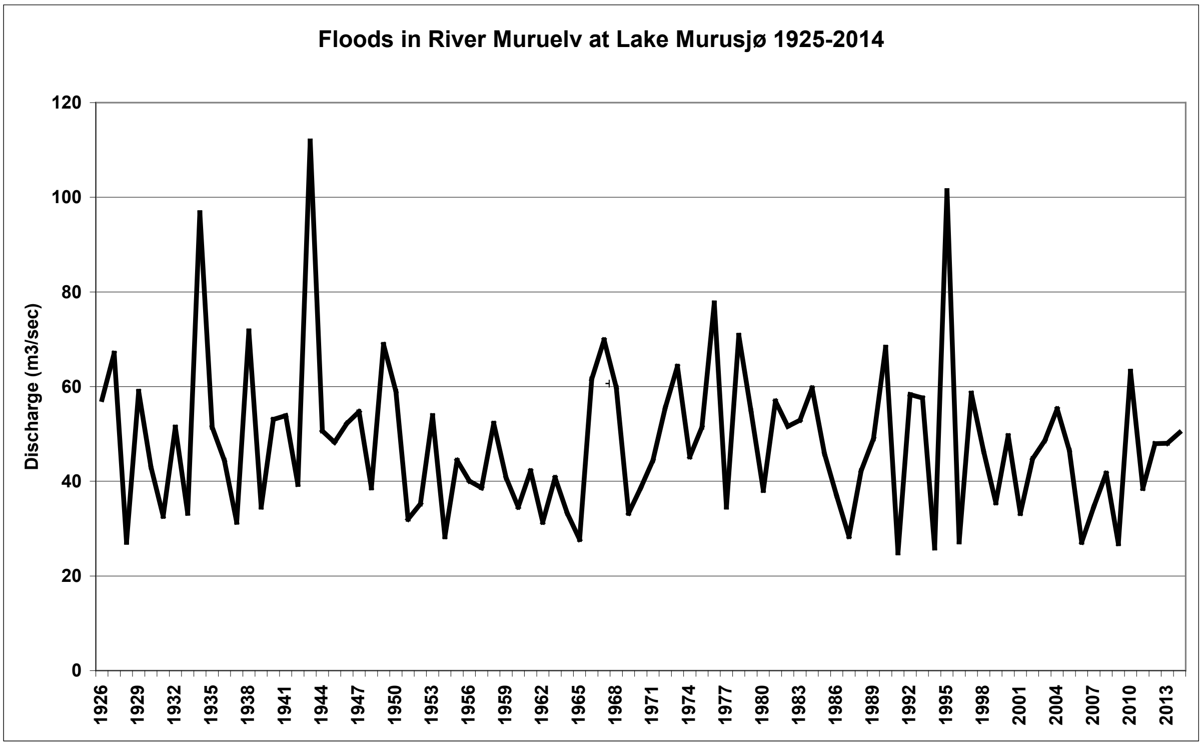


Figure 2.2.11 Annual floods (daily values) in River Huddingelv at Landbru.



Figur 2.2.12 Annual floods (daily values) at River Muruelv at Lake Murusjø 1926-2014.

2.2.12 RIVER INDALSÄLV

The gauging station 308.1 Lenglingen is located at Lierne municipality south of Røyrvik. Lake Lenglingen is located at River Holdeelva, which drains through Lake Rengen into Sweden. Catchment characteristics, the dates and ranks of the ten largest floods in Table 2.2.1.27. Observed floods 1926-2014 are shown in Figure 2.2.13.

Table 2.2.1.27 The catchment characteristics and the dates and the ranks of the ten largest floods observed in Lake Lenglingen in River Holteelv.

Station 308.1	Basin characteristics	The largest floods		
Lenglingen		Year	Date	Rank
Catchment area (km^2)	449,98	1934	10/5	2
Station altitude (m.a.s.l.)	354	1938	1/6	4
Mean altitude (m.a.s.l)	625	1943	15/6	5
Top altitude (m.a.s.l.)	1387	1949	22/5	6
Lake (%)	8,07	1973	2/6	9
Bog (%)	22,05	1976	23/5	8
Forest (%)	39,25	1984	28/5	9
Mountain (%)	24,83	1995	4/6	1
Glacier (%)	0	2004	7/5	7
		2010	18/5	3

The largest one-day flood occurred 4 June 1995 with a discharge of 188,28 m^3/sec corresponding to 418 l/sec km^2 or to a runoff of 36,2 mm/d.

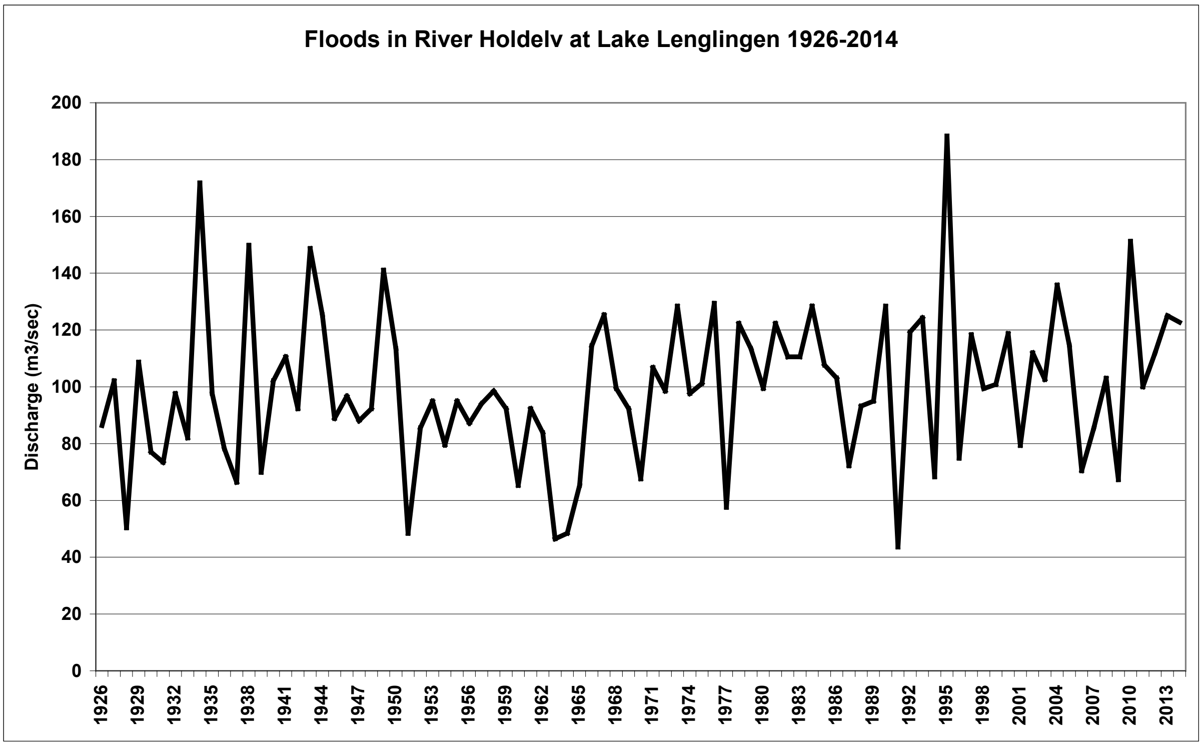


Figure 2.2.1.13. Annual floods (daily values) in River Holdelv at Lake Lenglingen.

2.3 Nordland

Helgeland

Helgeland is the southernmost districts of Nordland County, extending from the border towards Trøndelag to Saltfjellet and the Ranafjord to the north.

2.3.1 RIVER ÅBJØRA

River Åbjøra is located at Bindal municipality – the southernmost municipalty in Nordland County. The river is flowing westward from the water divide towards the Namsen catchment. The outlet of River Åbjøra is into the Bindalsfjord near Terråk. The catchment area is 519,4 square kilometres. The river was regulated 11 May 1979.

A long-term gauging station 144.1 Åbjørvatn has been operating from 1908 to 1992 with a break from 1950 to 1962. Catchment characteristics are listed in Table 2.3.1.1, the dates and ranks of the ten largest floods in Table 2.3.1.2 and the discharge of the largest flood in Table 2.3.1.3. The catchment area is 388,95 square kilometers. The largest one-day flood occurred 17 October 1931 at Åbjørvatn with a discharge of 443,55 m^3/sec corresponding to 1038 l/sec km^2 or to a runoff of 98,3 mm/d.

2.3.2 RIVER LOMSDALSELV AT VELFJORD

River Lomsdalselv is located at Brønnøy municipality in the southernmost part of Helgeland. The upper part of the catchment is located at Grane and Mosjøen municipalites. The river flows westward from the water divide toward River Vefsna. The outlet of the river is at Storbørja – a branch of the Velfjord.

The gauging station 148.1 Strompdal and the precipitation station 76400 Strompdal were both operating within the catchment from 1908 to 1954. The catchment was regulated in 1954 when both stations were closed. Naturalised discharge data have been estimated based on data from the power station afterwards. Catchment characteristics are listed in Table 2.3.1.1, the dates and ranks of the ten largest floods in Table 2.3.1.2 and the discharge of the largest flood in Table 2.3.1.3. The annual floods observed at Strompdal is shown in Figure 2.3.1

The catchment is located at the coastal maximum precipitation zone. Numerous events of more than 100 mm precipitation in a day have occurred, especially in the winter months. The precipitation has often fallen as sleet or rain at the level on the station, but since the catchment is steep, it fell as snow at higher altitudes. The annual flood has therefore not occurred in January or February when the daily precipitation peaked. The annual flood occurred instead in October (24 percent), September (22 percent), July (13 percent) and June and August (11 percent) of all years.

There is a transect of gauging stations from the coast running eastward into the Vefsna catchment comprising the extreme Sørra research catchment at the island Alsten, Strompdal and the previous station Kapskarmo at River Vefsna. The gauging station 181.2 Mevatn is located at River Sausvatnelv downstream Lake Sausvatn. The river flows into Heggefjord, a branch of the Velfjord. Catchment characteristics are listed in Table 2.3.1.1, the dates and ranks of the ten largest floods in Table 2.3.1.2 and the discharge of the largest flood in Table 2.3.1.3.

Table 2.3.1.1 Catchment characteristics of gauging stations in River Åbjøra, Lomsdalselv and Sausvatnelv.

Station	144.1 Åbjøra	148.1 Strompdal	148.2 Mevatnet
	Basin characteristics		
Catchment area (km^2)	388,95	193	108,5
Station altitude (m.a.s.l.)	14	73	15
Mean altitude (m.a.s.l)	625	660	158
Top altitude (m.a.s.l.)	1083	1234	783
Lake (%)	8,51	7,15	9,52
Bog (%)	0,63	0,17	2,15
Forest (%)	6,87	1,61	59,91
Mountain (%)	75,87	78,18	17,4
Glacier (%)	0,03	1,34	0

Table 2.3.1.2 The dates and ranks of the ten largest floods (daily values) observed in River Åbjøra, Lomsdalselv and Sausvatnelv.

144.1 Åbjøra			148.1 Strompdal			148.1 Mevatnet		
1908-2014			1908-1954			1973-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1911	7/7	9	1919	22/10	5	1981	29/1	4
1925	20/11	8	1923	14/7	9	1982	27/3	2
1930	5/12	2	1930	5/12	6	1991	26/1	3
1931	17/10	1	1931	16/10	2	1992	28/1	7
1932	29/1	3	1932	29/9	4	1997	23/1	5
1934	10/5	4	1943	29/10	8	2001	15/2	6
1948	1/12	5	1945	4/10	10	2004	21/2	8
1965	28/6	6	1949	15/10	3	2006	1/2	9
1971	11/1	7	1950	7/6	7	2011	18/4	10
1978	10/11	10	1953	9/10	1	2013	12/12	1

Table 2.3.1.3 The largest observed discharge (daily values) at the three gauging stations in River Åbjøra, Lomsdalselv and Sausvatnelv.

Station	144.1 Åbjøra	148.1 Strompdal	148.1 Mevatnet
Year	1931	1953	2013
Date	17/10	9/10	12/12
q (m^3/sec)	442,6	340,3	73,3
qsp (l/sec km^2)	1038	1765	676
qsp (mm/day)	98,3	152,5	58,4

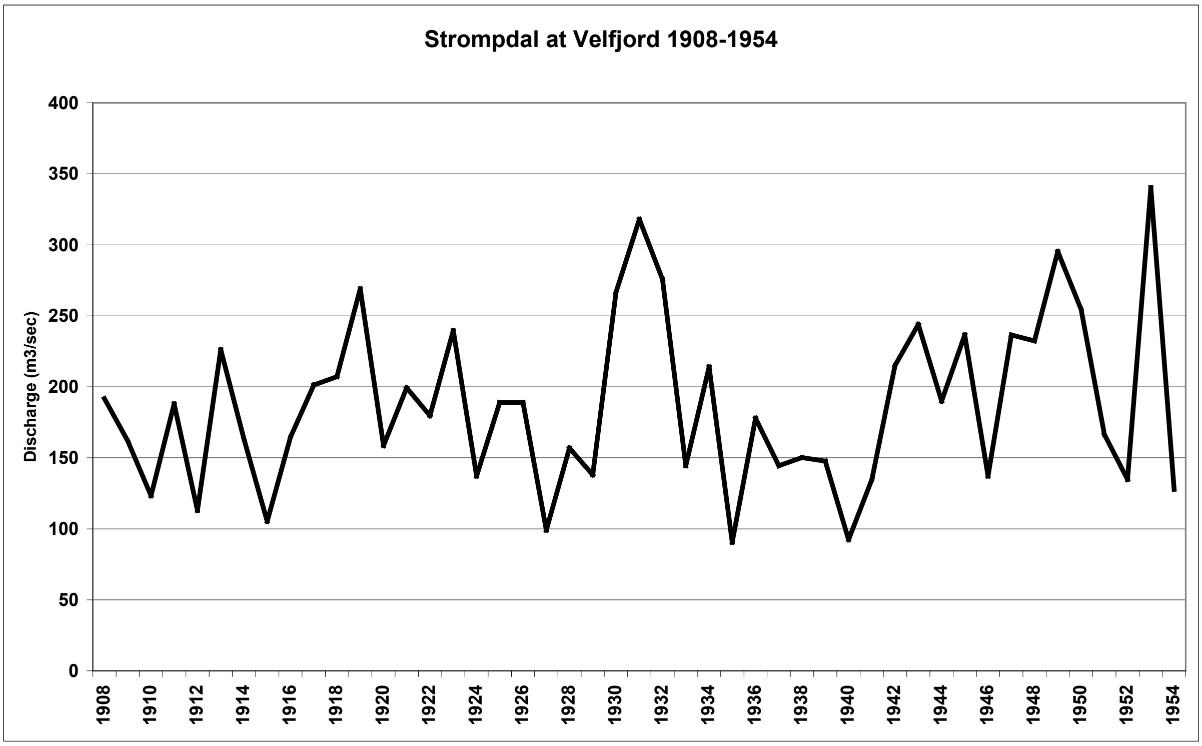


Figure 2.3.1 Annual floods (daily values) at Strompdal 1908-1954.

2.3.3 RIVER VEFSNA

River Vefsna origins at Børgefjell and Majavatn north of the water divide to River Namsen. A number of tributaries are flowing into Vefsna from east with the top of their catchments across the national border to Sweden. The main river flows northward to Trofors where it turns eastward and later southward to the Børgefjell National Park. River Svenningdalselv flows from Lake Majavatn through Svenningdal in Grane municipality and joins with the main river at Trofors. The main river flows northward from Trofors to Mosjøen in Vefsn municipality.

The gauging station 151.7 Kapskarmo in Svenningdal has been operating 1916-1986. Frequent ice runs caused the data quality to be suspect, and the station was therefore closed down in 1986. The catchment is in the inland, but some large floods has penetrated from the maritime Strompdal catchment further west. The annual flood has occurred in all månedene in the year except in August. The annual flood has occurred most frequently in October (27 percent), June (13 percent) and September (11 percent). Catchment characteristics are listed in Table 2.3.1.4, the dates and ranks of the ten largest floods in Table 2.3.1.5 and the discharge of the largest flood in Table 2.3.1.6.

The long term precipitation station 77300 located near the the gauging station, which has been active since 1895.

Another long term gauging station has been operating in 151.9 in Lake Unkervatn 1929-1990. River Unkerelv flows westward from the border towards Sweden and joins River Vefsna at Vefsenmoen upstreams Hattfjelldal. Catchment characteristics are listed in Table 2.3.1.4, the dates and ranks of the ten largest floods in Table 2.3.1.5 and the discharge of the largest flood in Table 2.3.1.6.

Another station 151.15 Nervoll is operating on Eiver Vefsna. Catchment characteristics are listed in Table 2.3.1.4, the dates and ranks of the ten largest floods in Table 2.3.1.5 and the discharge of the largest flood in Table 2.3.1.6.

This station is not affected by regulations and has been included among the stations used in climate change modelling.

Table 2.3.1.4 Catchment characteristics of gauging stations in River Vefsna.

Station	151.7 Kapskarmo	151.9 Unkervatn	151.15 Nervoll
Basin characteristics	1915-1991	1929-1990	1968-2014
Catchment area (km^2)	474	765	653
Station altitude (m.a.s.l.)	135	320	345
Mean altitude (m.a.s.l)	480	731	827
Top altitude (m.a.s.l.)	1234	1328	1692
Lake (%)	9,9	9,84	2,16
Bog (%)	5	5,99	4,95
Forest (%)	34,5	34,91	25,86
Mountain (%)	39,3	33,94	55,51
Glacier (%)	0,5	0	1,6

Table 2.3.1.5. Dates and ranks of the ten largest annual floods in River Vefsna.

151.7 Kapskarmo			151.9 Unkervatn			151.15 Nervoll		
1916-1989			1929-1990			1968-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1918	22/11	9	1935	19/6	9	1971	7/10	1
1919	22/10	7	1938	9/6	3	1972	8/6	8
1931	17/10	1	1943	15/6	1	1979	2/6	7
1932	29/9	3	1949	29/5	5	1984	3/6	9
1934	10/5	3	1961	4/6	8	1989	29/6	6
1949	15/10	6	1967	3/6	4	1995	4/6	2
1961	17/2	2	1971	3/6	7	1997	16/6	5
1962	6/10	8	1973	3/6	2	2005	13/6	10
1971	7/10	5	1980	4/6	10	2011	4/6	3
1978	10/11	10	1981	26/5	6	2013	22/5	4

Table 2.3.1.6 The largest observed discharge (daily values) at the three gauging stations in River Vefsna.

Station	151.7 Kapskarmo	151.9 Unkervatn	151.15 Nervoll
Year	1931	1943	1971
Date	17/10	15/6	7/10
q (m^3/sec)	909,5	104,63	294,73
qsp (l/sec km^2)	1919	321	451
qsp (mm/day)	166	27,8	39,0

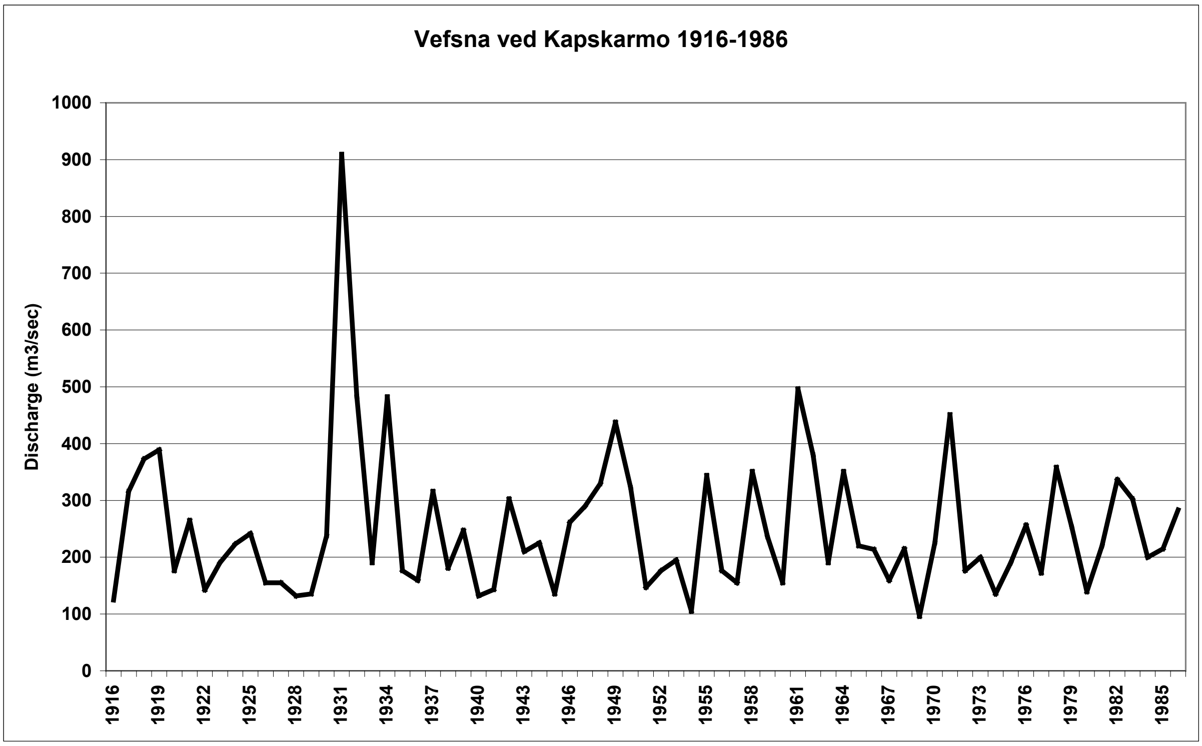


Figure 2.3.2 Annual floods (daily values) in River Vefsna at Kapskarmo 1916-1986.

2.3.4 RIVER FUSTA AT LAKE FUSTVATNET

River Fusta and Lake Fustvatn is located at Vefsn in Nordland northeast of Mosjøen. The river flows into the Vefsnfjord northeast of the outlet of River Vefsna. Catchment characteristics are listed in Table 2.3.1.7, the dates and ranks of the ten largest floods in Table 2.3.1.8 and the discharge of the largest flood in Table 2.3.1.9. The annual flood occurs most frequently in May (18 percent), June (22 percent) and October (18 percent) of all years, but also in the other autumn months and in January.

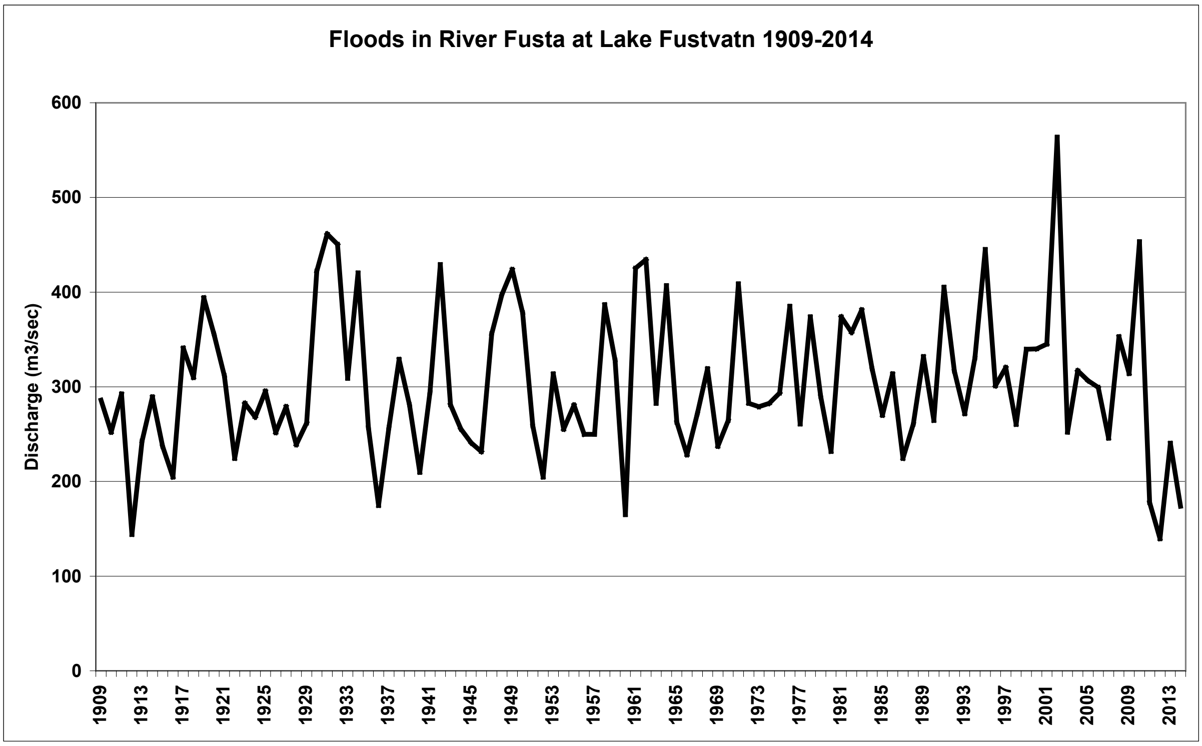


Figure 2.3.3 Annual floods (daily values) in River Fusta at Lake Fustvatn 1909-2013.

2.3.1.5 RIVER LEIRELV AT LAKE STORVATN

River Leirelva is a watercourse at Leirfjord in Nordland. The water divide to the east is towards the River Vefsna catchment and to the north towards small rivers draining to the Vefsna fjord. The gauging station 153.1 has been active since 1917. The annual floods 1917-2014 is skown in Figure 2.3.4. Catchment characteristics are listed in Table 2.3.1.7, the dates and ranks of the ten largest floods in Table 2.1.3.8 and the discharge of the largest flood in Table 2.3.1.9.

The flow regime is maritime. Most of the annual floods are in October (20 percent), January (13 percent) and September (12 percent), but floods can occur in all months of the year. The river is not regulated.

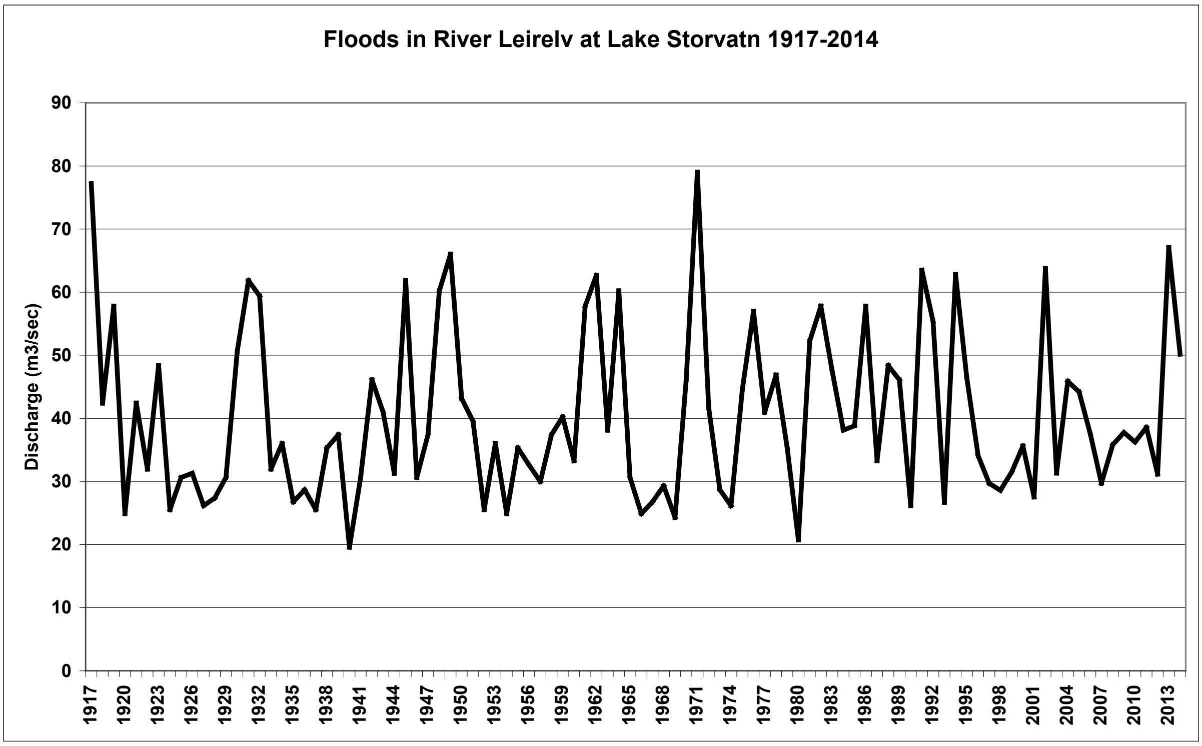


Figure 2.3.4 Annual floods in River Leirelv at Lake Storvatn 1917-2014.

2.3.1.6 RIVER STRAUMDALSELV

River Straumdalselv is a small watercourse draining southward into the Ranafiord. The catchment is located west of the town Mo i Rana. The gauging station 156.15 Forsbakk has been operating since 1963. Catchment characteristics are listed in Table 2.3.1.7, the dates and ranks of the ten largest floods in Table 2.3.1.8 and the discharge of the largest flood in Table 2.3.1.9.

Table 2.3.1.7 Catchment characteristics of gauging stations in River Fusta, Leirelv and Straumdalselv

Station	152.4 Fustvatn	153.1 Storvatn	156.15 Forsbakk
	Basin characteristics		
Catchment area (km^2)	525	48,9	56,3
Station altitude (m.a.s.l.)	39	51	49
Mean altitude (m.a.s.l)	436	516	445
Top altitude (m.a.s.l.)	1530	991	1194
Lake (%)	6	13	1,87
Bog (%)	5	0,33	2,69
Forest (%)	37	10	24,71
Mountain (%)	37	64	58,15
Glacier (%)	0,54	0	0

Table 2.3.1.8 The dates and ranks of the ten largest floods (daily values) observed

152.4 Fustvatn			153.1 Storvatn			156.15 Forsbakk		
1908-2014			1916-2014			1963-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1930	17/10	10	1917	3/10	2	1964	29/11	1
1931	17/10	2	1931	17/10	9	1966	19/9	4
1932	30/12	4	1945	7/4	9	1970	11/12	10
1942	13/9	7	1949	15/10	5	1971	19/8	5
1949	16/10	9	1962	21/10	8	1981	28/1	6
1961	19/2	8	1971	25/8	1	1989	2/12	9
1962	7/12	6	1991	25/11	6	1991	3/9	7
1995	4/6	5	1994	7/10	7	1999	30/10	8
2002	12/1	1	2002	11/1	4	2002	11/1	3
2010	18/5	3	2013	11/12	3	2013	11/12	2

Table 2.3.1.9 The largest observed discharge (daily values) at the three gauging stations in

Station	152.4 Fustvatn	153.1 Storvatn	156.15 Forsbakk
Year	2002	1971	1964
Date	12/1	25/8	29/11
q (m^3/sec)	293,1	79,0	126,6
qsp (l/sec km^2)	558	1646	2259
qsp (mm/day)	48	142	195

2.3.1.7 RIVER RØSSÅGA

River Røssåga flows from the outlet of Lake Røssvatn trpogh a wide valley to the Sørfiord, a branch of the Ranafiord.Catchment characteristics are listed in Table 2.3.1.10, the dates and ranks of the ten largest floods in Table 2.3.1.11 and the discharge of the largest flood in Table 2.3.1.12. The catchment is 2100 km^2 with some tributaries from the East. The catchment has two large power stations Nedre Røssåga from 1958 and Øvre Røssåga from 1972.

Table 2.3.1.10 Catchment characteristics of gauging stations in River Røssåga.

Station	155.6 Sjøfoss	155.5 Lille Målvatn	155.26 Tuven
	Basin characteristics		
Catchment area (km^2)	1.880,8	274,38	1.521,7
Station altitude (m.a.s.l.)	50	333	360
Mean altitude (m.a.s.l)	654	754	651
Top altitude (m.a.s.l.)	1906	1906	1906
Lake (%)	15,81	12,64	17,97
Bog (%)	3,68	1,52	3,41
Forest (%)	30,72	15,36	27,32
Mountain (%)	40,24	43,92	41,92
Glacier (%)	1,61	5,54	1,44

Table 2.3.1.11 The dates and ranks of the ten largest floods (daily values) observed in River Røssåga.

155.6 Sjøfoss			155.5 Lille Målvatn			155.26 Tuven		
1927-1958			1908-1970			1904-1960		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1927	1/7	6	1914	9/7	2	1905	30/6,1/7	7
1931	17/10	1	1923	15/7	6	1907	24/6	10
1935	28/6	9	1927	3-4/7	4	1914	8/7	3
1938	9/6	7	1935	28/6	7	1927	4/7	6
1942	12/9	10	1938	8-9/6	8	1938	12/6	8
1943	21/6	5	1939	21/6	4	1943	24/6	5
1946	30/6	8	1953	23/6	1	1949	7-9/6	4
1949	14/10	3	1956	13/6	9	1953	22/6	1
1953	21/6	2	1958	2/7	9	1958	31/10	2
1958	23/11	4	1962	22/10	3	1959	13/6	9

Table 2.3.1.12 The largest observed discharge (daily values) at the three gauging stations in River Røssåga.

Station	155.6 Sjøfoss	155.5 Lille Målvatn	155.26 Tuven
Year	1931	1953	1953
Date	17/10	23/6	22/6
q (m^3/sec)	565,37	122,33	408,73
qsp (l/sec km^2)	301	446	269
qsp (mm/day)	26,0	38,5	23,2

2.3.1.8 RIVER RANA

River Rana flows into the Ranafjord from the north at Mo. The river has a catchment area of 3847 square kilometres and comprises two branches. The eastern branch flows southward from the water divide towards River Saltdalselv at Saltfjellet.

The gauging station 156.4 Nevernes was operating from 1908 to 1980 in the eastern branch. Catchment characteristics are listed in Table 2.3.1.13, the dates and ranks of the 10 largest floods in Table 2.3.1.14 and the discharge of the largest flood in Table 2.3.1.15.

The annual flood has occurred in 9,1 percent of all years in May, 52,8 percent in June, 20,8 percent in July, 4,2 percent in August and September and 6,9 percent in October.

Table 2.3.1.13 Catchment characteristics of gauging stations in River Rana.

Station	156.4 Nevernes	156.9 Krokstrand	156.19 Bredek
	Basin characteristics		
Catchment area (km^2)	1.904	792,7	228,79
Station altitude (m.a.s.l.)	65	240	270
Mean altitude (m.a.s.l)	813	818	905
Top altitude (m.a.s.l.)	1737	1456	1486
Lake (%)	2,63	2,46	0,69
Bog (%)	1,08	1,21	0,68
Forest (%)	15,37	11,11	9,03
Mountain (%)	75,57	83,68	77,34

Table 2.3.1.14 The dates and ranks of the ten largest floods (daily values) observed in River Rana.

156.4 Nevernes			156.9 Krokstrand			156.19 Bredek		
1908-1980			1938-1970			1968-2000		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1909	25/6	7	1939	20/6	3	1971	26/8	6
1919	22/10	8	1940	20/7	2	1972	19/6	9
1922	20/6	4	1941	6/7	5	1973	8/7	3
1923	14/7	10	1946	19/6	10	1975	21/6	8
1930	26/6	3	1949	14/10	1	1982	20/7	2
1931	17/10	1	1953	20/6	6	1983	8/11	7
1939	21/6	9	1958	30/6,1/7	6	1984	3/6	10
1949	14/10	2	1962	22/10	3	1989	29/6	1
1953	21/6	6	1966	27/7	9	1993	11/7	4
1956	13/6	10	1968	25/6	6	1994	30/6	5

Table 2.13.1.15 The largest observed discharge (daily values) at the three gauging stations in River Rana.

	156.4 Nevernes	156.9 Krokstrand	156.19 Bredek
Year	1931	1949	1989
Date	17/10	14/10	29/6
q (m^3/sec)	1.387,4	437,44	211,77
qsp (l/sec km^2)	729	552	925
qsp (mm/day)	63,0	47,7	80,0

The western branch River Langvassåga has a catchment of 1119 square kilometers and flows from Østerdalsisen and River Leiråga. A gauging station is located at 156.27 Leiråga. Catchment characteristics are listed in Table 2.13.1.16, the dates and ranks of the ten largest floods in Table 2.13.1.17 and the discharge of the largest flood in Table 2.13.1.18.

The gauging station 156.10 Berget is located at Rana. The catchment characteristics are listed in Table 2.3.1.16, the dates and ranks of the ten largest floods in Table 2.3.1.17 and the discharge of the largest flood in Table 2.3.1.18. Berget has been regulated since 1955 and Svartisdal since 1959.

Table 2.3.1.16 Catchment characteristics of gauging stations in the western branch of River Rana.

Station	156.8 Svartisdal+Berget	156.10 Berget	156.27 Leiråga
	Basin characteristics		
Catchment area (km^2)	121,98	210,63	44,09
Station altitude (m.a.s.l.)	71	60	78
Mean altitude (m.a.s.l)	902	804	494
Top altitude (m.a.s.l.)	1578	1587	1287
Lake (%)	6,31	3,12	2,63
Bog (%)	0,1	0,46	0,41
Forest (%)	6,04	8,11	3,52
Mountain (%)	32,15	46,15	65,64
Glacier (%)	45,85	34,94	12,5

Table 2.3.1.17 The dates and ranks of the ten largest floods (daily values) observed in the western branch of River Rana.

156.8 Svartisdal+Berget			156.10 Berget			156.27 Leiråga		
1955-2014			1951-2014			1974-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1956	13/8	9	1961	18/9	5	1983	8/11	4
1957	13/8	1	1962	22/10	1	1986	12/10	8
1958	22/7	6	1971	26/8	10	1988	15/9	7
1961	18/9	10	1982	20/7	6	1991	3/9	6
1962	22/10	2	1983	28/8	9	1999		10
1982	20/7	5	1985	6/10	3	2002	11/1	1
1991	4/9	8	1988	15/9	7	2004	14/6	5
1995	18/8	4	1991	4/9	7	2009	9/8	2
1996	21/8	3	1995	18/8	4	2012	5/9	9
2009	10/9	7	1996	21/8	2	2013	11/12	3

Table 2.3.1.18 The largest observed discharge (daily values) at the three gauging stations in the western branch of River Rana.

Station	156.8 Svartisdal+Berget	156.10 Berget	156.27 Leiråga	
Year	1957	1962	2002	
Date	13/8	22/10	11/1	
q (m^3/sec)	372,10	248,38	63,48	
qsp (l/sec km^2)		1179	1440	
Qsp (mm/day)		101,9	124,4	

Salten

The district Salten extends from Helgeland to the south and to the Ofoten and Loftote districts to the north. The large glacier Svartisen is located at the southern part of the district near the western coast. The eastern part such as Saltdal is quite dry with annual rainfall comparable with that of Sjåk is the upper Gubrandsdalen is southern Norway.

2.3.2.1 RIVER FLOSTRANDELV

River Flostrandelv is a small watercourse located at Meløy municipality north of the Ranafjord. The river flows into Stigvågen, a bay on the northern side of the fjord Sjona. The gauging station 157.4 Flostrand has been operating since 1963. The flow regime is extremly maritime as at 157.4. The annual flood can occur in all months of the year, most frequently in October (21 percent), September (16 percent) and February (10 percent).

The catchment characteristics are given in Table 2.3.2.1. The catchment is located at the maximum precipitation zone southwest of the western Svartisen glacier. The dates and ranks of the ten largest annual floods are given in Table 2.3.2.2. The rating curve is unreliably, but the estimated discharge of the largest annual flood at Flostrand is given in Table 3.3.2.3 below. The longterm precipitation station 80400 Nordfjordnes is located on the eastern side of Melfjorden. This station has recorded many severe rainfall events causing large floods in rivers near the coast west of Svartisen glacier.

2.3.2.2 RIVER KJERRINGÅ AT LAKE VASSVATN

River Kjerringå is a small watercourse at the coast west of the Svartisen glacier in Meløy kommune. The entire catchment area is 22,9 square kilometres. The gauging station 157.3 Vassvatn is located near the meteorological station 60200 Lurøy. This station is known for many large precipitation events. The catchment characteristics are given in Table 2.3.2.1 below. The observations started in 1916. The annual floods 1917-2014 are shown in Figure 2.3.5.

The dates and ranks of the ten largest annual floods are given in Table 2.3.2.2. The rating curve is unreliably, but the estimated discharge of the largest annual flood at Vassvatn is given in Table 2.3.1.3 below.

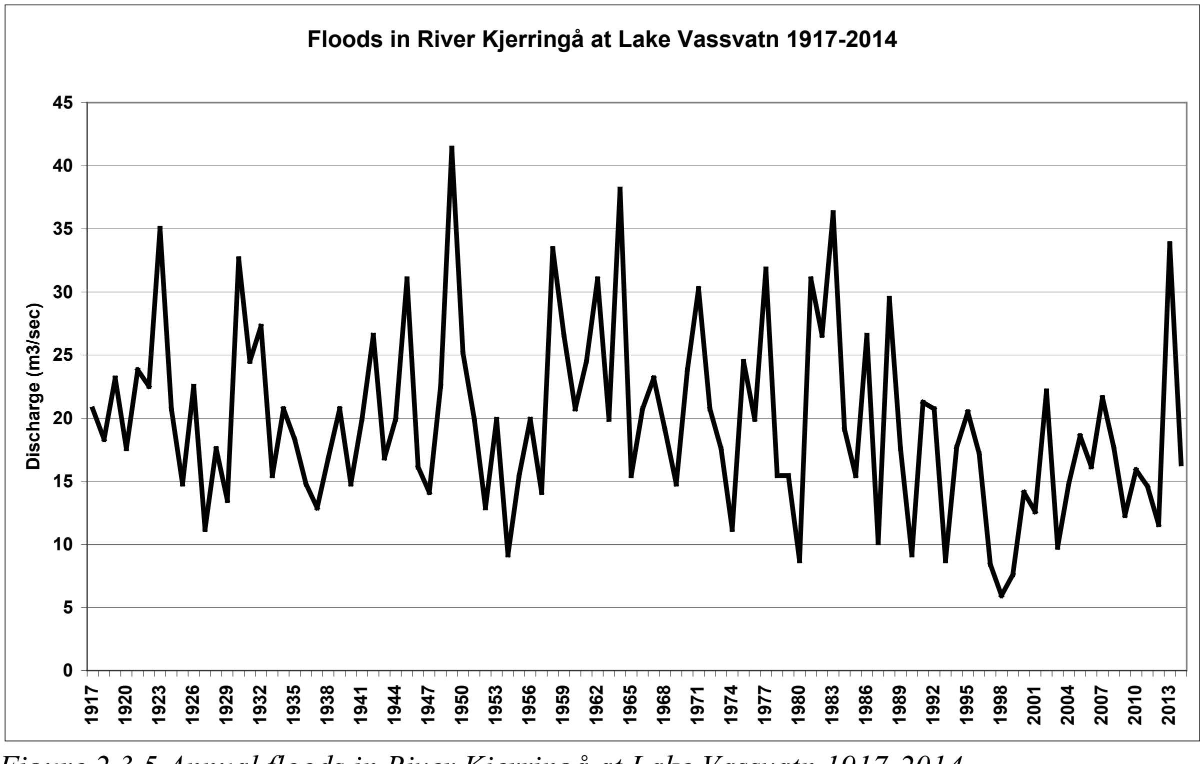


Figure 2.3.5 Annual floods in River Kjerringå at Lake Vassvatn 1917-2014.

2.3.2.3 RIVER BEIARELV

River Beiarelv is flowing from the water divide towards Saltdalselv and Rana towards the Beiarn fjord. The catchment drains part of Svartisen and smaller glaciers on the eastern side of Beiardalen and has a catchment area of 1067 square kilometers. The gauging station 161.2/18 Selfoss has been active since 1917. The annual floods 1917-2014 is shown in Figure 2.3.6. Catchment characteristics are listed in Table 2.3.2.1, the dates and ranks of the ten largest floods in Table 2.3.2.2 and the discharge of the largest flood in Table 2.3.2.3. The annual flood occurs in 41,1 percent of all years in June and 32,6 percent in July but have also occurred from September to January in some years.

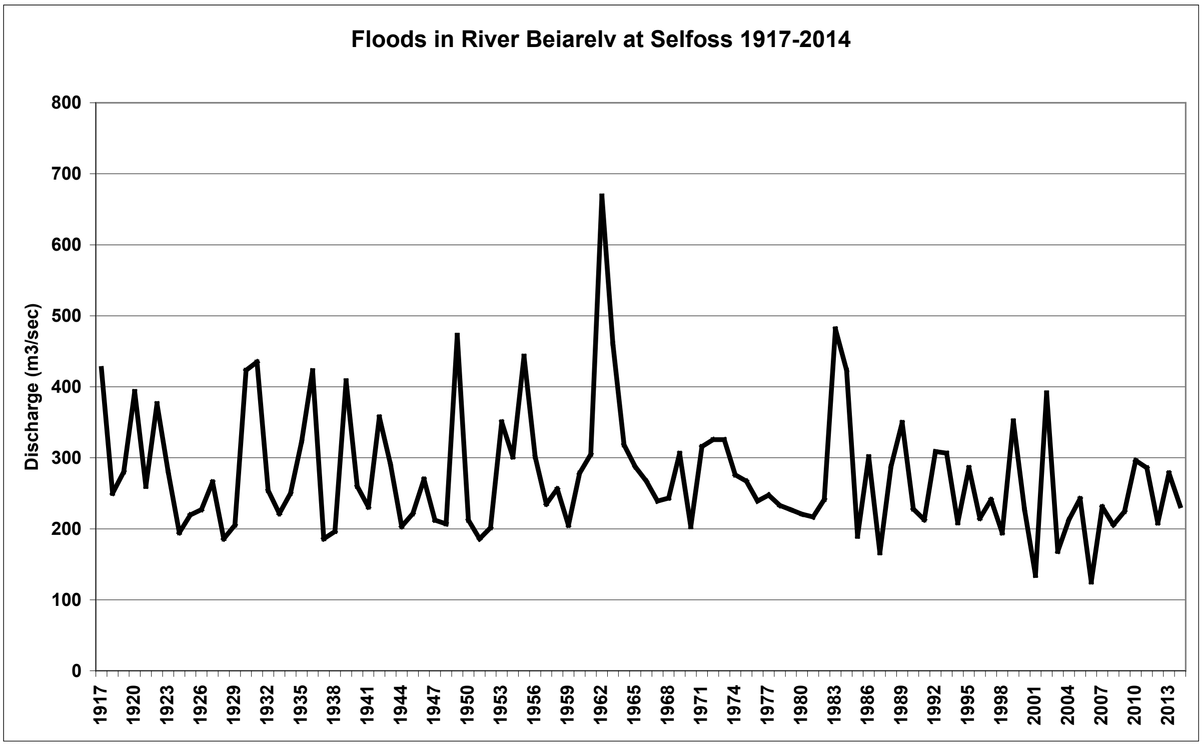


Figure 2.3.6 Annual floods in River Beiarelv at Selfoss 1917-2014.

Table 2.3.2.1 Catchment characteristics of gauging stations in River Flostrandelv, Kjerringå and Beiarelv.

Station	157.4 Flostrand	157.3 Vassvatn	161.2/18 Selfoss
	Basin characteristics		
Catchment area (km^2)	33,16	22,9	788
Station altitude (m.a.s.l.)	0	108	10
Mean altitude (m.a.s.l)	417	471	697
Top altitude (m.a.s.l.)	1152	1160	1626
Lake (%)	6,33	11	1,92
Bog (%)	0,12	0,2	2,03
Forest (%)	9,65	29	26,18
Mountain (%)	66,83	57,2	57,36
Glacier (%)	0	0	6,34

Table 2.3.2.2 The dates and ranks of the ten largest floods (daily values) observed at gauging stations in River Flostrandelv, Kjerringå and Beiarelv.

157.4 Flostrand			157.3 Vassvatn			161.2/18 Selfoss		
1963-2014			1916-2014			1916-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1964	9/1	2	1923	14/7	3	1917	25/6	7
1970	11/12	6	1930	3/3	6	1930	26/6	9
1971	25/8	8	1945	3/11	10	1931	17/10	6
1976	20/11	9	1949	15/10	1	1936	14/6	10
1983	28/8	10	1958	1/2	5	1949	14/10	3
1986	12/10	5	1962	21/10	8	1955	9/7	5
2004	20/2	4	1977	1/10	7	1962	22/10	1
2005	23/11	3	1981	29/1	9	1963	21/7	4
2013	11/11	1	1983	28/8	2	1983	28/8	2
2014	13/3	7	2013	11/12	4	1984	2/6	8

Table 2.3.2.3 The largest observed discharge (daily values) at the three gauging stations in River Flostrandelv, Kjerringå and Beiarelv.

Station	157.4 Flostrand	157.3 Vassvatn	161.2/18 Selfoss
Year	2013	1949	1962
Date	11/12	15/10	22/10
q (m^3/sec)	105,6	40,0	668,8
qsp (l/sec km^2)	3185	2449	847
qsp (mm/day)	275	211	73

2.3.2.4 RIVER FYKENÅGA

River Fykenåga flows from Lake Storglomvatn to the sea at Glomfjord. The lake is the main reservoir of the Svartisen Power Plant. There is a tributary to River Fykanåga from the north below the dam, River Namnløselv. Catchment characteristics are listed in Table 2.3.2.4, the dates and ranks of the ten largest floods in Table 2.3.2.5 and the discharge of the largest flood in Table 2.3.2.6.

2.3.2.5 RIVER LAKSELV AT LAKE SKARSVATN

River Lakselv is a not regulated watercourse, flowing north toward s Saltstraumen in Nordland at Misvær. The discharge has been observed at the gauging station 162.2 Skarsvatn since 1916. Catchment characteristics are listed in Table 2.3.2.4, the dates and ranks of the ten largest floods in Table 2.3.2.5 and the discharge of the largest flood in Table 2.3.2.6. The annual flood has occurred in 41,1 percent of all years in May and 32,6 percent in June, but occasionally from September to January.

River Valnesforsen is located further west close to med Saltenfjord south of Bodø and southwest of Saltstraumen. The gauging station 162.4 Valnesvatn has been active 1913-1950. The observations were resumed 1974, and the station is still active. Catchment characteristics are listed in Table 2.3.2.4, the dates and ranks of the ten largest floods in Table 2.3.2.5 and the discharge of the largest flood in Table 2.3.2.6.

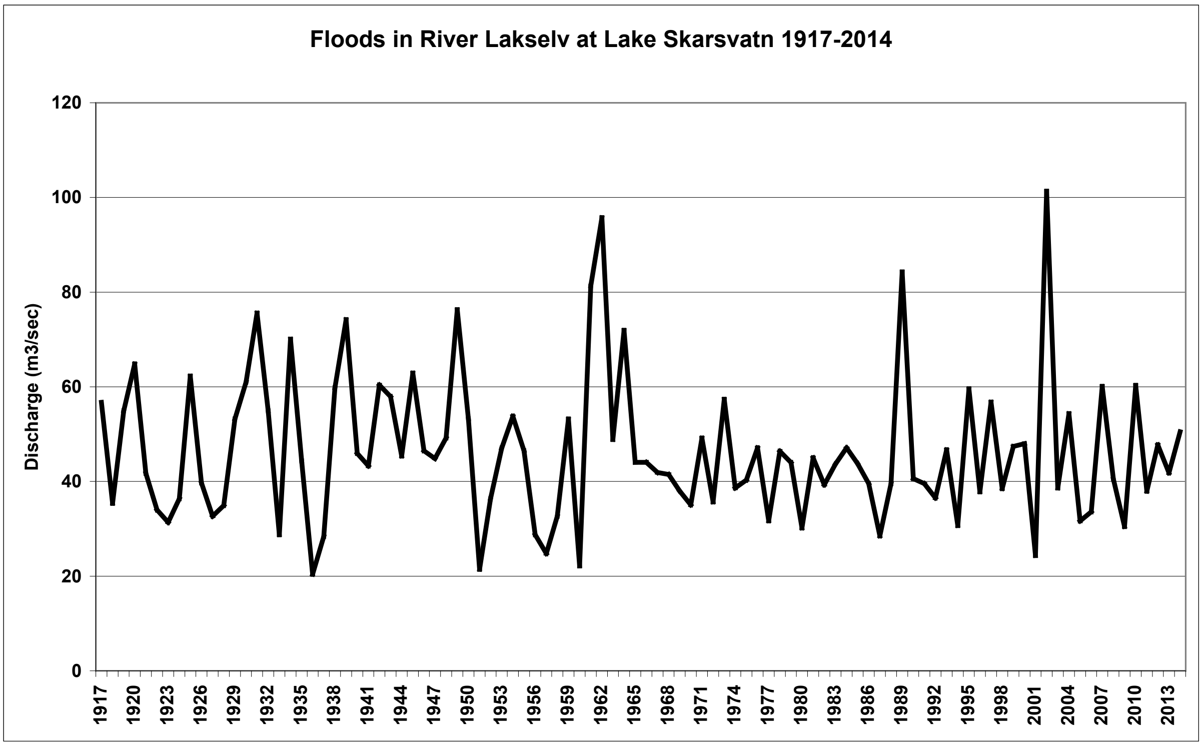


Figure 2.3.7 Annual floods (daily values) in River Lakselv at Lake Skarsvatn 1917-2013.

Table 2.3.2.4 Catchment characteristics of gauging stations in Rivers Fykanåga, Valneforsen and Lakselv.

Station	160.14 Navnløsvatn	162.4 Valnesvatn	162.3 Skarsvatn
	Basin characteristics		
Catchment area (km^2)	4,13	66,77	145,39
Station altitude (m.a.s.l.)	534	121	162
Mean altitude (m.a.s.l)	583	292	520
Top altitude (m.a.s.l.)	742	1115	831
Lake (%)	0	13,01	6,16
Bog (%)	0	3,74	6,03
Forest (%)	0	36,21	44,13
Mountain (%)	72,99	26,09	25,27
Glacier (%)	0	0	0

Table 2.3.2.5 The dates and ranks of the ten largest floods observed in River Fykanåga, *Lake Valnesvatn and River Lakselv.*

160.14 Navnløsvatn			162.4 Valnesvatn			162.3 Skarsvatn		
1959-2014			1913-1950,1975-2014			1917-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1962	22/10	1	1930	2/3	4	1920		10
1982	23/7	6	1932	19/2	8	1931	17/10	6
1983	8/11	10	1939	18/12	7	1934		9
1988	16/9	9	1948	6/3	10	1939	18/12	7
1989	3/12	3	1949	15/10	5	1949	14/10	5
1992	6/10	5	1981	29/1	3	1961	22/11	4
1993	6/7	7	1989	3/12	2	1962	22/10	2
1995	4/6	4	1991	26/11	9	1964	9/1	8
2002	11/1	2	1999	13/11	6	1989	3/12	3
2004	15/6	8	2002	11/1	1	2002	11/1	1

Table 2.3.2.6 The largest observed discharge (daily values) at the three gauging stations in River Fykanåga, *Lake Valnesvatn and River Lakselv.*

Station	160.14 Navnløsvatn	162.4 Valnesvatn	162.3 Skarsvatn
Year	1962	2002	2002
Date	22/10	11/1	11/1
q (m^3/sec)	14,59	151,6	101,3
qsp (l/sec km^2)	3533	2271	697
qsp (mm/day)	305,3	196,2	60,2

2.3.2.6 RIVER SALTDALSELV

River Saltdalselv flows northward from Saltfjellet to Saltdalsfjorden. The catchment area is 1544 square kilometers. The discharge has been observed at several locations. The longest continous data series is at the gauging station at the tributary Russå at Jordbrufjell starting in 1945 and at the tributary 163.5 Junkerdalselv starting in 1937. Two older series exist at Russånes 1913-1940 and at Junkerdal 1913-1933. River Saltdalselv is one of few rivers in Nordland where there is some knowledge of older floods based on damage assesment reports as shown in Table 2.3.6.7. Flood damages affected mostly farms in the lower reaches of River Saltdalselv in Saltdalen.

The tributary Junkerdalselv drains areas east of Saltdalen. The flow regime is typical of a dry inland climate. Catchment characteristics are listed in Table 2.3.2.8, the dates and ranks of the ten largest floods in Table 2.3.2.9 and the discharge of the largest flood in Table 2.3.2.10. The catchment area is 422 square kilometers, and the catchment is not regulated. The annual flood occurs most frequently in May (9,5 percent), June (63,5 percent) and July (21,6 percent), but rainfall floods has occurred occasionally in August and October.

The tributary Russå drains areas west of Saltdalen closer to the Saltdalsfjord. The flow regime is therefore more maritime than at Junkerdalselv. The catchment area of 163.6 Jordbrufjell is at 69,2 square kilometers. Catchment characteristics are listed in Table 2.3.2.8, the dates and ranks of the ten largest floods in Table 2.3.2.9 and the discharge of the largest flood in Table 2.3.2.10. The catchment is not regulated. Most annual floods occur in May (32,3 percent) and June (56,9 percent). Floods are more common at Jordbrufjell than in Junkerdalen from October to December.

Table 2.3.2.7 Historical floods in River Saltdalselv

Year	Date	Remarks
1665		1665 – Frequently riverbank failures.
1717		Deduction after inundation of close to 50 percent of the farmland.
1740's		Frequently riverbank failures.
1803	Spring	Flood damages - 20 % deduction granted
1804		Flood damages
1820		River bank failures - substantial damages
1877	Whitsunday	Severe flood
1883		Flood damages - deductions granted
1913		Flood damages - deductions granted
1917	24/6	Large flood
1920	5/8	Large rainfall flood. Level at Junkerdal 3,50 meter
1922	20/6	Severe flood - largest known. Level at Junkerdal 4,00 meter
1930	26/6	Large flood

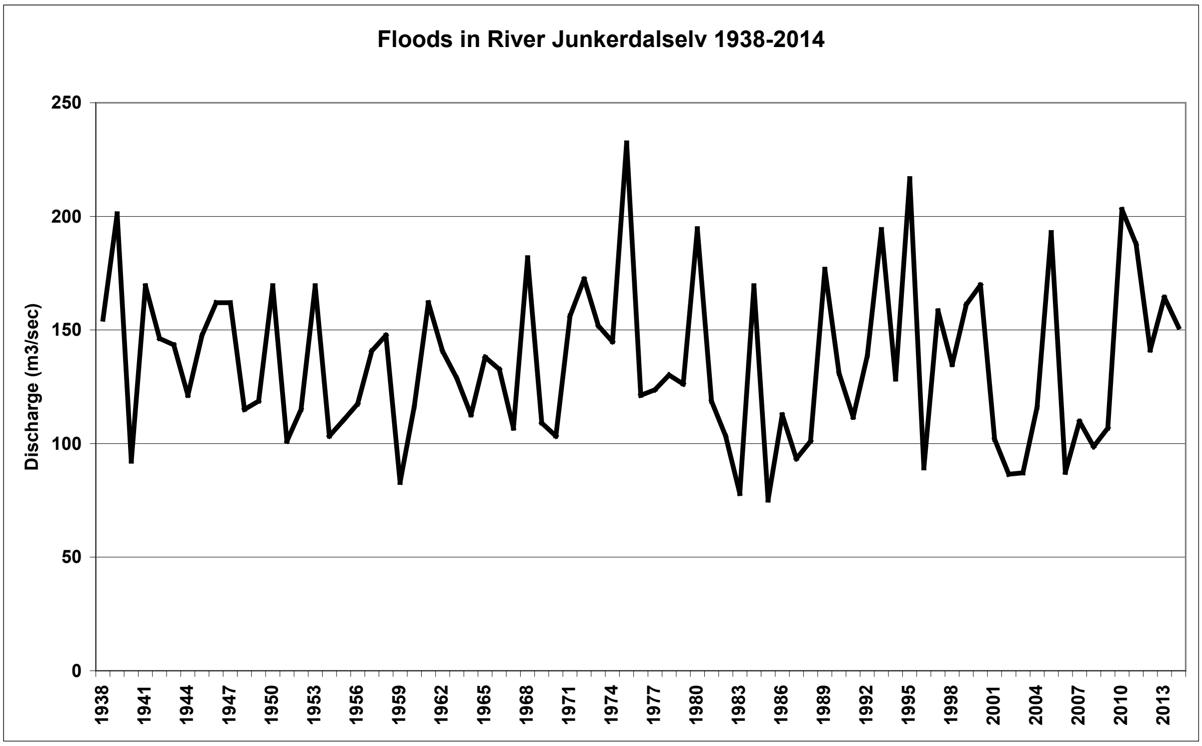


Figure 2.3.8 Annual floods (daily values) in River Junkerdalselv 1938-2014.

Table 2.3.2.8 Catchment characteristics of gauging stations in River Saltdalselv.

Station	163.5 Junkerdalselv	163.6 Jordbrufjell	163.7 Kjemåvatn
	Basin characteristics		
Catchment area (km^2)	421,98	69,91	36,48
Station altitude (m.a.s.l.)	117	434	626
Mean altitude (m.a.s.l)	834	664	935
Top altitude (m.a.s.l.)	1695	1013	1501
Lake (%)	2,08	4,69	7,48
Bog (%)	0,68	6,01	1,21
Forest (%)	18,29	4,69	4,88
Mountain (%)	66,89	62,71	82,73
Glacier (%)	0,55	0	0,41

Table 2.3.2.9 The dates and rank of the ten largest floods (daily values) observed in River Saltdalselv.

163.5 Junkerdalselv			163.6 Jordbrufjell			163.7 Kjemåvatn		
1938-2014			1945-2014			1969-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1939	21/6	4	1979	30/5	10	1973	9/7	4
1968	25/6	9	1961	3/6	3	1980	3/6	7
1975	25/7	1	1962	22/10	1	1984	4/6	9
1980	3/6	5	1973	2/6	3	1989	30/6	1
1989	29/6	10	1982	5/6	9	1992	15/6	3
1993	11/7	6	1995	4/6	2	1993	12/7	5
1995	4/6	2	1997	15/6	6	2005	22/6	10
2005	15/6	7	2010	18/5	5	2011	10/6	2
2010	18/5	3	2013	21/5	8	2013	23/5	8
2011	10/6	8	2014	23/5	7	2014	8/6	6

Table 2.3.2.10 The largest observed discharge (daily values) at the three gauging stations in

Station	163.5 Junkerdalselv	163. Jordbrufjell	163.7 Kjemåvatn
Year	1975	1962	1989
Date	25/7	22/10	30/6
q (m^3/sec)	232,36	47,21	12,99
qsp (l/sec km^2)	551	422	355
qsp (mm/day)	47,6	36,5	30,8,

2.3.2.7 RIVER STRANDÅ AT KJERRINGØY

River Strandå drains a small and steep catchment at Kjerringøy north of Bodø. The catchment area is 23,6 square kilometers. The gauging station 165.6 Strandå is located near the outlet to the sea. The observations started in 1916. The annual floods are shown in Figure 2.3.9. Catchment characteristics are listed in Table 2.3.2.11, the dates and ranks of the ten largest floods in Table 2.3.2.12, and the discharge of the largest flood in Table 2.3.2.13. The flow regime is maritime. The annual flood can therefore occur in all months of the year but has most frequently taken place in October (17 percent), March (13,5 percent), November (11,5 percent) and January and February (10 percent) each.

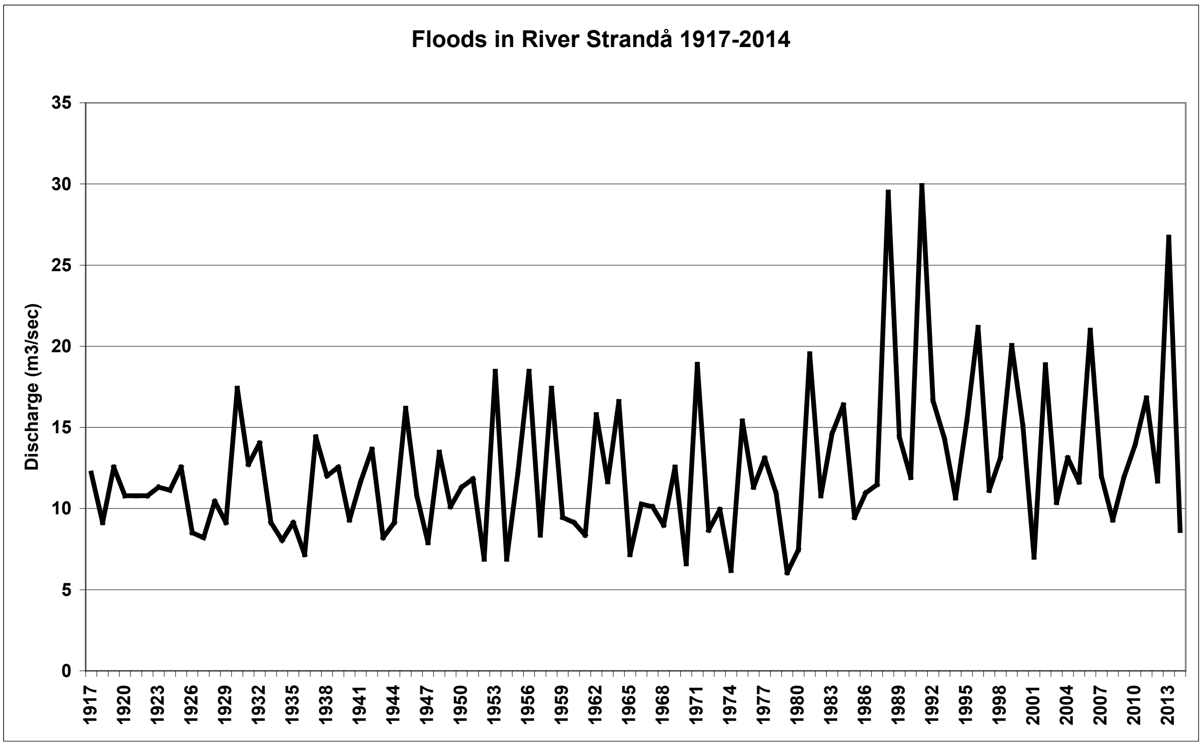


Figure 2.3.9 Annual floods in River Strandå 1917-2014.

2.3.2.8 RIVER LAKSÅGA AT LAKSHOLA

Laksåga is located at Salten north of Saltenfjorden. The gauging station 166.1 Lakshola has been operating since 1916. Catchment characteristics are listed in Table 2.3.2.9, the date and ranks of the ten largest floods in Table 2.3.2.10 and the discharge of the largest flood in Table 2.3.2.12. Lakshola has both a marked spring flood and rainfall floods in the autumn. The annual flood occurs mostly in June (31,6 percent), May (14,7 %) and September and October (12,6 percent) each of all years.

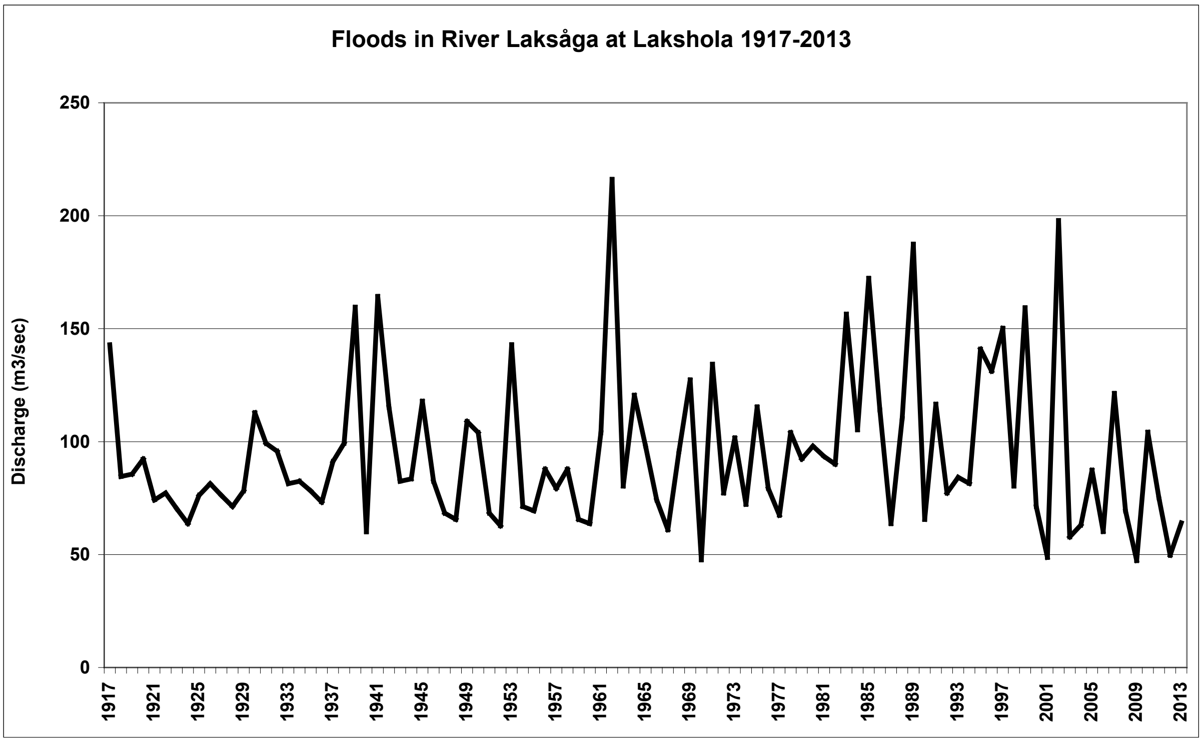


Figure 2.3.10 Annual floods (daily values) in River Laksåga at Lakshola 1917-2013.

Table 2.3.2.11 Catchment characteristics of gaunging stations in River Langvasselv, Strandå and Laksåga.

Station	164.5 Fjell	165.6 Strandå	166.1 Lakshola
	Basin characteristics		
Catchment area (km^2)	687,7	23,6	169 *
Station altitude (m.a.s.l.)	110	15	11
Mean altitude (m.a.s.l)	743	181	535
Top altitude (m.a.s.l.)	1811	932	1325
Lake (%)	14,89	3,64	7,39
Bog (%)	1,24	10,5	0,27
Forest (%)	9,34	30,78	15,7
Mountain (%)	67,09	22,18	53,38
Glacier (%)	1,97	0	1,64

* 166.1 Lakshola was regulated 1/12 1999 when 78 square kilometers of the catchment was diverted.

Table 2.3.2.12 The dates and ranks of the ten largest floods (daily values) observed

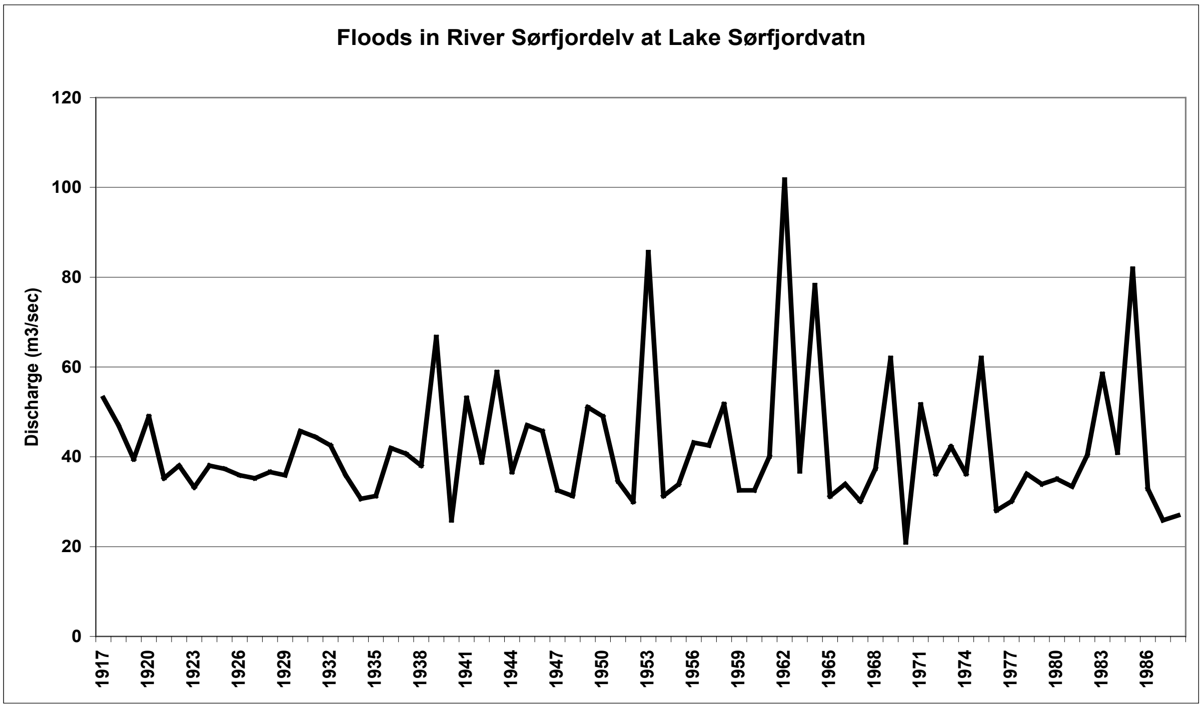
164.5 Fjell			165.6 Strandå			166.1 Lakshola		
1913-1920,1946-1983			1917-2014			1917-2013		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1914	8/7	2	1971	26/8	8	1917	17/6	10
1917	24/6	3	1981	29/1	7	1939	21/9	6
1949	7/7	7	1988	15/9	2	1941	21/9	5
1953	21/6	1	1991	25/11	1	1962	22/10	1
1956	14/6	10	1996	21/8	3	1983	8/11	8
1957	19/7	5	1999	12/10	6	1985	24/10	4
1958	2/7	9	2002	11/1	9	1989	3/12	3
1962	23/10	4	2006	21/12	5	1997	16/6	9
1973	21/7	6	2011	3/3	10	1999	13/11	7
1975	26/7	8	2013	11/12	3	2002	11/1	2

Table 2.3.2.13 The largest observed discharge (daily values) at the three gauging stations in

Station	164.5 Fjell	165.6 Strandå	166.1 Lakshola
Year	1953	1991	1962
Date	21/6	25/11	22/10
q (m^3/sec)	177,94	29,9	216,11
qsp (l/sec km^2)	259	1266	936
qsp (mm/day)	22,3	109	81

2.3.2.9 RIVER SØRFJORDELV

The catchment area is 109,31 square kilometers. The gauging station 167 Sørfjordvatn is located in Sørfolda. Catchment characteristics are listed in Table 2.3.2.14, the dates and ranks of the ten largest floods in Table 2.3.2.15 and the discharge of the largest flood in Table 2.3.2.16.



Figur 2.3.11 Annual floods (daily values) in River Sørfjordelv at Lake Sørfjordvatn.

2.3.2.10 RIVER KOBBELV

The gauging station 167.3 Kobbvatn has a catchment area of 387,14 square kilometers. Catchment characteristics are listed in Table 2.3.2.14, the dates and ranks of the ten largest floods in Table 2.3.2.15 and the discharge of the largest flood in Table 2.3.2.16.

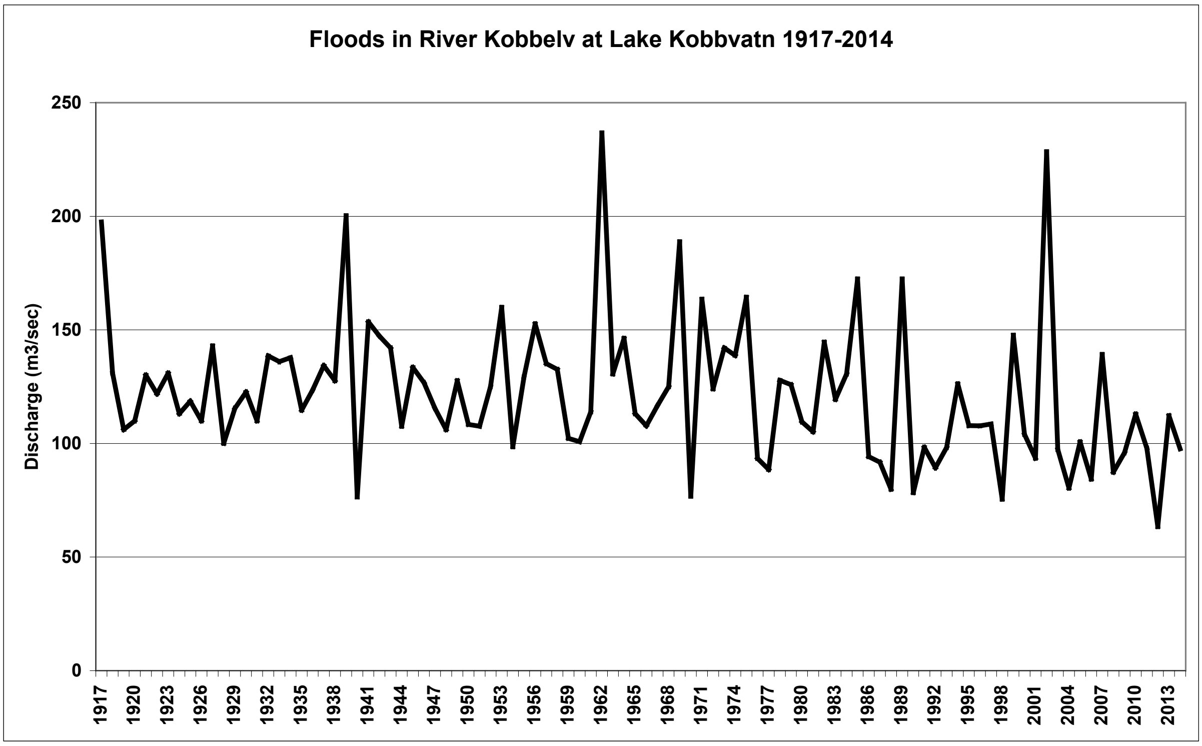


Figure 2.3.12 Annual floods (daily values) in River Kobbelv at Lake Kobbvatn 1917-2014.

2.3.2.11 RIVER LOMMERSELV AT LAKE STORVATN

River Lommerselv is located at Steigen. The catchment area of the gauging station 168.1 Storvatn is 71,3 square kilometers. Catchment characteristics are listed in Table 2.3.2.14, the dates and ranks of the ten largest floods in Table 2.3.2.15 and the discharge of the largest flood in Table 2.3.2.16.

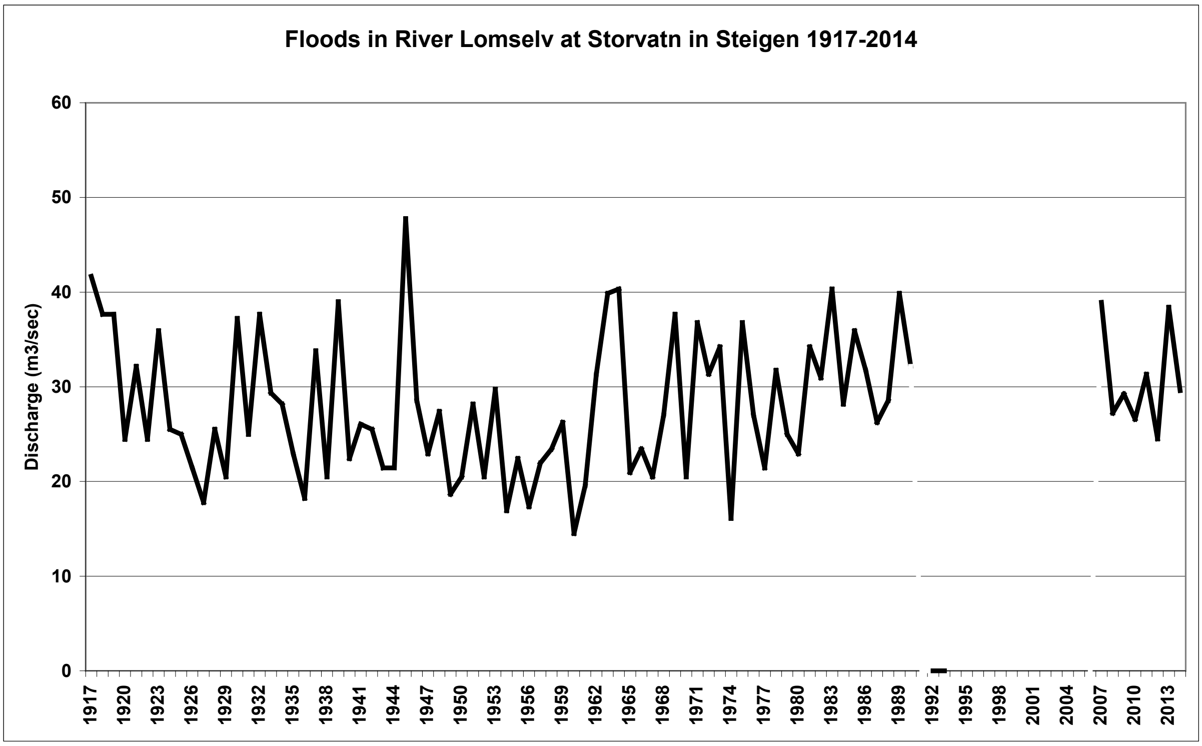


Figure 2.3.13 Annual floods at Lake Storvatn in Steigen 1917-2014.

Table 2.3.2.14 Catchment characteristics of gauging stations in Kobbelv, Sørfjordselv and Lommerselv.

Station	167.3 Kobbvatn	167.2 Sørfjordvatn	168.1 Storvatn
	Basin characteristics		
Catchment area (km^2)	387,14	109,31	71,3
Station altitude (m.a.s.l.)	8	82	56
Mean altitude (m.a.s.l)	680	622	453
Top altitude (m.a.s.l.)	1511	1324	1170
Lake (%)	13,89	21,22	12,92
Bog (%)	0,56	0,24	0,74
Forest (%)	15,62	7,36	20,62
Mountain (%)	63,28	59,81	56,3
Glacier (%)	2,29	0,3	0,42

Table 2.3.2.15 The dates and ranks of the ten largest floods (daily values) observed at stations in Kobbelv, Sørfjordselv and Lommerselv.

167.3 Kobbvatn			167.2 Sørfjordvatn			168.1 Storvatn		
1917-2014			1917-1988			1917-1990,2007-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1917	16/6	4	1939	21/9	5	1917	24-25/6	2
1939	21/9	3	1941	21/9	10	1918	6/2	10
1953	21/6	10	1943	5/10	8	1939	21/9	7
1962	22/10	1	1953	19/10	2	1945	4/10	1
1969	14/10	5	1962	22/10	1	1963	24/10	5
1971	26/8	9	1964	9/1	4	1964	9/1	3
1975	14/10	8	1969	13/9	6	1983	8/11	3
1985	25/10	6	1975	13/10	6	1989	3/12	5
1989	3/12	6	1983	8/11	9	2007	25/10	8
2002	11/1	2	1985	24/10	3	2013	12/12	9

Table 2.3.2.16 The largest observed discharge (daily values) at the three gauging stations in Kobbelv, Sørfjordselv and Lommerselv.

Station	167.3 Kobbvatn	167.2 Sørfjordvatn	168.1 Storvatn
Year	1962	1962	1945
Date	22/10	22/10	4/10
q (m^3/sec)	236,72	101,75	47,76
qsp (l/sec km^2)	613	947	677
qsp (mm/day)	52,8	80,4	58,9

Ofoten

2.3.3.1 RIVER FORSÅVASSDRAGET

The gauging station 172.5 Melkedal have been operating since 1938. The catchment area is 92,15 square kilometers. Catchment characteristics are listed in Table 2.3.3.1, the dates and ranks of the ten largest floods in Table 2.3.3.2 and the discharge of the largest flood in Table 2.3.3.3. The annual flood has occurred in 11,1 percent of all years in May, 30,6 percent in June, 9,7 percent in September and December and 15,3 percent of October. The river was regulated 1 January 1957.

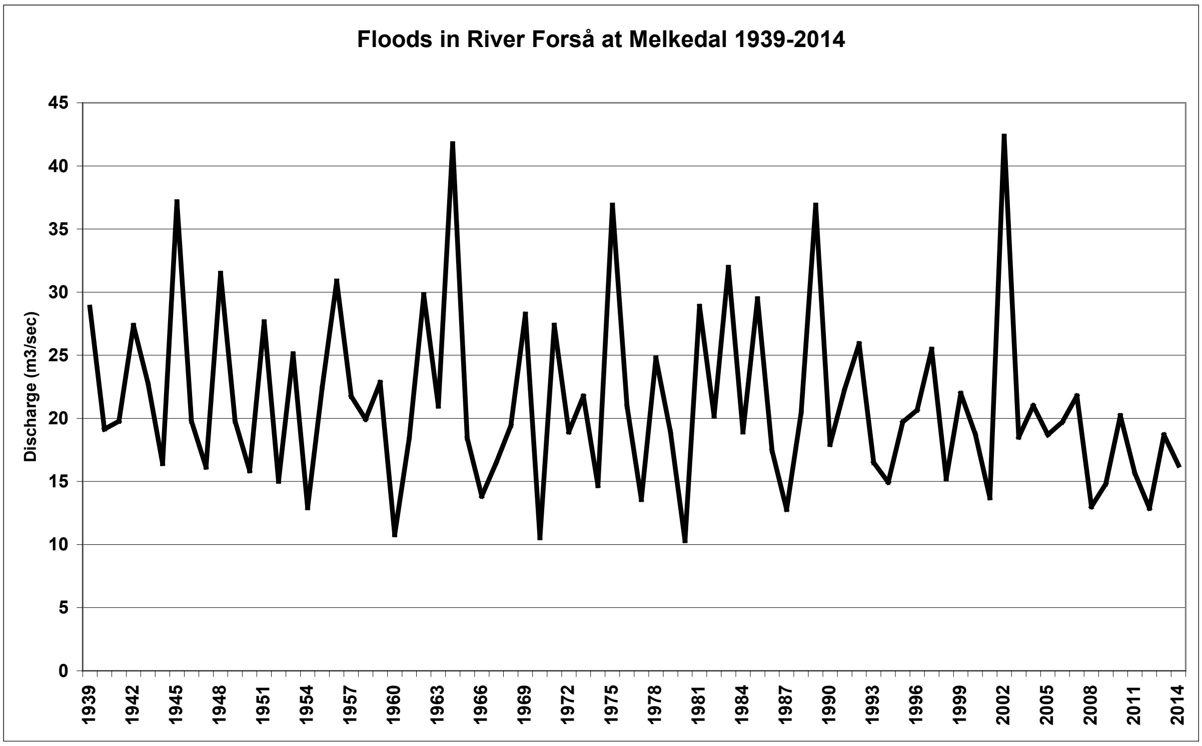


Figure 2.3.14 Annual floods (daily values) in River Forså at Melkedal 1939-2014.

2.3.3.2 RIVER SKJOMA

River Skjoma is located at the bottom of the Skjomafjord south of Narvik. The catchment area of the water course is 849,2 square kilometers. The gauging station 173.2 Gamnes has been operating since 1913. Catchment characteristics are listed in Table 2.3.3.1, the dates and ranks of the ten largest floods in Table 2.3.3.2 and the discharge of the largest flood in Table 2.3.3.3. The large rainfall flood in October 1959 destroyed the station. The observations were resumed in 1961. The river was regulated in 1976, causing strongly reduced floods.

Table 2.3.3.1 Catchment characteristics of gauging stations in River Forså and River Sjoma

Station	172.5 Melkedal	172.7 Leirpoldvatn	173.22 Gamnes
	Basin characteristics		
Catchment area (km^2)	92,15	18,84	797,59
Station altitude (m.a.s.l.)	55	25	42
Mean altitude (m.a.s.l)	412	216	982
Top altitude (m.a.s.l.)	1433	964	1880
Lake (%)	12,57	4,46	7,98
Bog (%)	3,28	4,67	0,35
Forest (%)	33,49	36,09	2,47
Mountain (%)	37,44	26,22	81,63
Glacier (%)	0,88	0	6,11

Table 2.3.3.2 The date and rank of the ten largest floods (daily values) observed in River Forså and River Sjoma

172.5 Melkedal			172.7 Leirpoldvatn			173.22 Gamnes		
1930-2014			1971-2014			1912-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1945	4/10	3	1971	13/5	8	1915	23/7	9
1948	6/3	7	1973	28/10	6	1917	24/6	2
1956	6/1	8	1975	22/2	3	1918	6/7	5
1962	22/10	9	1976	20/11	7	1932	8-9/7	9
1964	9/1	2	1977	18/10	5	1933	20/6	5
1975	9/11	4	1983	8/11	1	1934	15/7	4
1983	8/11	6	1990	18/12	8	1939	21/6	2
1985	24/10	10	1991	25/11	4	1943	23/6	8
1989	2/12	4	1992	28/1	2	1953	21/6	5
2002	11/1	1	1995	14/3	10	1959	6/10	1

Table 2.3.3.3 The largest observed discharge (daily values) at the three gauging stations in River Forså and River Sjoma.

Station	172.5 Melkedal	172.7 Leirpoldvatn	173.22 Gamnes
Year	2002	1983	1959
Date	11/1	8/11	6/10 ?
q (m^3/sec)	42,36	31,84	> 601
qsp (l/sec km^2)	458	1690	> 763
qsp (mm/day)	39,7	146,0	> 65,9

has been operating since 1916. Sneisvatn is located near the coast. Catchment characteristics are listed in Table 2.3.4.1, the dates and ranks of the ten largest floods in Table 2.3.4.2 and the discharge of the largest flood in Table 2.3.4.3. The annual flood can therefore occur in all months of the year. The annual flood has occurred most frequently in November (16,7 %), October (13,5 %) and December and June (12,5 percent) of all years. Figure 2.3.16 show observed annual floods at Lake Sneisvatn.

Table 2.3.4.1 Catchment characteristics of gauging stations in Rivers Sneiselv, Langvasselv and Ringstadelv.

Station	177.4 Sneisvatn	178.1 Langvatn	185.1 Gåslandsvatn
	Basin characteristics		
Catchment area (km^2)	29,25	18,41	7,7
Station altitude (m.a.s.l.)	18	27	16
Mean altitude (m.a.s.l)	302	41	34
Top altitude (m.a.s.l.)	970	96	171
Lake (%)	10,05	8,42	22,1
Bog (%)	1,71	4,56	33,55
Forest (%)	19,97	31,88	27,31
Mountain (%)	54,5	50,08	0,26
Glacier (%)	0	0	0

Table 2.3.4.2 The dates and ranks of the ten largest floods (daily values) observed in Rivers Sneiselv, Langvasselv and Ringstadelv.

177.4 Sneisvatn			178.1 Langvatn			185.1 Gåslandsvatn		
1917-2014			1953-2014			1934-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1918	29/5	10	1959	6/10	2	1961	22/2	8
1923	12/12	4	1964	9/1	2	1963	23/9	1
1928	18/3	4	1975	9/11	5	1971	10/5	10
1931	3/11	4	1981	28/1	6	1979	22/12	5
1937	26/12	3	1985	24/10	4	1981	29/1	7
1941	18/6	2	1989	2/12	9	1992	25/1	4
1971	11/7	7	1996	9/10	10	2002	11/1	2
1975	22/2	1	2000	19/5	8	2005	6/10	9
1978	26/5	7	2002	11/1	1	2006	22/12	6
1985	19/10	9	2007	17/12	7	2007	17/12	3

Table 2.3.4.3 The largest observed discharge (daily values) at the three gauging stations in Rivers Sneiselv, Langvasselv and Ringstadelv.

Station	177.4 Sneisvatn	178.1 Langvatn	185.1 Gåslandsvatn
Year	1975	2002	1963
Date	22/2	11/1	23/9
q (m^3/sec)	35,47	18,70	3,93
qsp (l/sec km^2)	1212	1016	511
qsp (mm/day)	105	88	44

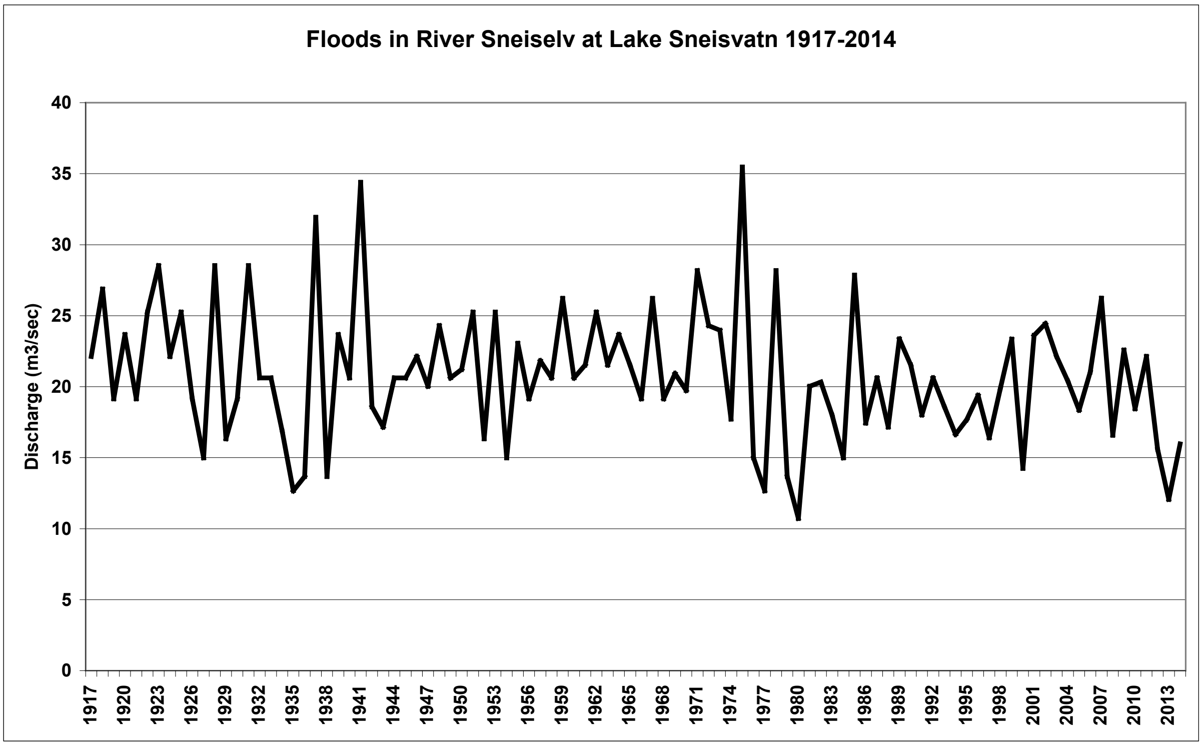


Figure 2.3.16 Annual floods (daily values) in River Sneiselv at Lake Sneisvatn 1917-2014.

2.3.4.2 RIVER LANGVASSELV

River Langvasselv is located at the western part of the Hinnøy on the western side of the Gullesfjord. The gauging station 178.1 Langvatn has a catchment area of 18,41 square kilometers. Catchment characteristics are listed in Table 2.3.4.1, the date and ranks of the ten largest floods in Table 2.3.4.2 and the discharge of the largest flood in Table 2.3.4.3.

2.3.4.3 RIVER RINGSTADELV AT LAKE GÅSLANDSVATN

River Ringstadelv is located at Langøya southwest in the Vesterålen archipelago and flows into the Vesterålsfjord at Ringstad. The gauging station 185.1 Gåslandsvatn has a catchment area of 7,7 square kilometers.
Figure 2. show annual floods at Lake Gåslandsvatn.2.3.17
Catchment characteristics are listed in Table 2.3.4.1, the dates and ranks of the ten largest floods in Table 2.3.4.2 and the discharge of the largest flood in Table 2.3.4.3. The station has been operating since 1934. The flow regime is maritime, and the annual flood occurs from October to May.

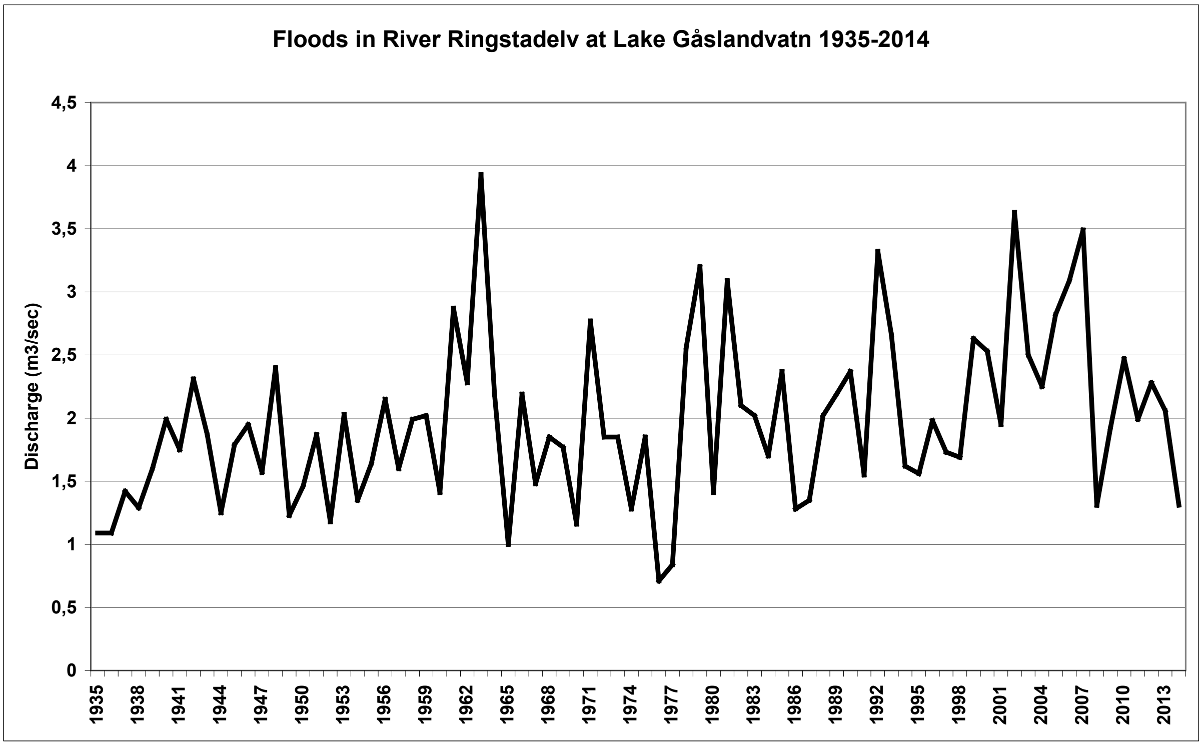


Figure 2.3.17 Annual floods in River Ringstadelv at Lake Gåslandsvatn 1934-2014.

2.4 Troms

The most common cause of floods in Troms County are snowmelt floods occurring typically from May to July. In the southern part of the County extending from Salangen to Lyngen and Kvaløya a small number of large rainfall floods has occurred, most frequently in early October. These floods extend from the northern part of Nordland and into Troms, such as the floods in October 1959 and in 1964. These floods are caused by the northernmost part of an atmospheric river, bringing warm and humid air masses from the central North Atlantic Ocean. A large flood occurred also in the inner Målselv catchment in 2012, caused by warm air from southeast penetrating over the national boundary to Sweden with heavy rainfall in combination with melting of remaining snow in the catchment.

2.4.1 RIVER SALANGSELV AT VASSÅS/ØVREVATN

River Salangselv is located at Sør-Troms and has et catchment area of 526 square kilometers, of which 1,16 square kilometers is in Finland. The data series have been observed at two gauging stations: 191.1 Vassås from 1913 to 1988 and at 191.2 Lake Øvrevatn from 1987. Catchment characteristics are listed in Table 2.4.1, the dats and ranks of the ten largest floods in Table 2.4.2 and the discharge of the largest flood in Table 2.4.3. The flow regime is dominated by the spring flood. The annual flood has occurred in 53 percent of all years in June and in 17 percent in July. A large rainfall flood occurred in the catchment in October 1959 and smaller flood in October 1964.

Table 2.4.1 Catchment characteristics of gauging stations in River Skoddebergelv, River Salangselv and Lake Mevatn

Station	189.4 Skodbergvatn ndf	191.1/2 Vassås/Øvrevatn	194.4 Mevatn
	Basin characteristics		
Catchment area (km^2)	107,7	533/524	180,4
Station altitude (m.a.s.l.)	32	8	14
Mean altitude (m.a.s.l)	316	564	242
Top altitude (m.a.s.l.)	1280	1503	894
Lake (%)	10,45	2,75	6,1
Bog (%)	7,46	2,54	14,34
Forest (%)	40,48	35,22	37,57
Mountain (%)	38,15	52,3	0,18
Glacier (%)	0,99	0,55	0

Table 2.4.2 The dates and ranks of the ten largest floods (daily values) observed in River Skoddebergelv, River Salangselv and Lake Mevatn

189.4 Skodbergvatn ndf			191.1/2 Vassås/Øvrevatn			194.4 Mevatn		
1929-2014			1913-2014			1926-1948,1978-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1932	31/12	10	1939	21/6	6	1937	8/11	10
1934	10/5	7	1959	7/10	2	1941	3/6	9
1935	23/6	4	1993	5/7	8	1946	21/12	4
1937	8/11	7	1995	7/6	9	1989	3/12	5
1942	1/6	9	1997	16/6	4	1990	4/5	7
1943	6/11	2	2000	29/6	5	2001	16/1	1
1953	16-17/6	5	2005	15/6	7	2002	11/1	3
1956	6/1	1	2010	18/5	1	2004	4/11	6
1984	20/12	3	2011	10/6	10	2007	18/12	2
1992	16-17/6	6	2012	15/7	3	2010	18/5	8

Table 2.4.3 The largest observed discharge (daily values) at the three gauging stations in River Skoddebergelv, River Salangselv and Lake Mevatn

Station	189.4 Skodbergvatn ndf	191.1/2 Vassås/Øvrevatn	194.4 Mevatn
Year	1956	2010	2001
Date	6/1	18/5	16/1
q (m^3/sec)	53,6	334,3	130,1
qsp (l/sec km^2)	498	636	721
qsp (mm/day)	43,0	54,9	62,3

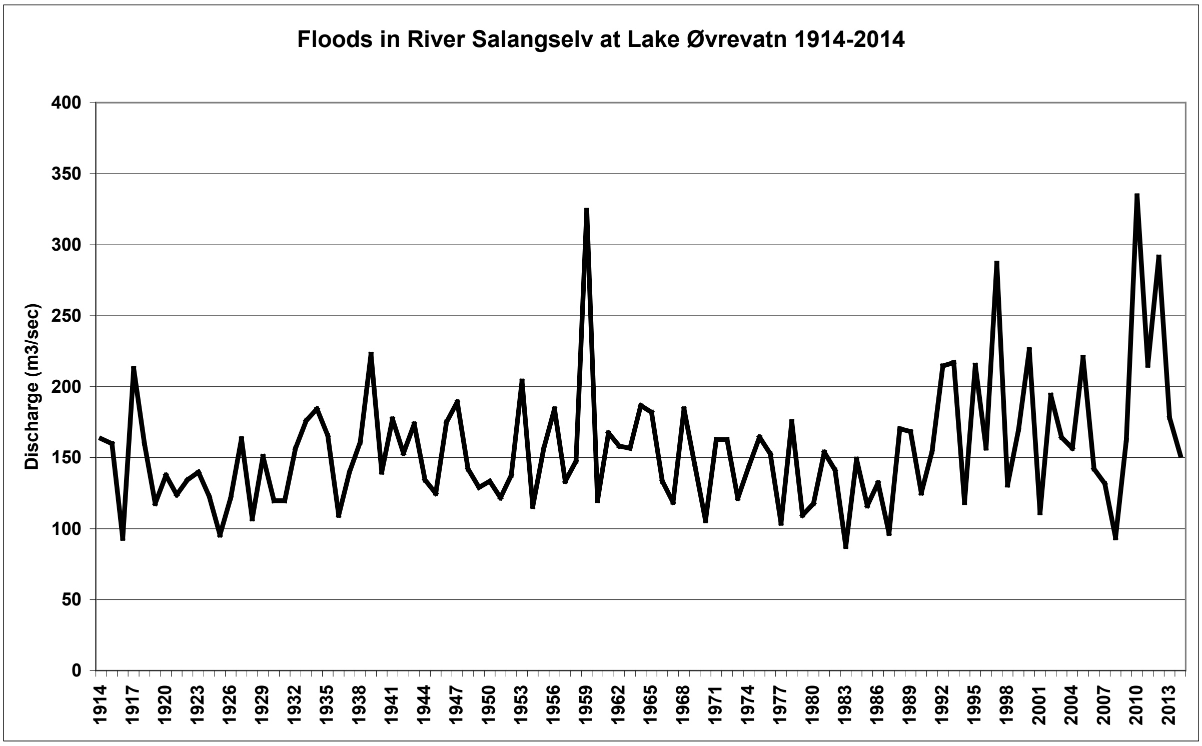


Figure 2.4.1 Annual floods (daily values) in River Salangselv 1914-2014.

2.4.2 RIVER MÅLSELV

River Målselv is the largest watercourse in Troms. The catchment area is 5720 square kilometres. The river has two main branches, River Målselv/Dividalselv to the north and east and River Barduelv further west and south. The flood regime is dominated by the spring flood from mid June to mid July.

The development of the Målselv catchment for agriculture occurred from the 1790's when farmers moving from mostly from Østerdalen and Gudbrandsdalen after Storofsen and subsequent floods ravaging their farms in southern Norway. The Målselv basin had wide opportuninties for farmers to develop new farms. The soil was suitable for developing new farms, but cold winters caused hardship in many years. A major flood occurred in June-July 1859.

There is a long-term dataseries from the gauging station 193.3/x Malangsfoss from 1907 and several gauging stations further upstreams. Observed floods are listed below from

River Dividalselv at 196.21 Skogly and River Rostaelv at 196.11 Lake Lille Rostavatn. The catchment characteristics are given in Table 2.4.4 and the dates and ranks of the ten largest observed floods (daily values) in Table 2.4.5. The discharges of the largest flood at the three stations are given in Table 2.4.6. The annual floods observed at Malangsfoss are shown in Figure 2.4.2.

Table 2.4.4 Catchment characteristics of gauging stations in River Målselv.

Station	196.3 Malangsfoss	196.11 Lille Rostavatn	196.21 Skogly
	Basin characteristics		
Catchment area (km^2)	3111	638,4	1187
Station altitude (m.a.s.l.)	23	102	120
Mean altitude (m.a.s.l)	713	740	779
Top altitude (m.a.s.l.)	1714	1586	1714
Lake (%)	3,78	7,14	2,85
Bog (%)	2,06	1,9	1,74
Forest (%)	24,31	12,91	16,33
Mountain (%)	64,17	70,77	76,21
Glacier (%)	0,73	0,44	0,39

Table 2.4.5 The date and rank of the ten largest floods (daily values) observed in River Målselv.

196.3 Malangsfoss			196.11 Lille Rostavatn			196.21 Skogly		
1908-2014			1959-2014			1974-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1911	28/6	10	1965	28/6	3	1979	26/5	7
1914	26/6	3	1984	30/5	6	1984	28/5	6
1917	16/6	6	1990	27/6	9	1993	5/7	2
1932	27/6	5	1992	15/6	2	1995	5/6	3
1933	20/6	4	1993	6/7	1	1997	10/6	5
1939	21/6	1	1995	7/6	4	2000	28/6	9
1946	14/6	1	1997	16/6	7	2004	21/7	10
1953	16/6	7	1999	15/6	10	2005	14/6	8
1956	14/6	9	2000	29/6	5	2010	18/5	4
2012	15/7	8	2005	14/6	8	2012	15/7	1

Table 2.4.6 The largest observed discharge (daily values) at the three gauging stations in River Målselv.

Station	196.3 Malangsfoss	196.11 Lille Rostavatn	196.21 Skogly
Year	1939, 1946	1993	2012
Date	16/6,14/6	6/7	15/7
q (m^3/sec)	1053,5	200,3	325,9
qsp (l/sec km^2)	339	314	275
qsp (mm/day)	29,3	27,1	23,7

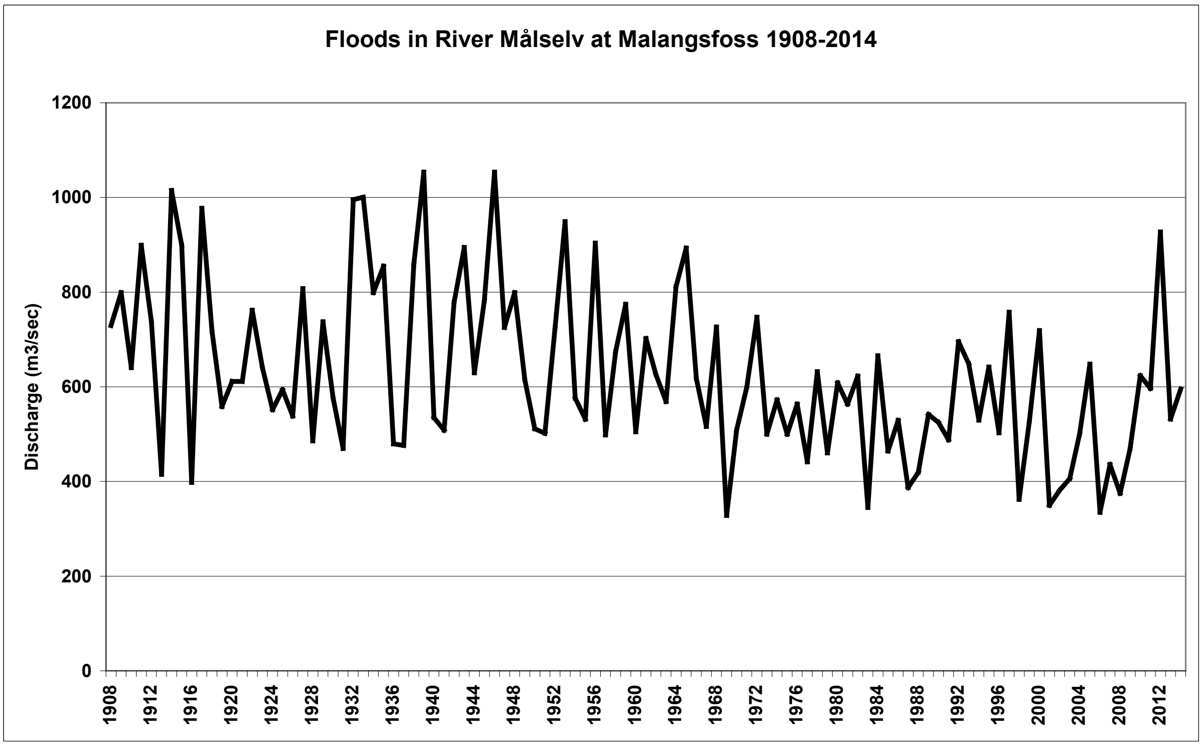


Figure 2.4.2 Annual floods (daily values) in River Målselv at Malangsfoss 1908-2014.

River Barduelv

River Barduelv flows southward from the junction with the main river through Sætermoen before turning southeastward towards the national boundary to Sweden. There is a large lake, Altevatn, in the upper part of the catchment. The water divide towards Salangselven is just west of Sætermoen.

Table 2.4.7 Catchment characteristics of three gauging stations in the Barduelv branch of River Målselv.

Station	196.1/2 Bardufoss	196.36 Fosshaug	196.12 Lundberg
	Basin characteristics		
Catchment area (km^2)	2.376,7	1962	246,5
Station altitude (m.a.s.l.)	18	69	93
Mean altitude (m.a.s.l)	685	738	868
Top altitude (m.a.s.l.)	1656	1656	1564
Lake (%)	6,94	8,08	0,6
Bog (%)	3,44	3,15	0,41
Forest (%)	22,7	17,67	16,36
Mountain (%)	61,09	65,83	76,95
Glacier (%)	0,72	0,75	2,15

Table 2.4.8 The dates and ranks of the ten largest floods (daily values) observed River Barduelv

196.1/2 Bardufoss			196.36 Fosshaug			196.12 Lundberg		
1907-1952			1962-2014			1962-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1910	13/6	8	1968	21/6	10	1965	27/6	6
1914	26/6	7	1992	14/6	3	1968	25/6	3
1917	25/6	2	1993	27/7	2	1972	8/6	5
1927	1/7	6	1995	16/6	6	1975	25/7	1
1932	29/6	10	1997	16/6	7	1982	5/7	6
1933	20/6	4	2000	29/6	5	1984	3/6	3
1939	21/6	1	2004	21/7	7	1988	22/6	9
1943	24/6	3	2005	14/6	9	1992	14/6	8
1945	16/6	9	2010	18/5	4	2011	10/6	10
1946	21/6	5	2012	15/7	1	2012	14/2	2

Table 2.4.9 The largest observed discharge (daily values) at the three gauging stations in River Barduelv.

Station	196.1/2 Bardufoss	196.36 Fosshaug	196.12 Lundberg
Year	1939	2012	1975
Date	21/6	15/7	25/7
q (m^3/sec)	817,0	346,3	151,9
qsp (l/sec km^2)	343	176	616
qsp (mm/day)	29,7	15,2	53,2

2.4.3 RIVER LAKSELV.

A small river, Lakselv, drains into Austefjorden, a branch of Malangen, east of the outlet of River Målselv. There is a gauging station in this small catchment 196.7 Ytre Fiskeløsvatn, which has been operationg since 1960. The river is not regulated, and it is therefore used for regional analyses.

2.4.4 RIVER SKOGFJORDSELV.

River Skogfjordelv is located at Ringvassøy north of Tromsø. The catchment area is 138 square kilometers. Lake Skogsfjordvatn is located southeast of the outlet into the Skogsfjord. The gauging station 200.3/4 Skogsfjordvatn has been active since 1957. Catchment characteristics are listed in Table 2.4.10, the dates and ranks of the ten largest floods in Table 2.4.11 and the discharge of the largest flood in Table 2.4.12.

2.4.5 RIVER JÆGERELV AT LAKE JÆGERVATN

River Jægerselv is located at Lyngen and drains westward into the Ullsfjord from Lyngsalpene. The gauging station 203.1/2 Jægervatn has been active since 1955. Catchment characteristics are listed in Table 2.4.10, the dates and ranks of the ten largest floods in Table 2.4.11 and the discharge of the largest flood in Table 2.4.12. There is a glacier at the top of the catchment. A small stream is flowing westward to the Lyngenfjord. The farm at Koppangen has suffered damages because of glacial outburst floods in recent years in this stream.

2.4.6 RIVER SIGNALDALELV

River Signaldalselv is located at Storfjord municipality in Troms. The river flows northwestwards through Signaldalen to the bottom of the Storfjord in Troms from the water divide to Skibotndalen. The gauging station 204.6 Kavlefoss has been active since 1957. Catchment characteristics are listed in Table 2.4.10, the dates and ranks of the ten largest floods in Table 2.4.11 and the discharge of the largest flood in Table 2.4.12.

Table 2.4.10 Catchment characteristics of gauging stations in Rivers Ringstadelv, Jægerelv and Signaldalselv.

Station	200.4 Skogsfjordsvatn	203.2 Jægervatn	204.6 Kavlefoss
	Basin characteristics		
Catchment area (km^2)	136,01	92,48	401,35
Station altitude (m.a.s.l.)	19	3	64
Mean altitude (m.a.s.l)	243	263	752
Top altitude (m.a.s.l.)	1047	1533	1584
Lake (%)	14,8	9,91	3,24
Bog (%)	1,29	5,92	0,25
Forest (%)	21,25	29,67	12,44
Mountain (%)	49,73	43,88	78,64
Glacier (%)	0	7,39	0,25

Table 2.4.11 The dates and ranks of the ten largest floods (daily values) observed at the three gauging stations in River Ringstadelv, Jægerelv and Signaldalselv.

200.4 Skogsfjordsvatn			203.2 Jægervatn			204.6 Kavlefoss		
1957-2014			1955-2014			1928-1993		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1964	5/10	1	1964	5/10	3	1934	22/6	9
1968	14/6	9	1968	15/6	9	1939	21/6	4
1971	1/11	10	1978	30/5	9	1943	23/6	5
1978	27/5	7	1990	5/5	6	1946	20/6	7
1985	24/10	4	1992	31/5	8	1948	6/6	8
1990	3-4/5	2	1995	23/8	7	1956	14/6	10
1992	31/1	3	1997	16/6	2	1959	16/6	2
2001	16/1	6	2000	27/5	5	1968	14/6	3
2007	18/2	5	2004	11/9	4	1970	4/6	1
2012	28/5	8	2010	18/5	1	1993	5/7	6

Table 2.4.12 The largest observed discharge (daily values) at the three gauging stations in River Ringstadelv, Jægerelv and Signaldalselv.

Station	200.4 Skogsfjordsvatn	203.2 Jægervatn	204.6 Kavlefoss
Year	1964	2010	1970
Date	5/10	18/5	4/6
q (m^3/sec)	93,63	37,27	274,83
qsp (l/sec km^2)	688	403	685
qsp (mm/day)	59,5	34,8	59,2

2.4.7 RIVER MANNDALSELV

River Manndalselv is located at Kåfjord in Troms. The river flows northward from the water divide at the border to Storfjord to the søuth side of the Kåfjord. The gauging station 206.3 Manndalen bru. Catchment characteristics are listed in Table 2.4.13, the dates and ranks of the ten largest floods in Table 2.4.14 and the discharge of the largest flood in Table 2.4.15.

2.4.8 RIVER REISAELV

River Reisaelv is located at Nordreisa municipality in Troms. The river flows from the border to Finland in northwestward direction to the Reisafjord at Storslett. The catchment area, 2705 square kilometres, is the largest of the rivers in the northern part of Troms County. The station was active from 1920 and was closed down in 1938. Another station 208.3 Svartfossberget is located further upstream. This station has been active since 1982.

Catchment characteristics of Moskusdal and Svartfossberget are listed in Table 2.4.13, the dates and ranks of the ten largest floods in Table 2.4.14 and the discharge of the largest flood in Table 2.4.15. The river is protected against hydropower development.

Table 2.4.13 Catchment characteristics of gauging stations in Northern Troms

Station	206.3 Manndalen bru	208.1 Moskudal	208.3 Svartfossberget
	Basin characteristics		
Catchment area (km^2)	200,48	2267	1932
Station altitude (m.a.s.l.)	20	18	90
Mean altitude (m.a.s.l)	933	678	673
Top altitude (m.a.s.l.)	1316	1361	1361
Lake (%)	2,27	2,64	2,76
Bog (%)	0,27	3,7	4,26
Forest (%)	19,98	16,58	15,19
Mountain (%)	77,28	71,9	72,78
Glacier (%)	0	0	0

Table 2.4.14 The dates and ranks of the ten largest floods (daily values) observed in Northern Troms.

206.3 Manndalen bru			208.1 Moskudal			208.3 Svartfossberget		
1972-2014			1920-1938			1982-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1975	25/7	2	1921	30/5	7	1984	28/5	1
1978	25/6	4	1922	14/6	4	1986	23/5	9
1982	5/7	3	1925	7/6	7	1989	10/6	10
1988	23/6	9	1927	23/6	3	1995	7/7	8
1989	30/6	7	1929	23/6	6	1997	15/6	6
1992	14-15/6	5	1930	15/6	10	2005	12/6	5
1993	12/7	1	1932	26/6	9	2010	19/5	3
1995	6/6	8	1934	22/6	1	2012	28/5	7
2004	2/7	10	1935	24/6	5	2013	23/5	4
2011	10/6	6	1938	5/6	2	2014	6/6	2

Table 2.4.15 The largest observed discharge (daily values) at the three gauging stations in.

Station	206.3 Manndalen bru	208.1 Moskudal	208.3 Svartfossberget
Year	1993	1934	1984
Date	12/7	22/6	28/5
q (m^3/sec)	96,66	1055,4	626,84
qsp (l/sec km^2)	482	466	324
qsp (mm/day)	41,7	40,2	28,3

2.4.9 RIVER FISKELVA AT OKSFJORDVATN

River Fiskelv is located at Nordreisa and drains westward into the Oksfjord. The gauging station 208.2 Oksfjordvatn has been operating 1955 to 2013. Catchment characteristics are listed in Table 2.4.16, the dates and ranks of the ten largest floods in Table 2.4.17 and the discharge of the largest flood in Table 2.4.18.

2.4.10 RIVER NATVITJOKKA

River Natvitelv is located at Kvænangen and drains eastward into the Kvænangen fjord. The gauging station 209.4 Lillefossen has been operating 1961 to 2012. Catchment characteristics are listed in Table 2.4.16, the dates and ranks of the ten largest floods in Table 2.4.17 and the discharge of the largest flood in Table 2.4.18.

Table 2.4.16 Catchment characteristics of gauging stations in Rivers Fiskelv and River Natvitelv.

Station	208.2 Oksfjordvatn	209.1Njemenjaikujokka	209.4 Lillefossen
	Basin characteristics		
Catchment area (km^2)	265,60	172,37	331,83
Station altitude (m.a.s.l.)	8	67	32
Mean altitude (m.a.s.l)	548	635	806
Top altitude (m.a.s.l.)	1335	1033	1318
Lake (%)	4,46	7,26	3,76
Bog (%)	0,87	1,33	1,04
Forest (%)	21,36	2,71	10,86
Mountain (%)	66,4	86,95	81,07
Glacier (%)	0,66	0	0

Table 2.4.17 The dates and ranks of the ten largest floods (daily values) observed in Rivers Fiskelv and River Natvitelv.

208.2 Oksfjordvatn			209.1Njemenjaikujokka			209.4 Lillefossen		
1956-2014			1928-1965			1962-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1961	5/6	6	1939	19/6	6	1974	16/6	6
1962	22/6	2	1942	1/6	7	1982	4/7	9
1978	26/6	7	1946	20/6	5	1986	29/5	1
1988	23/6	10	1952	18/6	2	1990	27/6	8
1993	12/6	4	1953	14/6	8	1991	20/6	7
1995	6/6	9	1958	19/6	10	1992	14/6	2
1997	11/6	3	1961	4/6	1	1993	12/7	2
2010	18/5	1	1962	21/6	4	1995	6/6	5
2011	11/6	5	1963	16/6	3	1997	11/6	4
2014	6/6	8	1965	27/6	8	2010	17/5	10

Table 2.4.18 The largest observed discharge (daily values) at the three gauging stations in in Rivers Fiskelv and River Natvitelv.

Station	208.2 Oksfjordvatn	209.1Njemenjaikujokka	209.4 Lillefossen
Year	2010	1961	1986
Date	18/5	4/6	29/5
q (m^3/sec)	162,36	117,56	304,37
qsp (l/sec km^2)	611	682	917
qsp (mm/day)	52,8	58,9	79,2

2.4.11 RIVER STORELV AT BURFJORD

Burfjorddalen is a valley extending from Didnovarre towards northwest to the Burfjord on the west side of Kvænangen. The gauging station 210.1 Øvrefoss was active from 1961 to 1994. Catchment characteristics and the dates and ranks of the ten largest floods are listed in Table 2.4.19.

Table 2.4.19 Catchment characteristics and dates and ranks of the ten largest floods at Øvrefoss in River Storelv.

Station 210.1 Øvrefoss		The largest floods		
Basin characteristics	Value	Year	Date	Rank
Catchment area (km^2)	196,96	1962	21/6	5
Station altitude (m.a.s.l.)	86	1965	27/6	5
Mean altitude (m.a.s.l)	597	1971	20/6	3
Top altitude (m.a.s.l.)	989	1972	8/6	7
Lake (%)	5,49	1978	25/6	1
Bog (%)	0,85	1984	29/5	10
Forest (%)	11,69	1988	22/6	4
Mountain (%)	78,9	1990	27/6	8
Glacier (%)	0	1992	14/6	8
		1993	5/7	2

2.5 Finnmark

The dominant cause of floods in Finnmark County is the spring snowmelt flood, typically in late May or June. The inland plateau, Finnmarksvidda, is protected by mountain ranges from mild airmasses from southwest, and the lowest winter temperatures observed at the Norwegian mainland occurs here. The plateau is quite flat, compared to most mountain districts further south. The snowmelt floods can therefore exceed the flood in the large rivers in southern Norway, since the melting occurs simultaneously over the entire catchment. Rainfall floods occur occasionally in some of the smaller coastal rivers, but they are usually quite small. Warm airmasses can however, penetrate from Finland to the easternmost part of the county, causing some summer floods.

2.5.1 RIVER ALTA AT MASI

River Altaelv has a catchment area of 7.408 square kilometers and drains the western part of Finnmarksvidda. The river is regulated with a dam downstream Masi. The discharges were observed at the gauging station 212.2 Stengelsen 1910-1969 near the outlet to the Alta fjord. Catchment characteristics are listed in Table 2.5.1, the dates and ranks of the ten largest floods in Table 2.5.2 and the discharge of the largest flood in Table 2.5.3.

The discharge data from Stengelsen were unreliable because the controlling section comprises of unstable sandbanks, which shifted after most floods. These data are the only data available from the catchment prior to the establishment of a better gauging station at Masi upstream the dam in 1967. Even if the discharge at Stengelsen is unreliable, the series gives an idea about which years there was large floods in River Altaelv. Below are shown the largest floods at Stengelsen in addition to the later floods at 212.10 Masi in Figure 2.5.1. Catchment characteristics are listed in Table 2.5.1, the dates and ranks of the ten largest floods in Table 2.5.2 and the discharge of the largest flood in Table 2.5.3. The annual flood occurs in 52 percent of all years in May and 48 percent in June.

Table 2.5.1 Catchment characteristics of gauging stations in River Altaelv.

Station	212.2 Stengelsen	212.7 Lille Mattisvatn	212.10 Masi
	Basin characteristics		
Catchment area (km^2)	6357	319,0	5620
Station altitude (m.a.s.l.)	0	64	0
Mean altitude (m.a.s.l)	448	599	450
Top altitude (m.a.s.l.)	1085	937	1085
Lake (%)	7,2	5,45	7,16
Bog (%)	15,73	1,82	19,97
Forest (%)	35,35	14,47	35,4
Mountain (%)	32,59	76,65	31,06
Glacier (%)	0	0	0

Table 2.5.2 The dates and ranks of the ten largest floods (daily values) observed at gauging stations in River Alta.

212.2 Stengelsen			212.7 Lille Mattisvatn			212.10 Masi		
1915-1991			1939-1990			1967-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1915	12/6	7	1939	20/6	9	1967	2/6	10
1916	8/6	9	1943	23/6	9	1968	18/6	1
1917	18/6	2	1946	20/6	4	1973	5/6	3
1920	23/5	1	1948	6/6	2	1978	26/5	2
1927	23-24/5	4	1949	5/7	6	1981	25/5	8
1932	17/6	7	1952	18/6	8	1984	20/5	7
1940	15/5	9	1956	13/6	1	1992	1/6	9
1952	3/6	6	1958	20/6	3	2000	2/6	6
1953	23/5	5	1962	21/6	4	2005	8/6	5
1968	8/6	3	1974	10/6	6	2013	25/5	4

Table 2.5.3 The largest observed discharge (daily values) at the three gauging stations in River Alta.

Station	212.2 Stengelsen	212.7 Lille Mattisvatn	212.10 Masi
Year	1920	1956	1968
Date	23/5	13/6	18/6
q (m^3/sec)	1.302	140,8	1.139
qsp (l/sec km^2)	205	441	203
qsp (mm/day)	17,7	38,1	17,5

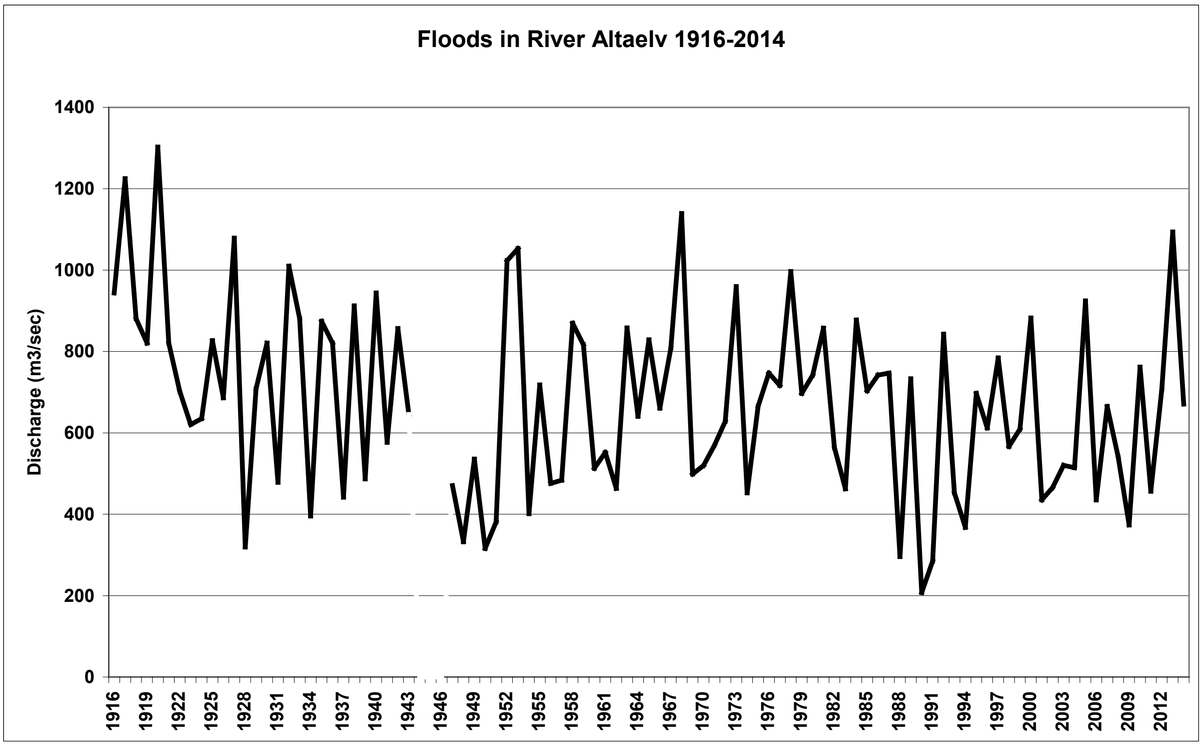


Figure 2.5.1 Annual floods (daily values) in River Altaelv at Stengelsen 1916-2014.

2.5.2 RIVER LEIRBOTNELV AT LEIRELVA

River Leirbotneiv is located east of the Altafjord north of Alta. The rivers flow from Sennalandet and the water divide to River Stabburselv, further east to the fjord at Leirbotn. The gauging station 213.2 Leirbotnvatn has been active since 1962. Catchment characteristics are listed in Table 2.5.4, the dates and ranks of the ten largest floods in Table 2.5.5 and the discharge of the largest flood in Table 2.5.6.

Table 2.5.4 Catchment characteristics of gauging stations in River Leirelva, River Stabburelv and River Lakselv.

Station	213.2 Leirbotnvatn	223.2 Lombola	224.1 Skoganvarre
	Basin characteristics		
Catchment area (km^2)	135,5	877,1	943,4
Station altitude (m.a.s.l.)	161	58	69
Mean altitude (m.a.s.l)	457	435	345
Top altitude (m.a.s.l.)	716	1136	1043
Lake (%)	5,6	4	6,13
Bog (%)	2,2	3,86	6,47
Forest (%)	12,88	10,12	41,75
Mountain (%)	76,55	77,38	40,76
Glacier (%)	0	0	0

Table 2.5.5 The dates and rank of the ten largest floods (daily values) observed in River Leirelva, River Stabburelv and River Lakselv.

213.2 Leirbotnvatn			223.2 Lombola			224.1 Skoganvarre		
1962-2014			1924-2014			1923-2013		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1965	28/6	3	1932	27/6	5	1925	3/6	2
1968	26/6	2	1938	5/6	2	1927	1/6	6
1971	19/6	7	1942	31/5	1	1935	20/6	9
1977	9/6	7	1943	6/6	9	1938	6/6	5
1979	3/6	7	1948	19/6	3	1940	15/5	3
1985	14/6	5	1952	11/7	9	1942	1/6	9
1986	23/5	10	1958	19/6	6	1952	2/6	4
1997	11/7	4	1992	30/5	7	1958	20/6	8
2010	18/5	1	1997	11/6	4	1997	12/6	1
2014	7/6	6	2010	19/5	6	2000	6/6	7

Table 2.5.6 The largest observed discharge (daily values) at the three gauging station in River Leirelva, River Stabburelv and River Lakselv.

Station	213.2 Leirbotnvatn	223.2 Lombola	224.1 Skoganvarre
Year	2010	1942	1997
Date	18/5	31/5	12/6
q (m^3/sec)	74,27	423,2	253,0
Qsp (l/sec km^2)	548	483	268
Qsp (mm/day)	47,4	41,7	23,7

2.5.3 RIVER STABBURELV AT LOMBOLA

River Stabburelv flows eastward through Stabburdalen to Porsangen at Stabbursnes. The catchment area of the watercourse is 1106 square kilometres. There are two long-term discharge series in the Rivers 123.1 Stabburselv and 113.2 Lombola, both with data from 1923 to 2014. Data are missing 1944-46 at both stations as on most stations in Finnmark. The catchment area of the gauging station 113.2 Lombola. Catchment characteristics are listed in Table 2.5.4, the dates and ranks of the ten largest floods in Table 2.5.5 and the discharge of the largest flood in Table 2.5.6.

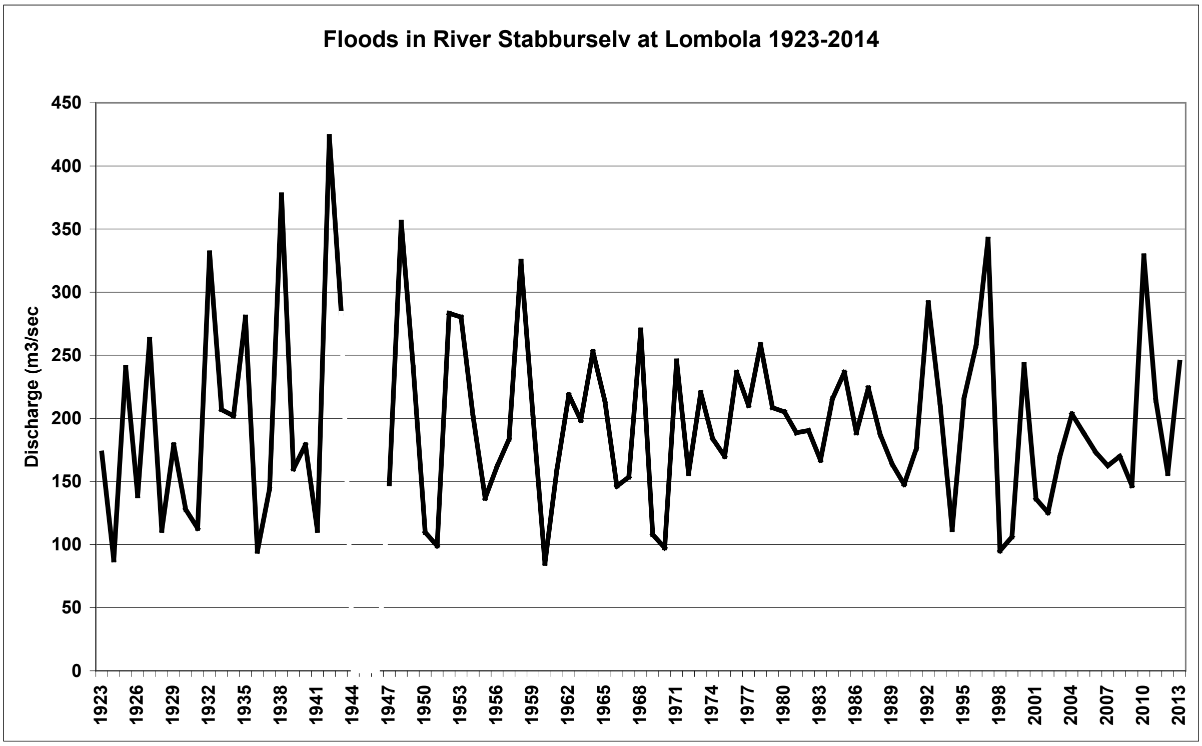


Figure 2.5.2 Annual floods (daily values) in River Stabburselv at Lombola 1923-2014.

2.5.4 RIVER LAKSELV AT SKOGANVARRE

River Lakselv flows from the water divide towards River Tana to the south and east into Porsangen at Lakselv to the north. The catchment area of the watercourse is 1528 square kilometers. The long-term gauging station 224.1 Skoganvarre has been active since 1921.

The catchment characteristics are given in Table 2.5.4 above, the dates and ranks of the ten largest annual floods (daily values) and the discharge of the largest flood in the data series are found in Tables 2.5.5 and 2.5.6 above.

2.5.5 RIVER NORDMANNSETELV AT NORDMANNSET

The gauging station at Normannset is located at the southwest corner of the Nordkinn Penninsula. The gauging station 230.1 Nordmannset is the northernmost gauging station in Norway except for stations at Spitsbergen. The catchment area is 19,31 square kilometres. Catchment characteristics are listed in Table 2.5.4, the dates and ranks of the ten largest floods in Table 2.5.5 and the discharge of the largest flood in Table 2.5.6.

Table 2.5.4 Catchment characteristics of gauging stations in coastal rivers in Finnmark.

Station	229.1 Adamfjordelv	230.1 Normannset	234.4 Smalfjord
	Basin characteristics		
Catchment area (km^2)	710,5	19,31	30,05
Station altitude (m.a.s.l.)	41	72	20
Mean altitude (m.a.s.l)	326	246	123
Top altitude (m.a.s.l.)	796	368	325
Lake (%)	9,18	10,36	16,64
Bog (%)	2,35	0	6,66
Forest (%)	6,12	5,18	56,57
Mountain (%)	79,3	72,5	6,66
Glacier (%)	0	0	0

Table 2.5.5 The dates and ranks of the ten largest floods (daily values) observed in coastal rivers in Finnmark.

229.1 Adamfjordelv			230.1 Normannset			234.4 Smalfjord		
1927-1960			1961-2014			1960-1986		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1929	30/6	1	1962	24/2	8	1961	4/6	1
1932	22/6	2	1965	7-8/6	1	1963	14/5	7
1933	10/6	9	1966	10/6	8	1965	8/6	6
1935	20/6	3	1968	26/6	4	1968	7/6	2
1938	8/6	6	1970	13/5	2	1970	30/5	9
1939	18/6	8	1971	20/6	5	1971	3/6	4
1942	3/6	7	1973	1/11	8	1976	23/5	4
1952	10/6	10	1975	12/5	7	1978	28/5	3
1953	5/6	4	1979	4/6	3	1979	30/5	9
1958	19/6	5	1996	10/6	6	1984	18/5	7

Table 2.5.6 The largest observed discharge (daily values) at the three gauging stations in coastal rivers in Finnmark.

Station	229.1 Adamfjordelv	230.1 Normannset	234.4 Smalfjord
Year	1929	1965	1961
Date	30/6	7-8/6	4/6
q (m^3/sec)	241,6	13,50	17,88
Qsp (l/sec km^2)	340	699	595
Qsp (mm/day)	29,4	60,39	51,4

2.5.6 RIVER ADAMSFJORDELV

River Adamsfjordelv is located on the eastern side of the inner Laksefjord. The river flows from the water divide to River Tana in Lebesby and Tana municipalities to the bottom of the Laksefjord west of Banak.The catchment area is 710,1 km^2. The river is regulated. The gauging station Adamfjordelv is located close to the sea. Catchment characteristics are listed in Table 2.5.4, the dates and ranks of the ten largest floods in Table 2.5.5 and the discharge of the largest flood in Table 2.5.6.

2.5.7 RIVER TANA

River Tana is located at Karasjok and Tana municipalities in Norway and Utsjok municipality in Finland. The catchment area of River Tana is 16386 square kilometres. This is the fourth largest catchment draining to the Norwegian coast after Glomma, Pasvikelv and Drammenselv. The gauging stationen 234.18 Polmak has a catchment area of 14174 square kilometers, which 9645 square kilometers is in Norway. Catchment characteristics are listed in Table 2.5.7, the dates and ranks of the ten largest floods in Table 2.5.8 and the discharge of the largest flood in Table 2.5.9. The annual flood is the spring flood, which often starts with an ice run. The annual flood occurs in May in 65 percent of all years and 33 percent in June.

Table 2.5.7 Catchment characteristics of gauging stations in River Tana and River Bergebyelv.

Station	234.18 Polmak	234.6 Vækkave	241.1 Bergeby
	Basin characteristics		
Catchment area (km^2)	14161	2086	247,6
Station altitude (m.a.s.l.)	10	176	24
Mean altitude (m.a.s.l)	347	413	235
Top altitude (m.a.s.l.)	1064	1020	470
Lake (%)	4,1	10,52	2,26
Bog (%)	11,59	10,68	12,71
Forest (%)	52,48	31,87	18,45
Mountain (%)	19,66	37,37	54,13
Glacier (%)	0	0	0

Table 2.5.8 The dates and ranks of the ten largest floods (daily values) observed in River Tana and River Bergebyelv.

234.18 Polmak			234.6 Vækkave			241.1 Bergeby		
1911-2014			1973-2010			1960-1996		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1917	13/6	2	1978	25/5	4	1963	18/5	7
1920	21/5	1	1979	27/5	1	1969	26/6	9
1927	19/6	7	1986	16/5	10	1977	10/6	6
1932	15/6	4	1992	30/5	6	1979	4/6	2
1948	14/5	10	1996	10/6	3	1986	5/6	5
1968	8/6	3	1997	11/6	2	1988	9/6	10

1978	26/5	5	2000	1/6	5	1989	17/5	3
1981	25/5	9	2005	7/6	7	1990	25/6	1
1984	19/5	8	2007	26/5	9	1992	29/5	7
1987	22/5	6	2013	23/5	8	1996	10/6	4

Table 2.5.9 The largest observed discharge (daily values) at the three gauging stations in River Tana and River Bergebyelv.

Station	234.18 Polmak	234.6 Vækkave	241.1 Bergeby
Year	1920	1979	1990
Date	21/5	27/5	25/6
q (m^3/sec)	3.843,7	332,8	82,8
qsp (l/sec km^2)	271	160	335
qsp (mm/day)	23,4	13,8	28,9

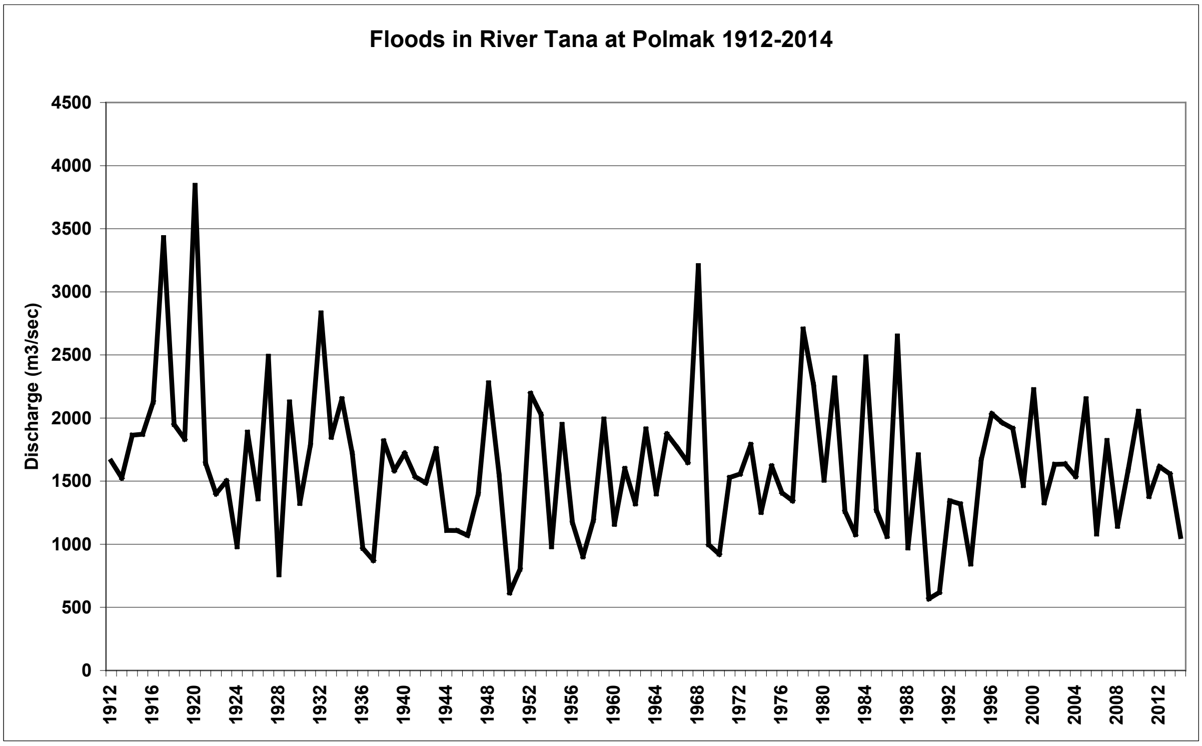


Figure 2.5.3 Annual floods in River Tana at Polmak 1912-2014.

2.5.8 RIVER NEIDEN

River Neiden has a catchment area of 2941 square kilometers. A large part of the catchment is located at Finland. Discharge has been observed at two locations, first at 244.1 Neset 1911-1980 and later at 244.2 Neiden from 1978. The catchment area is 2911 square kilometers at

Neset, of which 596 square kilometers is in Norway and 2.905 square kilometers at Neiden. Catchment characteristics are listed in Table 2.5.10, the dates and ranks of the ten largest floods in Table 2.5.11 and the discharge of the largest flood in Table 2.5.12. The largest flood is the spring flood. The annual flood in 61 percent of all years in May and 36 percent in June. Ice runs are also frequent in River Neiden.

2.5.9 RIVER PASVIKELV

River Pasvikelv has a total catchment of 18403 square kilometres. Most of the catchment is located within Russia and Finland. The part within Finland includes the large lake Enare. The river is regulated both on the Norwegian and the Russian side of the river along the national border. There was a long-term gauging station 246.1 Bjørnevatn operating prior to the delevopment 1911 - 1960. Catchment characteristics of this station is given in Table 2.5.10, and the dates and ranks of the ten largest annual floods in Table 2.5.11. The largest observed flood is presented in Table 2.5.12.

2.5.10 RIVER KARPELV

River Karpelv is located further east in Finnmark and drains a catchment area of 139 square kilometers. The gauging station 247.1/3 Karpelv Catchment characteristics are listed in Table 2.5.10, the dates and ranks of the ten largest floods in Table 2.5.11 and the discharge of the largest flood in Table 2.5.10. The spring flood dominates the flow regime; the annual flood occurs in May in 65 percent of all years and in June 31 percent.

Table 2.5.10 Catchment characteristics of gauging stations in River Neiden, Pasvikelv and Karpelv.

Station	244.1/2 Neiden	246.1 Bjørnevatn	247.1/3 Karpelv
	Basin characteristics		
Catchment area (km^2)	2947	18110	128,9
Station altitude (m.a.s.l.)	32	20	20
Mean altitude (m.a.s.l)	212	210	192
Top altitude (m.a.s.l.)	440	625	404
Lake (%)	12,43	10,85	4,99
Bog (%)	19,01	10,64	12,55
Forest (%)	58,96	57,86	51,25
Mountain (%)	7,88	0,8	11,97
Glacier (%)	0	0	0

Table 2.5.11 The dates and ranks of the ten largest floods (daily values) observed in River Neiden, Pasvikelv and Karpelv.

244.1/2 Neiden			246.1 Bjørnevatn			247.1/3 Karpelv		
1912-2014			1912-1960			1928-2014		
Year	Date	Rank	Year	Date	Rank	Year	Date	Rank
1914	4/6	4	1914	7/6	4	1931	2/5	3
1917	16/6	7	1917	17/6	6	1932	14/6	6
1920	21/5	1	1920	21/5	9	1938	1/6	7
1952	2/6	5	1932	18/6	5	1942	31/5	2

1953	22/5	10	1935	19-20/6	10	1943	14/5	9
1968	8/6	8	1943	16-17/5	3	1984	18/5	9
1984	19/5	6	1949	20-21/5	2	1996	10/6	5
1996	10/6	2	1952	4/6	1	2000	30/5	1
2000	31/5	3	1953	23/5	8	2003	16/5	4
2005	26/5	9	1955	30/7	7	2005	25/5	8

Table 2.5.12 The largest observed discharge (daily values) at the three gauging stations in River Neiden, Pasvikelv and Karpelv.

Station	244.1/2 Neiden	246.1 Bjørnevatn	247.1/3 Karpelv
Year	1920	1952	2000
Date	21/5	4/6	30/5
q (m^3/sec)	557,9	823,4	62,8
qsp (l/sec km^2)	271	45,46	488
qsp (mm/day)	23,4	3,93	42,1

3.1 Large floods in Mid-Norway

3.1.1 The severe rainstorm at Oppdal 19-20 July 1698.

A severe thunderstorm with abundant rainfall caused severe damages at Oppdal from the large flood in River Driva and its tributaries Tronda, Vinstra, Svorunda and Garåa. The rivers and brooks flooded out of their riverbeds, and landslides and rockfalls occurred at several locations.

Flood damages:

The damages were examined, and tax deductions were granted one year later.

The Los farms: The farm Nerlo was not damaged, but the other farms suffere damages from River Driva, which had shifted as well as from River Tronda, which had shiftet to a new riverbed through the grassland of the farms.

Hevle: Two farmers suffered damage because of riverbank failures.

Engan: Three farmers suffered damages to six "lass" grassland and 6 "mæling" fields from rockfall.

Vognild: Several farms near Driva suffered damages.

Snøve: Grassland worth 6 mkl was totally destroyed.

Skoren: Two farmers suffered from riverbank failures caused by Rivers Tronda and Driva. Bridges and mills were damaged.

Slipersæter: River Svorunda was dammed by debris. The subsequent dam failure damaged grassland and fields. The local road was destroyed.

Stølen: Two farmers suffered damages from River Garåa. The river was dammed, and the subsequent flood caused damage to the buildings which was partly filled with sand. The deduction at the farm was 18 mkl or 50 % of its previous value.

3.1.2 The flood and iceruns at Surna and Orkla before Christmas in 1727.

In March 1727 a number of avalanches caused 23 fatalities in Møre og Romsdal. The ice cover built up late in the autumn in many rivers at Nordmøre and in Trøndelag. Shortly before Christmas a severe rainstorm caused large ice run floods in River Surna at Nordmøre and River Orkla at Sør-Trøndelag. The ice runs led to severe damages next to these rivers.

Simultaneously with the ice runs a landslide caused severe damages at the farm Skrondalen at Øksendalen at Nordmøre. The damages were assessed in late May 1728, and 14 farms at Øksendalen, 14 farms at Surnadal and 23 farms at Orkdal obtained deductions.

3.1.3 The severe flood at Møre and Romsdal in December 1743.

The large flood which ravaged Vestlandet in December 1743 extended also to rivers in Møre and Romsdal. River Langedalselv skifted to another bed at Hellesylt. The farms at Bjørndal sufferet badly from River Holedalselv.

3.1.4 The severe flood at Barstadvik and Vartdal 16 July 1873.

Intense rainfall caused severe damages in three valleys on the coast at Sunnmøre at Vartdalsfjord. The valleys, Barstaddal and Nordre and Søndre Vartdal has short rivers flowing towards north-northwest from steep mountain walls. Some farms are located near the outlet of these rivers to the sea. The rivers are fast flowing, and without any natural lakes or reservoirs which could reduce the floods. The catchments are exposed to lows from the Atlantic, which can cause heavy rainfall and large floods. The discharge is low in most of the time, but can grow to exceptional high specific values during heavy rainfall.

The rainfall causing the flood 16 July 1873 was characterised as the worst in living memory. An extratropical rainstorm moved in from the west. The resulting flood caused a number rockfalls into the three rivers. The slides dammed each river to a level of 1,2 - 1,5 meter above all previous floods. This caused the rivers to shift to new riverbeds, through farmland, buildings and forests. One woman was killed by the flood as well as some farm animals (Kanalvæsenets historie, bd- IX).

3.1.5 The severe rainfall flood at Barstadvik and Vartdal 3 October 1878.

The national river authority, "Kanalvæsnet", had planned to start removing the rocks and debris and seal off six new river bed created by the 1773- flood in late 1878, when another even more intense rainfall flood occurred (Kanalvæsenets historie, bd- IX). An anticyclone was located over the European mainland, extending to the southwest across Britain. North of this ridge humid air was flowing from southwest causing the heavy rainfall on 3 October.

3.1.6 The spring flood from Sunnmøre to Sør-Trøndelag in May-June 1879.

The large spring flood in May-June 1879 penetrated over the water divide to rivers draining to the bottom of the Storfjord at Sunnmøre and rivers in Sør-Trøndelag.

Damages:

The flood destroyed four bridges in Geiranger at Sunnmøre (Lillebø, 1941,1999).
The flood in River Surna is described as a large flood (Kanalvæsenets historie, bd- IX).

The flood caused riverbank failures at three farms next to the outlet of River Orkla. It was proposed to regulate River Orkla in order to avoid future damages to the riverbanks of Orkla.

The flood in River Gaula had eroded the basis of the railway bridge at Støren and caused a bank failure on the right-hand bank. The eroded masses were replaced to secure the railway bridge. The farm Bogen in Gauldalen suffered damages to the grassland but obtained no compensation.

3.1.7 The ice run flood in Driva and Gaula in the Christmas 1881.

Ice dams and ice run floods occurred in several rivers in Mid-Norway in 1880 to 1882. These floods can occur after heavy rainfall following a cold period which allow ice to form on the rivers affected. Heavy rainfall occurred 25 to 27 December 1881 causing severe floods in the upper parts of River Driva, Surna, Orkla, Gaula and Stjørdalselv. The level of the flood in River Surna was 3,5 meter above the normal level. The flood level upstreams Haltdalen in River Gaula was comparable to the level during the large floods 24 August 1940 and 16 August 2013.

The weather type 13-25 December **BM** and 26-28 December **HM** (Grosswetterlagen) and 23-28 December **A** (Lamb-Jenkinson).

3.1.8 The severe flood at Valldal, Øksendal and Surnadal 7-10 October 1883.

The volcanic island Krakatau exploded 26 August 1883, causing shockwaves, which went around the Earth 2 1/2 times. The resulting tsunami was 40 metres high in Java, killing at least 40.000 people. The tsunami reached the east coast of Africa carrying floats of pumice. The tsunami penetrated the Atlantic and was observed at tidal gauges at the south coast of Britain. The trajectories of tropical hurricanes shifted this autumn to move in the direction of Northwest Europe.

The autumn was wet in the southern part of Norway. A major clayslide occurred at Romerike, north of Kristiania (Oslo). A cold spell in late September and early October caused snow to accumulate in the mountains in Møre og Romsdal. A widespread anticyclone was extending from the Azores across southern Britain, France and Germany. North of the anticyclone humid air masses from the Atlantic Ocean was moving towards the west coast of Norway, causing the temperature to rise to around 12°C in the mountains. Intense snowmelt in combination with heavy rainfall caused severe floods in River Valldøla at Sunnmøre, River Surna and River Yksna in Øksendalen at Nordmøre.

The weather types 7-10 October were: **HM** (Grosswetterlagen) and **A/AW**(Lamb-Jenkinson).

The resulting flood caused widespread damages in Valldal. Almost every farm in the valley suffered damages to farmland, forests, buildings, mills, bridges and roads. The flood damaged or destroyed 14 bridges and 8 mills. The main road was cut. The cost of reparing the road was eastimated to 3.500 NOK.

Three farms in Øksendalen suffered damages from the tributary Gaudøla. The damages were assessed later this year. The farms obtained a tax deduction of 14 - 18 percent for some years by royal decree.

3.1.9 The large rainfall flood in Orkla and Gaula 25 June 1918.

A large spring flood occurred in River Orkla and Gaula in June 1918 causing extensive damages and cutting the communication between Kristiania and Trondheim for some days. The flood was documented in Heggstad, Sæter and Killingmark (1975).

Initial conditions:

January had a temperature deficit of 1,8° C at Trondheim. The precipitation was close to normal. February to April had a temperature surplus of 1,8 to 2.4° C. These months had a precipitation deficit of 25 to 51 mm or 52 percent of the normal in February, 67 percent in March and 10,8 percent in April. May had a temperature of 1,1° C and a precipitation deficit of 12 mm or 76,5 % of the normal. June was cold with a deficit of 1,3° C, but a precipitation surplus of 53 mm corresponding to 216 % of the normal.

The temperatures rose in early June to a peak 6-7 June, when the temperatres dropped sharply as shown for observed temperatures in Figure 3.1.9.1.

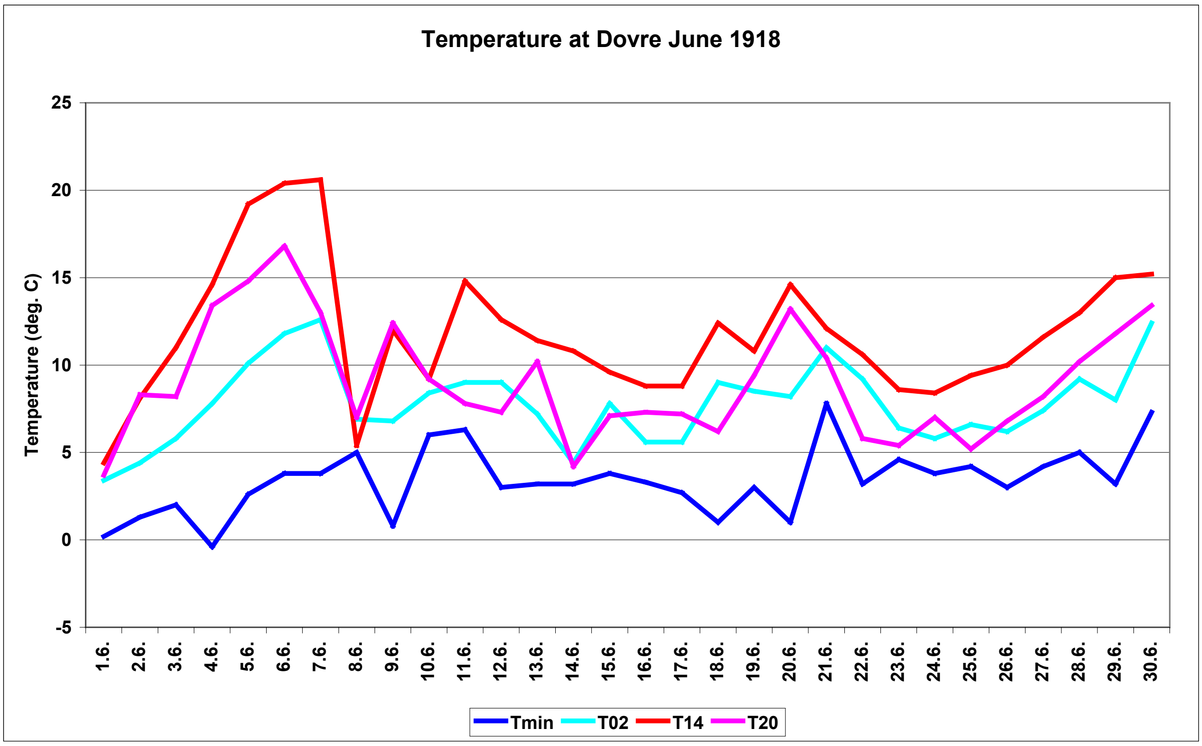


Figure 3.1.9.1 Observed air temperatures at Dovre in June 1918.

The observed snow depths at three stations in Trøndelag in the spring of 1918 are shown in Figure 3.1.9.2. These stations are Ølset at Kvikne (544 m.a.s.l.), Stuedal at Tydal (613 m.a.s.l.) and Østås at Hegra (175 m.a.s.l) . The snow had melted at these stations around 20 May, but some snow remained at higher altitudes, and snowmelt contributed to the flood.

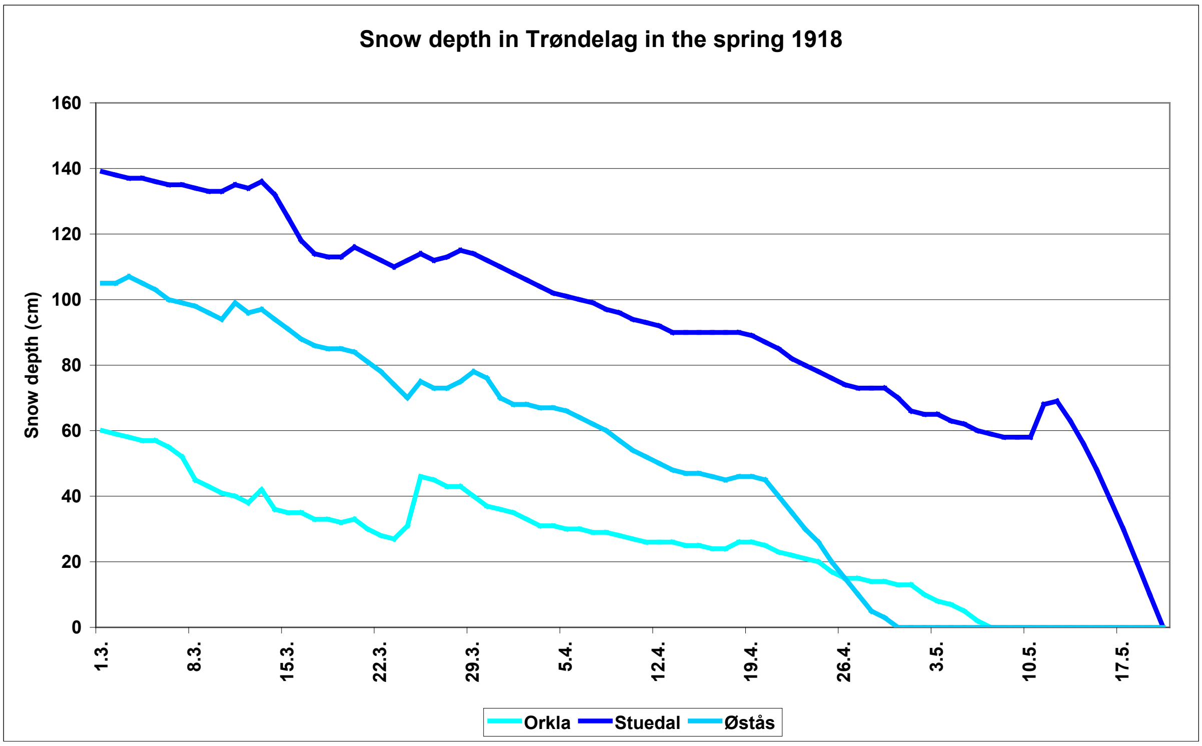


Figure 3.1.9.2 Observed snow depths at Kvikne, Tydal and Hegra in the spring 1918.

A large rainfall event occurred in West Norway from Nordhordaland to Rivers on the southern side of the Trondheimsfjord 24-25 June 1918 causing local floods although exceeded by the large rainfall flood in October in the west.

The flood:

The flood peaked on 25 June the day with the most intensive precipitation as shown in Figure 3.1.8.3.

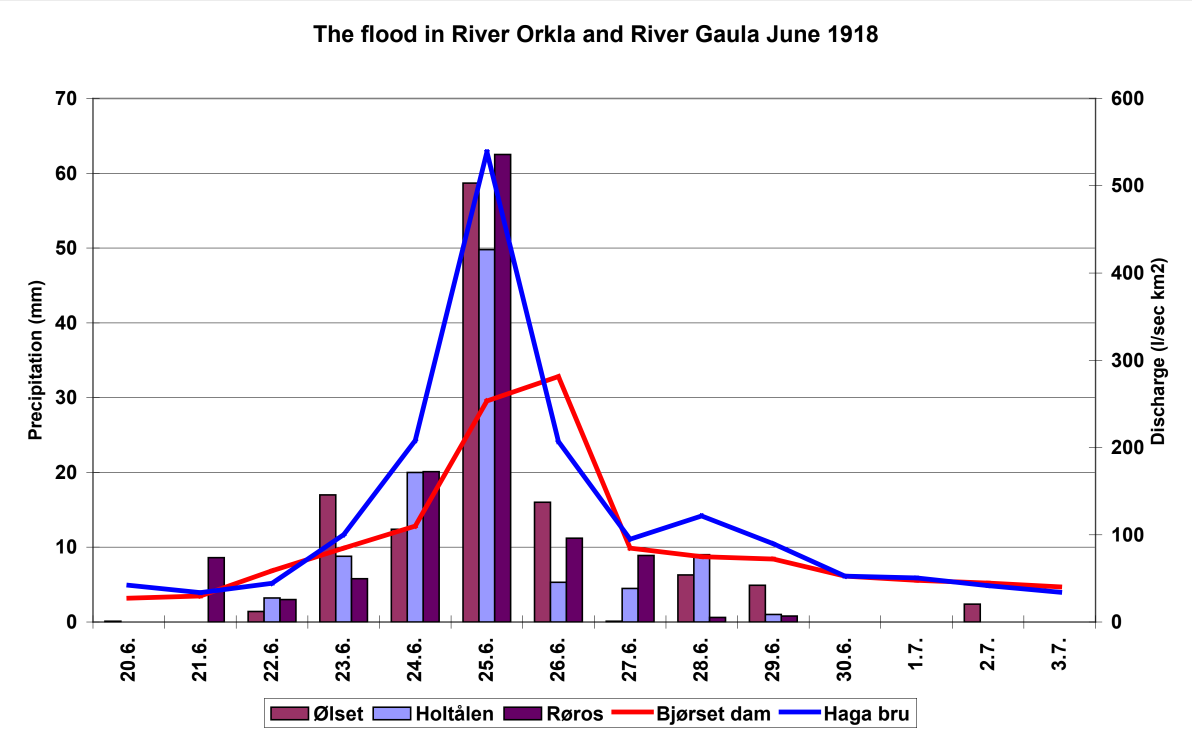


Figure 3.1.9.3 Observed rainfall and daily discharge during the large flood in Orkla and Gaula in June 1918.

Extension and ranks of the flood:

The floods were the second largest observed in River Gaula at Haga bru 1912-2014, the thirteen largest observed in River Orkla at Bjørset dam 1912-2014, the second largest at Rathe in River Nidelv and the third largest in River Todalselv 1908-1938. The flood does not rank among the largest in River Driva at Elverhøy bru 1908-2014 or at River Stjørdalselv at Høggås bru 1912-2014.

Cause of the flood:

Most of the surplus rainfall in Nord-Østerdal and Trøndelag in June 1918 fell between 23 and 26 June. The accumulated precipitation amounts from 77 to 120 mm in these four days.

A depression moved northwards from East Norway towardsTrøndelag resulting in heavy rainfall at Røros and in Stuedalen in the catchment of River Tya further east. Colder oceanic air masses moved in from northwest over mid-Norway causing heavy rainfall in the frontal zone between the cold air in the west and the warmer air masses to the east. Heavy rainfall fell in Møre og Romsdal as well as at stations south of the Trondheimsfjord. The weather type was classifised as **NWZ** (Grosswetterlagen) and **N** (Lamb/Jenkinson). This is the same weather type, which caused the extreme flood in River Gaula in August 1940, but snow melt did not contribute to this later flood. The initial conditions prior to the 1918-flood were different from the flood in 1940.

Flood damages:

The flood damages are described in Heggstad et al (1975). Several thousands daa farmland were inundated at the farms Flåøyen, Stor-Rønningen, Blekesøyen, Tranmælsøyen, Bagøyen, Brubaksøren and a substantial part of Øysanden. The river eroded the banks, causing erosion of at least 500 daa fields and grassland. The onset of the flood came so soon that the population had to evacuate their homes in a hurry. Those who did not escape the flood, were evacuated in boats. Some farm animals drowned, while others were rescued at the last moment.

All bridges were taken downstream Støren except the new railway bridge at Gaulfossen. The old railway bridge was taken at the peak of the flood at Hovin station. This bridge as well as the bridge on the main road caused backwater causing larger damages than if the bridges were not existing during the flood. The water level dropped 1/2 meter when the railway bridge disappeared.

The railway connection between Kristiania and Trondheim went through Østerdalen over Røros through Gauldalen. The flood damaged the railway line at several locations in Gauldalen. This railway line was a narrow gauge track. After the flood, the gauge was changes to normal gauge on the line. People travelling from Kristiania to Trondheim had to travel either via Kongsvinger, Stockholm and the Meråker railway line or by train to Bergen and steamship to Trondheim before the railway line were repaired. The railway through Gudbrandsdalen to Trondheim was under construction. The line was finished to Hjerkinn, but not further north. The flood damages also the telephone and telegraph lines from Kristiania to Trondheim, and the traffic were routed over Sweden until the connection could be reestablished.

The flood caused damages at Støren and further upstream. The farm Tilset suffered badly and the farms at Bonesplassene suffered damages of 74.000 NOK. At Buosen where the tributary Bua joins River Gaula, the flood destroyed 7 daa farmland and 4 daa other land. The total damage was assessed to 3 million NOK.

3.1.10 The rainfall flood at Nordmøre to Gaula 18 August 1925

Longterm rainfall without high daily values except in Surnadal west of River Orkla 15 August caused a flood in rivers at Nordmøre and Trøndelag. Figure 3.1.10.1 show observed daily rainfall and discharge.

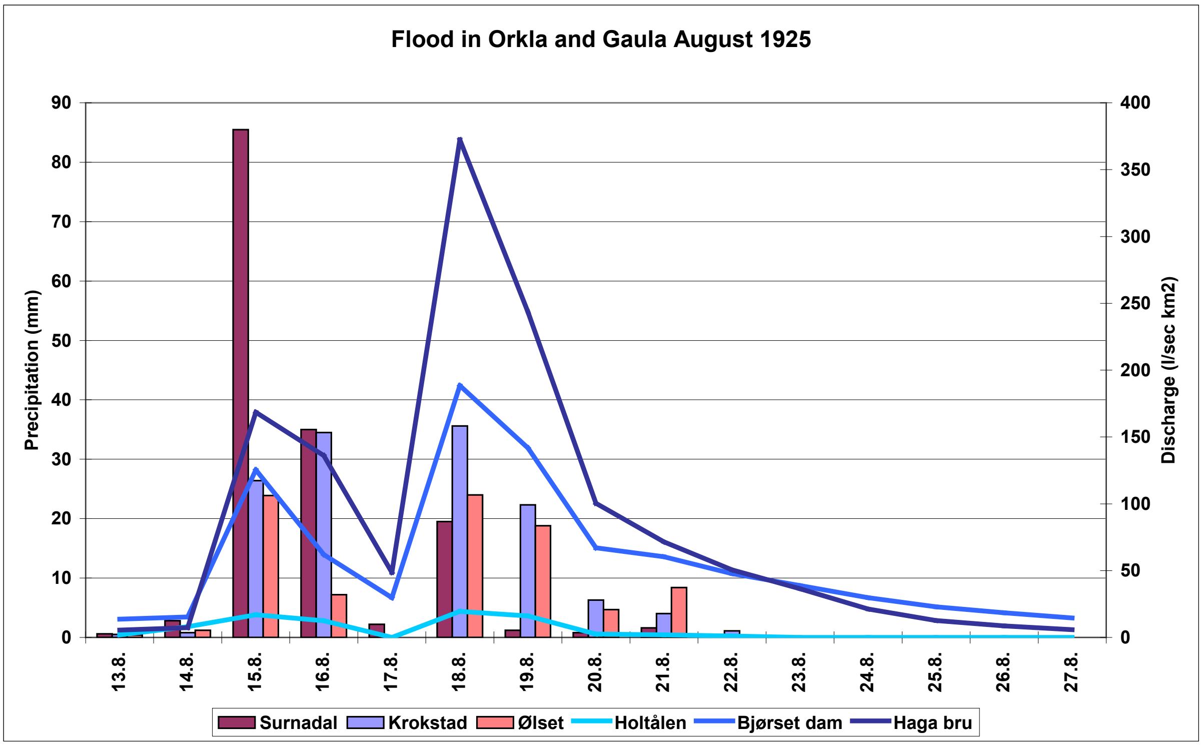


Figure 3.1.10.1 Observed rainfall and daily discharge during rainfall flood in Gaula and Orkla in August 1925.

Extension and ranks of the flood:

The flood was the ninth largest in 101 years at Haga bru.

Cause of the flood:

Between an anti-cyclone across Great Britain and a depression over Bottenviken humid air masses flowed from northwest towards Trøndelag. These northwestern weather types are typical for many large floods in the watercourses south of Trondheimsfjorden. The weather types were: **NWA/WZ** (Grosswetterlagen) and **A/NE** (Lamb/Jenkinson).

Flood damages:

The flood caused riverbank failures. No less than 19 new flood protection works were damaged for 321.000 NOK.

3.1.11 The large flood at the Fosen peninsula in Trøndelag in January 1932

28 -29 January 1932 heavy precipitation caused a large flood in coastal rivers in Sunnfjord, in Trøndelag and Helgeland. The flood was worst at the Fosen peninsula where the flood is comparable to the extreme flood in January 2006. Figure 3.1.11.1 show observed daily precipitation and discharge at stations in the district affected by the flood.

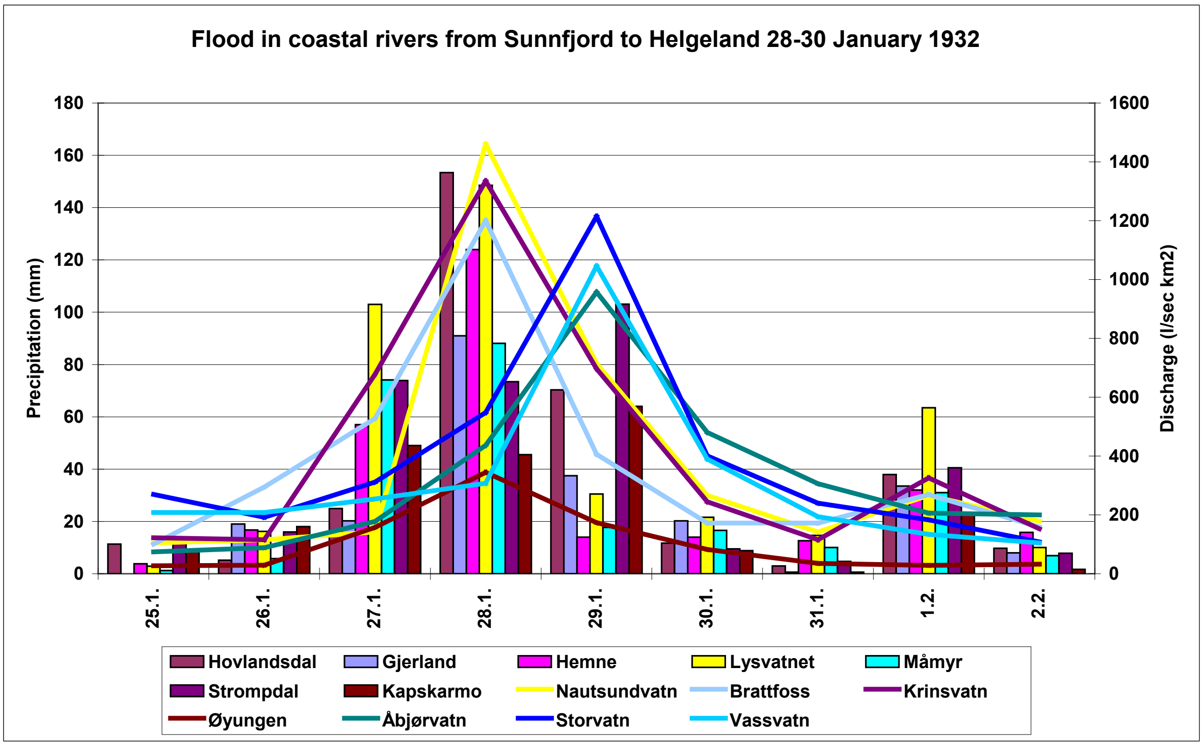


Figure 3.1.11.1 Observed precipitation and daily discharge in coastal rivers from Sunnfjord to Helgeland during the winter flood in January1932.

Extension and ranks of the flood:

The flood was second largest observed flood in River Vassdalselv at Håland bru in Sunnfjord, in River Stjørdalselva at Høggås bru since 1912, in River Verdalselv, River Stjørna at Lake Krinsvatn, in River Årgårdselva at Lake Øyungen and third largest in Lake Salsvatn in Nord-Trøndelag and the largest in River Åbjøra in Nordland 1908-2002. At Fiskumfoss in River Namsen the naturalised flood was the tenth largest in 90 years. At Strompdal in Velfjord the flood was fourth largest 1908-1954 and in River Vefsna at Kapskarmo third largest 1915-2000.

The cause of the flood:

Initial conditions:

The weather from December 1931 to February 1932 was warm and with abundant rainfall, typical of the largescale weather phenomena known as an atmosperic river. The temperature in Trøndelag was from 3 to 5,7° above the normal in January. In February the excess was from 2,6 to 6,0°, as seen in Figure 3.1.11.2. The excess in the coastal districs in Fjordane was 3,1 to 4,9° in January and 1,8 to 2,6° in February. In Vest-Agder and Rogaland the excess was 3,2 to 4,6° in January and 1,4 to 3,2° in February. The excess of precipitation was 14 to 169 percent in January and 13 to 116 percent in February in Trøndelag, 36 til 248 percent in coastal districts in Fjordane and 37 to 149 percent from Vest-Agder to Rogaland. February had a deficit in preciptation of 55 to 116 percent on catchments on the southern coast.

There was some snow at intermediate and higher levels as seen from Figure 3.1.11.3, but hardly any snow contributing to the flood in lowlying catchments.

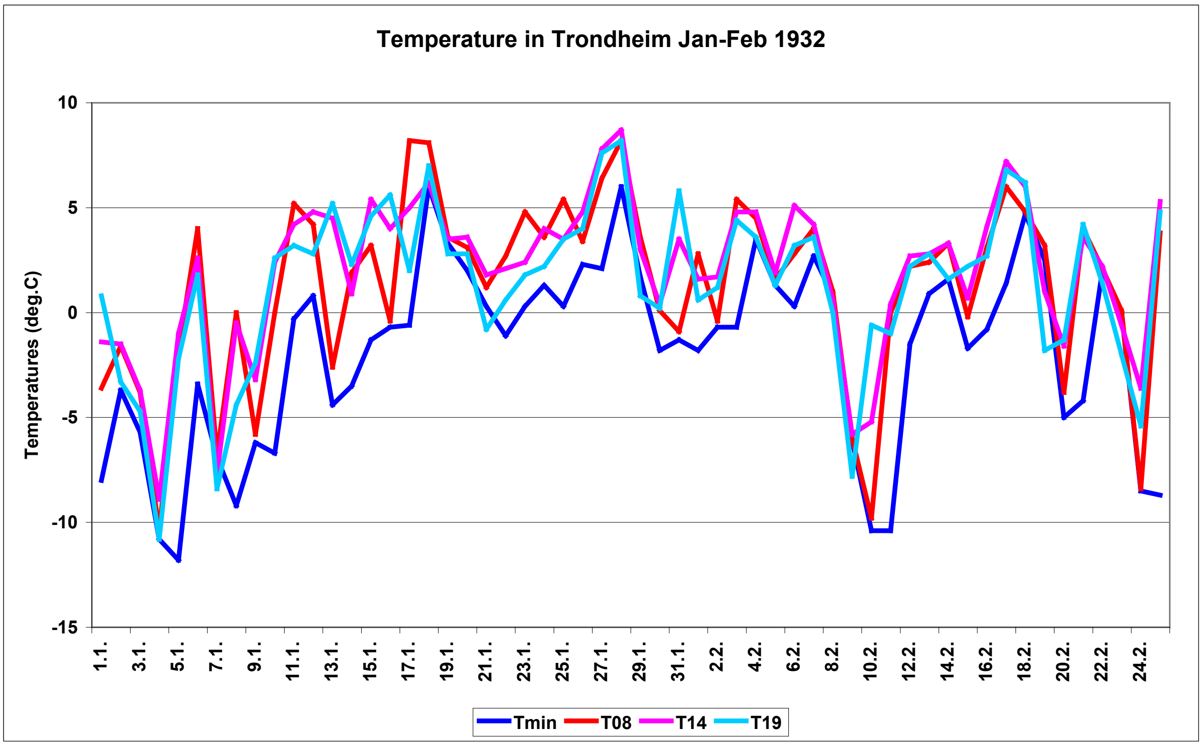


Figure 3.1.11.2 Observed temperatures in Trondheim in January and February 1932.

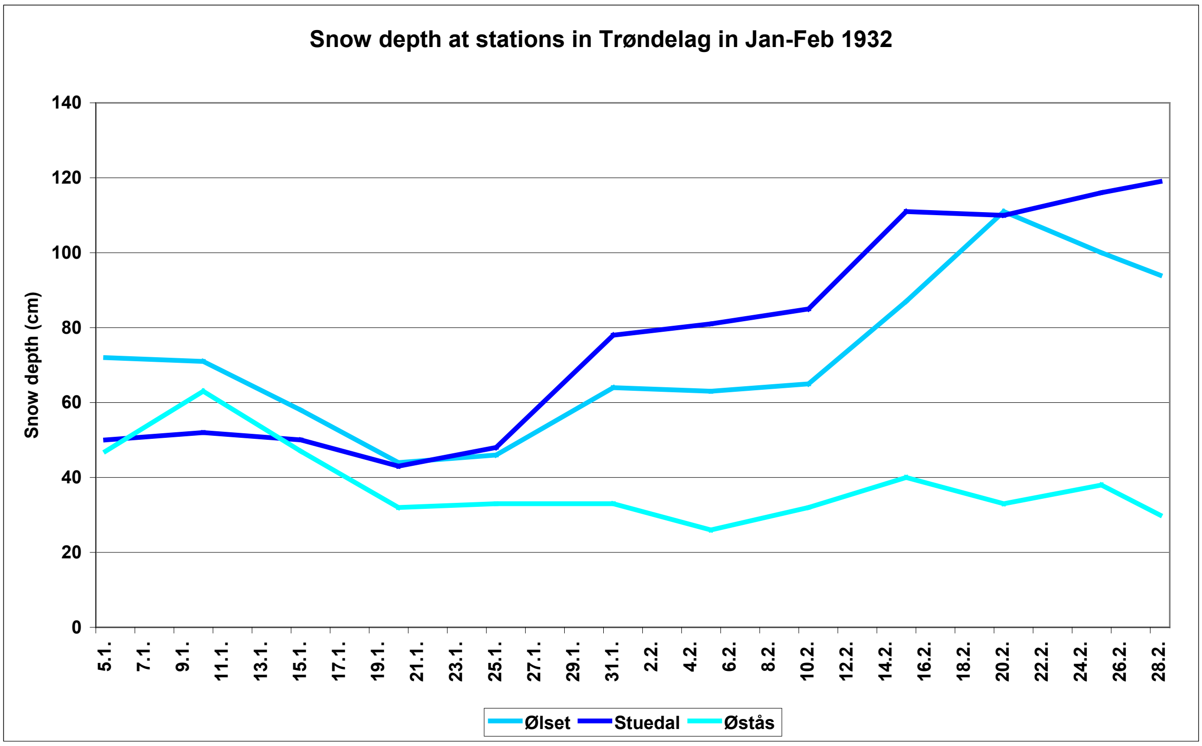


Figure 3.1.11.3 Observed snow depth at three stations in Trøndelag in Jan-Feb 1932.

The weather

The weather types were: **HFNA** 23-28 and **SA** 29-30 January (Grosswetterlagen) and **A** or **ASW** (Lamb-Jenkinson).

3.1.12 The large flood in River Driva from the Dovre massif in July 1932.

The largest observed flood until the flood in August 2003 occurred in River Driva 7 July 1932. Simultaneously an extreme flood occurred in River Jora at Dombås. The gauging station Dombås were established in 1966/67, consequently there are no observations of the actual flood level, but the flood is mentioned as the largest flood in Jora since Storofsen. According to some descriptions the flood was extreme in the mountains between Lesja, Dombås, Hjerkinn and Drivdalen. Further west a flood occurred in other rivers at Nordmøre. Heavy rainfall was observed simultaneously 7 July in Valdres, Hallingdal and Telemark. Figure 3.1.12.1 show daily precipitation and discharge for stations at Dovre and Nordmøre. Figure 3.1.12.2 show observed daily precipitation and discharge for stations in River Otta, Sjoa, Drammenselv and Skienselv.

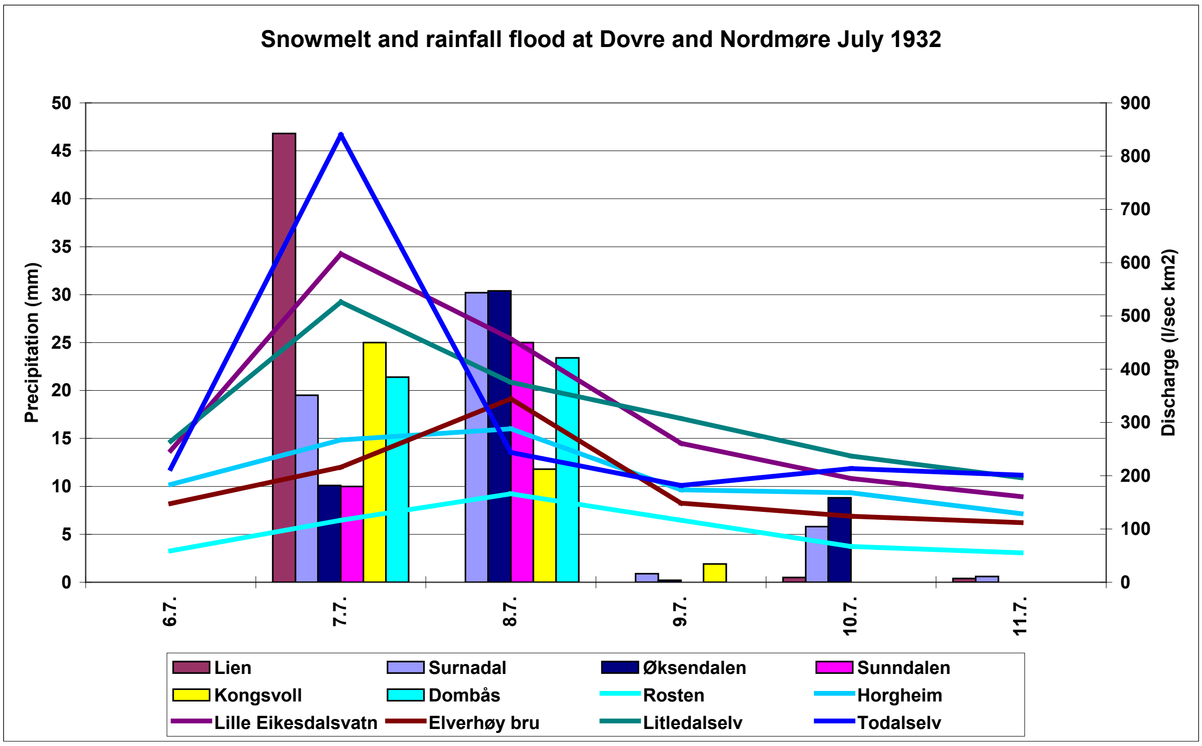


Figure 3.1.12.1 Observed rainfall and daily discharge during snowmelt and rainfall flood in River Driva and smaller rivers from the Dovre massif in July 1932.

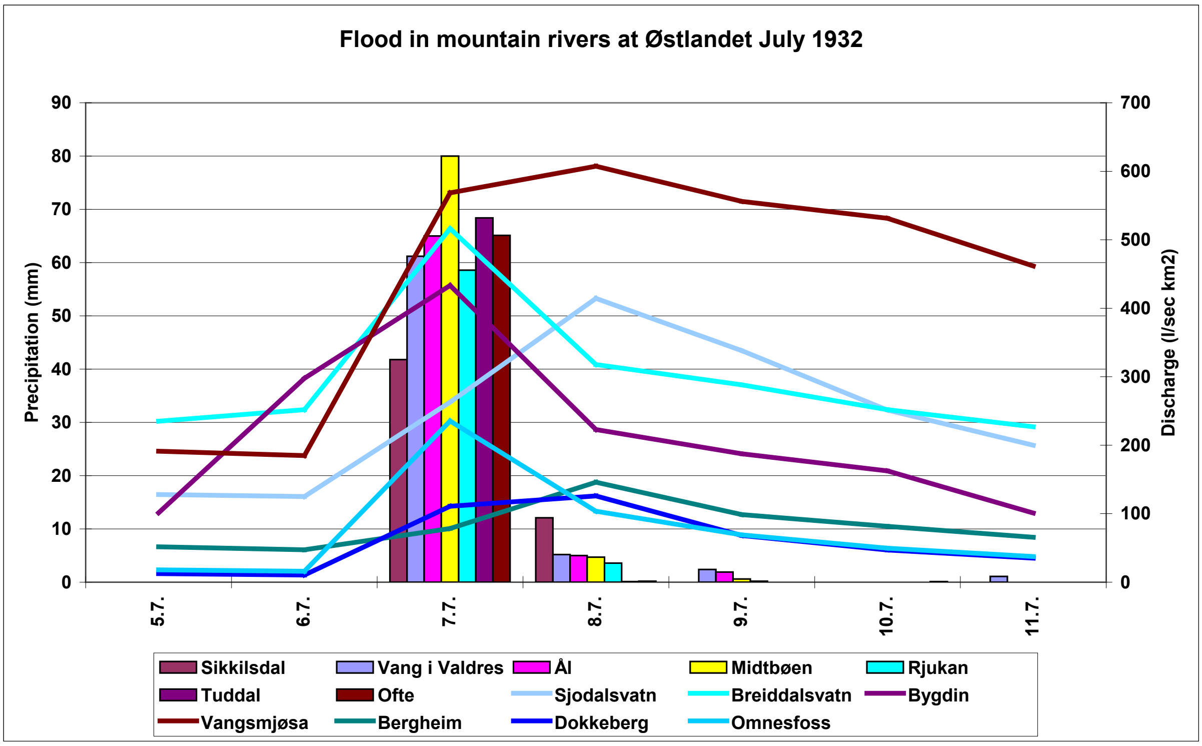


Figure 3.1.12.2 Observed rainfall and daily discharge during the flood in mountain rivers in Gudbrandsdalen, Valdres and Telemark July 1932.

Extension and ranks of the flood:

The flood was second largest observed in River Driva at Elverhøy bru since 1908. In the upper part of the catchment at Drivdalen the flood was considered as the largest since Storofsen. The flood was third largest in Lille Eikesdalsvatn 1902-2001, second largest flommen 1912-1960 in River Litledalselven i Sunndal and third largest in River Todalselv 1908-1938. With exception of the flood in River Jora the flood in River Gudbrandsdalslågen was moderate. The flood was the largest naturalised flood in Lake Breiddalsvatnet in the westernmost part of River Otta 1917-2001 and fourth largest in River Vinstra at Lake Bygdin 1922-2000. The flood in River Rauma was the largest in 1932. The flood was exceeded by the snowmelt flood in May/June this year in rivers in Buskerud and Telemark except River Hallingdalselv at Bergheim.

Cause of the flood:

The snow storage was above normal in the winter 1931/32 at Dovre and in adjacent mountain districts as shown in Figure 3.1.12.3.

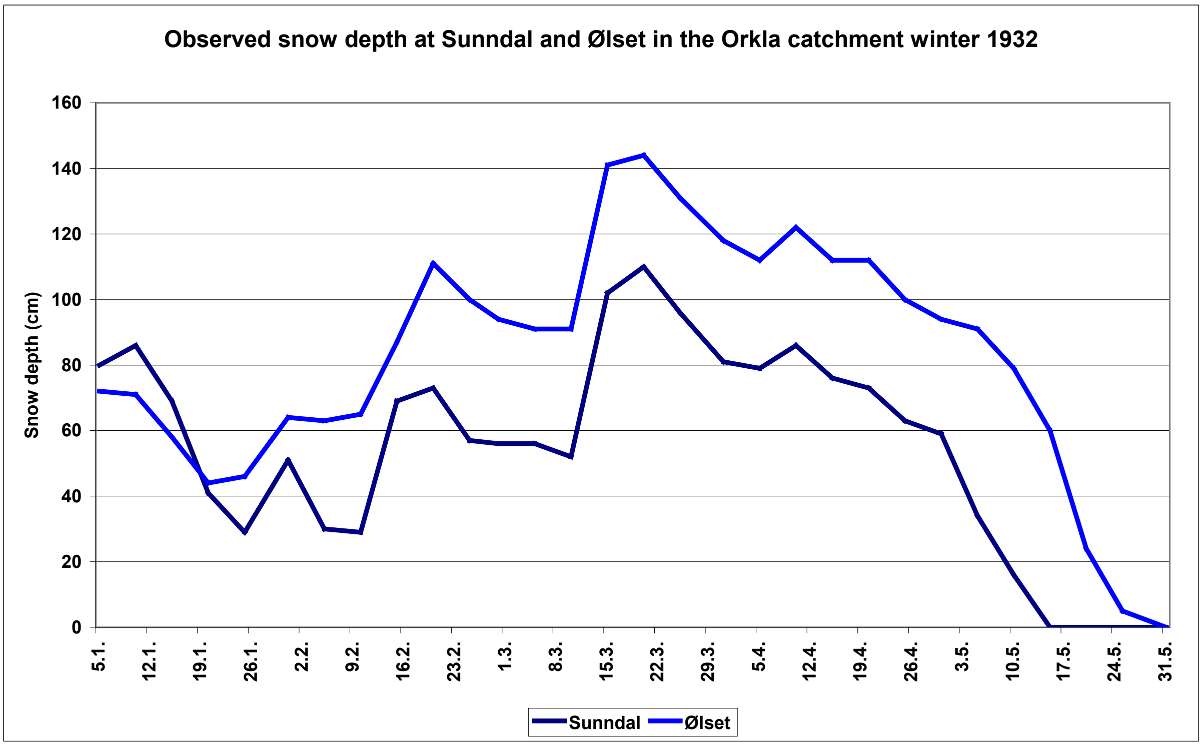


Figure 3.1.12.3 Observed snow depth in Sunndal (200 m.a.s.l) and at Ølset at Orkla (500 m.a.s.l). Much of the district is at higher levels than these two stations, and snow remained at higher altitudes well into July.

The snowmelt started late in the spring in the Dovre district in 1932. Observations from Oslo and Trondheim show a heat wave occurring to the end of June and early July as shown in Figure 3.1.12.4 and 3.1.12.5. The temperature was lower in the Dovre region, but sufficient to cause heavy melting of the remaining snow. The maximum temperatures observed at Dombås were in 24° observed 23 June and 22,5° observed 14 July. At Fokstua 20,4° was observed 23 June and 18,4° 14 July and at Berkåk 23,2° 30 June and 23,2° 2 July. The precipitation was abundant at Dovre in July on both sides of the water divide between River Glomma and rivers draining towards Trøndelag. Between an anti-cyclone over Sverige and Finland and a depression in the Norwegian Sea air was streaming from south-southwest luftstrøm towards South Norway. Local descriptions indicate that foehn wind occurred in the Dovre district resulting from heavy rainfall in southwest on the other side of the mountain divide. The rainfall causing the flood was convective and locally intense at some locations in the mountains from Lesja to Snøhetta during the night between 6 and 7 July. The official precipitation stations have not recorded extreme precipitation anywhere within the Dovre region. The extensive flood damage was most likely caused by ice runs and failure of natural dams. Melting snow contributed also to the flood.

The weather types 7 July were: **TRW** (Grosswetterlagen) and **SW** (Lamb/Jenkinson)

Flood damages:

The flood caused widespread damages at Lesja (Wigenstad, 1987). River Jora took a mill, and the building was crushed at the old bridge across the river. The flood in River Driva caused widespread damages at the upper and lower Drivdalen (Mork and Hoel, 1987, Dørum, 1989). The flood caused damages to the railway line and to the roads in the valley. The main road was inundated and the traffic was maintained along the old road. Most of the bridges was taken by the flood, two at Engan and the bridges at Gottem, Vika, Bøsæter, Nysæter, Svartøya and several smaller, a total of 18 bridges. Only two bridges survived Storbrua and Skorebrua. The farmland was inundated at many farms, and the fields were damages by erosion or deposition of sand and gravel from the rivers.

Dams at the lakes: Kaldvellsjøen and Åmotsvatna failed simultaneously aggravating the flood in river Driva. The failure was caused both by the exceptional inflow and ice runs.

3.1.13 Rainfall flood at Fosen and in Helgeland in September 1932.

Rivers from Nidelv to Vefsna had a flood caused by rainfall 29.September 1932. Figure 3.1.13.1 show observed daily precipitation and discharge.

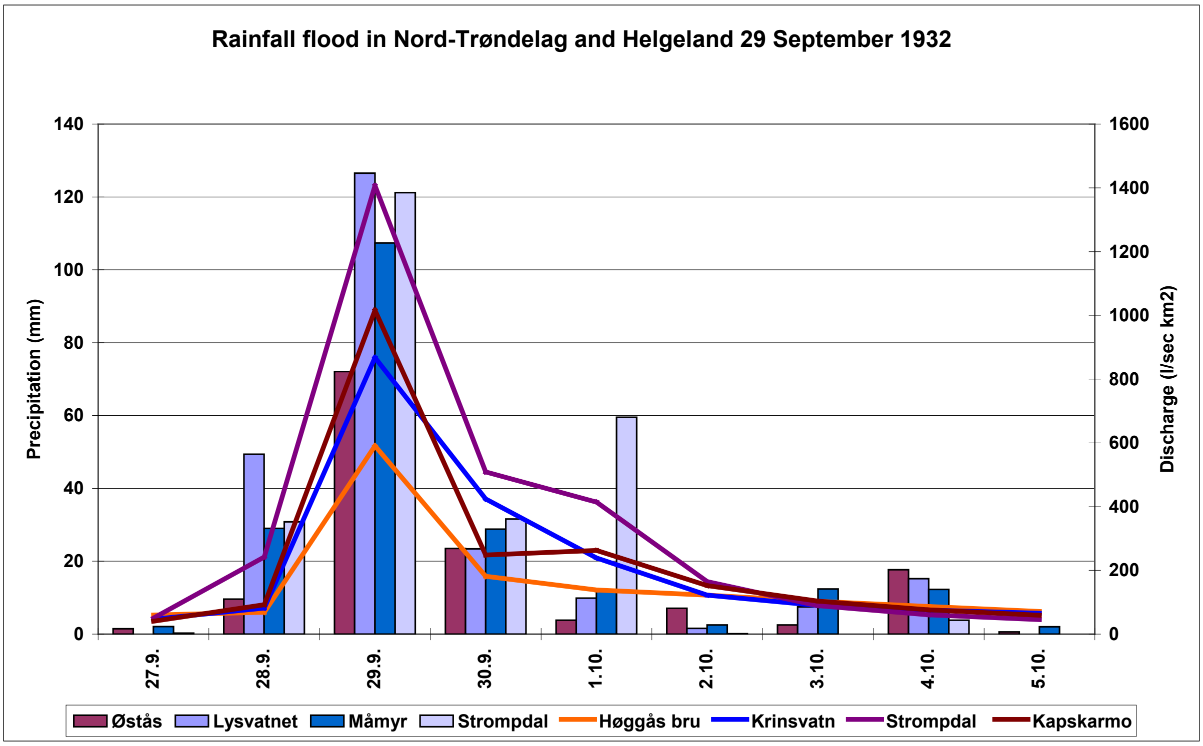


Figure 3.1.13.1 Observed precipitation and daily discharge in North-Trøndelag and Helgeland during the rainfall flood in September 1932.

Extension and ranks of the flood:

The flood was the second largest since the observations started in 1912 in River Stjørdalselv at Høggås bru. The flood was not the largest flood of the year in spite of high rainfall at the Fosen peninsula. At Fiskumfoss in Namsen the naturalised flood was the tenth largest in 90 years. At Strompdal the flood was the fourth largest 1908-1954 and in River Vefsna at Kapskarmo the third largest 1915-2000.

Cause of the flood:

September and October 1932 were 0,4 to 1,9° colder than the normal in Trøndelag and Nordland. The precipitation had a surplus of 11 to 153 percent in September. Trøndelag had a small surplus in October when it was somewhat dryer in the southern part of Nordland. Between a ridge from the Atlantic over Storbritannia mot Denmark and depressions far north in the Norwegian Sea mild air from the Atlantic was streaming from southwest toward Vestlandet and Midt-Norge. A depression appeared over southern England as the anticyclone moved toward northeast over the North Sea. The wind towards Vestlandet and Mid-Norway weered west- northwest. Weather types 28-29 September were **BM** (Grosswetterlagen) and **A ANE** (Lamb/Jenkinson).

3.1.14 The spring flood in Trøndelag and Helgeland in May 1934.

A major spring flood occurred at Østlandet and in the larger rivers in Trøndelag in May 1934. The flood occurred in Rivers Orkla, Gaula, Nidelva, Stjørdalselva og Namsen, as well as in River Vefsna at Helgeland. The flood occurred also in rivers draining from the water divide to the fjords at Vestlandet ie Rivers Årdalelv, Strynselv, Rauma and Surna. The flood at Østlandet is described in Vol 2, and at Vestlandet in Vol 3. Daily precipitation and discharge is shown in Figure 3.1.14.1 for River Orkla and Gaula and in Figure 3.1.14.2 in Nord-Trøndelag and at Helgeland.

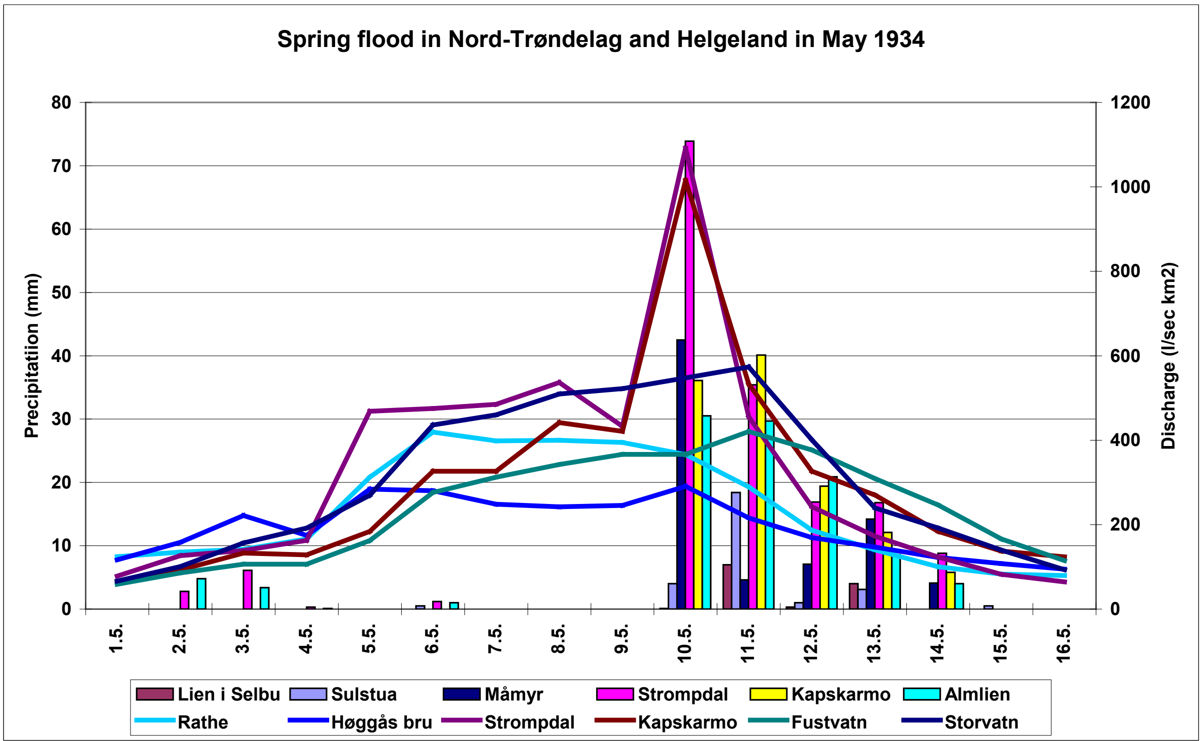


Figure 3.1.14.1 Observed precipitation and daily discharge in Nord-Trøndelag and Helgeland during the spring flood in May 1934.

Extension and ranks of the flood:

The floods observed in River Gaula at Haga bru and in Orkla at Bjørset dam were fourth largest in the data series 1908-2014 and 1912-2014.

Cause of the flood:

The flood was initially caused by intensive snow melting. Some rainfall fell initially prior to the start of the melting, but the peak coincided with a heat wave with dry weather between 2 and 10 May. Some snow remained in the upper part of the catchments as shown in Figure 3.1.14.2 at some stations at Vestlandet and Mid-Norway. The snowmelt was over at low and intermediate altitudes during April, but some snow remained at high levels da until fhe flood peaked 10 May. The air temperature in Trondheim during the spring of 1934 is shown in

Figure 3.1.14.3. The temperature fell as heavy frontal rain started to fall 10 May and the subsequent days were cooler and with some additional rainfall.

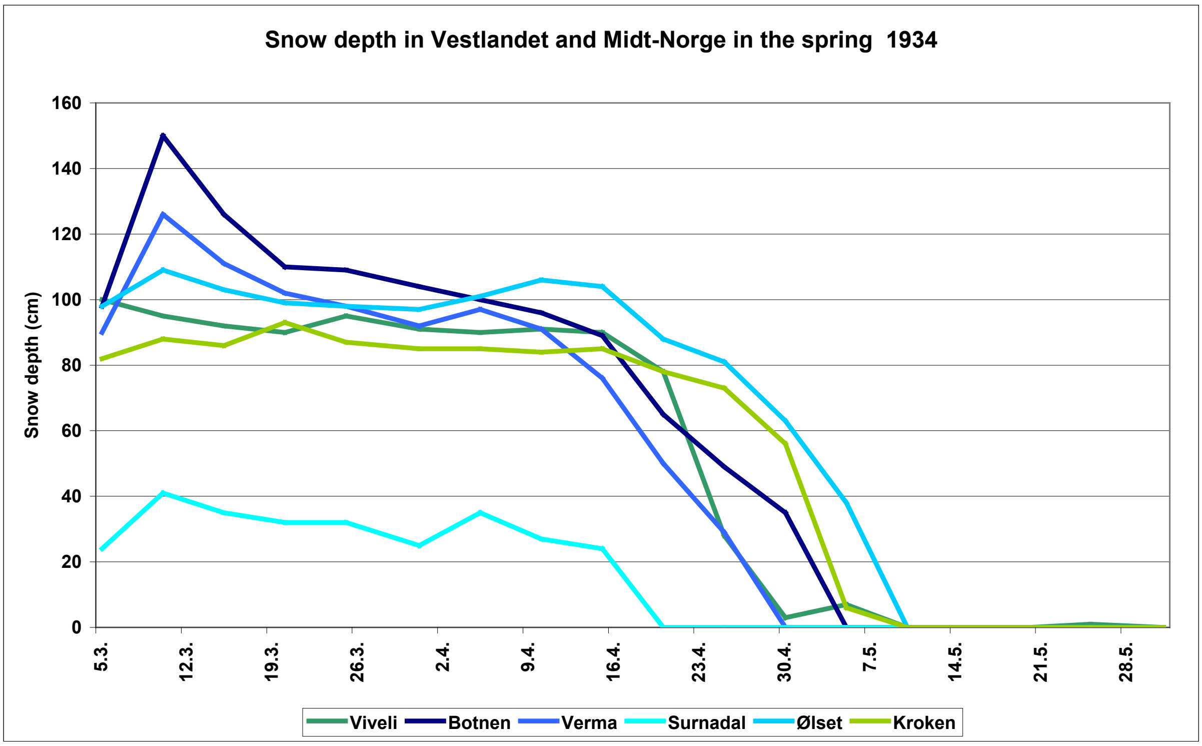


Figure 3.1.14.2. Observed snow depth at stations in West and Mid Norway in the spring 1934.

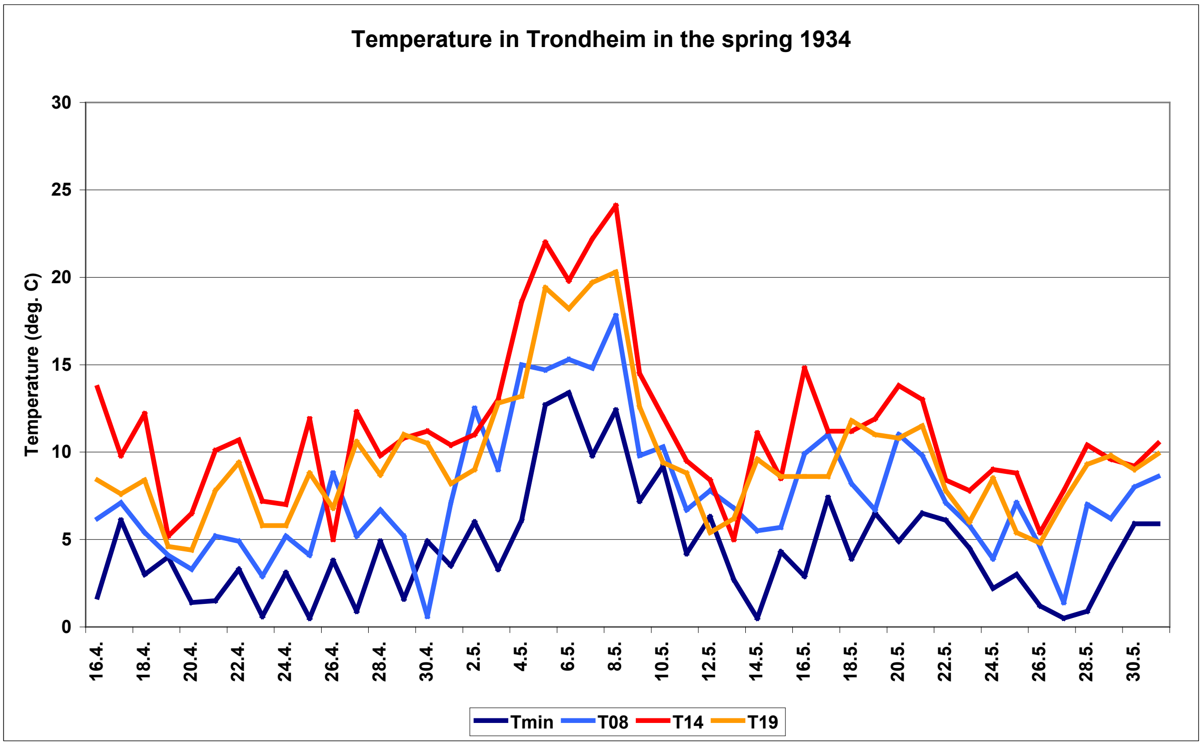


Figure 3.1.14.3. Observed air temperature in Trondheim during the spring 1934.

The weather maps for the period 5 to 10 May show that a mild air current was streaming over Norway between a depression in the Norwegian Sea and an anti-cyclone over Finland. The weather types were: **TM** and **WW** (Grosswetterlagen) and **CS** and **SW** (Lamb/Jenkinson).

3.1.15 The extreme flood in Gaula and Gaula 24-25 August 1940.

Intense rainfall caused a disastrous flood in River Gaula 24-25 August 1940. The flood and flood damages are documented in Strand (1941). Figure 3.1.15.1 show daily rainfall and discharge at stations in River Orkla and River Gaula. Based on the stage at the peak at Haga bru the peak discharge was estimated to 3060 m^3/sec. The mean 24-hour discharge at the peak is estimatede to 2140 m^3/sec. The flood was also den largest observed in River Orkla since the start of the observation in 1912. The one-day peak in Orkla was estimated to 1454 m^3/sec.

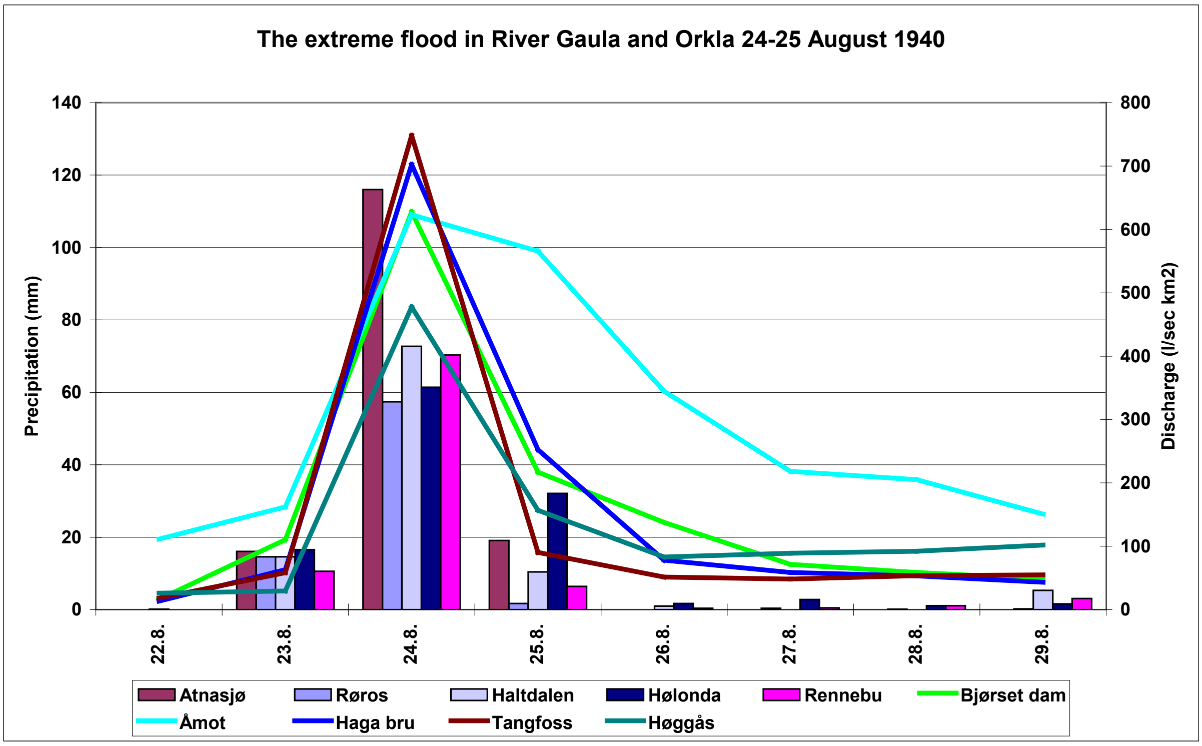


Figure 3.1.15.1. Observed rainfall and daily discharge during the extreme rain flood in River Gaula in August 1940.

Extension and ranks of the flood:

The floods in River Gaula at Haga bru, in River Orkla at Bjørset dam and in River Todalselv at Talgøyfoss were the fourth largest in the series 1908-2014, 1912-2014 and 1937-2014. Minor floods occurred in River Nidelv and River Stjørdalselv as shown in Figure 3.1.15.2.

River Glomma had a moderate flood, which was less intense at stations further south in Østerdalen. At Atnasjø, however, a one-day rainfall of 116 mmm was observed, but the resulting flood had only a return period of 10 years. The flood was not the largest flood in 1940 at any of the stations in the main river in Østerdalen or further south. Figure 3 show daily precipitation and discharge at some stations in River Glomma.

Cause of the flood:

Initial conditions:

The summer had been wet, and the soil- and groundwater storages were saturated when the flood started.

The weather:

Weather maps for 20- 25 August (source: www.wetterzentrale.de) show that warm air masses from the Mediterrainian moved northward through Østerdalen. The weather type can be characterized as a weak versjon of a Vb-depression. The weather types were: **NWZ** (Grosswetterlagen) and **N/ANW/AW** (Lamb/Jenkinson).

The warm air masses from southeast penetrated across the water divide from Glomma into the upper Orkla and Gaula catchments. Cooler maritime air masses penetrated into the catchments from northwest causing intense showers in the quasi-stationary frontal zone. This northwesterly weather type has caused some of the largest rainfall floods in River Orkla and River Gaula, which are protected by mountain ranges to precipitation from south west to west. The highest on-day rainfall 116 mm was observed at Atnasjø and 86 mm in Vauldalen east of Lake Aursunden 24 July. These stations are both located at the Glomma catchment. The one-day rainfall observed at the station network in the Gaula basin, did not exceed 70-80 mm, but it is likely that more rain fell at stations outside the station network as described by teacher Bøe at Valdum school. The intense rainfall started in the evening Thursdag 22 August at 20:00. The rain was pouring down until Saturday 24 at 12:00 Hrs. According to Mr. Bøe the l Lake Asbjørgvatn at Sør-Tømme chalet rose 2 meters from Thursday evening to Saturday noon. One meter of this increase occurred from 19:00 Hrs Friday to 12:00 Hrs on Saturday. Teacher Bøe measured the rainfall in a milk pail from Friday 19:00. By Saturday 19:00 Hrs 120 mm rain had fallen into the pail. Teacher Bøe estimated that approx 300 mm rain had fallen from Thursday 20:00 to Saturday evening. This estimate is however uncertain.

At Haltdalen met. station a one-day rainfall of 72,7 mm was observed in 23-24 August. Observations from the nerwork operated by the Meteorological Institute show a rainfall in excess of 70 mm over most of the catchment of River Gaula. In Strinda 90 mm rainfall was observed.

Flood damages:

A woman from Støren drowned in the flood, and it is possible that the flood caused other fatalities. The flood occurred some months after the occupation of Norway by Germany, and the sources are therefore unreliable. There were rumors that a German soldier had perished, but that was later shown to be not true.

Strand (1941) has documented the damages caused by the 1940-flood as summarised in Table 3.1.15.1. The most severe damages were consentrated along the main river, not along the tributaries.

Holtålen

Upstreams Haltdalen the damages were small and did not cause any significant losses. This was also the case at Haltdalen where some farmland was covered by sand. En small suspension bridge was lost. The railway line was undermined at a few locations.

Singsås

The damages were moderate upstreams the railway station at Singsås. A suspension bridge had been taken. Flood water penetrated into the living quarters at at farms and deposited some sand at the farmland. The flood cut across the railway line at the railway station, flooded down the road and filled the basement of several buildings. Downstream the station the river had shifted, eroding farmland, flood protection works and the railway line.

Three buildings were taken by the flood at Kirkvolløy and other buildings had the basements and part of the ground floor flooded. The fundaments of some buildings were damaged. The railway line was cut at two locations and covered by sand elsewhere. The main road through Gauldalen was also damaged at several locations.

Støren:

The severe damages at Støren was caused by erosion. Between Bua og Bones the railway line was undermined and the rails were hanging in the air. The line was completely cut at one location. The buildings as well as most of the tracks had disappeared at the railway station at Rognes station. Approx. 6-700 m of the railway line had vanished at Røttem. The railway line was also damaged at the bridge over River Gaula at Støren. One kilometer of the line was partly taken on the righthand side of the river and completely on the lefthand side to the station at Støren.

Failing riverbanks caused extensive damages to the flood protection works. Buildings and farmland were lost because of the riverbank failures and land slides. Eight farmhouses were taken at the farms at Røttem with furnitures as well as crops. The farms lost 30-40 daa farmland.

Horg:

Virtually all farms to Gaulfossen suffered larger or smaller damages at Horg. Alle fields and grassland near the river were covered by var 0,5 to 1,5 meters depth of sand and gravel.

Flå:

The damages at Flå were small.

Melhus:

Farmland, buildings, flood protection works and roads at Melhus. The floodwater penetrated buildings at Flåøyen, at Kvåls bro, at Gimsan bro and at Brubakkøra. The bridge at Kvål was lifted of its fundament and taken by the river. The downstream Gimsan eller Udduvoll bridge was fortunately not damaged. Fields and meadows were covered by sand and gravel.

Leinstrand:

River Gaula broke through the riverbank on the righthand side at Leinstrand and eroded the road oppstreams Udduvoll bridge. The flood water inundated the fields to Gaulosen.

Tributaries to River Gaula:

The tributary Holta caused damages at Brubakk bru in Haltdalen.

The tributary Fora at Singsås eroded the road from the bridge in Fordalen to the confluence with Gaula at Singsås.

River Sokna caused severe damages on the main road through Soknedal. Several small brooks caused landslides. The flood and slides threatened the main railway line. Downstreams Haukedal bridge the road was cut at two locations. The brook Grøvja cut a new bed across the main road. Two landslides moved a barn to the middle of the road.

The tributary Gaua, which joins River Gaula below Gaulfossen damaged several bridges, washed away the main road and deposites gravel on the farmland. The tributary Lundesokna did not cause substantial damages, but the power station had to stop when water penetrated the station hall.

Table 3.1.15.1. Flood damages caused by the flood in August 1940 in River Gaula.

Municipality	Costs (NOK)			Sum
	Farmland, forests, houses and furniture	Flood protection works	Roads	
Haltdalen	30.000	2.000	20.000	52.000
Singsås	200.000	171.000	344.000	715.000
Budal	20.000		5.000	25.000
Soknedal	100.000			100.000
Støren	400.000	272.000	734.000	1.406.000
Horg	341.000	93.000	15.000	449.000
Flå	40.000	4.000	0	44.000
Melhus	253.000	84.000	82.000	419.000
Leinstrand	50.000		20.000	70.000
Sum	1.434.000	626.000	1.220.000	3.280.000

In addition:
Temporary repair of roads: 300.000
Damages on the railway: 2.500.000

Total: 6.080.000
The damages on the railway lines is also descibed in Sveie (1987).

3.1.16 The large flood in Orkla, Gaula and Nidelva in 1941.

A major spring flood occurred in rivers south of the Trondheimsfjord 27-28 May 1941. The flood is the largest observed in River Gaula at Eggafoss prior to the flood 16 August 2011. The flood in 2011 may have been exceeded by the flood 24-25 August 1940, which occurred prior to the start of observations at Eggafoss. The height of water level was measured to 5,5 eller 6,05 metres above reference level used in 24.8.1940. The water level in 2011 is said to have been 5,20 m at the station even if the instrument recorded lower values.

Extension and ranks of the flood:

The flood was third largest observed in Garbergelva at Kjelstad since observations started in 1912, only exceeded by the floods in 1940 and 1938. Figure 3.1.16.1 show daily discharges during the flood in River Orkla, River Gaula and River Nidelv. Since the precipitation was insignificant during this flood, it is not shown in the Figure.

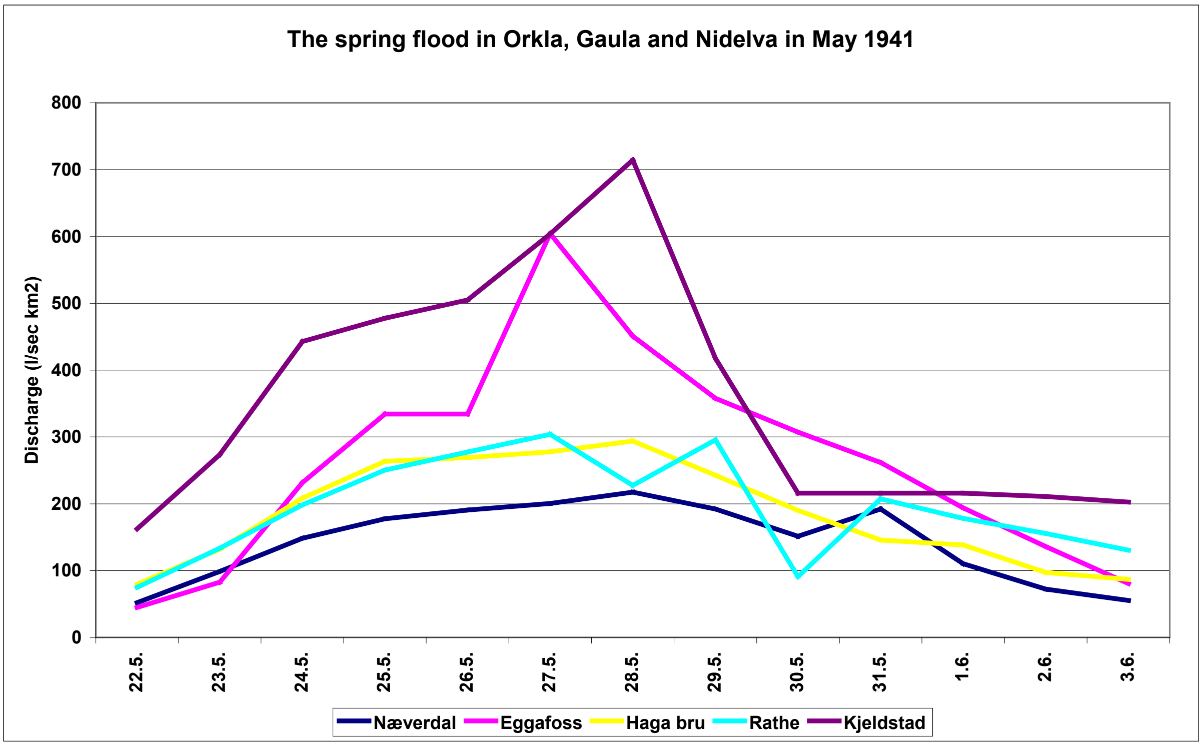


Figure 3.1.16.1 Observed daily discharges in rivers in Sør-Trøndelag during the spring 1941.

The cause of the flood:

Initial conditions

The winter 1941 was very cold and with ample snow fall in Trøndelag. Figure 3.1.16.2 shows the observed depth of snow at selected stations of the Meteorological Institute, and Figure 3.1.16.3 show the air temperature in Trondheim during the flood. The cool weather lasted to mid May when an anticyclone started a heatwave, which peaked 28 May. The rainfall was insignificant from 22 May to the end of the month in the catchments of River Orkla, River Gaula, River Nidelv and River Stjørdalselv. The flood was therefore a snowmelt flood, although triggered by a Vb-type heatwave.

The weather

A stationary depression was located over Great Britain while an anticyclonic ridge was located from East Europe across Finland and North Norway towards Spitsbergen. South of the ridge warm and humid air masses were streaming from southeast over Norway. The highest temperatures were observed 27-28 May da the flood peaked. The weather types were: **TB** (Grosswetterlagen) and **C** (Lamb-Jenkinson).

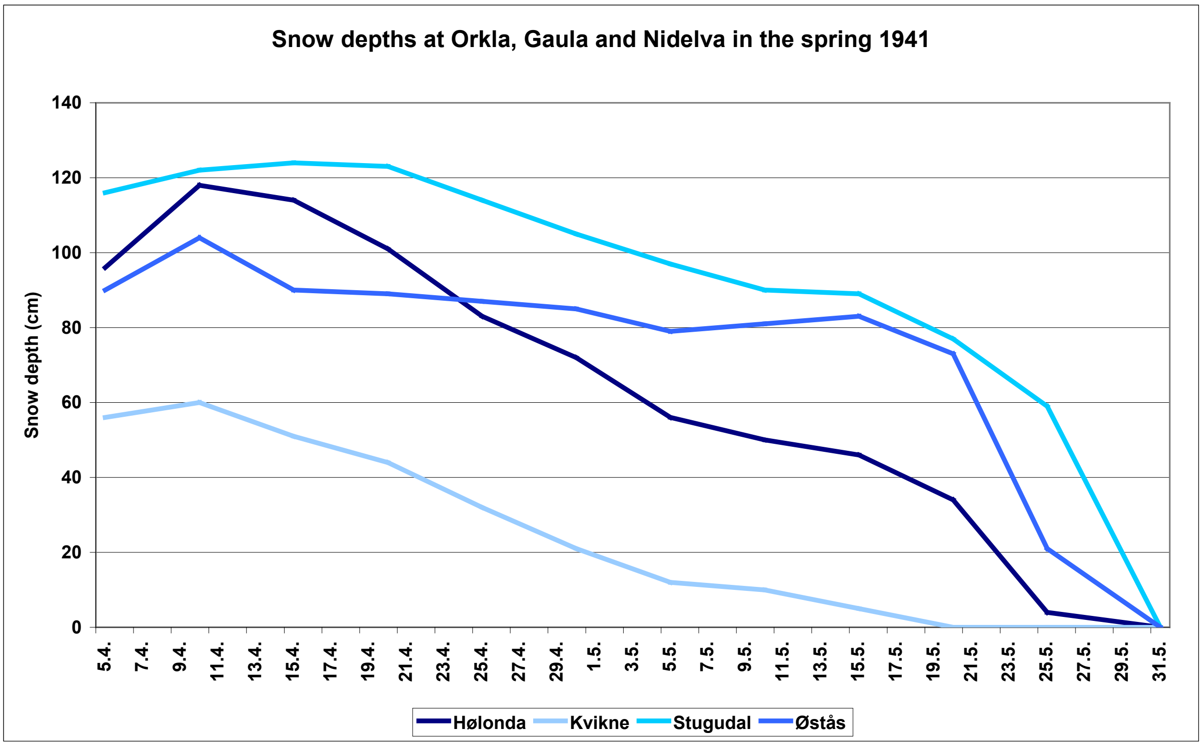


Figure 3.1.16 2 Observed snow depths at stations in Trøndelag.

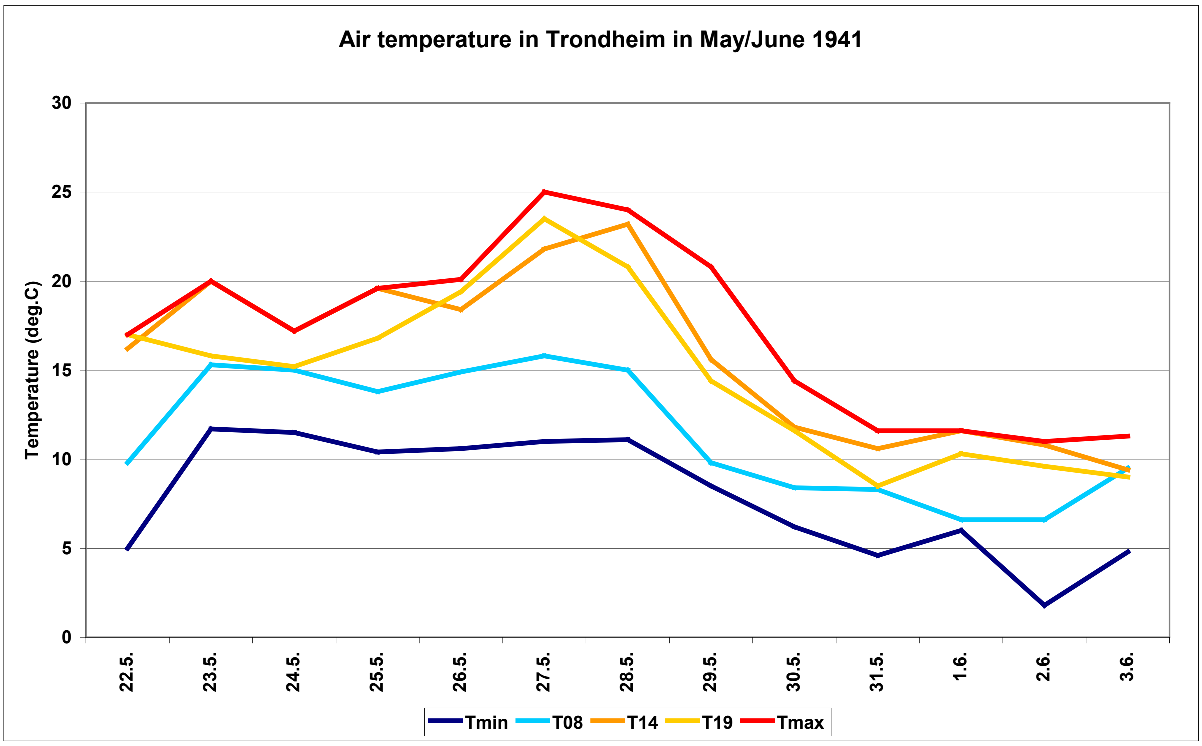


Figure 3.1.16.3 Observed temperature in Trondheim during the spring flood in 1941.

3.1.17 The autumn flood in Trøndelag 8 September 1941.

A large autumn flood occurred in the upper part of River Gaula 8 September 1941 caused by long duration rainfall. Figure 3.1.17.1 show observed daily rainfall and discharge at stations in River Orkla, River Gaula and River Nidelv.

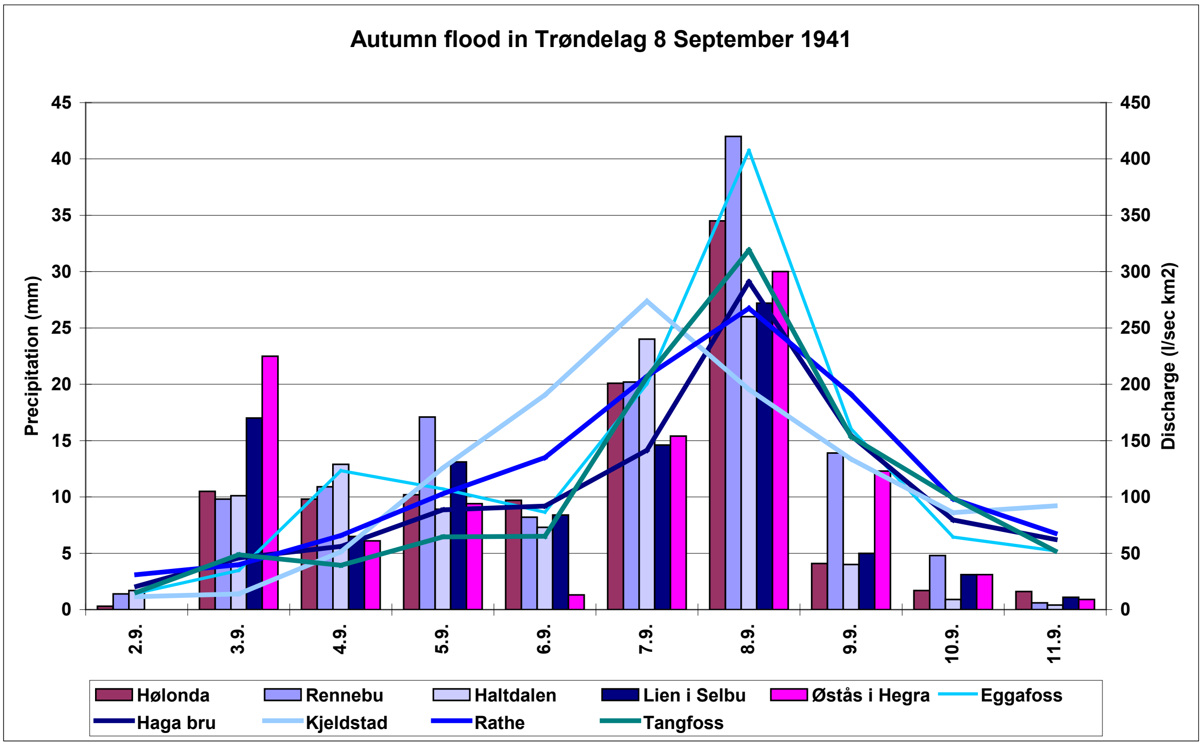


Figure 3.1.17.1 Observed rainfall and daily discharge during the rainfall flood in Trøndelag in September 1941.

Extension and ranks of the flood:

The flood at Eggafoss in Holtålen was the largest autumn flood observed at the station 1941-2013 prior to the large flood 16 August 2011. It was not however the annual flood at Eggafoss, which was the flood occurring 27 May 1941, see above. The flood occurring 24-25 August must have exceeded this flood, but the observations at Eggafoss had not started at that time.

The cause of the flood:

The weather types were: **HM** (1-5), **HB** (6-9) (Grosswetterlagen) and **A ASW ASE SE** (1-5) **A** (6-9) (Lamb-Jenkinson).

3.1.18 Floods in coastal rivers from Stadt to Helgeland in March 1942.

Local floods occurred in coastal rivers in 1942 from Stadtlandet to Lurøy in Helgeland. Observed discharges and precipitation is shown in Figure 3.1.18.1.

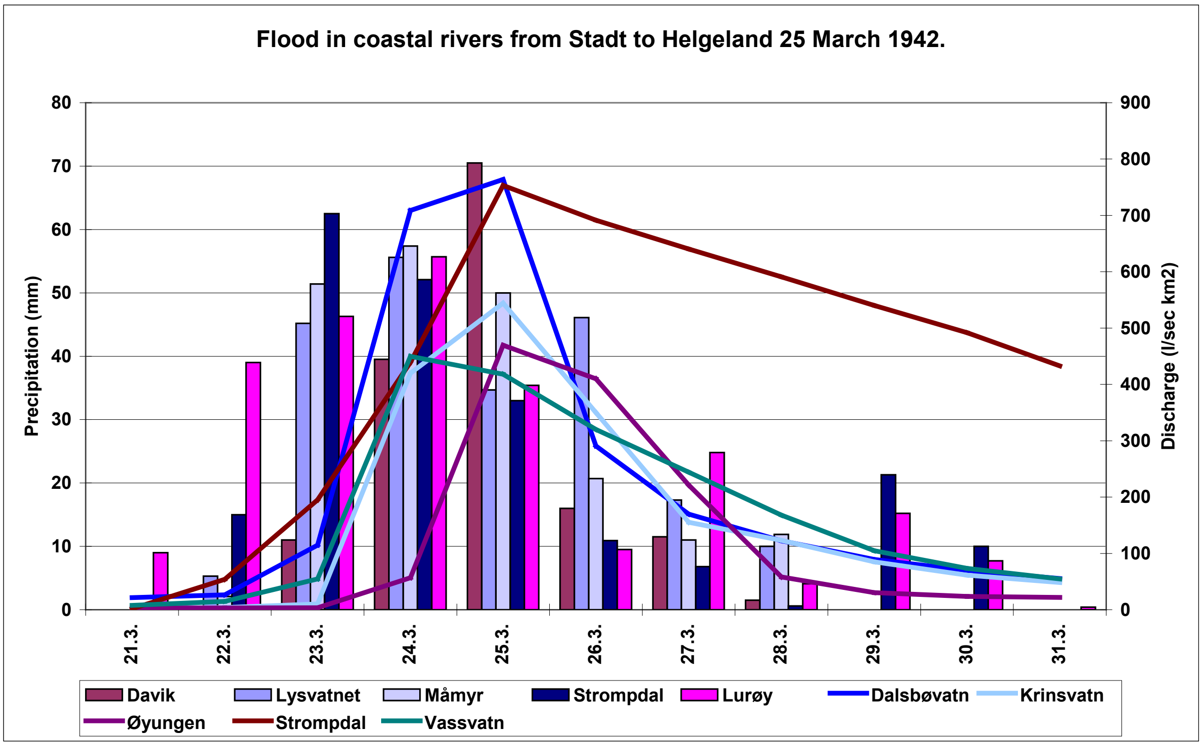


Figure 3.1.18.1. Observed precipitation and daily discharge from Stadt to Helgeland in March 1942.

Extension and ranks of the flood:

The flood was fourth largest observed in Lake Dalsbøvatn at the Stadt Penninsula but does not rank among the highest floods in the other coastal rivers.

Cause of the flood:

Prior to the flood snow was present even on the coast, but rising temperatures caused the snowmelt to start 22 March. Figure 3.1.18.2 show the air temperature observed in Trondheim. The flood was the consequence of melting snow combined with high rainfall. The melting and rainfall did not penetrate far innland. This is the reason why only catchments on the extreme outer coast had floods.

An anticyclone was located over Central- Europe, the Baltics and southern Sweden. Initially the air pressure was also high over Norway, but a depression moved from southwest from the Norwegian Sea toward Nordland. The depression moved inland 25 March. South of the depression a stream of mild and humid air was streaming toward Mid-Norway. The wind weered toward northwest 26 March, bringing cooler air masses in over the coast. The weather types were: **HNA** (Grosswetterlagen) and **E/C** (Lamb/Jenkinson)

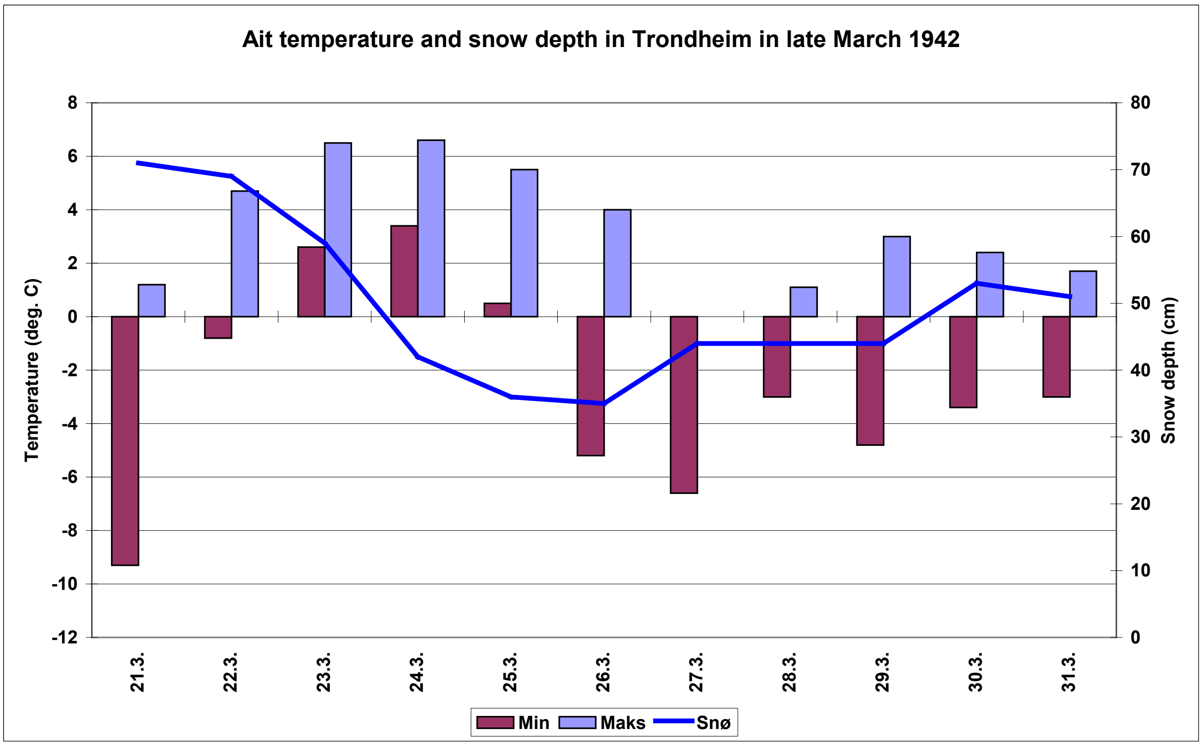


Table 3.1.18.2 The range of the air temperatures and snowdepths in Trondheim during the flood in coastal rivers in March 1942.

3.1.19 Mountain floods in upper Glomma and in Trøndelag in June 1944.

In the early summer 1944 a large flood occurred in the mountain catchments of Nord-Østerdalen, Gudbrandsdalen and Trøndelag. Observed daily rainfall and discharge are shown in Figure 3.1.19.1 for River Glomma in Nord-Østerdal, for tributaries to River Glomma in Østerdalen in Figure 3.1.19.2, for River Gudbrandsdalslågen in Figure 3.1.19.3 and for River Orkla and Gaula in Figure 3.1.19.4. The discharges in River Glomma were modified by regulations, and the discharges shown in Figure 3.1.19.1 is therfore naturlised discharges.

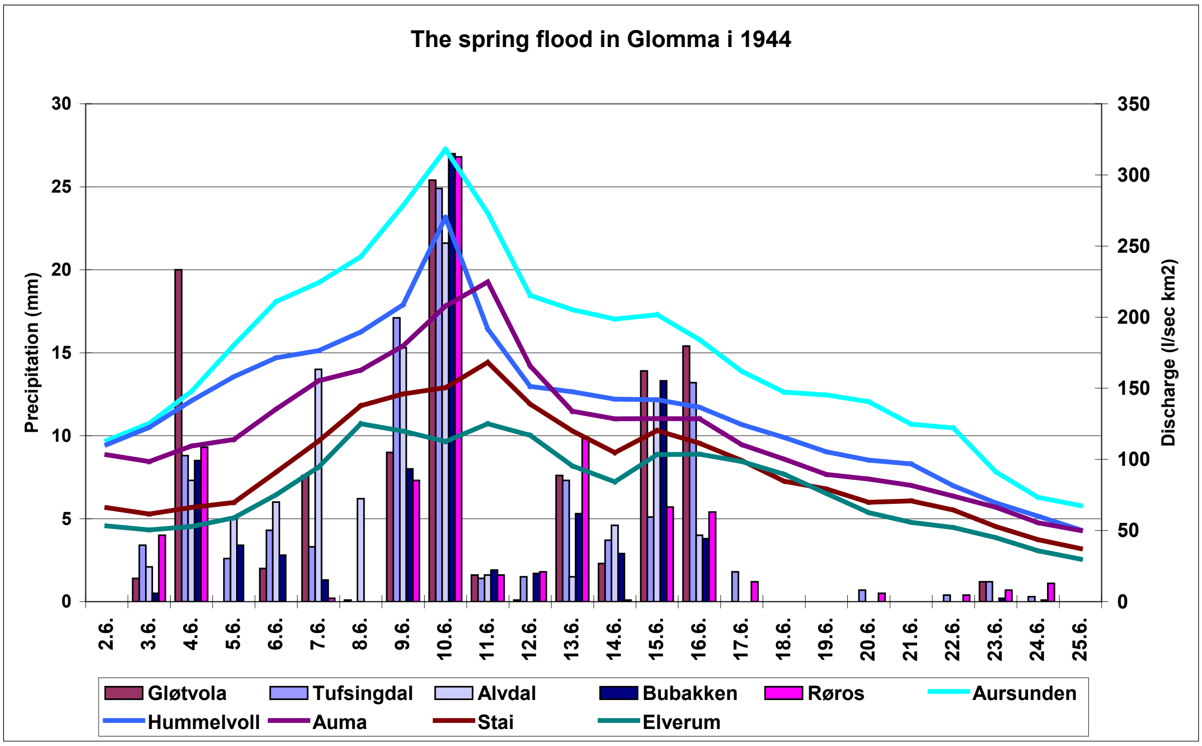


Figure 3.1.19.1 Daily precipitation and discharge at stations in the upper Østerdalen in June 1944.

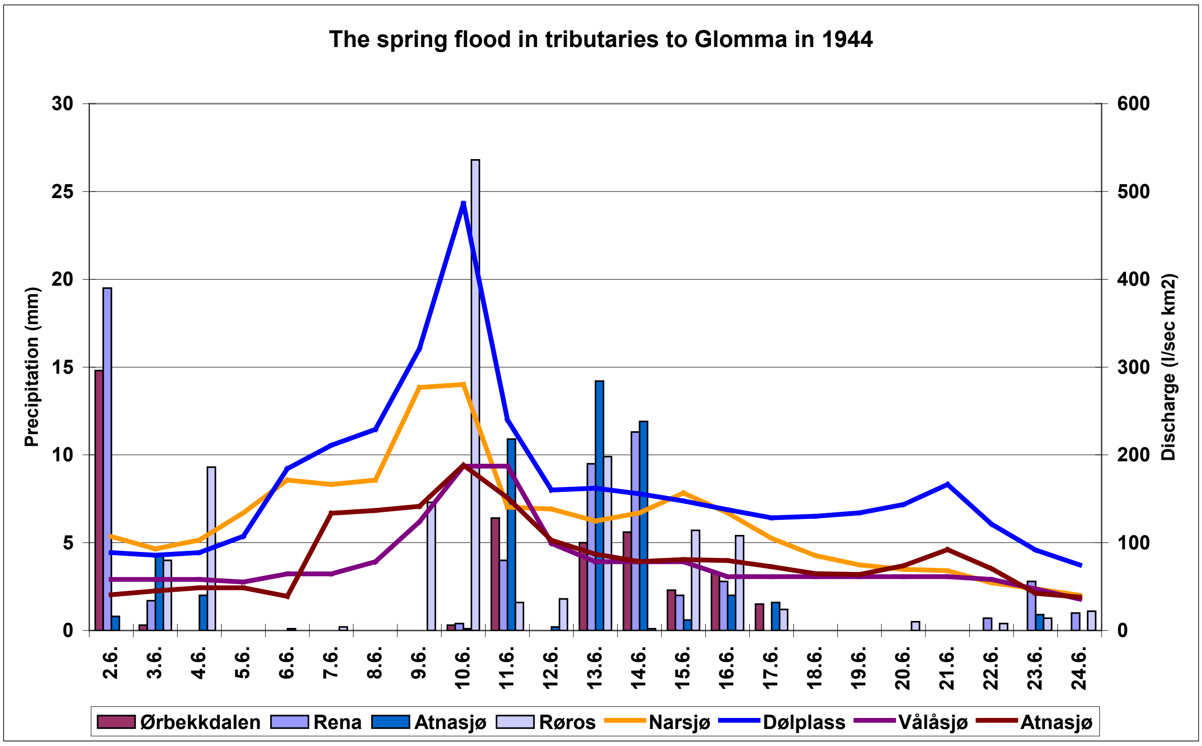


Figure 3.1.19.2 Daily precipitation and discharge at stations in tributaries to River Glomma at Østerdalen in June 1944.

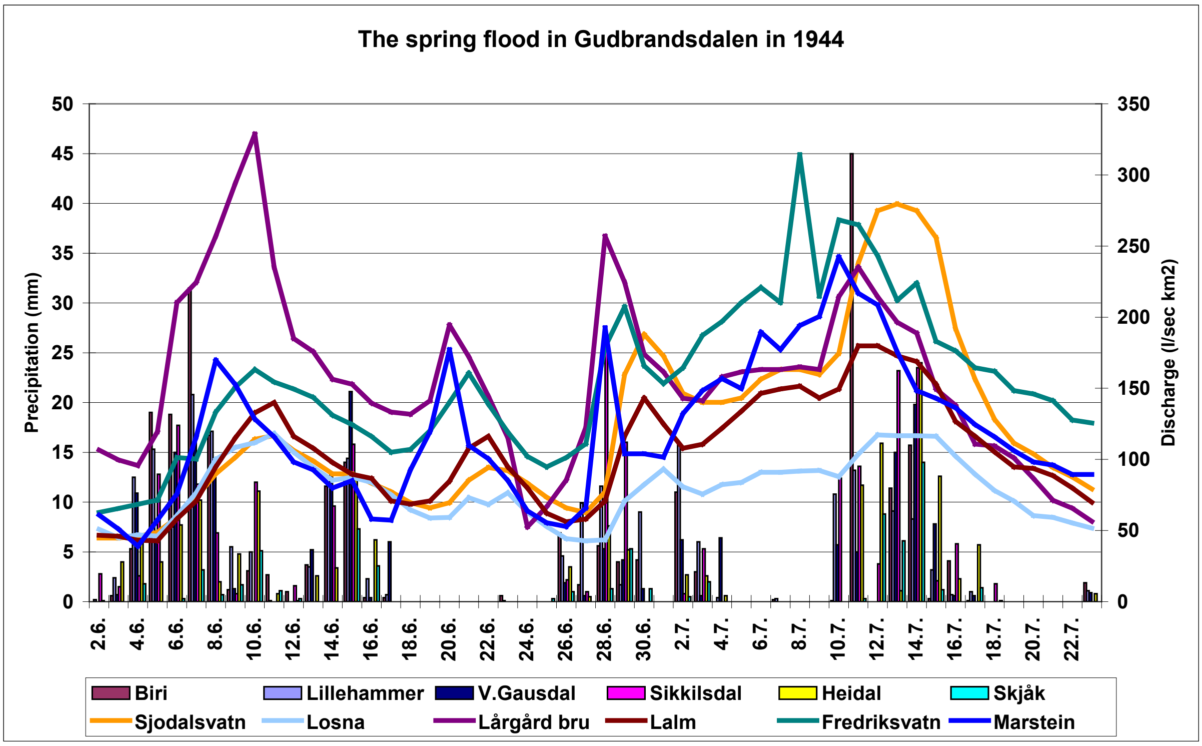


Figure 3.1.19.3 Daily precipitation and discharge at stations in River Gudbrandsdalslågen in June 1944.

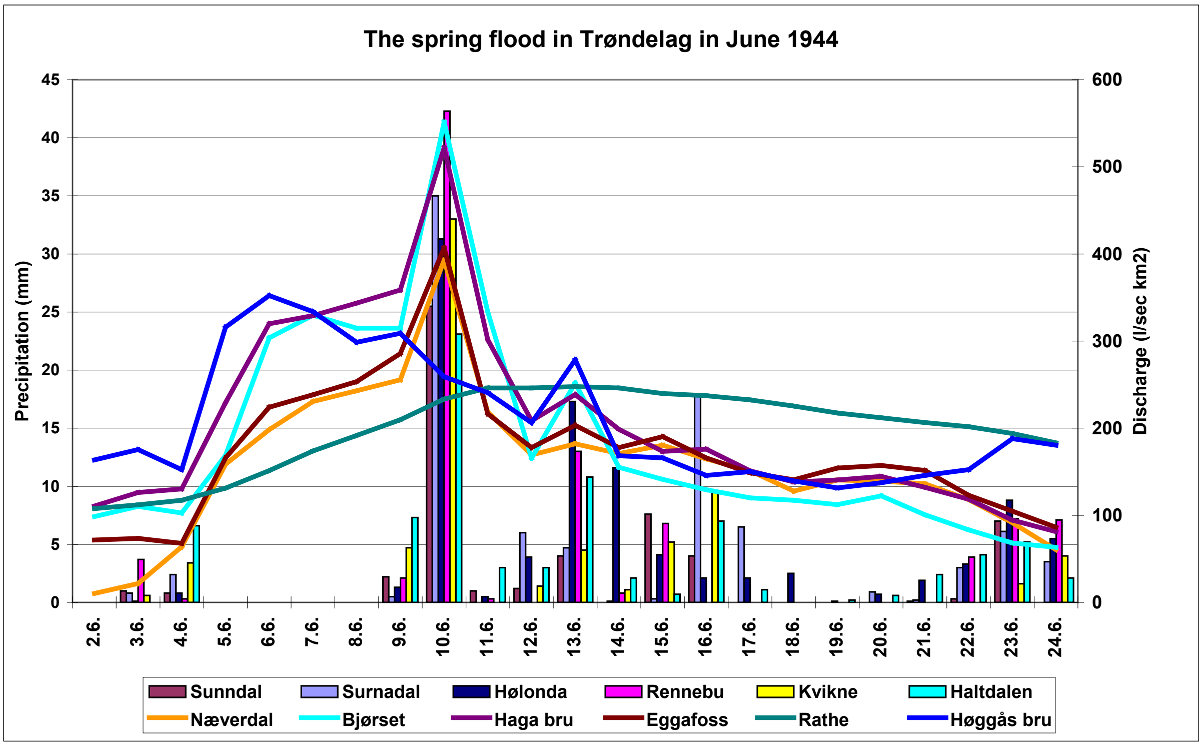


Figure 3.1.19.4 Observed precipitation and daily discharge at Nordmøre and Sør-Trøndelag in the spring June 1944.

Extension and ranks of the flood:

The flood was second largest in River Glomma at Lake Aursunden since 1902, and at at Auma since 1921 and in River Folla at Dølplass since 1908. In River Glomma the flood was largest at Hummelvoll and Ehrlibru since 1935 and at Stai since 1908. River Gudbrands-dalslågen was also in flood, but the flood magnitude was less extreme there.

The flood was largest since 1913-2014 in River Orkla at Bjørset and second largest at Næverdal 1922-1982. It was third largest in River Gaula at Haga bru since 1909 and fifth largest at Eggafoss. The flood was the third largest naturalised flood since 1899 in River Nidelva and third largest in River Stjørdalselva at Høggås bru 1908-2014.

Cause of the flood:

The winter 1943/44 much snow accumulated in North-Østerdalen and in Trøndelag as shown in Figure 3.1.19.3. The spring was cool, and no heat wave occurred during the snow melt as seen from Figure 3.1.19.4 showing the air temperature in Oslo during the meltingen. The flood peaked 10. June resulting from rainfall combined with snowmelt. Observed snow depths at selected mountain stations in southern Norway is shown in Figure 3.1.19.5.

The heaviest rainfall fell in Nord-Østerdalen and over the large catchments in South Trøndelag. The rainfall was caused by a depression from the Norwegian Sea with extension toward East Norway, especially on 10 June with most of the rainfall precipitation.

The weather types were 8–9 June 1944: **TRM** and **WZ** (Grosswetterlagen) and **CW** and **CNW** (Lamb/Jenkinson).

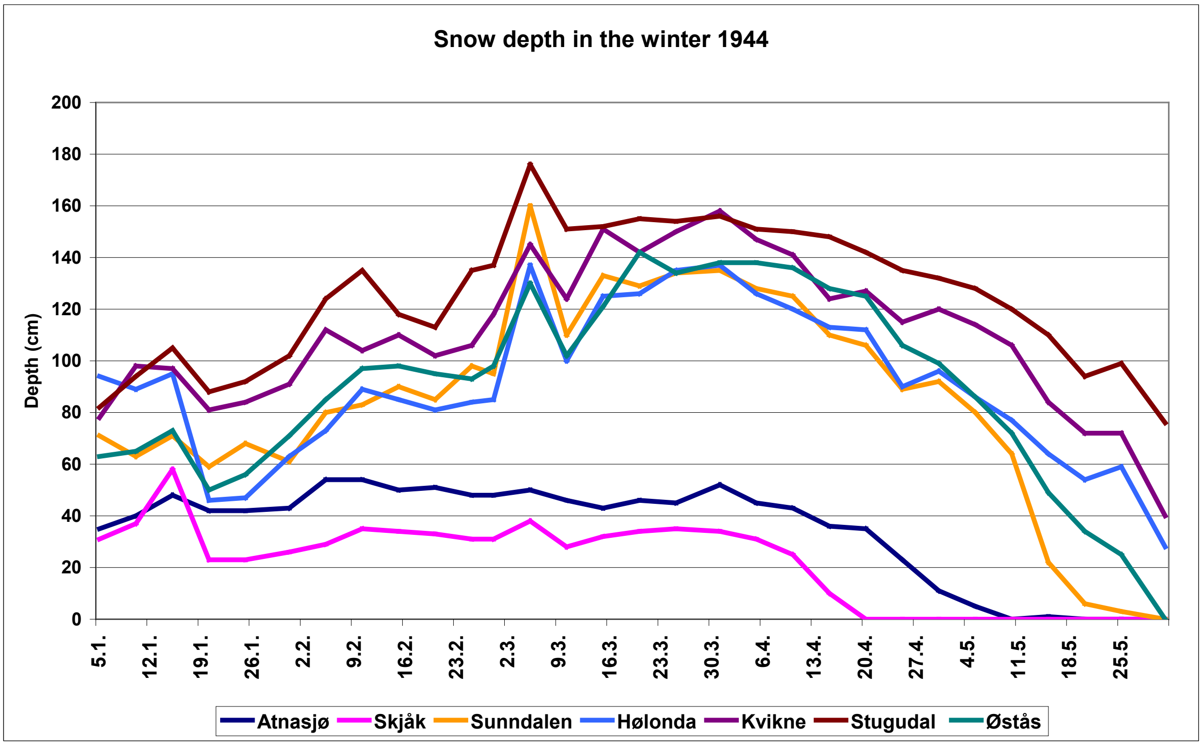


Figure 3.1.19.5 Observed snow-depths at selected meteorological stations at both sides of the water divide between Østlandet and Trøndelag.

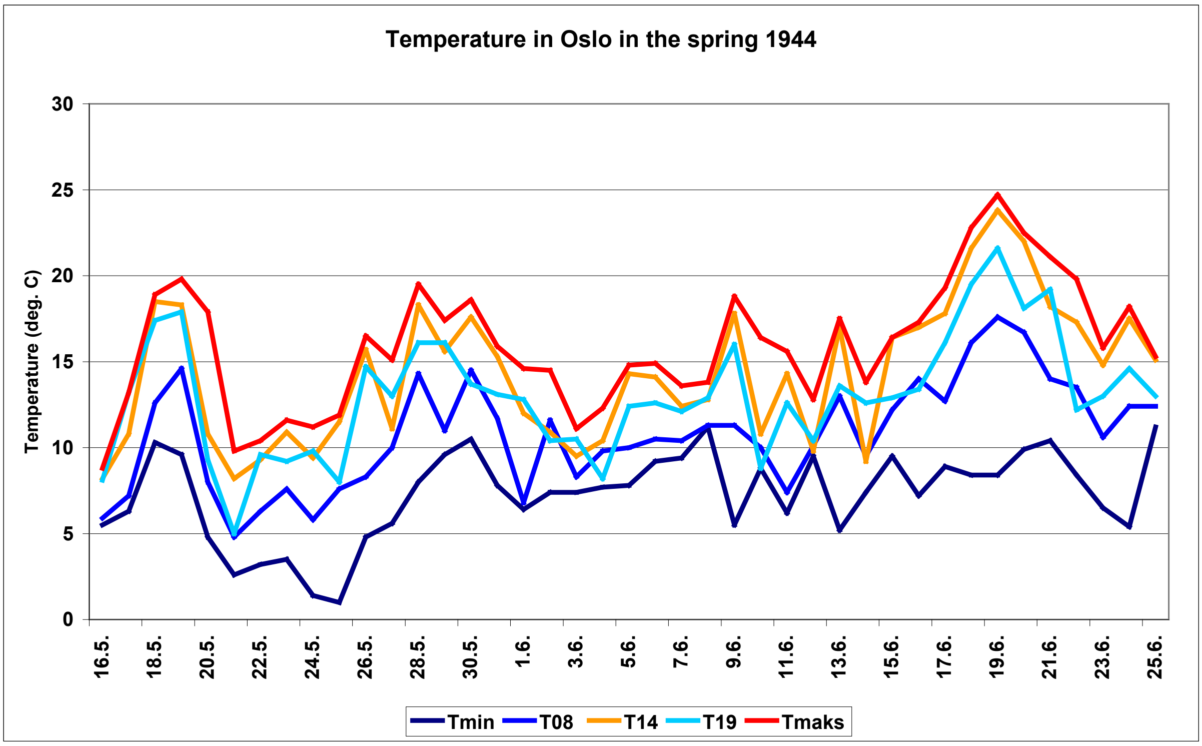


Figure 3.1.19.6 Observed temperature in Oslo in the spring 1944.

3.1.20 Severe autumn flood in Nord-Trøndelag in October 1947.

A severe flood occurred in rivers east and north of the Trondheimsfjord 20-21 October 1947. Figure 3.1.20.1 show observed daily precipitation and discharge in district affected by the flood.

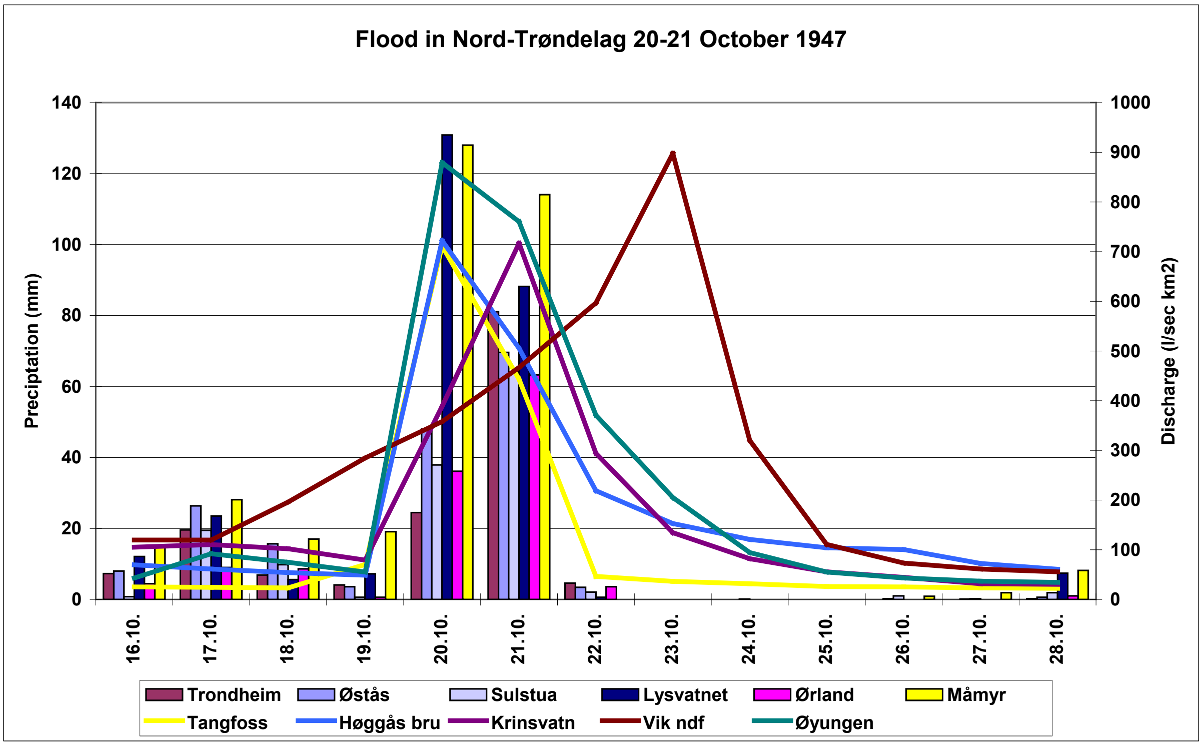


Figure 3.1.20.1 Observed precipitation and daily discharge in North-Trøndelag during the flood 20-21 October 1947.

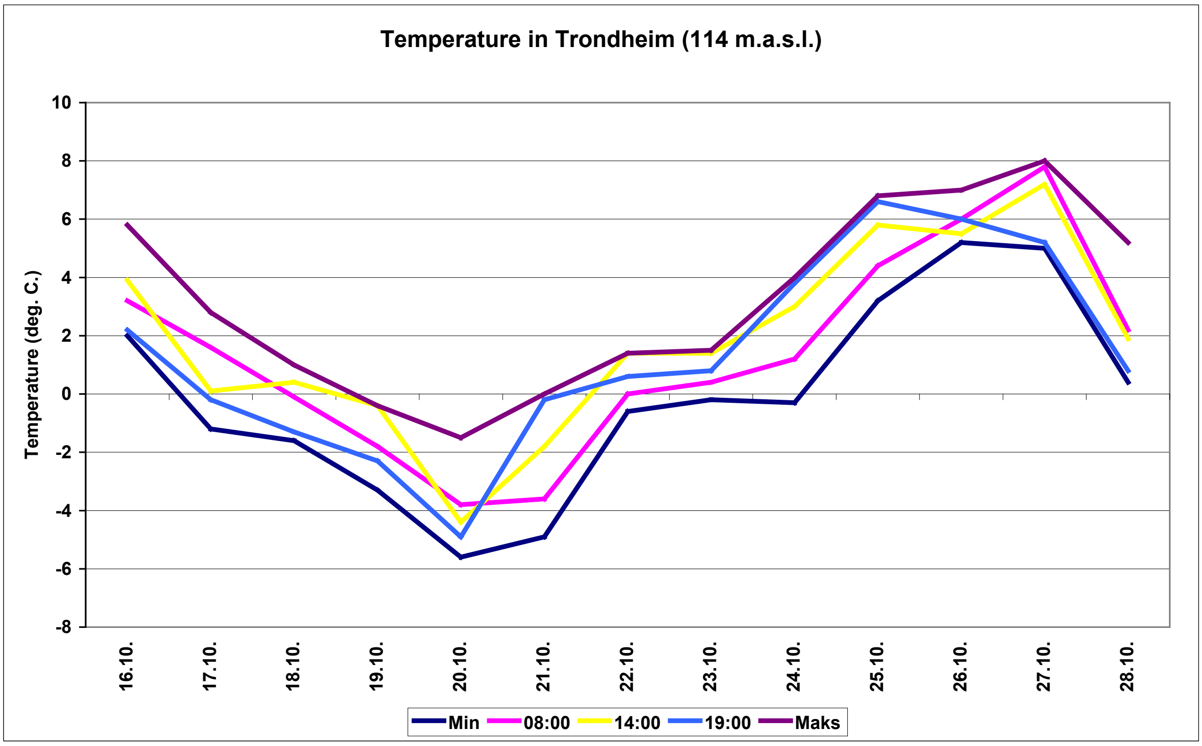


Figure 3.1.20.2 The temperature in Trondheim in late October 1947.

Extension and ranks of the flood:

The flood is the largest observed in River Stjørdalselv at Høggås 1912-2013 and the largest naturalized flood in River Hopla at Fossing 1932-2002. Direct observations are unfortunately missing in River Verdalselv. The discharge at Grunnfoss has been estimated based on the water line in the terrain, where it was estimated to be the largest 1908-2013. The rainfall was more intense at the Fosen penninsula and the specific discharges were higher than in the rivers further east in River Stjørna at Lake Krinsvatn, River Svartelv at Lake Storvatn, River Vikselv at Vik and in River Årgårdselv at Lake Øyungen. The flood at Lake Krinsvatn was only 26 largest and at Øyungen seventh largest 1916-2013. River Namsen and in Lake Salsvatn had also smaller floods corresponding to a return period of 5 years.

In the rivers south of the Trondheimsfjord the naturalized flood was fourth largest in River Nidelva at Rathe in Trondheim 1899-2005. At Haga bru in River Gaula the flood was the largest in 1947 but ranks only as the 63 largest 1912-2013. Further upstream in River Gaula at Eggafoss the flood was not highest in 1947. A small flood occurred in River Velledalselv at Sunnmøre, but the flood ranks only as elleveth largest in the dataserien 1934-2013.

Cause of the flood:

After a mild start of October, the temperature fell from 16 October causing snow to accumulate at higher altitudes in Trøndelag until 19 October. A total falt ½ m snow fell in the mountains before the precipitation turned into rain. The flood was caused both from high rainfall and snowmelt. Figure 3.1.20.2 show the air temperature in Trondheim16-28 October.

Behind an intense depression moving eastward over Lofoten arctic air masses with snow showers toward the coast of Mid- and North Norway. The wind weered toward southwest 19 October as an anti-cyclone appeared east of Greenland and a depression appeared southwest of Iceland causing raising temperatures. The rainfall was caused by a frontal passage linked to the depression south of Iceland. The weather types during the flood were: **HM** (Grosswetterlagen) and **AS/S** (Lamb-Jenkinson).

Flood damages:

The flood caused damages at Stjørdal.

3.1.21 Ice run floods at River Orkla and Gaula in March 1953.

Ice run floods occur when mild weather and rainfall sets in after the ice cover has developed in the rivers. This happened 22-25 March 1953 in Trøndelag resulting from heavy rain-fall and mild weather. The precipitation was most intense 24-25 March, when between 92 and 208mm rain fell in two days at many stations north and eEast of the Trondheimsfjord in Trøndelag. At Lake Lysvatn at the village Å fell 208,8 mm and at Måmyr at Fosen fell 186 mm rain in two days. This is of the same magnitude as the two-day rainfall at the Fosen penninsula in late January 1932 and 2006. In Trondheim fell 84,7 mm, but only 29,2 mm i Haltdalen in the Gaula catchment. Mild weather and rainfall caused nevertheless a major ice run, which blocked the roads and the railway traffic between Østlandet and Trøndelag. Observed daily precipitation and discharge in River Orkla and River Gaula are shown in Figure 3.1.21.1 and in River Stjørdalselv, River Verdalselv and at the Fosen penninsula in Figure 3.1.21.2.

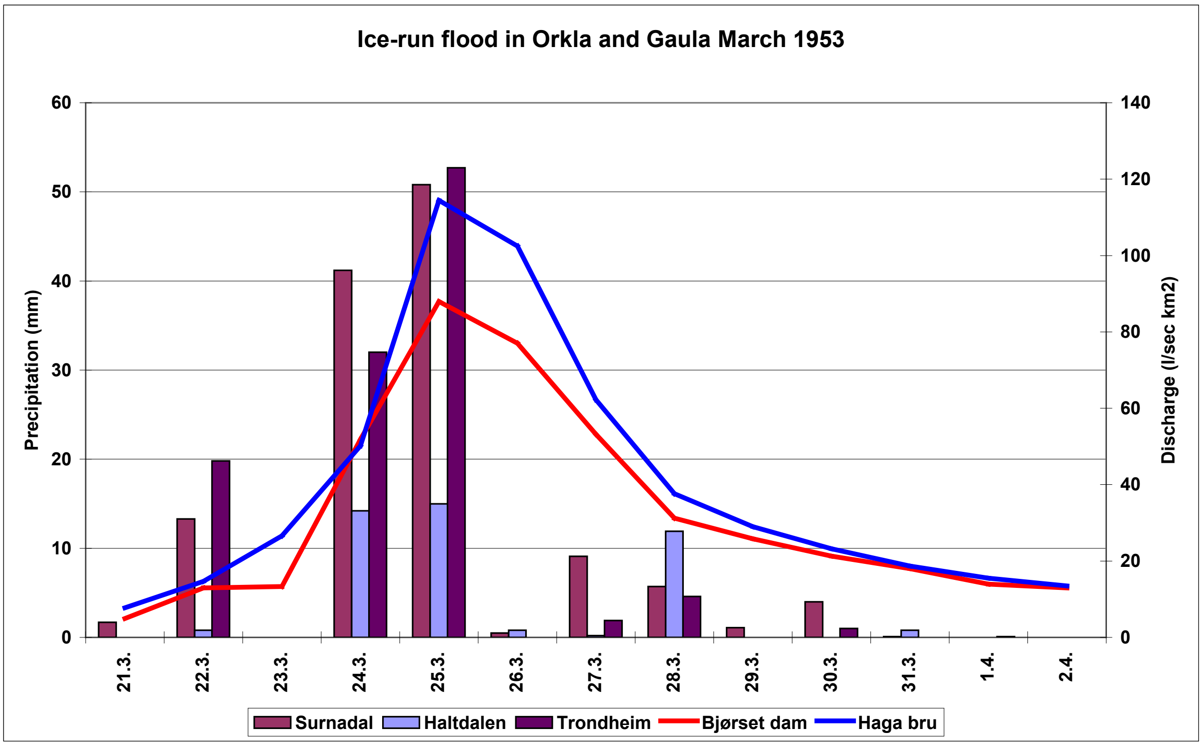


Figure 3.1.21.1 Observed precipitation and daily discharge during the ice run flood in Orkla and Gaula in March 1953.

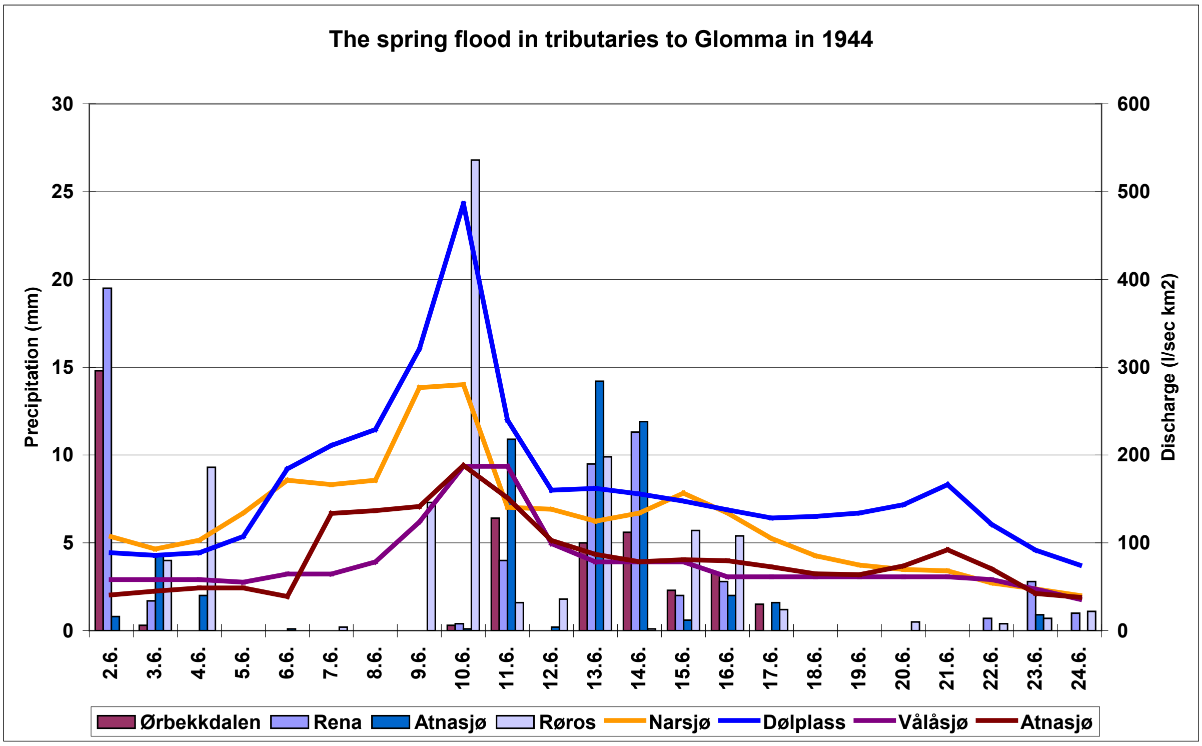


Figure 3.1.21.2 Observed precipitation and daily discharge during the ice run flood in upper Glomma and at Fosen in March 1953.

Extension and ranks of the flood:

The flood was third largest in River Stjørdalselv at Høggås bru 1912-2013 and fourth largest in River Verdalselv at Grunnfoss. It was large, but not among the largest in River Stjørna at Lake Krinsvatn, third largest in River Årgårdselv at Lake Øyungen 1916-2013, den third largest in River Namsen at Fiskumfoss and largest in Lake Salsvatn 1916-2013. The rainfall penetrated into the southern part of Helgeland but did not cause large floods in this district.

Cause of the flood:

A strong anti-cyclone over the North Sea directed a mild air stream from west-southwest along the polar front toward Trøndelag. The rainfall 24 and 25 March was caused by a frontal passage over Mid- Norway. The weather types were **HM** (Grosswetterlagen) and **A/ASW** (Lamb/Jenkinson).

3.1.22 Spring flood in Trøndelag in May-June 1973.

A large flood occurred in mountains rivers in South Norway during the summer 1973. River Folla, River Atna, River Gudbrandsdalslågen, Riva Driva, Riva Orkla, River Gaula and River Nidelva did all flood. Figure 3.1.22.1 show observed rainfall and discharge during the flood in catchments in Østerdalen and Gudbrandsdalen. Figure 3.1.22.2 show daily rainfall and discharge in catchments in Trøndelag.

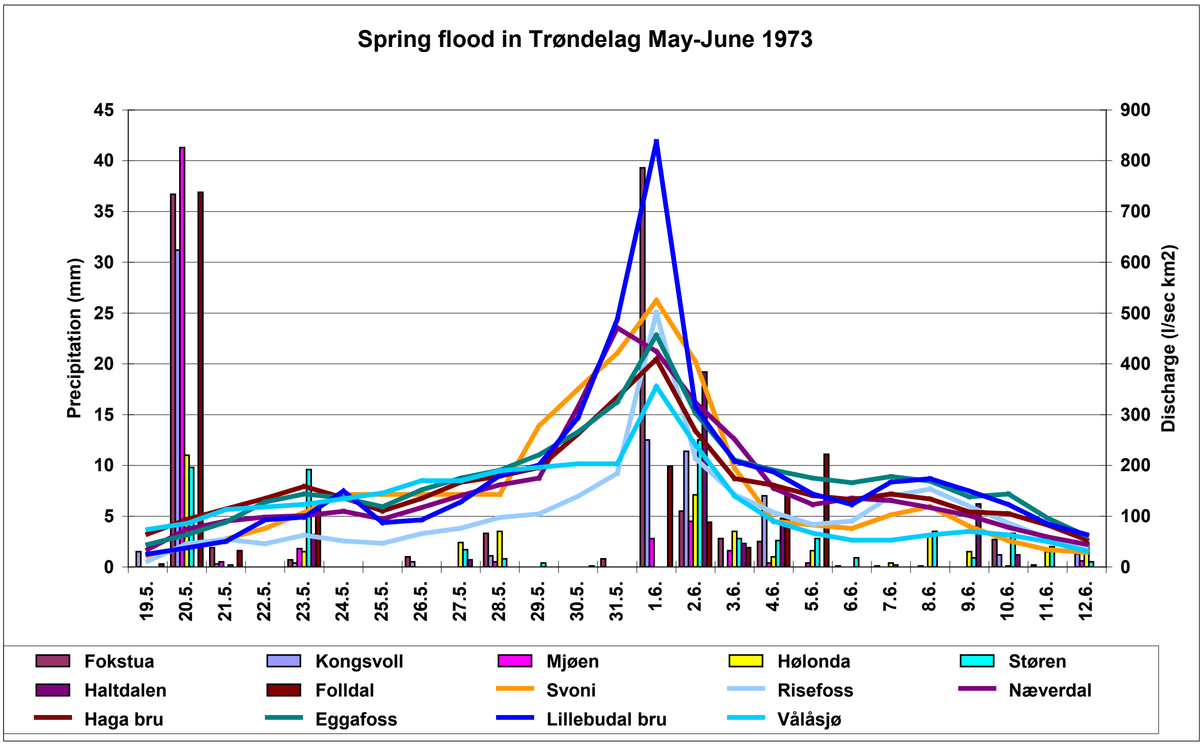


Figure 3.1.22.1 Observed precipitation and daily discharge during the spring flood in Trøndelag in 1973.

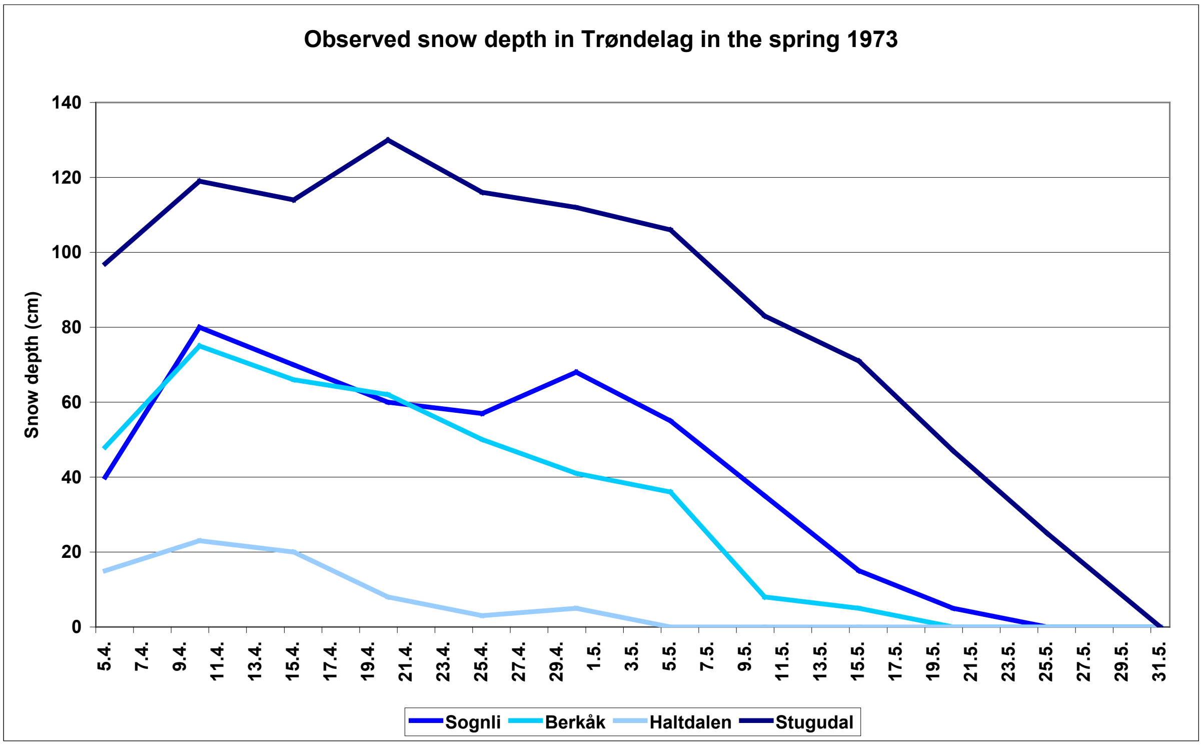


Figure 3.1.22.2 Observed snow depths in Trøndelag prior to the spring flood in 1973.

Extension and ranks of the flood:

The flood was the largest observed in River Driva at 109.20 Grensehølen 1965-2014 and 109.9 Risefoss 1935-2014 and in River Svoni 1970-2002. The flood was the largest observed in River Orkla at 121.9 Næverdal 1922-1982 and fifth largest at 121.10 Bjørset 1912-2014. In River Gaula at 122.9 Eggafoss the flood was third largest 1941-2014, largest at 122.x Vilmansøyen 1941-2010, second largest in the tributary Bua at 122.14 Lillebudal bru 1963-2010 and largest at 122.13 Økdalsmo bro 1963-1980. The flood was the eight largest in 123.31 River Garbergelva at Kjellstad 1912-2014.

Cause of the flood:

The flood was primarily caused by snowmelt. The peak 1 June was, however, caused by rainfall moving in from southeast.

Between an anti-cyclone in the Central North Atlantic west of the Iberian peninsula and another anti-cyclonic ridge extending from Russia across the Mediteranian to Libya, a trough extended from a low in the Norwegian Sea across the UK to the Mediteranian west of the ridge. Warm and humid air was moving northwestward over Southeast Norway to Trøndelag, causing rainfall at the tail of the snowmelt from 1 to 22 June. The rainfall event was was a weak Vb- type event. The weather types were: 31 May-2 June **TRW** (Grosswetterlagen) and **N**, **SW** and **W** (Lamb-Jenkinson)

3.1.23 Vesleofsen in Trøndelag in June 1995.

The large flood, Vesleofsen, was also severe in the large rivers in Trøndelag draining northward to Trondheimsfjorden. Figure 3.1.23.1 show observed daily precipitation and discharge ar selected stations in River Gaula and Orkla.

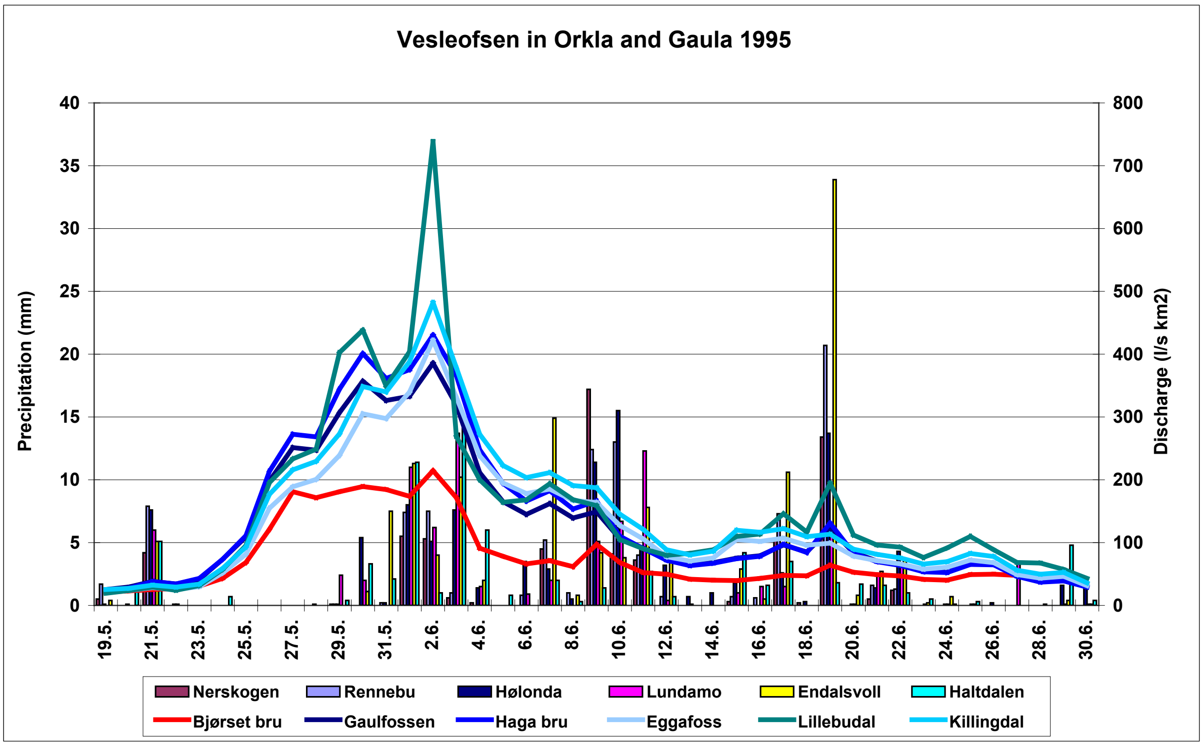


Figure 3.1.23.1 Observed precipitation and daily discharge in Trøndelag during Vesleofsen in 1995.

The weather causing the flood is described in Appendix B of the report.

3.1.24 The flood in Trøndelag in August 2003.

Warm air from southeast caused locally intense rainfall west of Oslo 13 August 2003. The warm and humid air penetrated northward into the rivers flowing toward the Trondheimsfjord, causing record high floods at some stations as shown in Figure 3.1.24.1. The heavy rainfall caused also floods and landslides at Sunnmøre 14-15 August 2003. Figure 3.1.24.2 show observed daily rainfall and discharge in some rivers in Møre and Romsdal. There are however no gauging stations in the rivers where the flood damages were most severe in this county. The event has similarities with the flood occurring 15 August 1909 at Romsdal, Nordmøre and in River Driva.

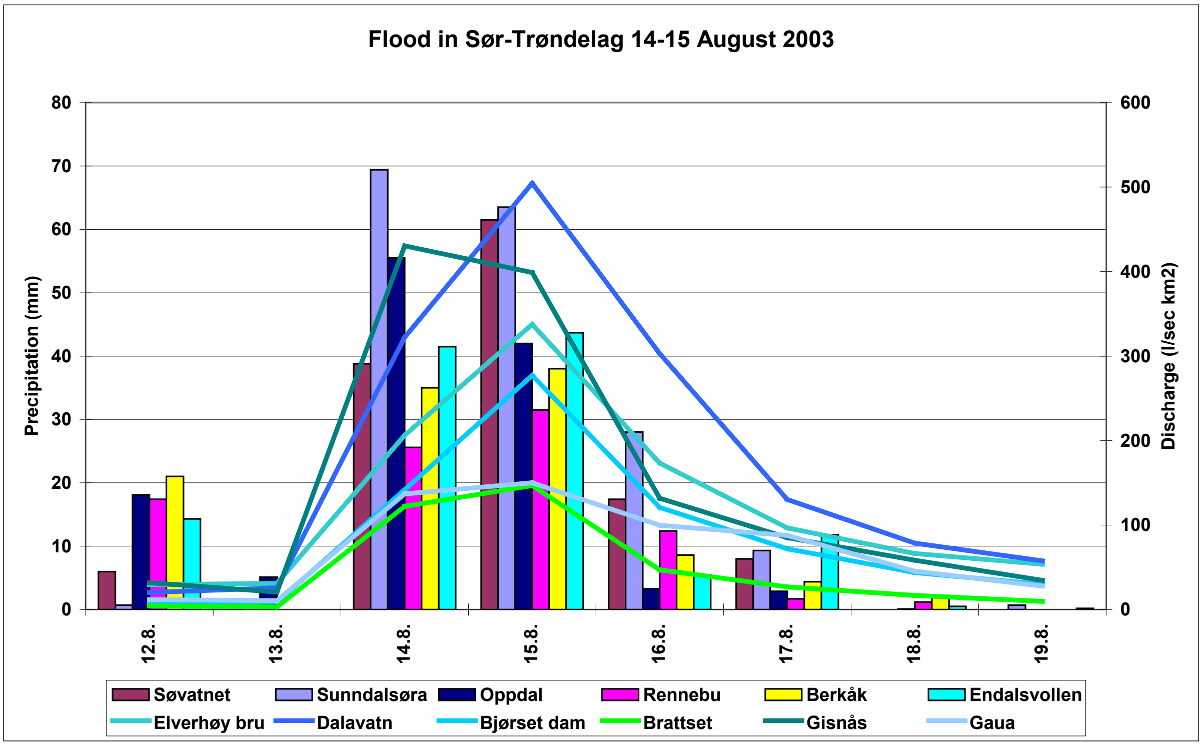


Figure 3.1.24.1 Observed precipitation and daily discharge in Sør-Trøndelag during the flood in August 2003.

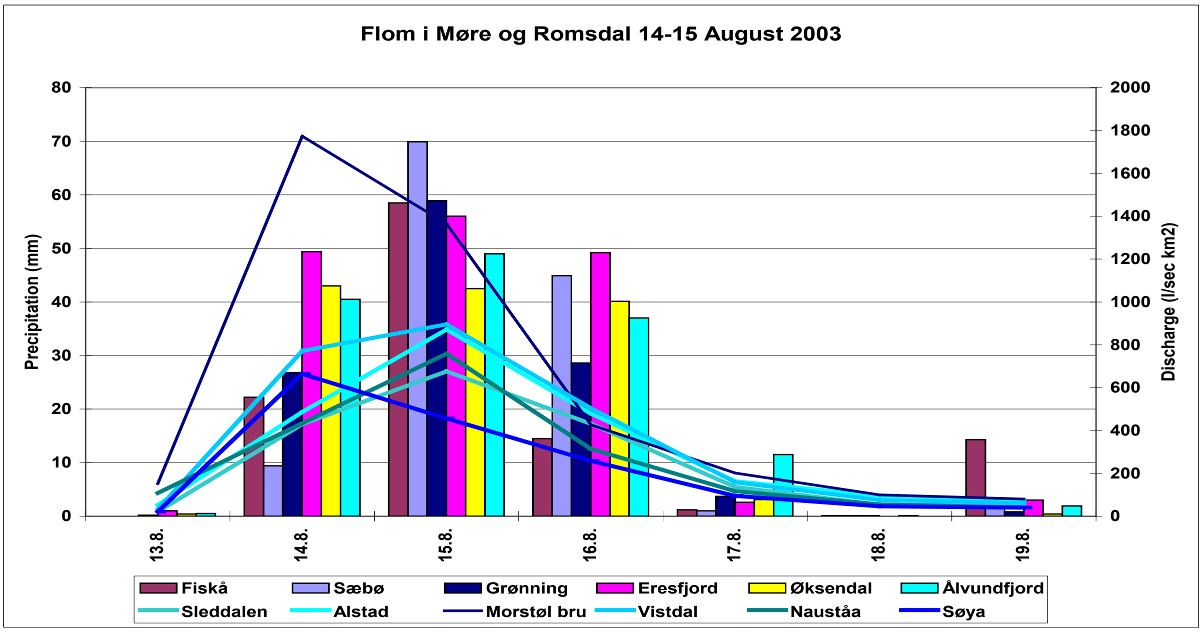


Figure 3.1.24.2 Observed discharge and rainfall at gauging stations in Møre and Romsdal in August 2003.

Extension and ranks of the flood:

The flood was the largest observed in River Driva at Risefoss 1935-2007 and in River Svoni 1970-2002, largest in River Orkla at Næverdal 1922-1982 and fifth largest at Bjørset 1912-2007. In River Gaula at Eggafoss the flood was second largest 1941-2011, largest at Vilmansøyen 1941-2010, second largest in River Bua at Lillebudal bru 1963-2010 and the largest at Økdalsmo bro 1963-1980. The flood was the eight largest in River Garbergelva at Kjellstad in the Nidelv basin 1912-2010.

Cause of the flood:

A weak anti-cyclone with warm kernel was located over Storbritannia and the European mainland 12– 16 August. A weak depression moved toward East Norway from southeast sørøst, causing intense showers in the Oslo region. The depression moved northwards toward Sør-Trøndelag, where it turned westward and later southwestward over Møre and Romsdal. The distribution of the precipitation is shown in Figure 3.1.24.3. The heavy showers caused locally large floods where the rainfall was most intense. Some melting of remaining snow at the highest levels of the mountains may also have contributed, especially in glacier streams. The rainfall and flood were also large in some rivers in Sogn og Fjordane.

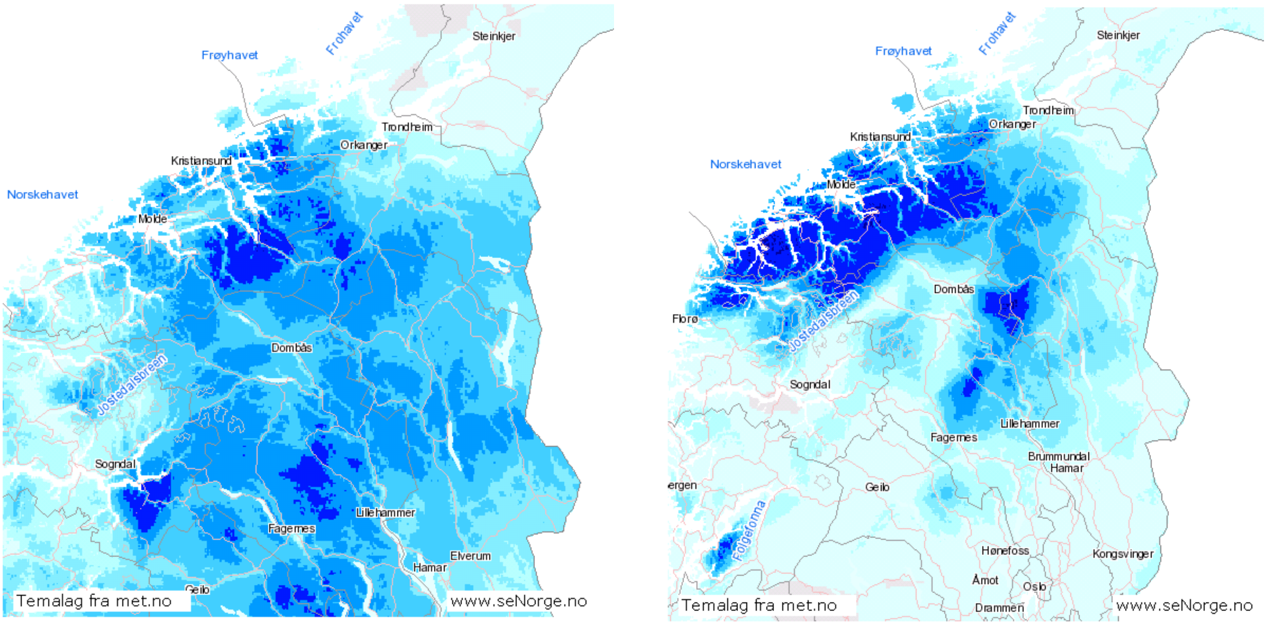


Figure 3.1.24.3. The distribution of the rainfall 14-15 August 2003.

Flood damages:

The main road RV 65 was cut by a landslide between Skei and Betna at Surnadal. The slide damaged also the buildings on a farm, killing som farm animals. The rainfall caused also floods and landslides at Oppdal and at Eikesdal where the road on the northern bank of Lake Eikesdalsvatn was cut at Vik by River Vikselv. Landslides caused also substantial damages to the road at the Norangsdal at Sunnmøre. Kleiva at Måndalen in Rauma was damaged by land slides. Flood and landslides blocked the tourist road Trollstegen at Isterdalen for the rest of the season. A bridge was damaged on E39 by the flood in River Liadalselva at Ørsta. The tourist road through Norangsdalen was also blocked by landslides. De most severe damages occurred in small rivers without any gauging stations.

3.1.25 The winter rainfall flood at Fosen in January 2006.

A rainfall flood occurred at the Fosen peninsula at the end of January 2006. This flood exceeded the extreme flood in late January 1932. Figure 3.1.25.1 show daily precipitation and discharge at stations in Nord-Trøndelag during the flood.

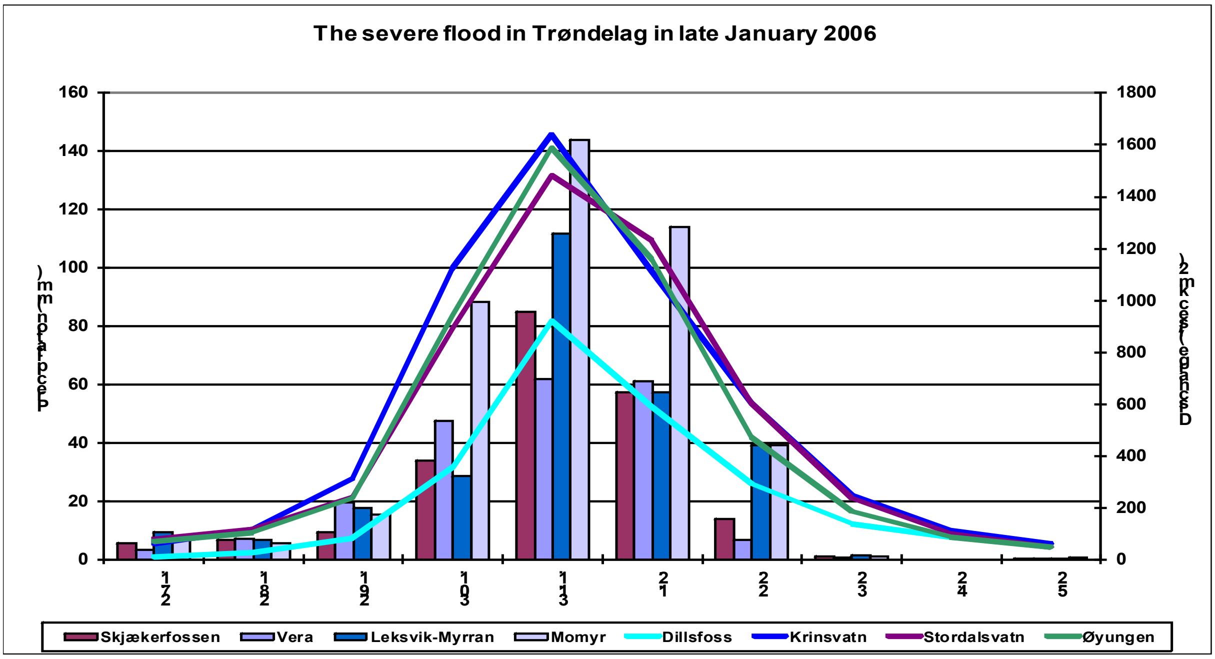


Figure 3.1.25.1 Observed precipitation and daily discharge during the large winter flood at Fosen in January 2006.

Extension and ranks of the flood:

The flood is the largest observed in River Verdalselva at Dillfoss 1973-2014 and in Lake Veravatn 1966-2014, in River Stjørna at Krinsvatn, in River Årgårdselv at Øyungen and in River Salsvatnelv at Salsvatn 1916-2014. It is the fourth largest in River Stjørdalselv at Haga bru 1912-2014.

Cause of the flood:

The flood was primarily caused by intensive rainfall. Initially some snow was present in the catchments, but it melted quickly and comtributed only marginally to the flood. Some ice was also present initially, but it did not cause any ice run as the ice melted quickly as well. The Fosen peninsula is lowlying and the precipitation fell as rain throughout the flood. The distribution of the rainfall is shown in Figure 3.1.25.2.

At Måmyr in Åfjord 143,9 mm rain was observed 31 January. An unofficial observation at Mørra powerstation in Åfjord was 218,9 mm observed from 30 January 07:00 to 31 January 07:00 according to Trønderenergi AS. A total of 440,8 mm was observed in 84 hours at the power station until the connection to the station was broken because of the flood and landslide at 18:00 31 January.

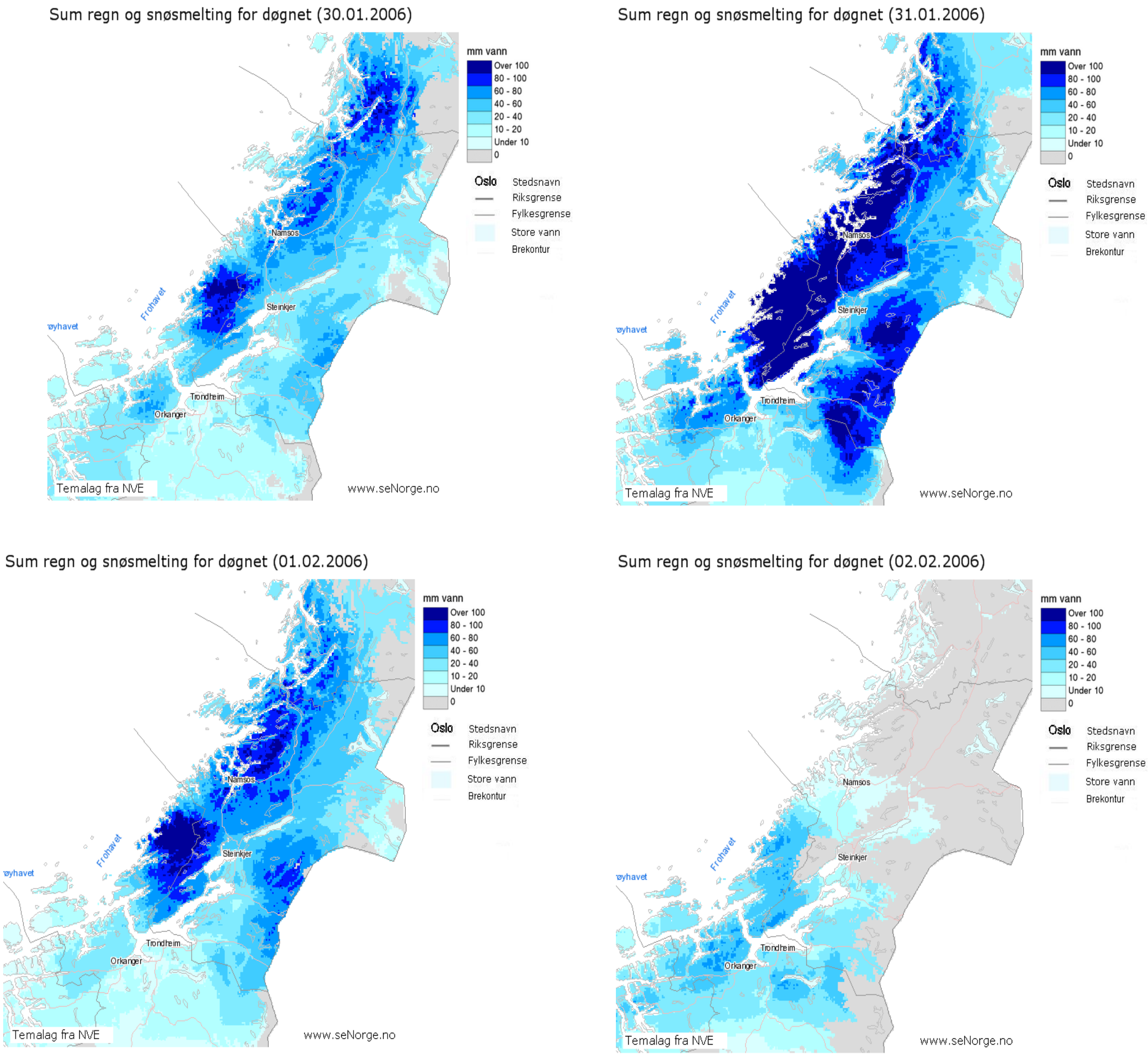


Figure 3.1.25.2 The distribution of the preciptation in Trøndelag during the flood in Januar February 2006.

North of a strong anti-cyclone over the North Sea var humid oceanic air masses were streaming along the polar front from west 28 January - 2 February 2006. Weather types were **HB** (Grosswetterlagen) og **A** (Lamb-Jenkinson).

Damages:

The flood caused a house to be taken by River Lauvsneselv at Flatanger to the sea. Several hundred peoples were evacuated. A bridge was taken by the river and one man was drowned, when driving over the bridge when it was taken by the flood.

3.1.26 The flood in March 2010 in Møre and Romsdal.

Heavy snowfall turning into rainfall caused floods in several coastal catchments at Vestlandet, at Møre og Romsdal and Trøndelag. The floods caused ice-jams in rivers in Trøndelag and Helgeland to Mosjøen. Observed discharge and precipitation in Møre og Romsdal is shown in

Figure 3.1.26.1. Figure 3.1.26.2 show discharge and precipitation for stations at Fosen to Helgeland.

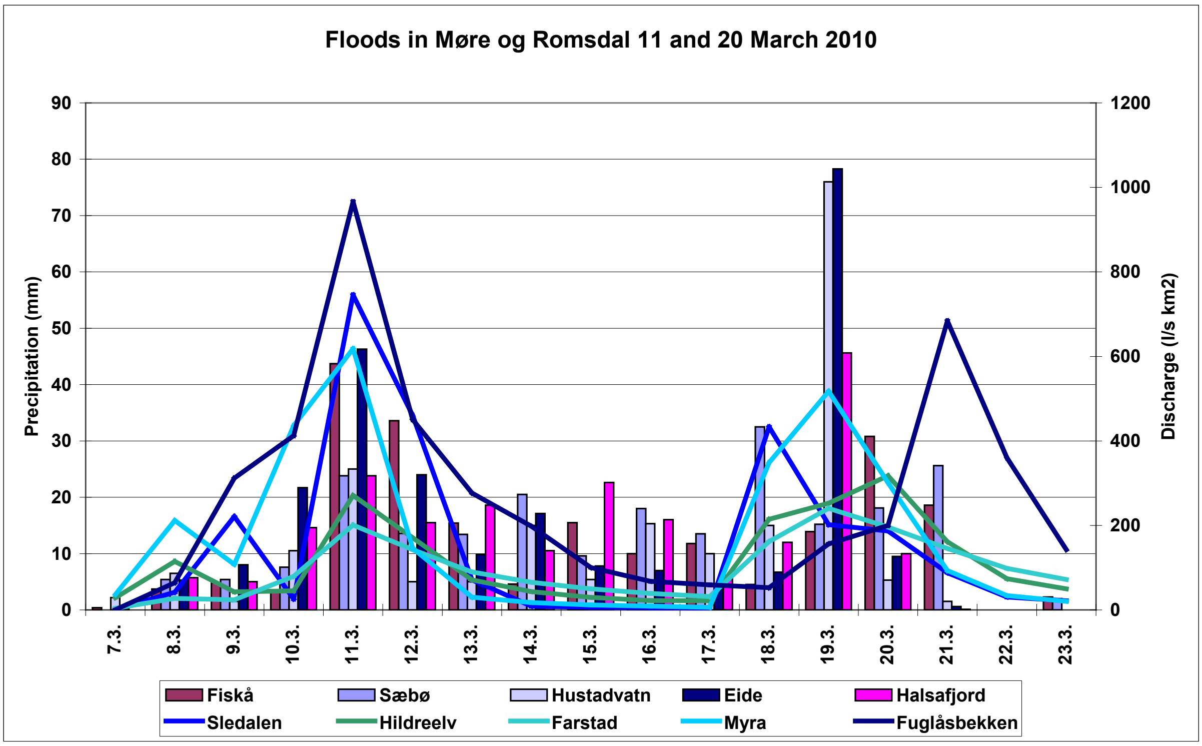


Figure 3.1.26.1 Observed precipitation and daily discharge in rivers in Møre and Romsdal in March 2010.

Cause of the floods:

The first rainfall event:

An anticyclone was located over Ireland and extensing a ridge with mild air to west Norway. North of this anticyclone a low was located south of Spitsbergen with a trough extending to Finnmark. Between the anticyclone and the low, mild airmasses was flowing toward the west coast of Norway, causing the first flood event this month. After the passage of the front, cooler air moved in from northwest, causing snow to accumulate in coastal catchment near the west coast of Norway. This event penetrated to coastal basins at Helgeland, but the floods were not the largest floods in 2010.

The second rainfall event

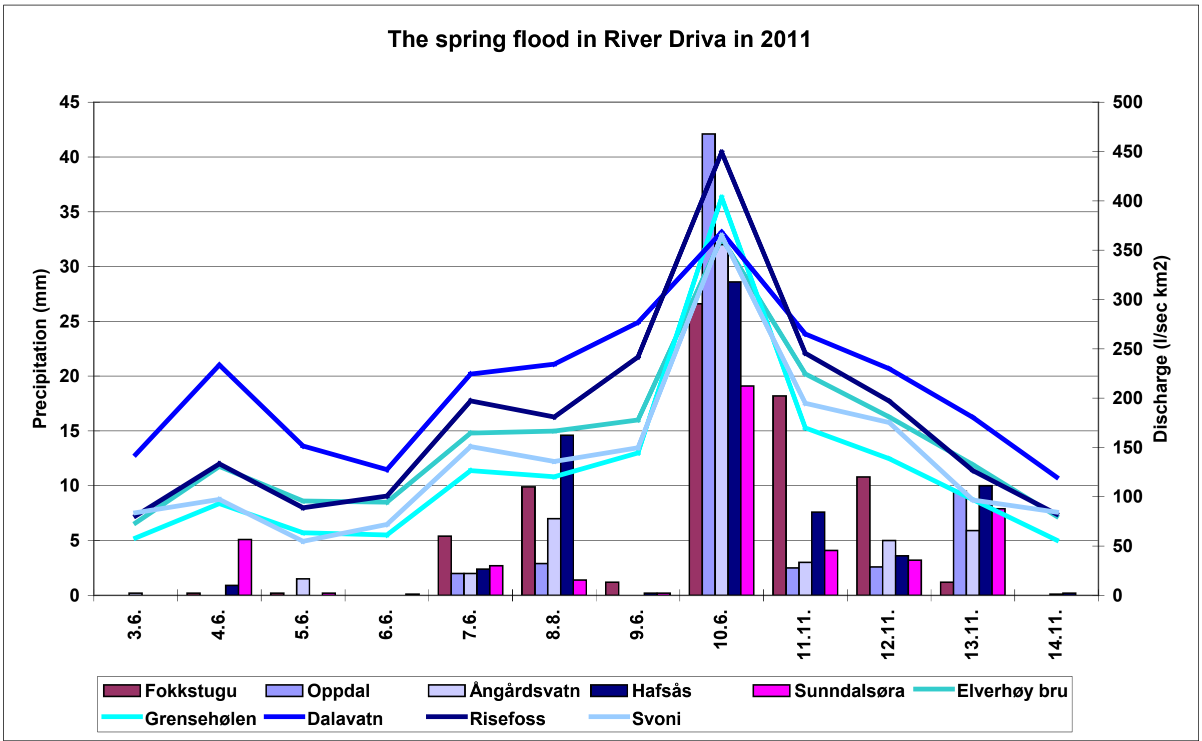
Between an anticyclone located over the Mediteranian ans another anticyclone located at the Atlantic west of the Iberian penninsula and a low located at the Norwegian Sea at the coast of Trøndelag with a through extending northward to Finnmark, a strong stream of mild air was moving in from the Atlantic from southwest. The second rainfall event did not cause largeflods in Trøndelag or Norlland.

Damages:

The heavy snowfall 15-19 March blocked all the major roads out of Møre og Romsdal. The ice jams blocked many roads as well as the railway line through Helgeland.

3.1.27 The severe spring flood in River Driva in 2011.

The severe spring flood that cauged severe damages in River Glomma in May 2011 extended also into River Driva, where the flood at 109.42 Elverhøy exceeded the previous flood record from 1932. Figure 3.1.27.1 show observed precipitation and discharge at gauging stations in the Driva catchment. The causes of the flood and the damages are descibed in Appendix B.



'Figure 3.1.27.1 Observed precipitation and discharge in River Driva during the severe spring flood in June 2011.

The flood was the second highest at 109.20 Grensehølen 1964-2014 and the fifth largest at Risefoss 1933-2014.

3.1.28 The severe flood in River Gaula at Holtålen 16 August 2011.

Heavy rainfall caused a severe flood in the upper reaches of River Gaula at Holtålen and floods in the Røros district 16 August 2011.

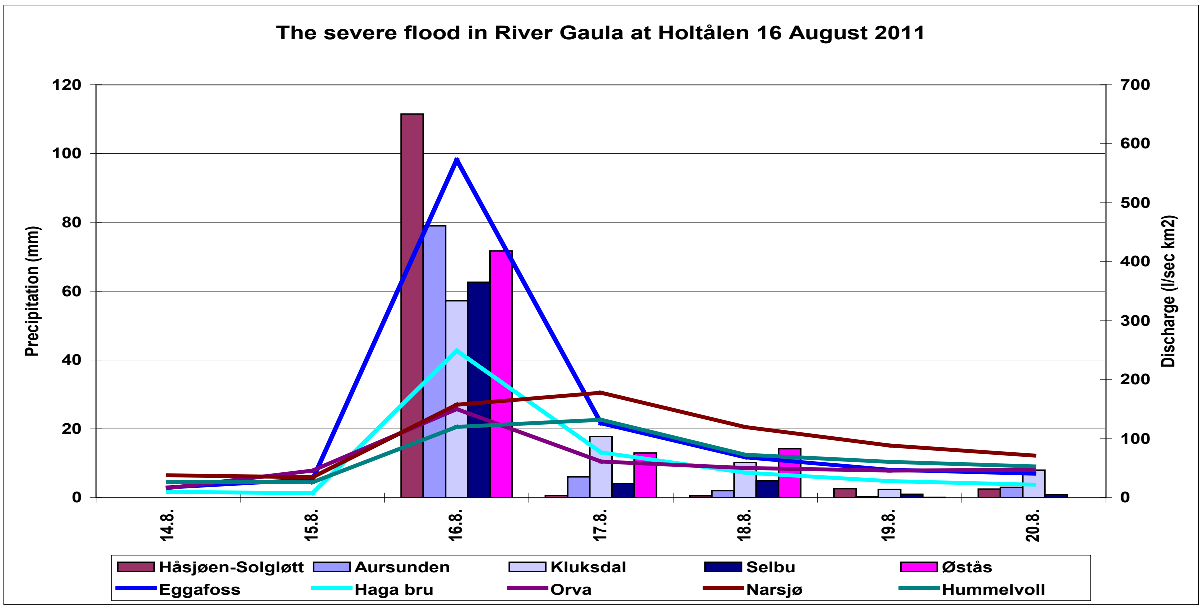


Figure 3.1.28.1 Observed rainfall and daily discharge during the large rainfall flood in River Gaula at Holtålen 16 August 2011.

Extension and ranks of the flood:

The flood was the largest observed at 122.11 Eggafoss 1941-2014. The levels during the extreme flood in August 1940 are known from surveying, and this flood may have exceeded the flood in 2011 at Eggafoss. Further downstream the flood was less severe. At 122.2 Haga bru the flood ranks as one of the largest 1912-2014 and at 122.9 Gaulfoss among the largest 1958-2014. Some of the tributaries to River Gaula had also floods such as River Bua at 122.14 Lillebudal bru 1963-2014. Some stations in the uppermost reaches of River Glomma had also smaller floods such as 2.269 Humelsvold 1962-2014, at 2.9 Narsjø 1934-2014 and at 2.626 Tunna 1991-2013.

Cause of the flood:

Initial conditions:

Transport of warm air from southeast caused intense local floods at Østlandet and at Nordfjord in June and July 2011. July 2011 was, however, dry in Trøndelag, and the discharge was below the normal. Some rainfall penetrated into Trøndelag in the first part of August causing the discharge to be close to the normal.

Most of Nord-Trøndelag had a large soil moisture deficit and a low ground water level, the conditions were normal further south and above the normal in the southernmost part in the Trondheim district and in the Orkla catchment 14 August.

The weather conditions:

15-16 August a front moved in from southeast over Østlandet and toward Trøndelag. The front weakened as it moved northward. When it reached Nord-Østerdal, the front was characterised as an old occluded front. The northward movement stopped for several hours. Strong convective cells started to develop on the cold front causing heavy rainfall in the upper reaches of River Trysilelv, River Glomma and River Gaula. High rainfall was also observed further north in River Stjørdalselv and River Verdalselv 16-18 August.

The rainfall started around 16:00 on Monday 15 August. The most intense rainfall fell during the evening. Figure 3.1.26.2 show observed hourly rainfall observed at the metstation Kotsøy downstream Eggafoss. The intensities were low around midnight but increased through the night and morning 16 August. The event lasted around 16 hours. The highest oneday rainfall was observed at the station Håsjøen-Solgløtt (111 mm). The station is located at the Glomma catchment southeast of Røros close to the water divide toward River Trysilelv. The observed oneday rainfall is close to the maximum rainfall observed at Atnasjø in August 1940 (116 mm) and to the rainfall observed at Folldal 28 July 1935 (125,5 mm).

The rainfall at the precipitation stations near Lake Aursunden was 50-80 mm, in the upper Gaula, Nea, Stjørdalselv and Verdalselv catchments 55-70 mm rainfall was observed. The distribution of the one-day rainfall 15-16 August 06:00 is shown in Figure 3.1.27.2.

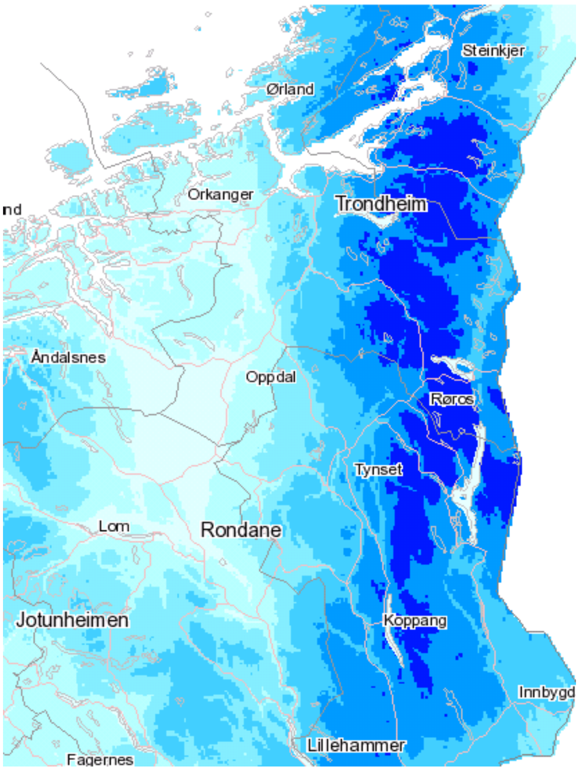


Figure 3 when the flood.1.27.2 Rainfall 16 August 2011.

Flood damages:

The flood inundated most of Ålen in Gauldalen. The railway line and two county roads were closed. Between 40 and 50 inhabitans were insulated in the village Aunagrend when the bridge was damaged. Five inhabitants were evacuated by helicopter. Camping sites and cabins were inundated and some cars taken by the river. The damages at Holtålen was estimated to 16 Mill. NOK.

3.2 Large floods in North Norway

3.2.1 The flood in Troms and Finnmark in June 1917.

The second largest flood at Finnmarksvidda occurred 13- 18 June 1917. Figure 3.2.1.1 show observed daily precipitation and discharge at the stations in Troms and Finnmark, which were in operation as early as in 1917.

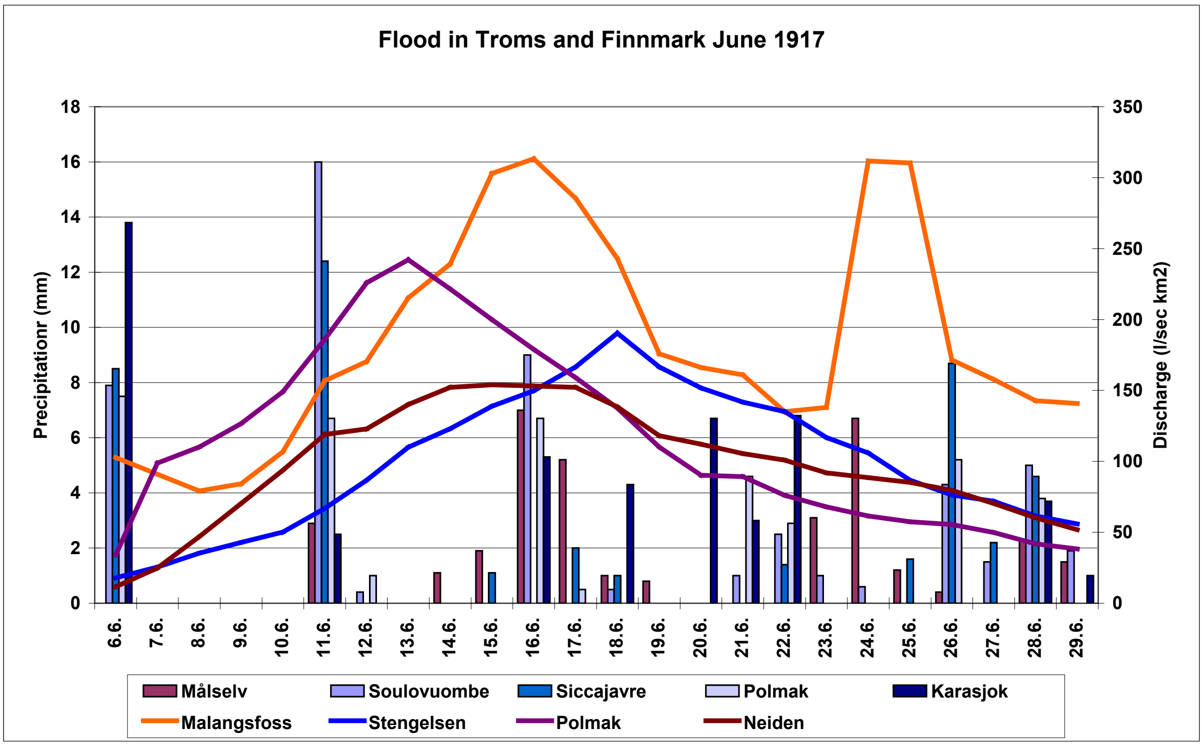


Figure 3.2.1.1 Observed precipitation and daily rainfall during the flood in Troms and Finnmark in June 1917.

Extension and ranks of the flood:

The flood was the second largest in River Alta at Stengelsen 1915-1969 and in River Tana at Polmak 1911-2013. In River Pasvikelv the flood was the sixth largest 1912-1960, in River Neidenelv the eight largest 1916-2013, in River Salongselv at Øvrevatn the tenth largest 1913-2013 and in River Målselv at Malangsfoss the sixth largest 1909-2013.

Floods occurred also in many rivers in Nordland. The flood was the second largest in River Lommerselv at Lake Storvatn 1916-1991 and in River Forså at Lake Leirpoldvatn 1916-2008. Elsewhere in Nordland the floods ranked between the sixth and tenth largest in 70 to 90 years.

Cause of the flood:

Initial conditions:

February to May had a large temperature deficit as shown in Table 3.2.1.1 lasting to the end of May. The melting starter when the teperature rose as milder air penetrated into Finnmark 2 June.

Table 3.2.1.1 Deviation from normal temperatures in Troms and Finnmark January-June 1917.

	Januar	Februar	Mars	April	Mai	June
Tromsø	-0,7	-2,7	-2,8	-2,7	-3,3	0,3
Alta	0,8	-3,2	-3,8	-3,4	-2,7	1,2
Karasjok	-1,2	-5,3	-7,0	-2,1	-3,2	1,5
Kirkenes	-1,7	-2,1	-3,5	-0,9	-2,3	0,3

Table 3.2.1.1 show moderate deviations from the normal monthly precipitation from January to April at most of the stations operated by met.no. May had a surplus in Troms and Pasvik, the other stations had a moderate deficit. The melting lasted through much of June, which had a surplus of precipitation in all the rivers except River Pasvikelv.

Table 3.2.1.2. Deviation from from normal precipitation (mm) in Troms and Finnmark January-June 1917.

	January	February	March	April	May	June
Målselv	4	8	-11	-4	24	21
Tromsø	33	-1	-52	-24	32	29
Alta	-1	13	6	16	2	40
Polmak	-1	-6	-10	9	-13	11
Karasjok	-7	-3	-2	2	-17	20
Kirkenes	5	30	-3	3	25	-20

Figure 3.2.1.2 show the snow depth at Sætermoen in Bardu (88 m.a.s.l) and at Polmak (25 m.a.s.l) in May. The snow had melted 4 June at Sætermoen and 5 June at Polmak. These two stations are both located at low levels, and snow remained at higher altitudes throughout most of the melting period.

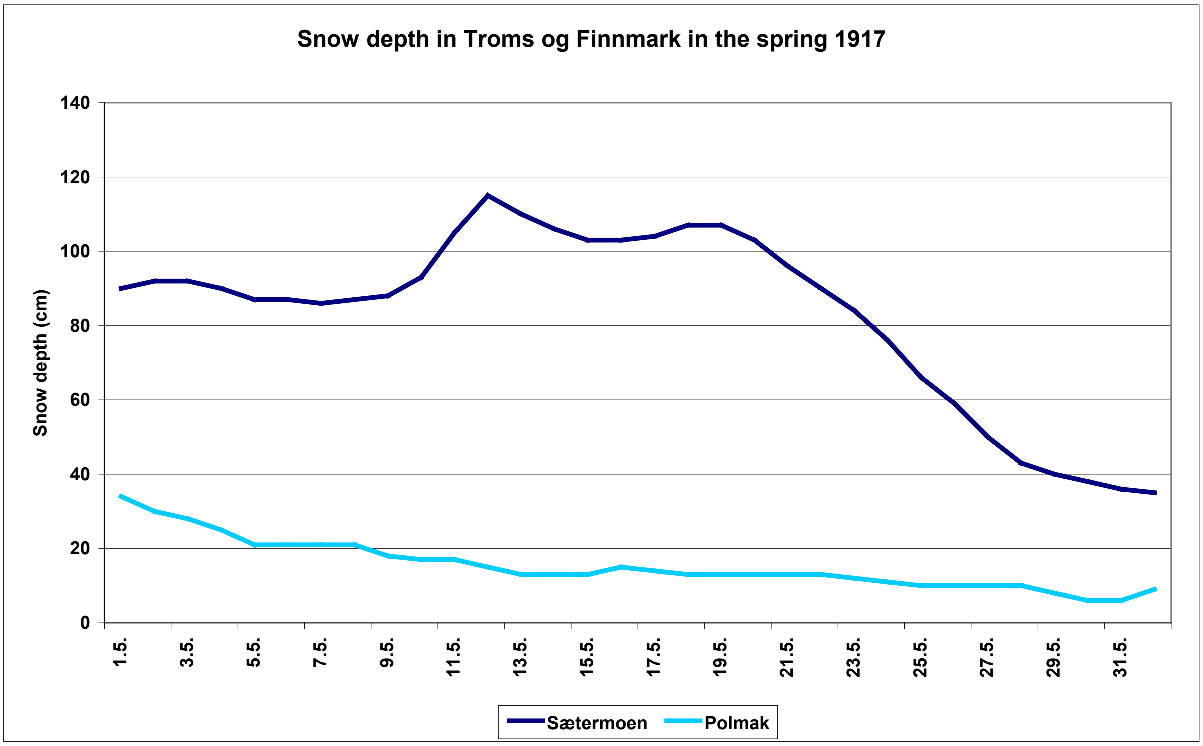


Figure 3.2.1.2 Observed snow depth at Sætermoen in Troms and Pasvik in Finnmark in the spring 1917.

The air temperature at Alta is shown in Figure 3.2.1.3. The temperature became positive from 19 May and rose gradually unto some warm days occurred 1- 4 June. This rise in temperatures was caused by a depression between Iceland and the coast of Norway kysten directing mild air masses towards North-Norway.Weather type: type: **HM** (Grosswetterlagen) and **W** (Lamb/Jenkinson).

After a temporary drop in the temperature, the rise in temperatures continued from 7 June. An anticyclonic ridge was situated from Finland toward the Baltic states and Scandinavia. A depression near Iceland moved toward the coast of Southern Norway. The weather type: **HFA** 7- 13 June and **HM** 14-18 June (Grosswetterlagen) and **AW/A** 8- 12 June, **S** 13 June and **ASW/A/W** 14- 18 June)

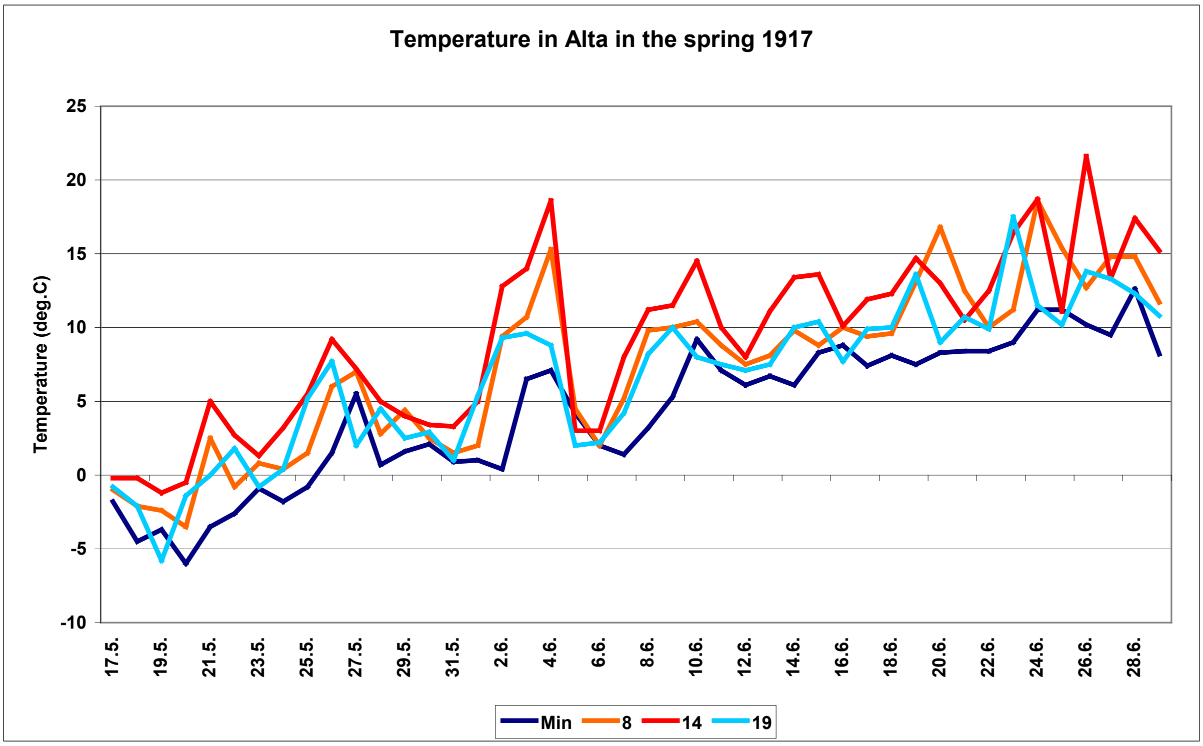


Figure 3.2.1.3 Observed temperature in Alta in the spring 1917.

3.2.2 A rainfall flood in coastal rivers in Helgeland in October 1917.

The autumn on the west coast of Norway was dominated by a stream of was m and humid air masses from the southwest Atlantic. A second depression caused heavy rainfall in two coastal rivers in Helgeland 3 October 1917. Observed discharge and precipitation are shown in Figure 3.2.2.1.

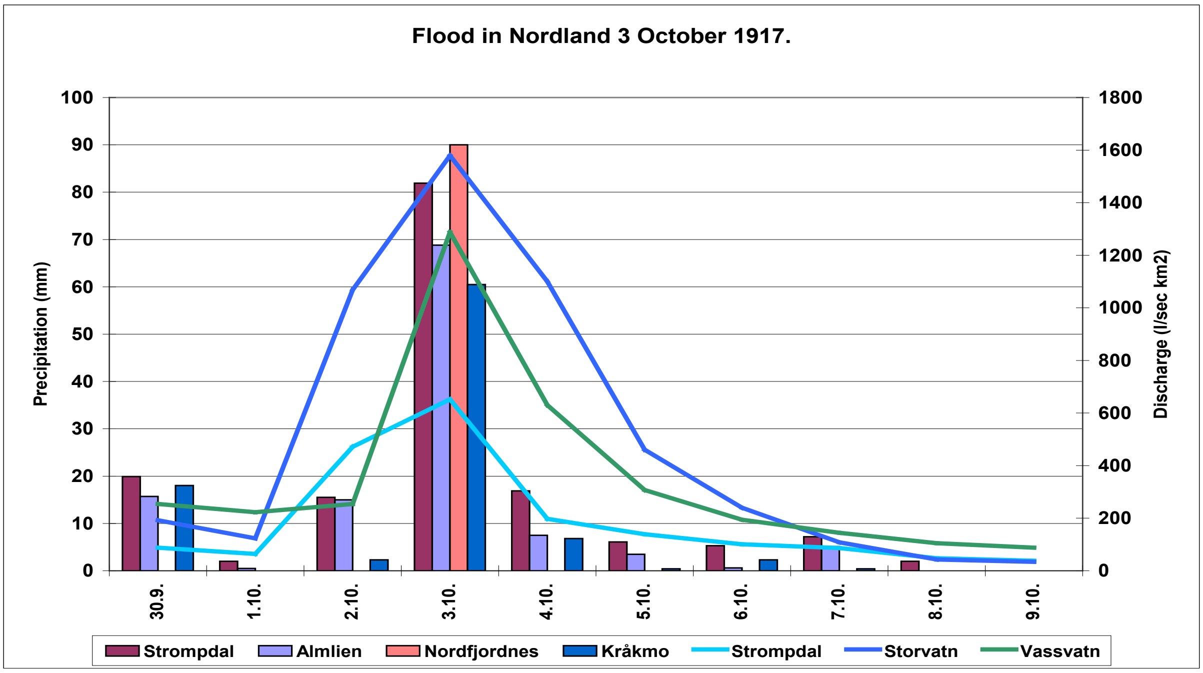


Figure 3.2.2.1 Observed precipitation and daily discharge during the flood in Nordland in October 1917.

Extension and ranks of the flood:

The flood was the second largest in River Leirelv at Lake Storvatn 1916-2007 and the largest in River Kjerringå at Lake Vassvatn 1916-2014.

Cause of the flood:

Initial conditions:

The maximum rainfall observed 3 October was 89 mm at Nordfjordnes at Helgeland. Prior to the flood a few cm of snow was present, but all had melted before the rainfall started. The weather types were **HM** (Grosswetterlagen) and **W** (Lamb-Jenkinson).

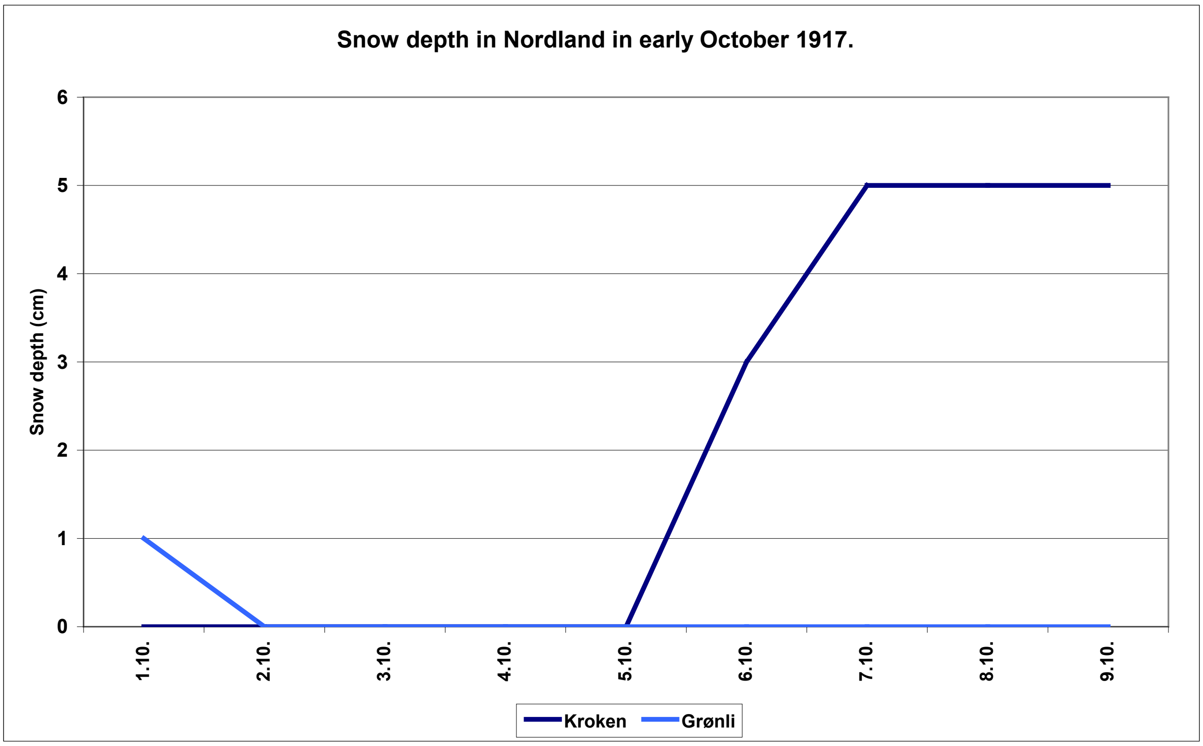


Figure 3.2.2.2 Observed snowdepths at Brønnøysund 1-9 October 1917.

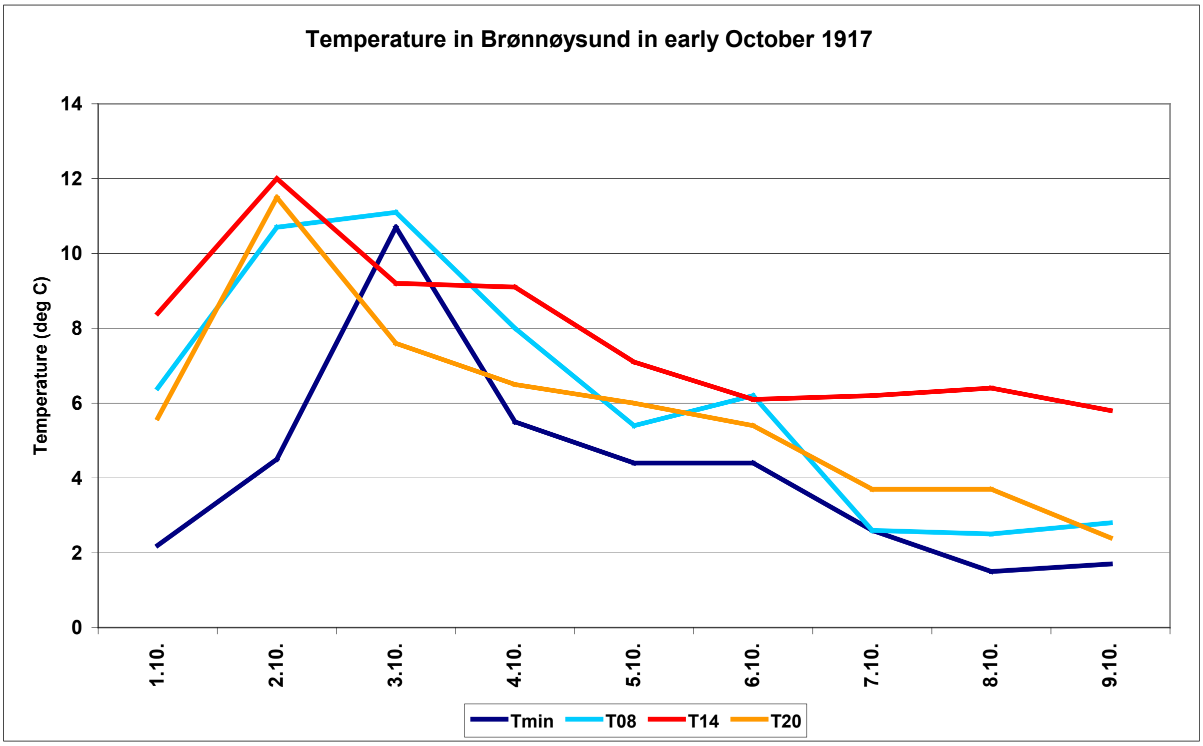


Figure 3.2.2.3 Observed air temperatures at Brønnøysund 1-9 October 1917.

3.2.3 The large snowmelt flood in Finnmark in 1920.

The largest flood observed in Finnmark was the spring flood, which culminated in River Tana at Polmak 21. May and in the other large rivers in Finnmark, such as River Alta, Neiden and Pasvik. The flood peaked at 3844 m^3/sec at Polmak, a discharge, which exceeds most of the largest floods in River Glomma. Observed precipitation and discharge is shown in Figure 3.2.3.1for stations in Troms and Finnmark. Floods occurred simultaneously in other Rivers in Nordland and in southern Norway.

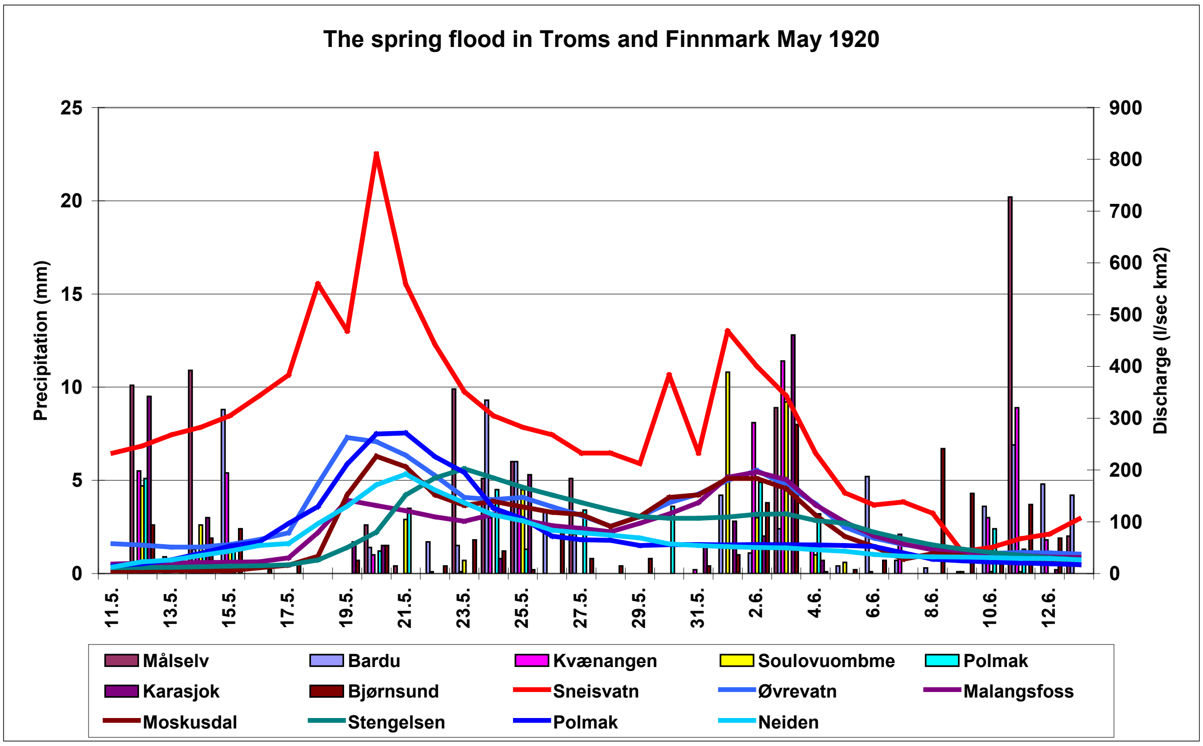


Figure 3.2.3.1.Observed precipitation and daily discharge in Troms and Finnmark during the large spring flood in May 1920.

Extension and ranks of the flood:

The flood was the largest observed in River Alta at Stengelsen since 1916, in River Tana at Polmak and in Neiden at Neset since 1912. The flood was the ninth largest 1907-1971 in River Pasvikelv. The flood was not among the largest in River Målselv at Malangsfoss, in River Salongselv at Vassås/Øvrevatn in Troms and in River Sneiselv at Sneisvatn in Nordland. The second largest spring flood in Finnmark was the flood in 1917, except in River Neiden where the flood in 1996 was second largest.

Cause of the flood:

While January had normal temperatures, the following months had a large surplus as shown in Table 3.2.3.1.

Table 3.2.3.1 Deviation from normal temperatures in Troms and Finnmark January-June 1920.

Station	January	February	March	April	May	June
Tromsø	-0,9	-1,6	3,4	2	2,9	0,1
Alta	-1,1	4	6,2	2,2	3,2	0,6
Karasjok	0,5	5,7	7,6	3,7	3,8	2,1
Kirkenes	-1	4,3	6,4	3,2	4,6	2,7

The precipitation in Troms and Finnmark was fairly normal except at Alta from February to April, at Målselv in February and March and in Tromsø in January as shown in Table 3.2.3.2.

Table 3.2.3.2 Deviation from normal monthly precipitation (mm) at stations in Troms and Finnmark firste halvår in 1920.

Station	January	February	March	April	May	June
Målselv	-16	41	20	-3	24	4
Tromsø	-73	-1	31	-38	5	-8
Alta	-11	34	20	31	5	0
Polmak	8	-16	5	6	4	-20
Karasjok	-6	1	9	0	2	-5

Figure 3.2.3.2 show snow depth at Sætermoen in Bardu (88 m.a.s.l) and at Polmak (25 m.a.s.l). The snow had melted at these lowlying stations when the flood started.

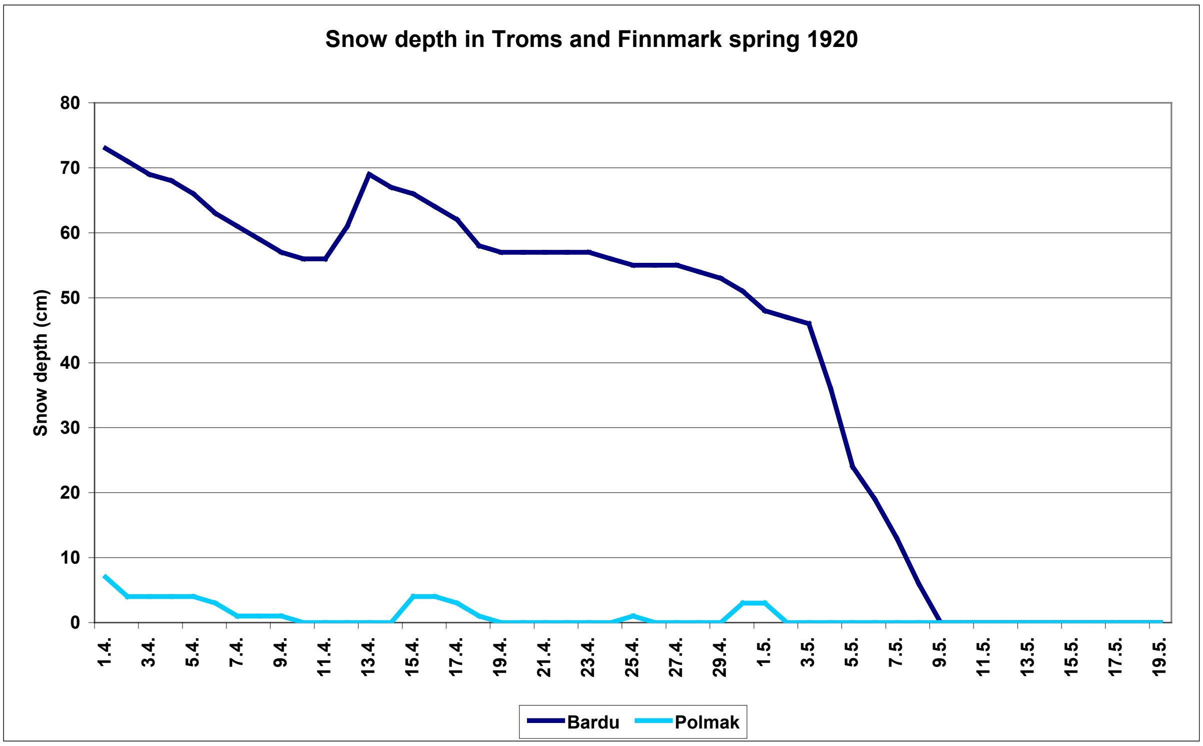


Figure 3.2.4.2 Observed snow depth at Bardu in Troms and Polmak in Finnmark in the spring 1920.

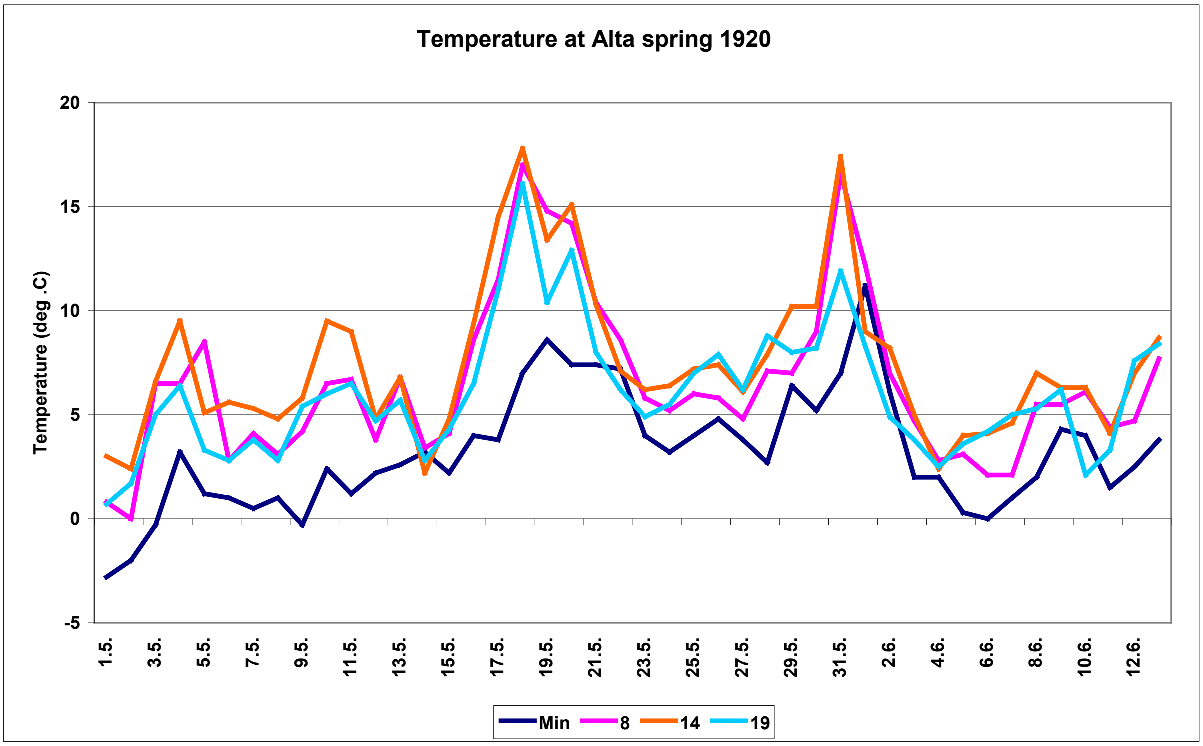


Figure 3.2.3.3

A large snow reservoir remained at higher altitudes in the catchments in inner Troms and at Finnmarksvidda. At Inset in Bardu (324 m.a.s.l) the snowdepth was 106 cm 1 May and at Sætermoen at Bardu 48 cm remained 1 May.

In Altaelva at Suolovombme (350 m.a.s.l) 120 cm snow remained and at Siccajavre (380 m.a.s.l) 90 cm snow 1 May. The snow cover lasted unto 19 May at Suolovombme and unto 17 May at Siccajavre. The average snow depth in May was 60 and 40 cm respectively at the two stations. In the Tana catchment at Levojok (70 m.a.s.l) 47 cm was still present 1. May. Only 2 cm remained at Karasjok (128 m.a.s.l) and all had melted 5 days later. In the Pasvikelva catchment at Bjørnsund (8 m.a.s.l) 46 cm remained 1. May. The snow cover lasted unto 13. May.

Figure 3.2.3.3 show observed temperature at Alta in the spring 1920. A pronounced heat wave from 15 to 23 May caused intense melting. The heatwave peaked 18 May. The flood was caused by snowmelt and culminated between17 and 23 May, as shown in Figure 1. A secondary warm period, culminating 31 May and followed by rainfall, but the resulting flood was minor as most of the snow had melted between 14–23 May and 31 May– 1 June. Between an anticyclonic ridge from the Azores toward Great Britain and extending eastward over the European mainland and depressions moving toward the Norwegian Sea from south of Iceland mild air masses were streaming toward Norway. The depressing strengthened on approaching the coast of Norway. Warm air came streaming from south-southeast toward Finnmark. The second period was caused by another depression from Iceland moving toward coast of Troms and Finnmark, with a front causing the rainfall in early June. The weather types were: **HNA** (15-18 May) and **WW** (19. -22 May) (Grosswetterlagen) and **A** (15 May), **C** (18 -19May) and **CW** and **AW** 20- 22 May (Lamb/Jenkinson).

3.2.4 The servere spring flood in River Saltdalselv 23 June 1922.

A severe flood occurred in Saltdal and at Saltfjellet in June 1922. Figure 3.2.4.1 show observed precipitation and discharge in River Saltdalselv and River Rana.

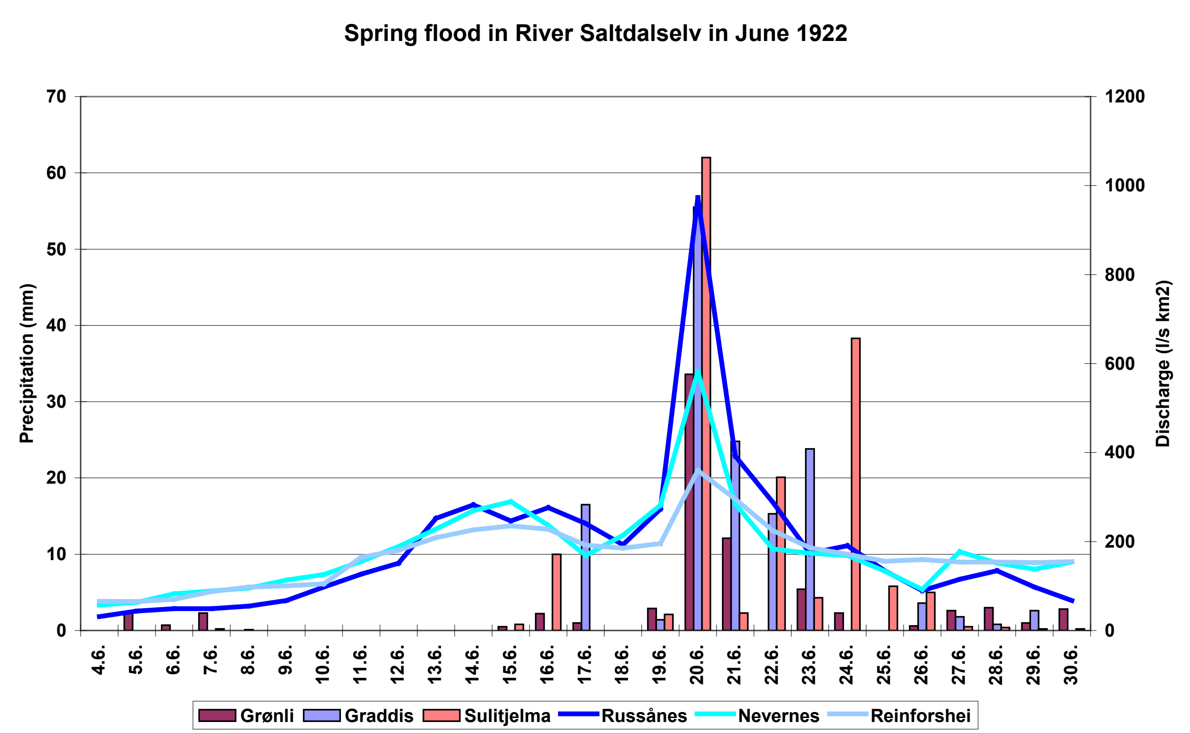


Figure 3.2.4.1 Observed precipitation and discharge (daily values) in Saltdal and Rana in late June 1922

Cause of the flood:

A widespread anticyclone was located at the Atlantic west of France. Another anticyclone was located across the Kola penninsula with a ridge extending to Spitsbergen. A low was located over Iceland setting up transport of warm air masses from southeast. A weak low was located over the Mediteranian with warm air masses penetrating toward Sweden and to Norwegian catchments near the border to Sweden. (A weak Vb-type).

The weather types were **NWA** (Grosswetterlagen) and **W** and **AW** (Lamb/Jenkinson).

Flood damages:

The flood caused damages in the valley next to River Saltdalselv.

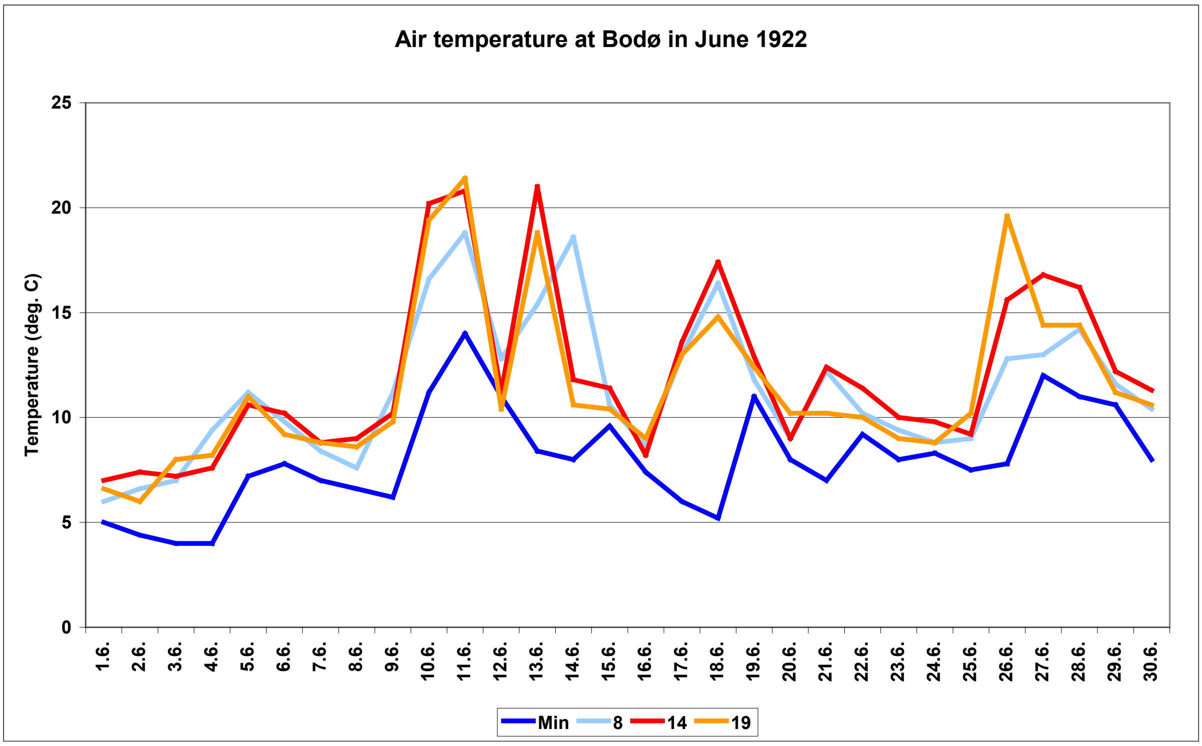


Figure 3.2.4.2 Observed temperatures in Bodø in June 1922.

3.2.5 A rainfall flood at Helgeland in July 1923.

The most frequent locations where intense showers were observed in Nordland, is at Strompdal in Brønnøy muncipality and at Lurøy in Lurøy muncipality. In July 1923, a large flood occurred in many mountain rivers on both sides of the water divide between East and West Norway Further north local rainfall caused large floods in rivers in the coastal maximum zone at Nordland.

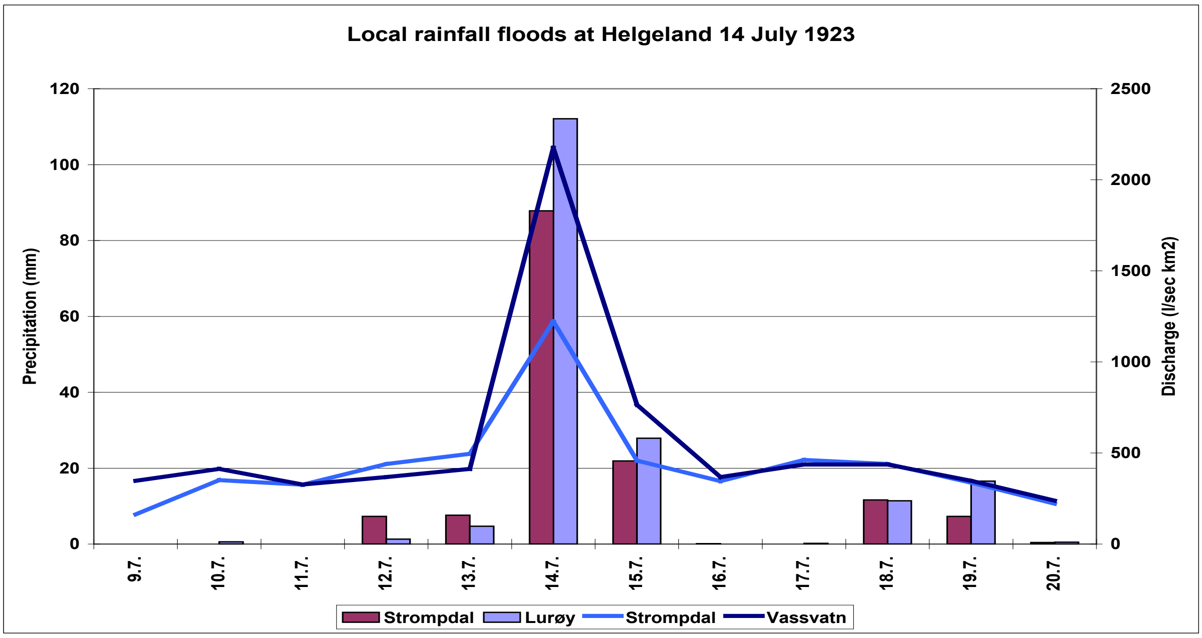


Figure 3.2.5.1 Observed rainfall and daily discharge at locations in the maximum precipitation zone in Helgeland in July 1923.

Extension and ranks of the flood:

The flood was the ninth largest at Strompdal 1908-1954 and the fourth largest at Vassvatn 1916-2007.

Cause of the flood:

Initial conditions:

An intense summer rainfall event caused large floods at Strompdal in River Lomsdalselv and at Vassvatn in River Kjerringelv. The temperatures fell as a cold front moved in from west as a depression moved toward Nordland fom the Norwegian Sea 13 July. The weather types were **HM** (Grosswetterlagen) and **A** (Lamb/Jenkinson).

3.2.6 A rainfall flood at Helgeland in October 1931.

In October 1931 a series of fronts moved from the Norwegian Sea over the coast of Helgeland. The heaviest precipitation fell 16 and 17 October. Figure 3.2.6.1 show daily precipitation and discharge at a number of stations.

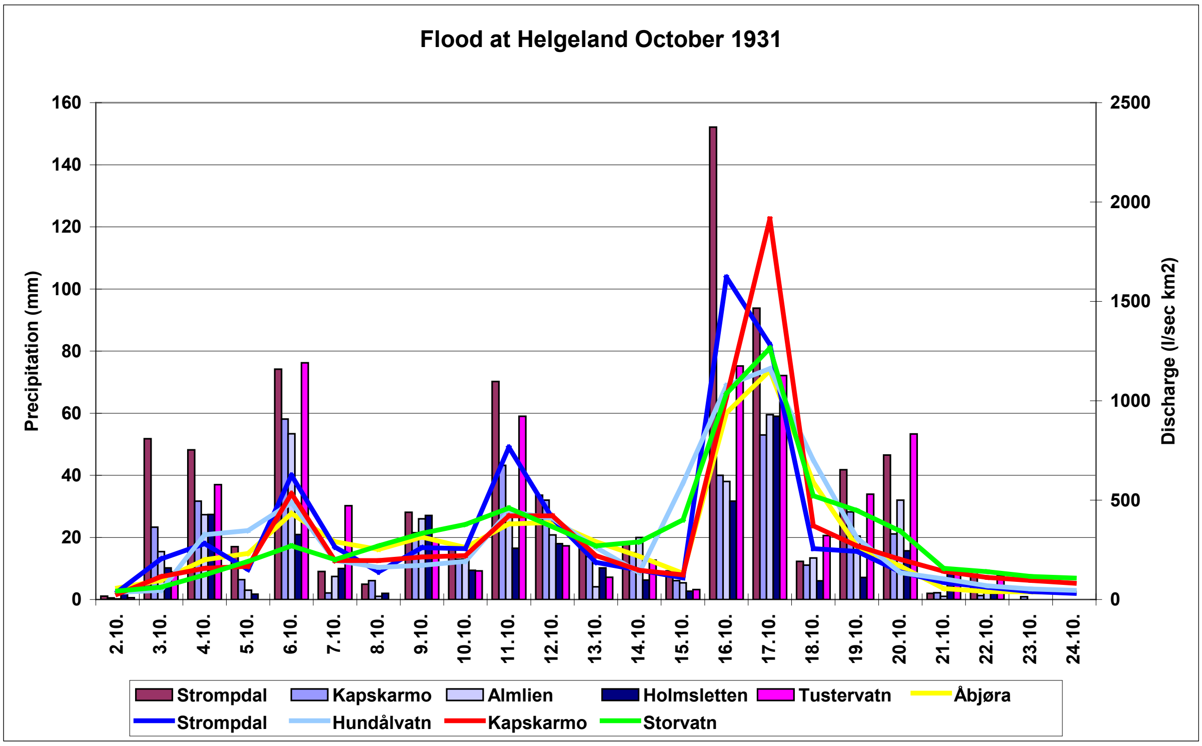


Figure 3.2.6.1 Observed rainfall and daily discharge during the flood in October 1931 in Helgeland.

Extension and ranks of the flood:

The flood was the largest in River Åbjøra 1908-2002, in River Vefsna at Kapskarmo 1915-2000 and the largest naturalised flood in River Rana at Nevernes 1908-1970. The flow was the second largest at River Lomsdalselv at Strompdal 1908-1954 and at River Fusta in Lake Fustvatn 1908-2002. In River Hundåla the flood was the fourth largest 1908-1962 and in River Beiarelv at Selfoss and in River Lakselv at Skarsvatn the sixth largest 1916-2014.

Cause of the flood:

Initial conditions:

Between an anticyclone over Central Europe and depressions near Iceland mild and humid air was streaming toward the west coast of Norway from southwest. Three fronts passed over the coast at Helgeland 2-17 October producing ample rainfall.
Weather types were **HB**/**HNA** (Grosswetterlagen) and **A** (Lamb/Jenkinson).

3.2.7 Winter flood in coastal rivers in Nordland in December 1932.

Heavy rain fell at the coast of Nordland 27 to 29 December 1932, causing floods from Velfjord to Tysfjord in coastal rivers. Figure 3.2.7.1 show observed precipitation and daily discharge during the flood. These floods were not among blant the largest in coastal rivers in Nordland in spite of a one-day precipitation of more than 160 mm.

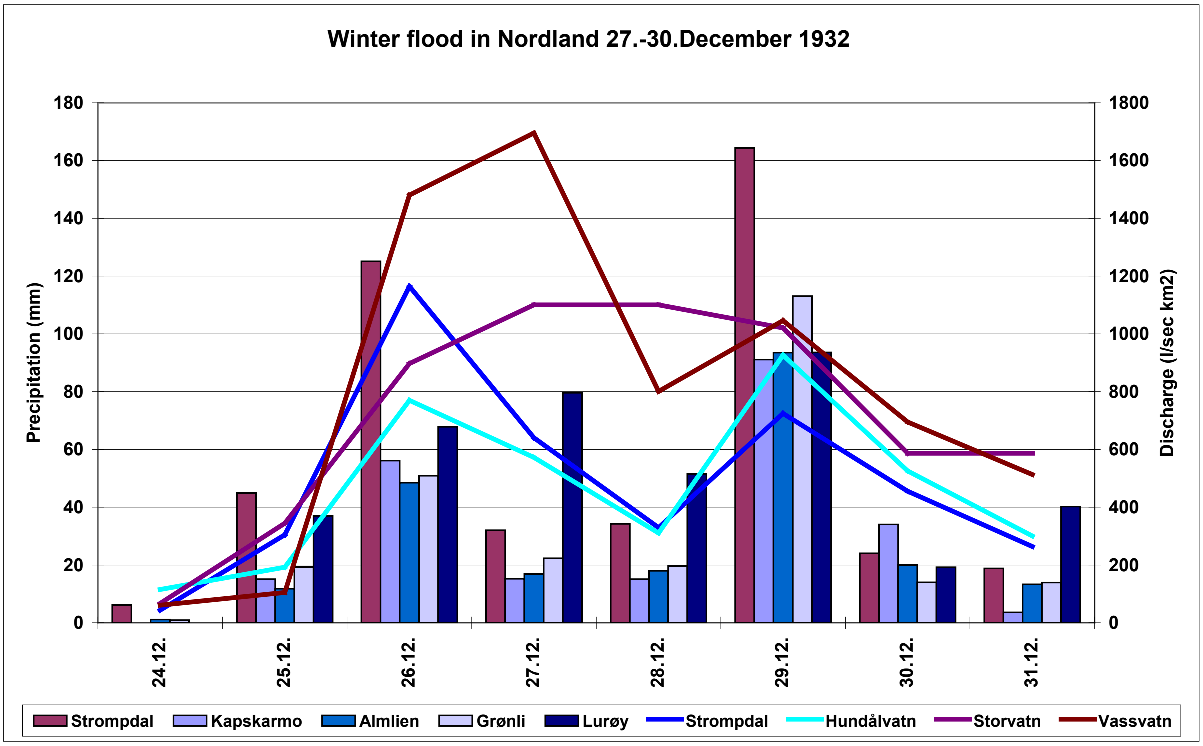


Figure 3.2.7.1 Observed rainfall and daily discharge during the flood in December 1932 in coastal rivers in Nordland.

Extension and ranks of the flood:

The flood was the fourth largest at 152.4 Fustvatn 1908-2014 and the tenth largest at 189.4 Skodbergvatn 1929-2014.

Cause of the flood:

Initial conditions:

December 1932 was extremely mild. The temperature surplus in Nordland was from 4,1 to 7,2°; further south at west landet from 1,6 to 3,4°. The precipitation in Nordland was from 42 to 152 mm above the normal in December. Further south from Trøndelag to Northfjord there was a deficit from17 to 76 % of the normal precipitation of December. Further south from Sunnfjord to Bergen was det et surplus of 24 to 94 mm above the normal on the coast and a deficit in the inner fjords. It was also a surplus in the precipitation in December at Rogaland and west -Agder.

The weather types were **HM** (Grosswetterlagen) and **SW/W** (Lamb/Jenkinson) 27-30 December.

3.2.8 The winter flood at Helgeland in February 1934.

From the end of January and during February 1934 mild weather and rainfall caused several short duration floods in coastal rivers at west landet and at Helgeland. Figure 3.2.8.1 show daily precipitation and discharge during a flood 2 February at Helgeland.

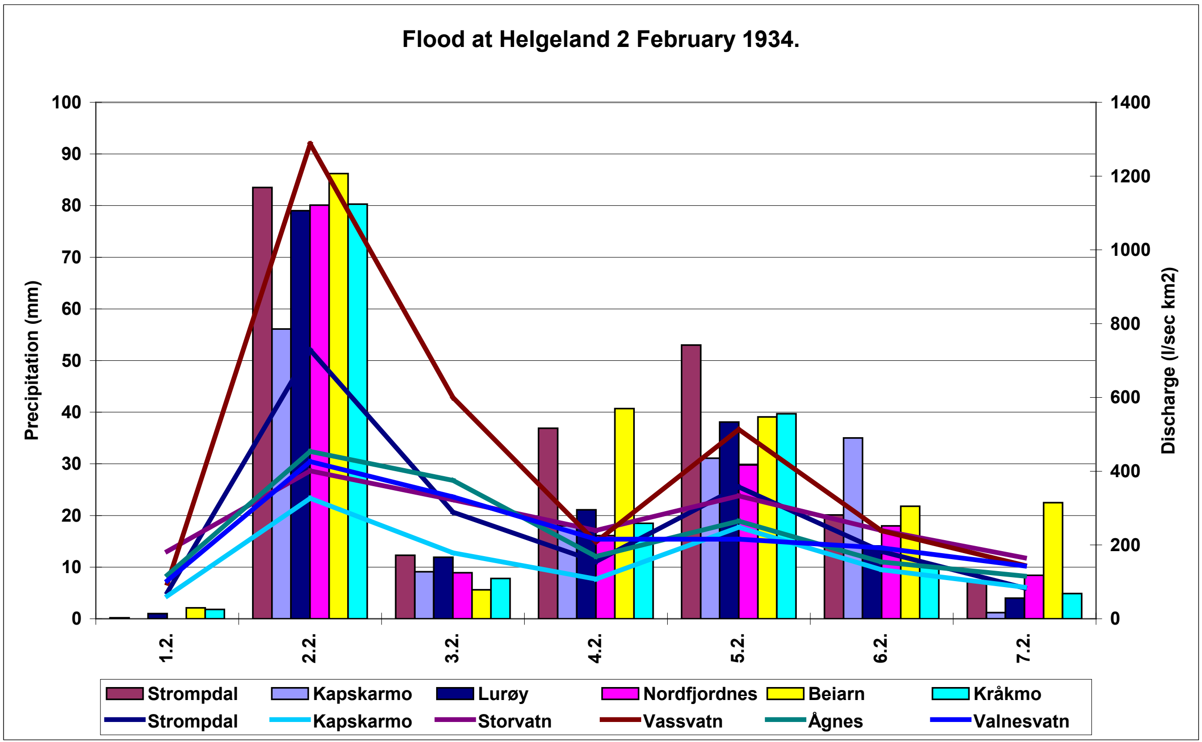


Figure 3.2.8.1 Observed precipitation and daily discharge during the flood at Helgeland in February 1934

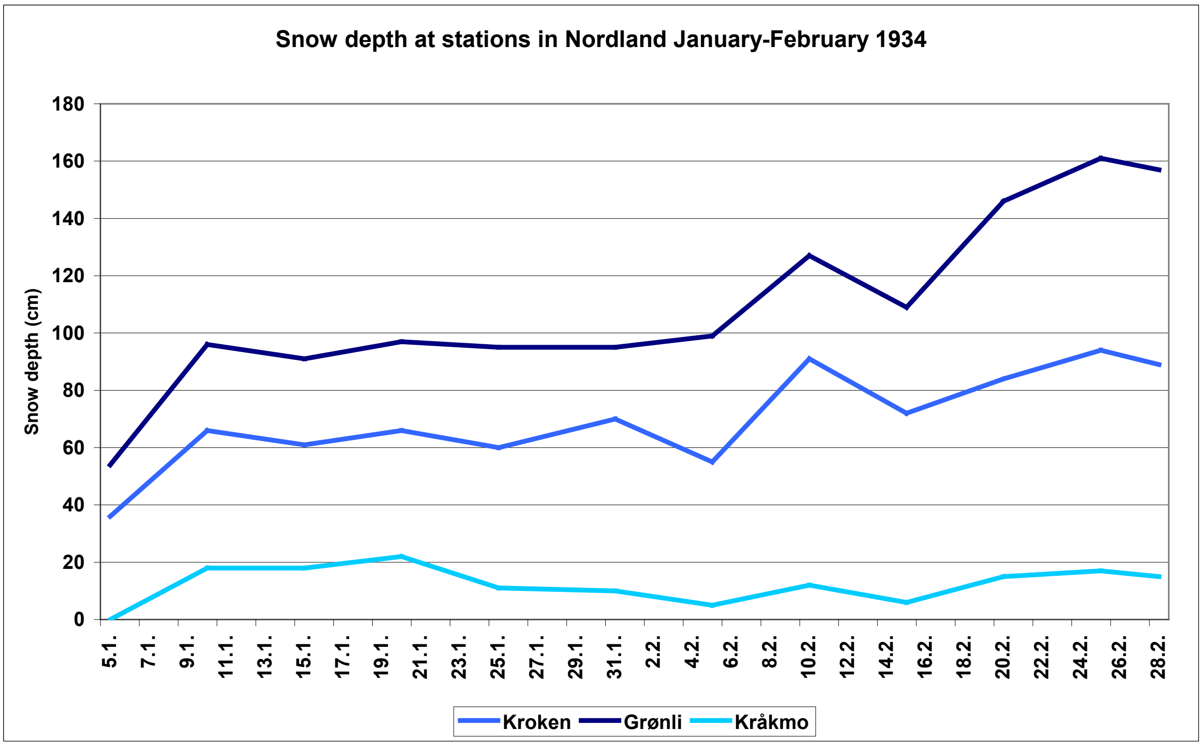


Figure 3.2.8.2 Observed snowdepth in Nordland in January-February 1934.

Extension and ranks of the flood:

The flood does not rank among the ten largest among the stations where floods were observed at Helgeland.

Cause of the flood:

Initial conditions:

An anti-cyclone extended from the Atlantic over Britain with a ridge over southern Scandinavia. Mild and humid air streamed from the Atlantic north of the ridge over Nordland from southwest. Several depressions moved toward Nordland causing several rainfall events on the coast. One of these depressions caused the rainfall on the 2 February.

The weather types were 1-2 February: **HB** and **BM** (Grosswetterlagen) and **A** (Lamb/Jenkinson).
The weather types were 6 February: **BM** (Grosswetterlagen) and **A** (Lamb/Jenkinson).

3.2.9 The spring flood in Nordland and Troms in June 1939.

The spring flood in 1939 was large both in mountain catchments in southern and northern Norway. The flood in North Norway occurred simultaneously in rivers from Saltdal in Nordland to Alta in Finnmark. Figure 3.2.9.1 show observed precipitation and discharge in rivers in Nordland and Troms.

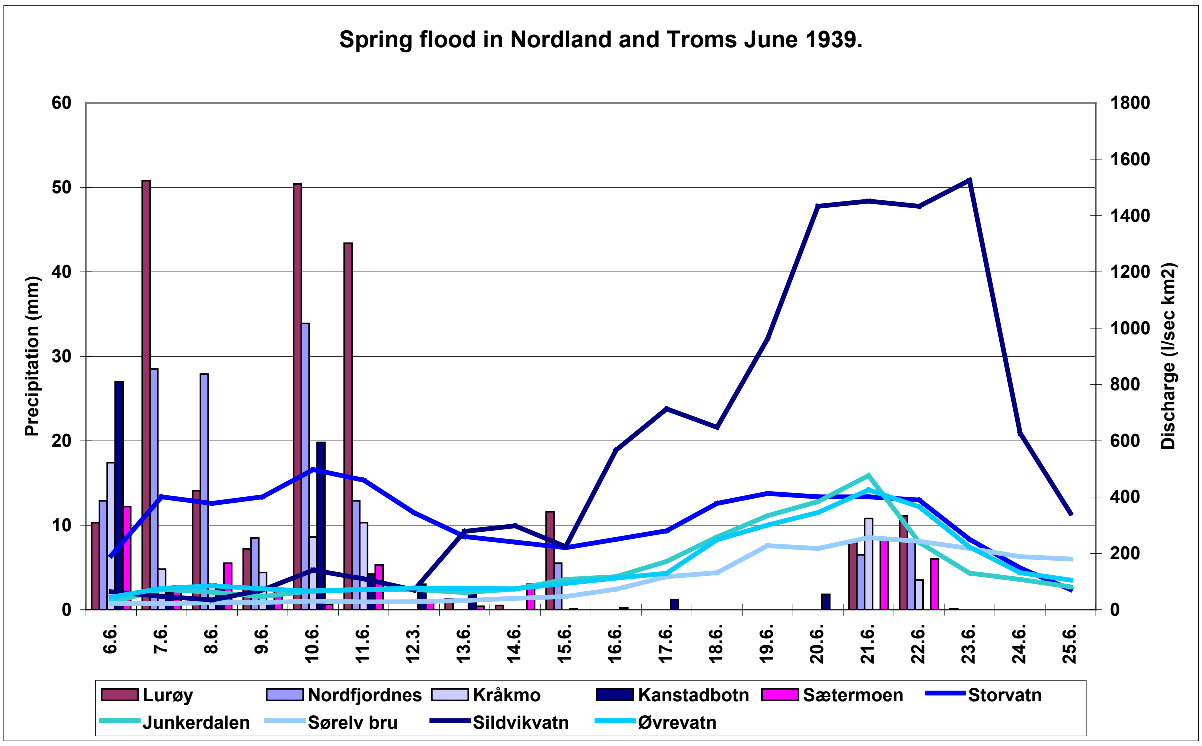


Figure 3.2.9.1 Observed precipitation and daily discharge in Nordland and Troms during the spring flood of June 1939.

Extension and ranks of the flood:

The flood was third largest in River Junkerdalselv 1937-2010, largest in River Kjårdaelv 1918-1939, fifth largest in River Skjoma 1918-1972, largest in Lake Sildvikvatn 1910-1979, fourth largest in River Salangselv 1912-2010, largest in River Målselv at Malangsfoss 1907-2010, fifth largest in River Kvænangselv 1927-1965 and second largest in River Eibyelva in Alta since 1920.

Cause of the flood:

Initial conditions:

Figure 3.2.9.2 show the depth of snow observed at four stations in North Norway. The temperature observed in Tromsø in June is shown in Figure 3. The early days of May were cold, and the temperatures started to rise above 0 degrees 6 May. The snow melt started om 7 May. The temperatures were comparative low throughout May, with some precipitation in most days from 11 May. This precipitation fell partly as snow or sleet. The intensity of the precipitation increased from 31 May, and most of the precipitation fell as snow until 4 June. From 6 June to 14 June the preciptation fell as rain.

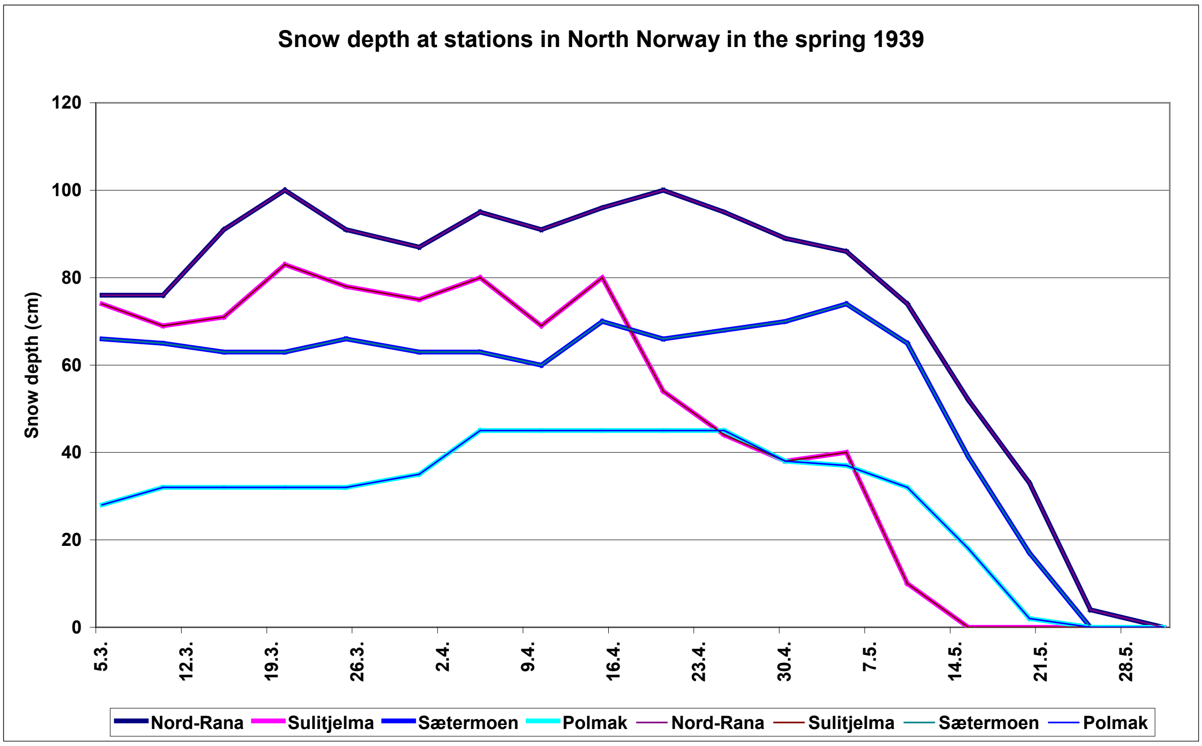


Figure 3.2.9.2 Observed snow depths in the spring 1939 at stations in Nordland, Troms and Finnmark.

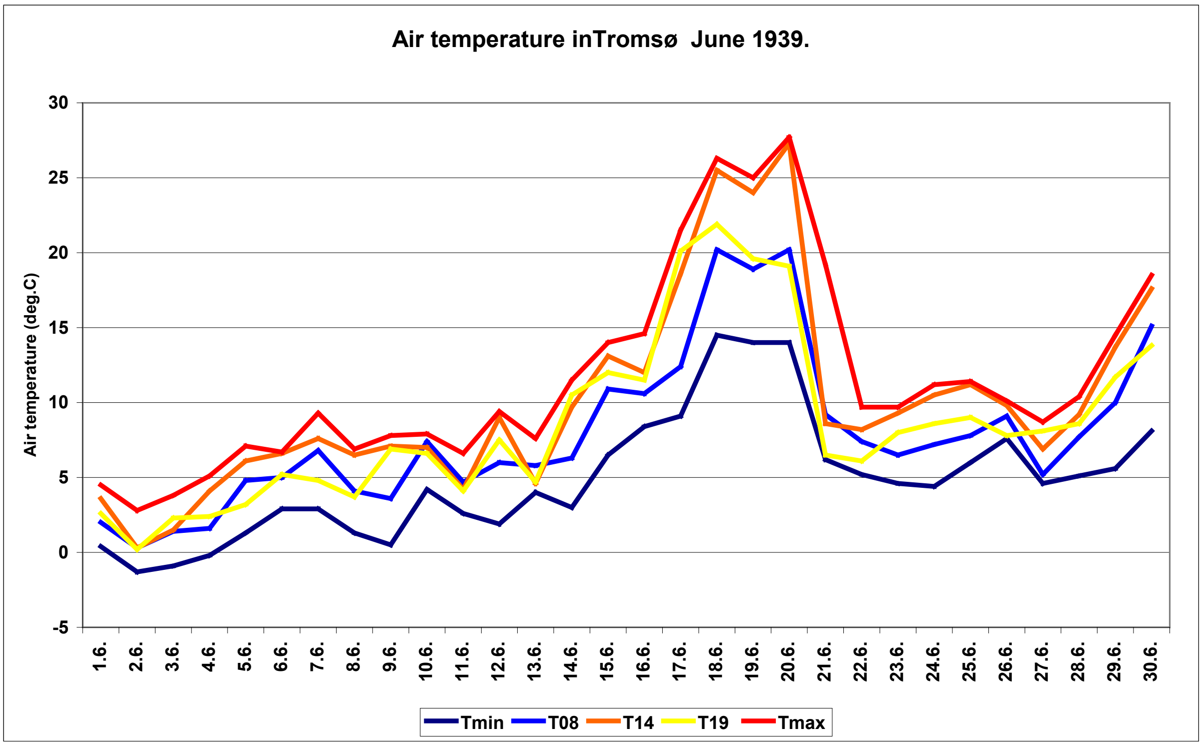


Figure 3.2.9.3 Observed air temperature at Tromsø in June 1939.

The flood:

The temperature started to rise 14 June and peaked in a heat wave 18-20 June causing intense melting of the remaining snow. The temperature dropped as a front with some precipation moved in 21 June terminating the flood.

3.2.10 A rainfall flood at Salten in Nordland in September 1939

A second flood occurred in the Salten district in September 1939. Figure 3.2.10.1 show daily precipitation and discharge during the flood.

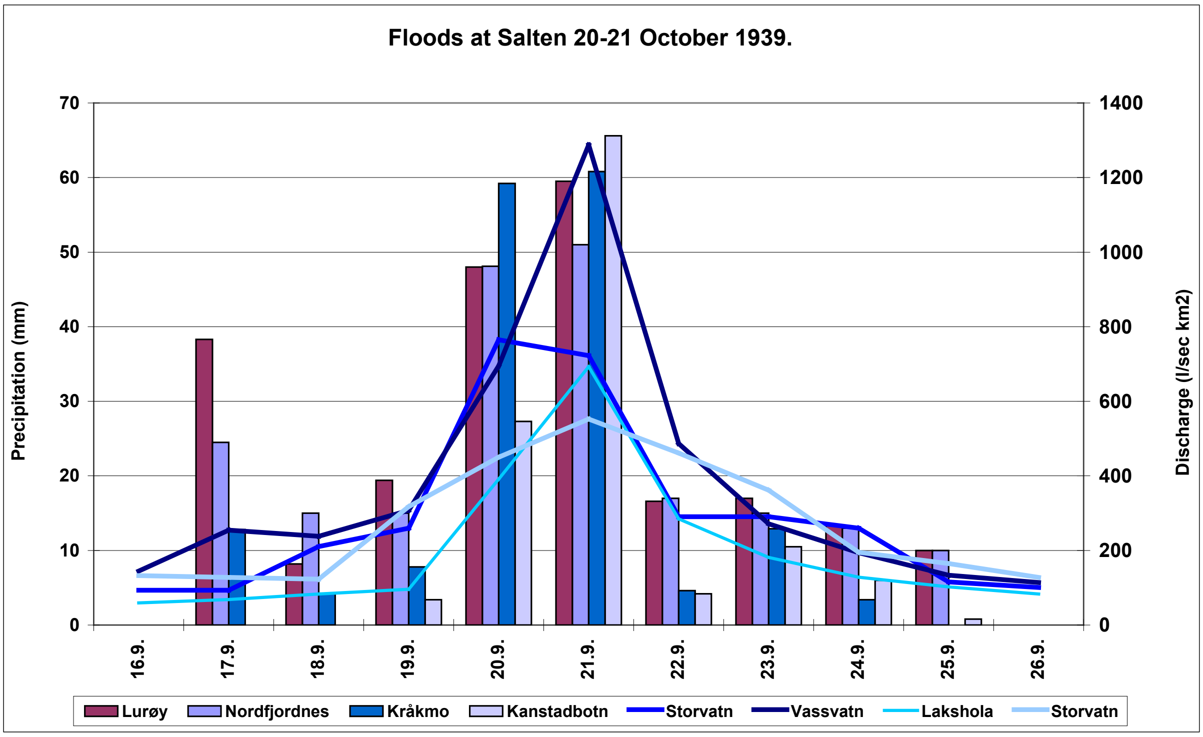


Figure 3.2.10.1 Observed rainfall and daily discharge during a flood at Salten in Nordland 20- 21 September 1939.

The flood did not rank among the largest floods this year as the spring flood in June exceeded the later rainfall flood.

Cause of the flood:

The flood was caused by rainfall. A strong anti-cyclonic ridge extended from the central Atlantic across Great Britain and Scandinavia toward the Kola Peninsula Northwest of this ridge da number of depressions in the Norwegian Sea set up a stream of maritime air masses from southwest toward North Norway. A front moved across Nordland and Troms 20 September. Behind the front the wind shifted to northwest. The weather types were **HB** (Grosswetterlagen) and **A** (Lamb-Jenkinson).

3.2.11 A rainfall flood at Helgeland in September 1942.

Some rainfall floods occurred in the late summer end early autumn 1942 in coastal rivers at Vestlandet and Helgeland. Figure 3.2.11.1 show observed daily rainfall and discharge for the flood at Helgeland 12 September.

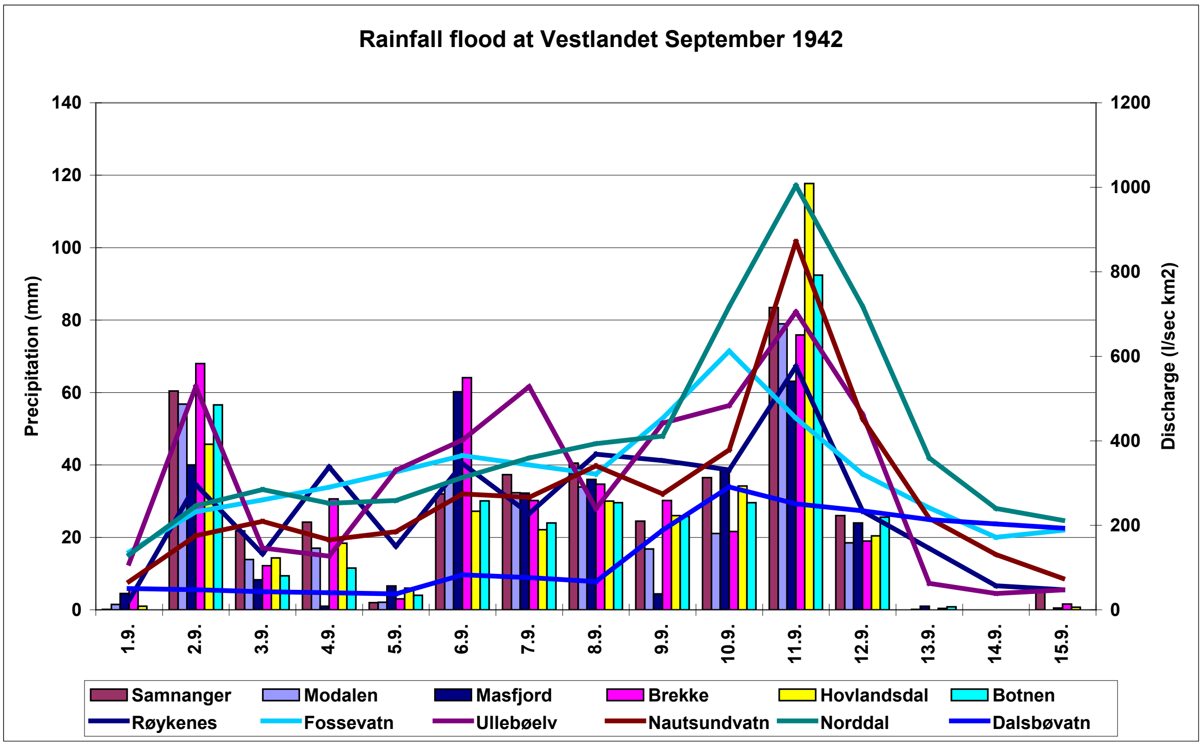


Figure 3.2.11.1 Observed precipitation and daily discharge at Helgeland in September 1942.

Extension and ranks of the flood:

None of the floods are among the largest observed in the coastal rivers at Helgeland in spite of a one-day rainfall of 154 mmm at Nordfjordnes and 145 mm at Lurøy

Cause of the flood:

Initial conditions:

The flood was a typical rainfall flood occurring after some days with moderate rainfall raising the ground water content prior to a frontal passage with intense rainfall. Figure 4 show daily weathermaps for 15– 20 August and Figur 5 for 9– 14 September 1942. An anti-cyclonic ridge extended from Russia across Central Europe and Great Britain and into the Atlantic south of the Icelandic depression.in August. Maritime air masses were streaming from southwest towards the coast of Norway. The depression over Iceland moved eastward to a location north of Scotland setting up a stream of humid air from south over Vestlandet. The weathertypes 15-20 August were **HM** (Grosswetterlagen) and **SW** and **S** (Lamb/Jenkinson)

The flood in September:

An anti-cyclone was located across Great Britain and the European Mainland. Northwest of the anticyclone maritime air masses were streaming toward the Norwegian coast. A depression moved over Lofoten 11 September. An associated front caused the heavy rainfall during the night of 12 September. The wind shifted to northwest and increase to gale force after the passage of the front. The weather types were **BM** (Grosswetterlagen) and **A** (Lamb/Jenkinson)

3.2.12 A rainfall flood in Nordland in October 1945.

Intense rainfall caused floods in some coastal rivers in Nordland 3–4 October 1945. Figure 3.2.12.1 show observed daily precipitation at selected stations in the district.

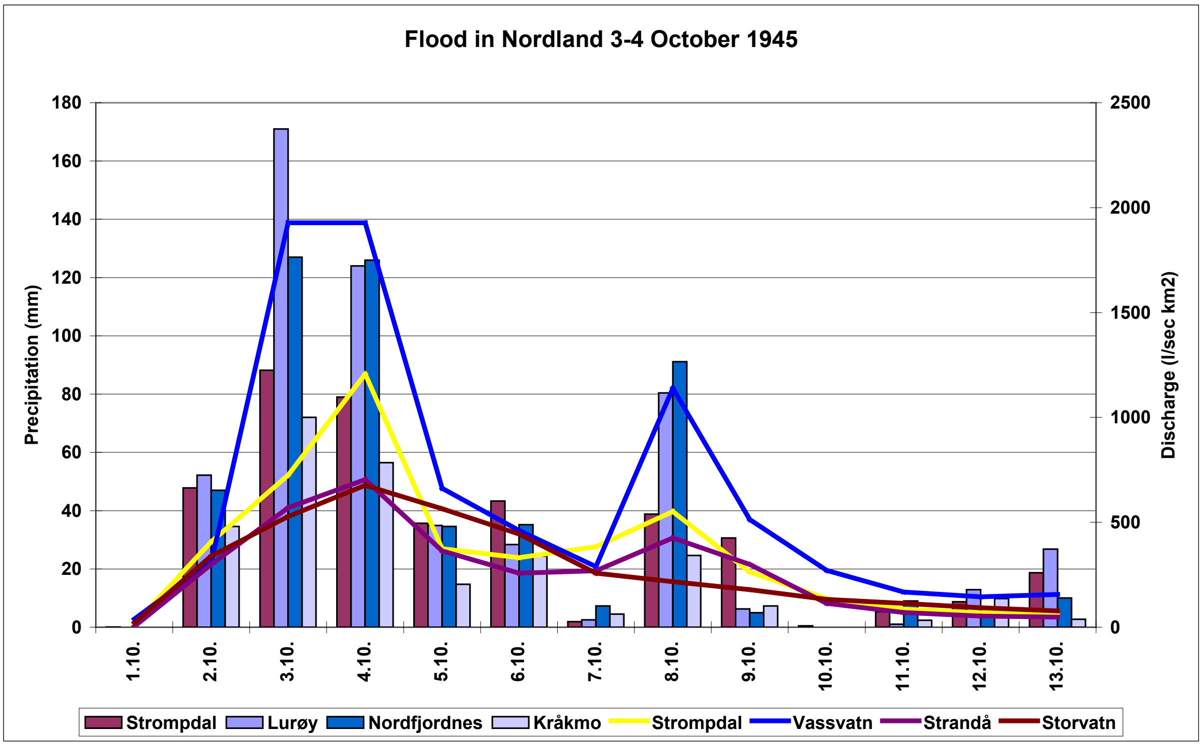


Figure 3.2.12.1 Observed precipitation and daily discharge during a rainfall flood in Nordland in October 1945.

Extension and ranks of the flood:

The flood is ranked as the tenth largest in 45 years at Strompdal, the eight largest since 1916 at Vassvatn, the sixteenth largest since 1916 at Strandå and the largest since 1916 at Storvatn.

Cause of the flood:

The flood was caused by the intense rainfall easpecially in rivers west of Svartisen glacier. The precipitation turned into snow at several of the stations from 10 October.

An anti-cyclonic ridge extended from Great Britain across southern Norway, Sweden, Finland and toward the Ural mountain in Russia 2-5 October. Maritime air masses were streaming from the central Atlantic toward the coast of North Norway from west and north of the anti-cyclonic ridge. The heavy rainfall was caused by a frontal passage linked to a depression near the coast of Nordland and Troms.

The weather types were: **HB** (Grosswetterlagen) and **SW/W** (Lamb/Jenkinson)

3.2.13 The rainfall flood at Helgeland in October 1949.

Heavy rainfall occurred at Helgeland 14-15 October 1949 and caused a severe flood at Lake Vassvatn in Lurøy and large floods in several other rivers, as shown in Figure 3.2.13.1.

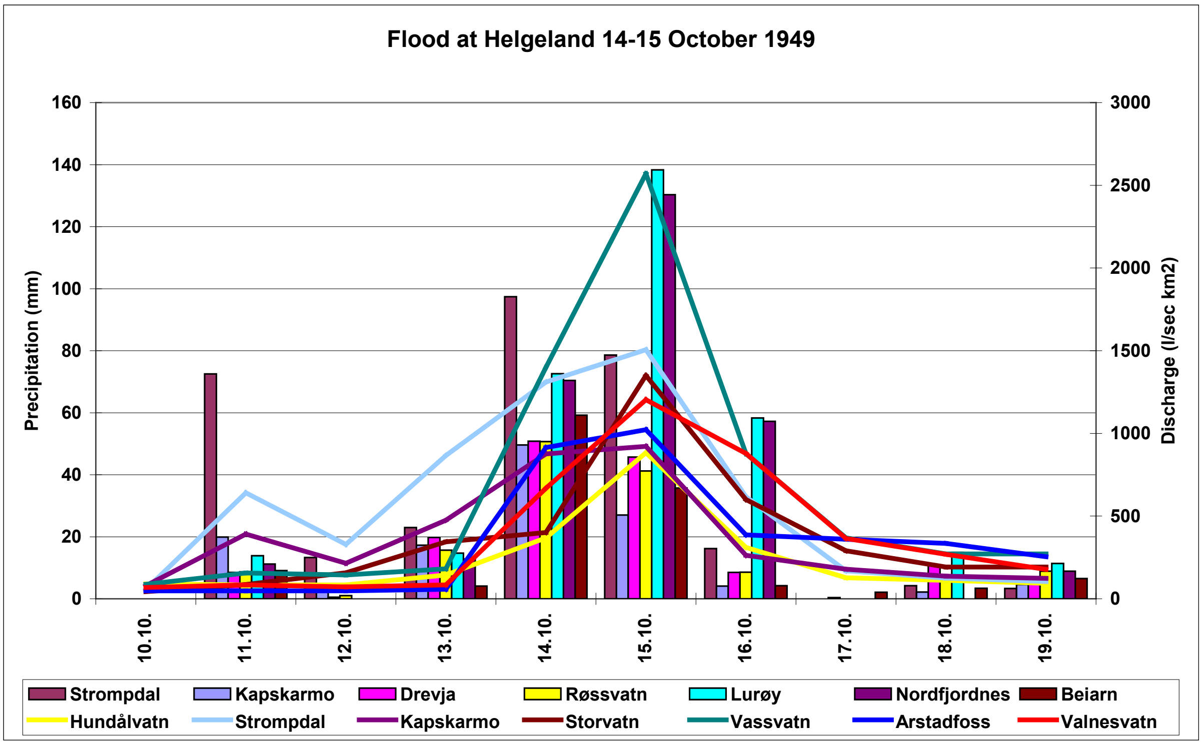


Figure 3.2.13.1 Observed precipitation and daily discharge at Helgeland during the rainfall flood in October 1949.

Extension and ranks of the flood:

The flood was third largest in River Leirelva at Lake Storvatn 1916-2013, second largest naturalised flood in River Rana at Nevernes 1908-1970, largest flood in River Kjerringå at Lake Vassvatn 1916-2007, third largest flood i Beiarelv at Arstadfossen 1916-1963, fifth largest flood in River Lakselv at Valnesvatn 1912-2013 and at Skarsvatn 1916-2013.

Cause of the flood:

Between a depression south of Cape Farvel and an anti-cyclone extending across the European Mainland most of Norway enjoyed a spell of warm air. The polar front crossed Helgeland 14-15 October with heavy rainfall causing the flood. The weather types were: **SWA** (Grosswetterlagen) and **S/SW** (Lamb/Jenkinson).

3.2.14 A flood in Nordland 1 February 1958.

Mild weather moving in from southwest towards Nordland countycaused a local flood in coastal basins at Salten. Figure 3.2.14.1 show daily precipitation and discharge at stations affected by the event.

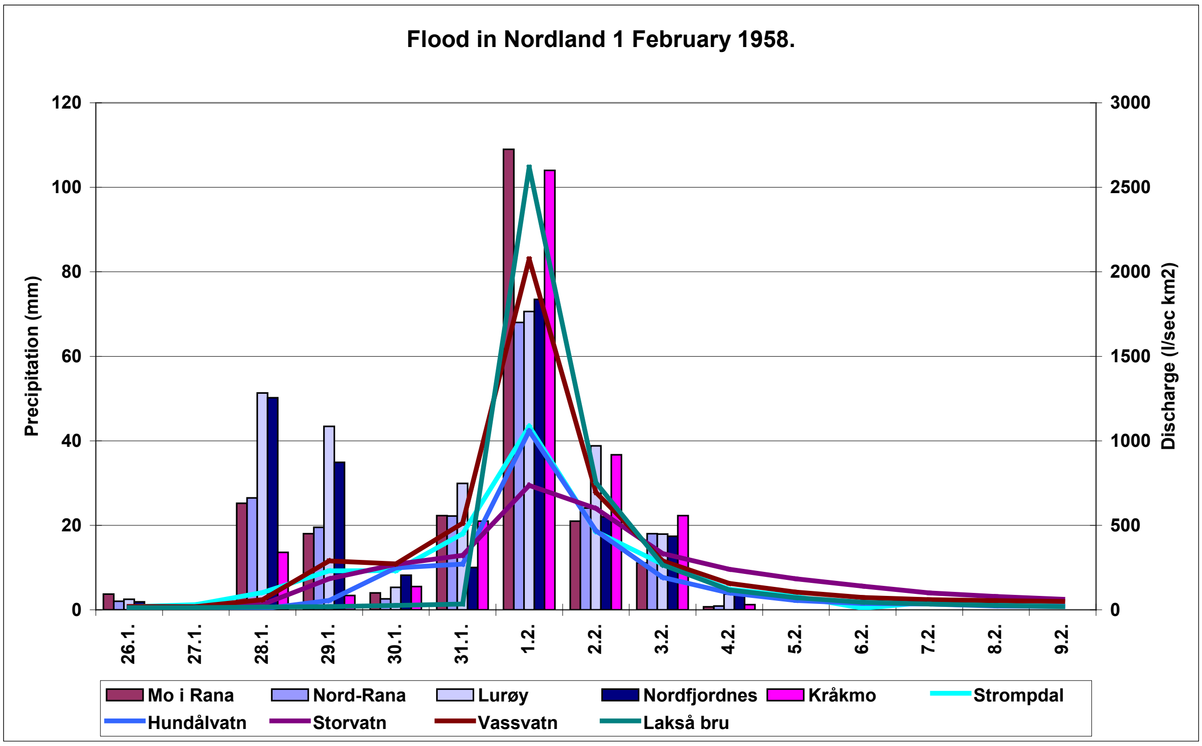


Figure 3.2.14.1 Observed precipitation and daily discharge in Nordland 1 February 1958.

Extension and ranks of the flood:

The flood was the fifth highest at 157.3 Vassvatn 1917-2007 and the third highest at Lakså 1953-2008.

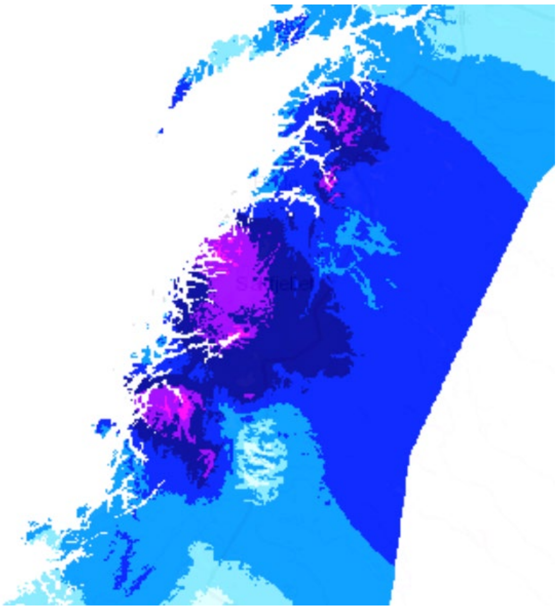


Figure 3.2.14.2 The distribution of the precipitation 1 February 1958 in Nordland.

Cause of the flood:

The weather types 31 January and 1 February were **HM** (Grosswetterlagen) and **W** and **AW** (Lamb-Jenkinson).

3.2.15 The severe rainfall flood in Salangen in October 1959.

Some heavy rainstorms can penetrate into the southern part of Troms, causing occasional floods, which are among the largest observed floods in the county. Further north snowmelt is the dominating cause of floods. The rainfall floods are caused by transport of varm and humid air masses from south-southwest. These rainstorms cause also large floods in rivers in the northern part of Nordland. The flood 6-7 October 1959 is an example of this type of floods. The flood was most severe in the inner districts from Ofoten to River Målselv. Figur 3.2.15.1 show observed daily precipitation og discharge at selected stations in the district. The distribution of the rainfall 6 Octber 1959 is shown in Figure 3.2.15.2.

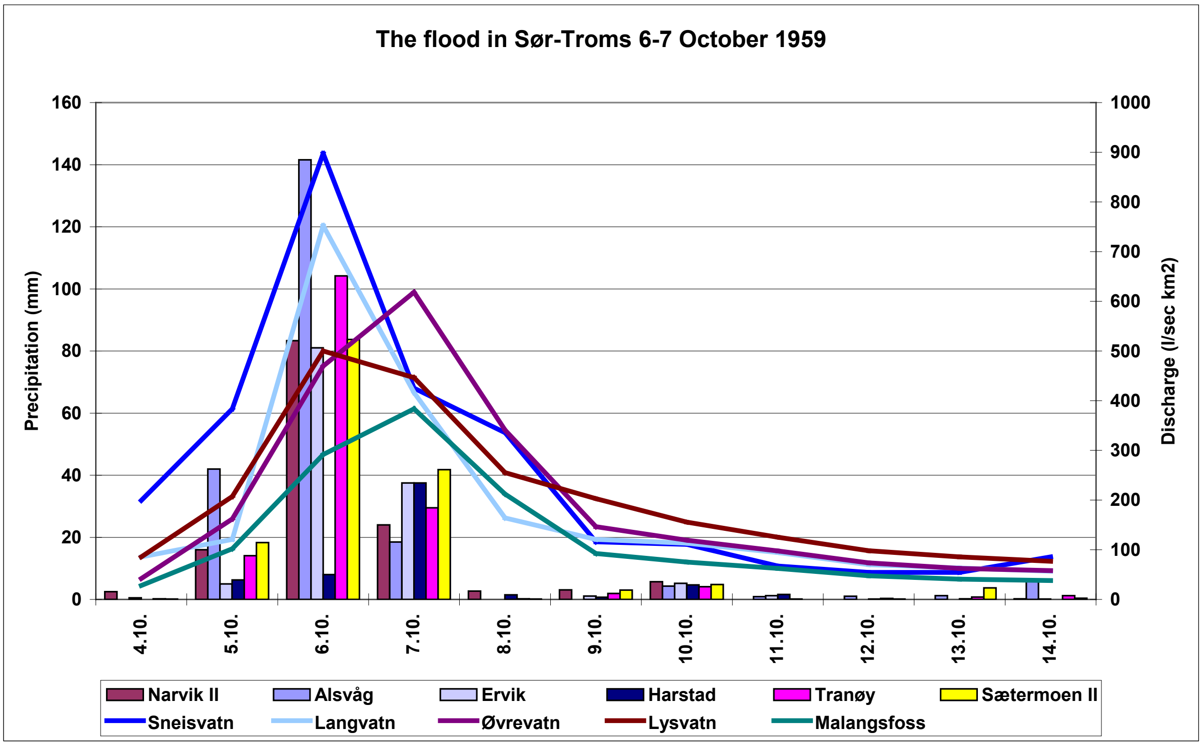


Figure 3.2.15.1Observed precipitation and daily discharge during a flood in Sør-Troms in 1959.

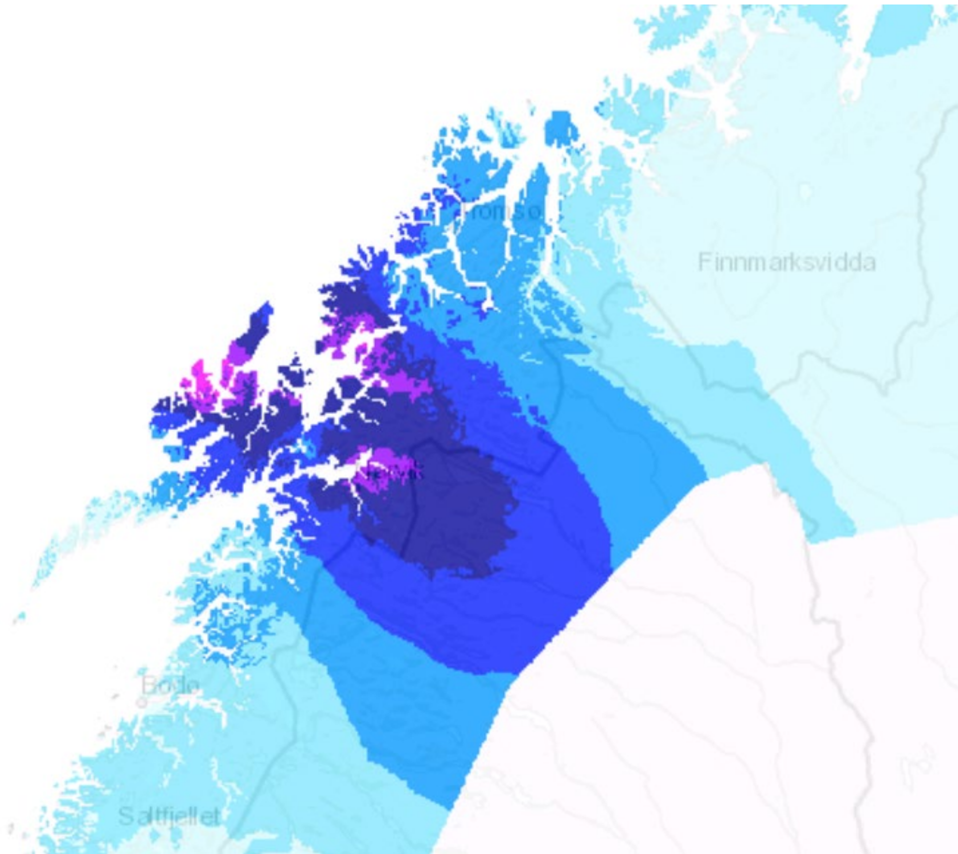


Figure 3.2.15.2 The distribution of the rainfall in Troms and Salten 6 October 1959.

Extension and ranks of the flood:

The flood is the second largest observed in River Salangselv at 191.1/2 Vassås/Øvrevatn 1916-2014. the largest naturalised flood in River Målselv at 196.3 Malangsfoss since 1930. In River Skjoma the flood destroyed the gauging station Gamnes, where the discharge was by far the largest since 1913. The rank of the flood is lower at other stations. The one-day rainfall of 142 mm which was observed at Alsvåg during the flood is the sixth largest which is observed in the district.

Cause of the flood:

The source of several rivers in Troms reaches altitudes around 1300 m.a.s.l. Some snow can therefore be present in the upper parts of the catctchment, but this was not the case in early October 1950, as no snow was observed at any of the stations in the region. The flood was therefore a rainfall flood. Weather maps show that a warm anticyclone was located over Skandinavia, while cold airmasses was located from Sibiria to Greenland and extending far southward in the Atlantic. The polar front had large amplitudes, typical for the negative phase of the North-Atlantic Oscillasjon (NAO). The heavy rainfall was caused by a frontal passage linked to a depression north of Troms. Weather types were: **SEA** (Grosswetterlagen) and **S** (Lamb/Jenkinson).

Flood damage:

The rainfall and flood caused several slides in Ofoten, Vesterålen and Sør-Troms.
A landslide in Narvik caused probably damming of the outlet of Nedre Skamdalsvatn, resulting in a flood in the downstream taking farm buildings with farm animals and farmland.
A landslide destroyed several buildings at Kvalneset at Dyrøy, where two persons were killed.

Flood and landslide caused severe damages to the farmland at the farm Hesjeberg at Gratangen.

3.2.16 Large winter floods in Nordland in February 1961

Mild weather and rainfall caused two floods in mid-February 1961 in Nordland. Figure 3.2.16.1 show daily precipitation and discharge at stations in Nordland.

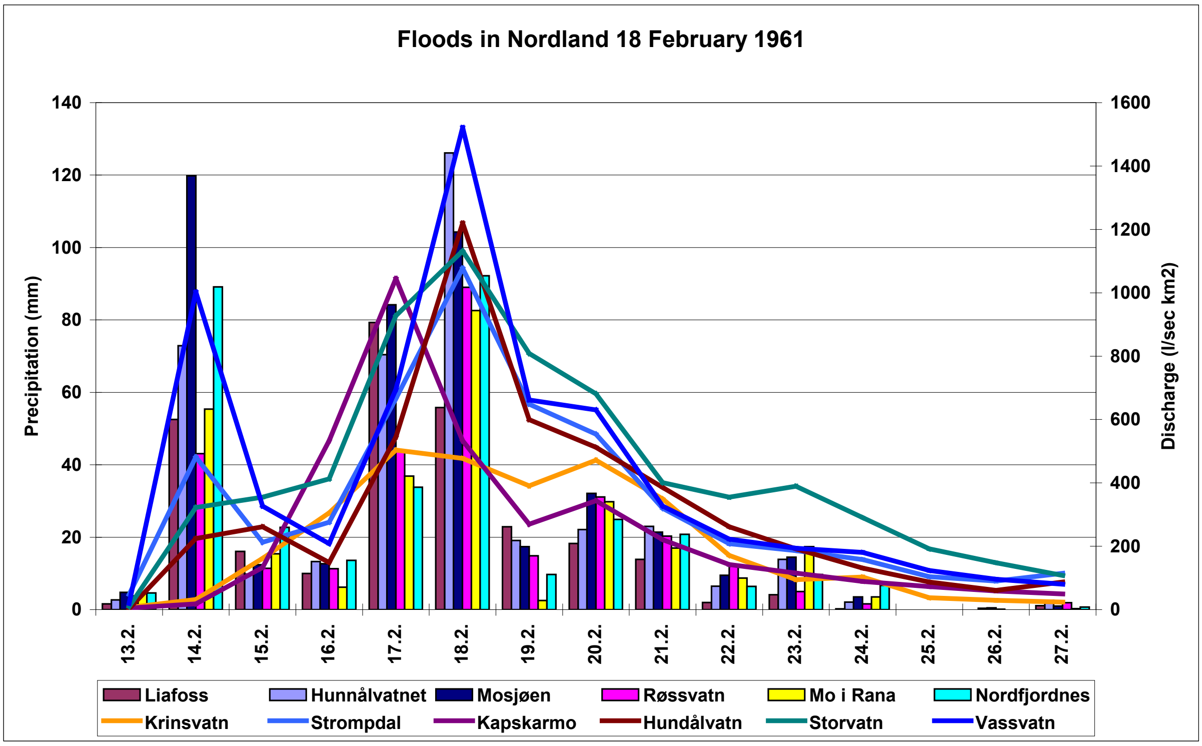


Figure 3.2.16.1 Observed precipitation and daily discharge in Nordland during the floods in February 1961.

Extension and ranks of the flood:

The flood was second largest observed in River Vefsna at Kapskarmo 1915-1991 and third largest in Lake Hunnålvatn 1908-2000.

Cause of the flood:

Figure 3.2.16.2 show the distribution of the snow, temperature, snow melting and precipitation 17 and 18 February. With the exception of a few catchments on the outer coast, snow cover was present everywhere when the flood started. The air temperature is shownin Figure 3.2.216.3, the estimated snowmelt in Figure 3.2.16.4 and the distribution of the precipitation 17 and 18 February in Figure 3.2.16.5.

Melting snow contributed to the flood as seen from the changes in the snowdepth through the month as shown in figur 3.2.16.6. The main contribution to the flood was however from rainfall. An anti-cyclone was located over Germany with a ridge extending toward southern Norway. A tongue of varm air was located over Norge, with the polar front northwards of Mid-Norway. West of the anticyclonic ridge, mild and humid airmasses were moving in from the Atlantic from southwest as an atmospheric river. This weather type is typical for most of the winter floods in Nordland county, and is classified as **HM** (Grosswettelagen) and **AS** and **AW** (Lamb/Jenkinson).

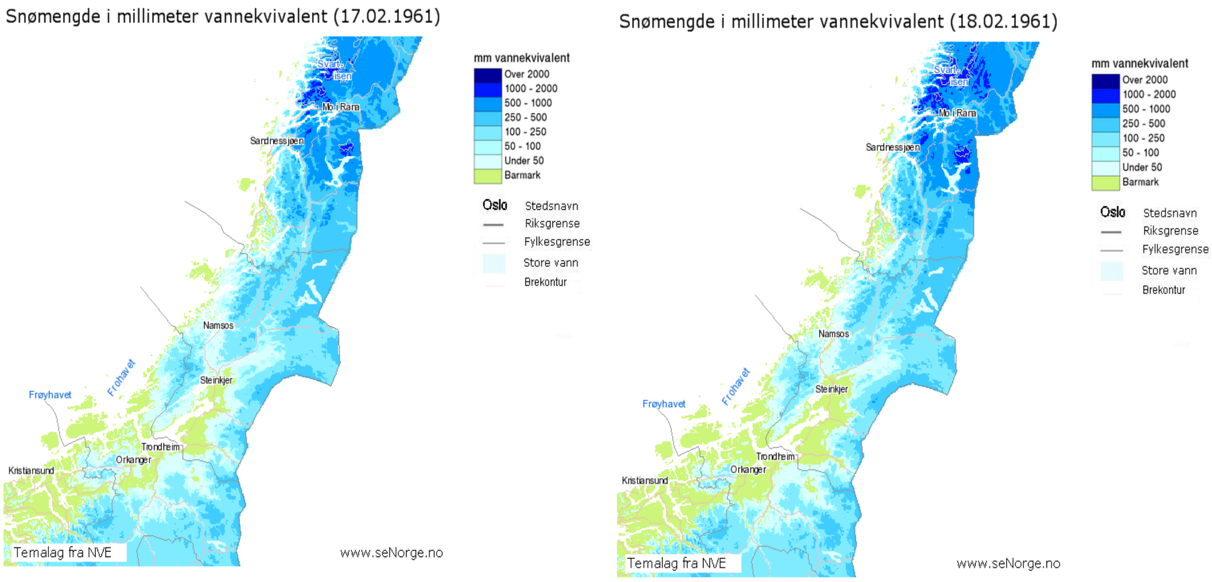


Figure 3.2.16.2 Distribution of the snowcover 17 and 18 February 1961.

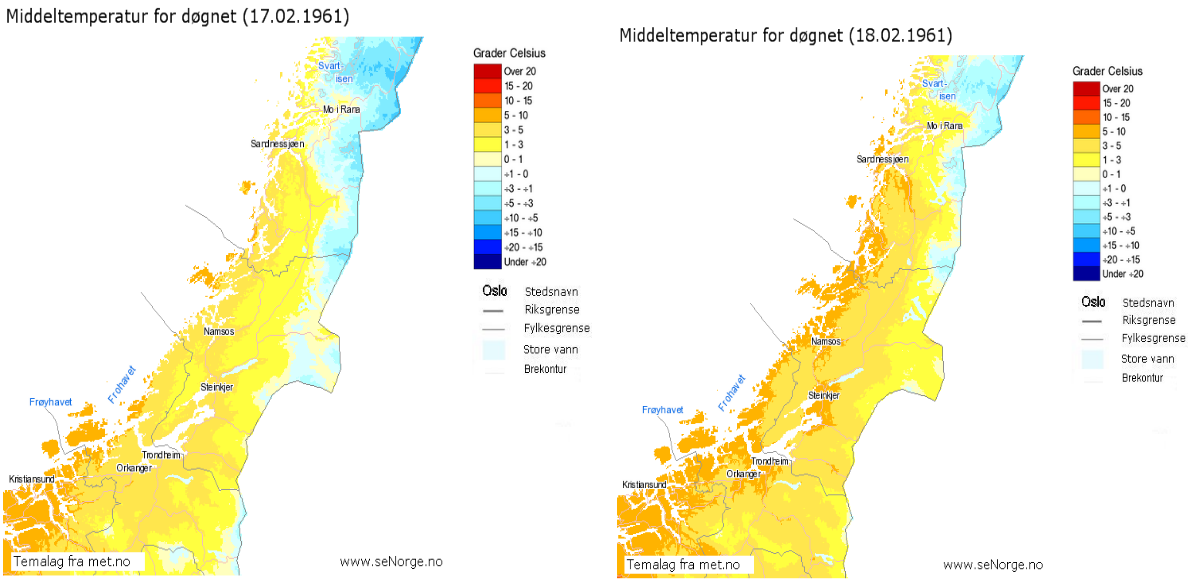


Figure 3.2.16.3. Temperature 17 and 18 February 1961.

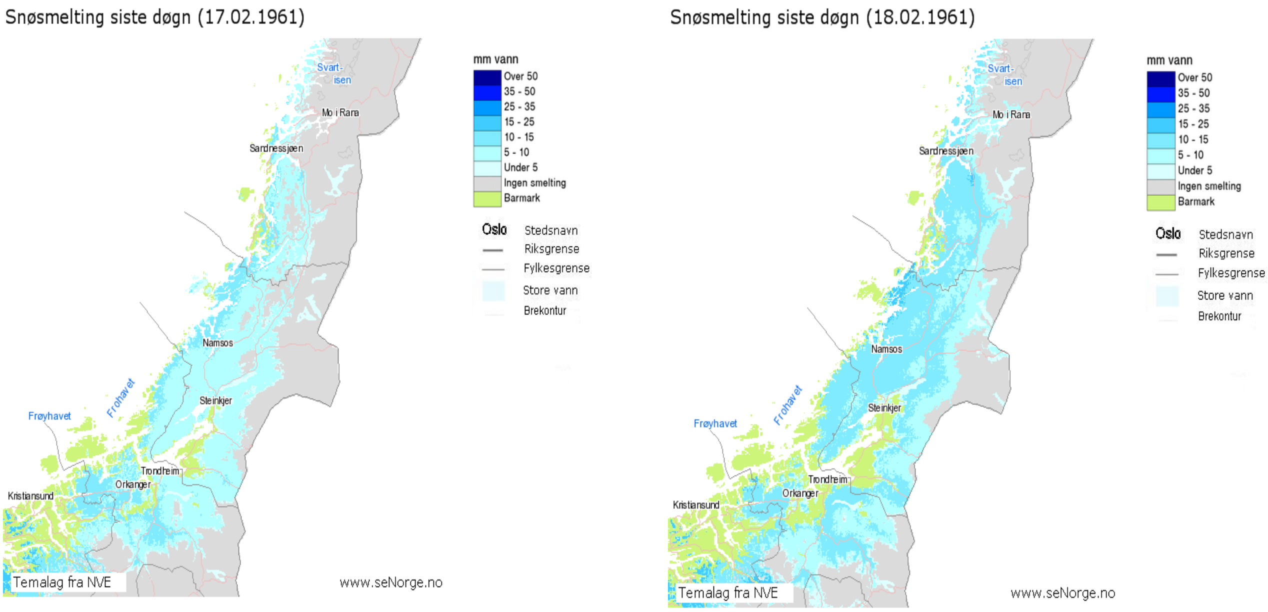


Figure 3.2.16.4. Snowmelt 17 and 18 February 1961.

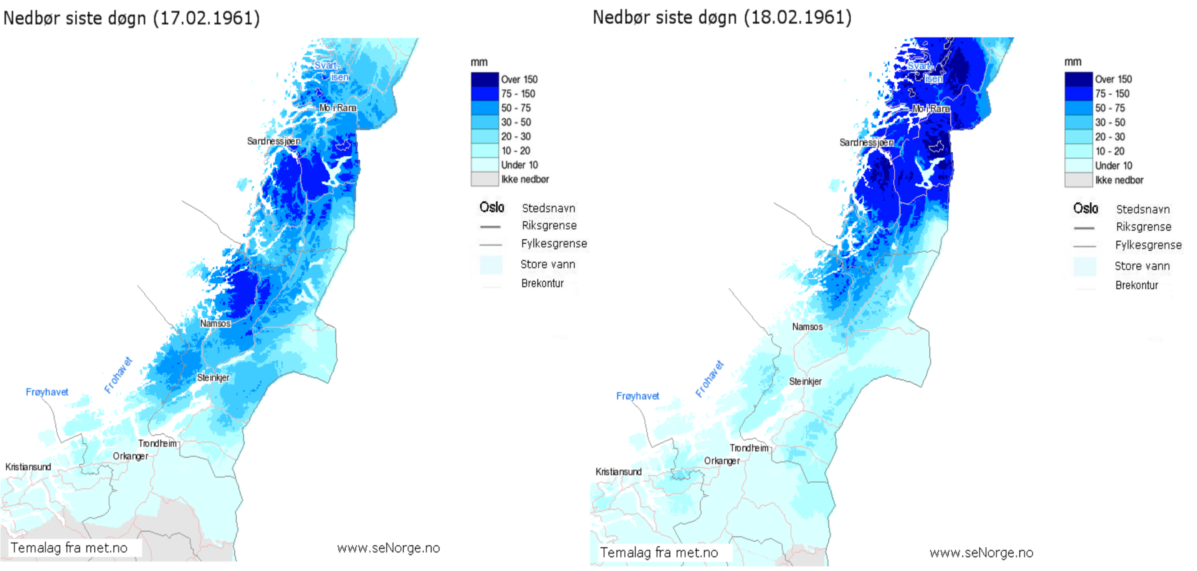


Figure 3.2.16.5. Distribution of the precipitation 17 and 18 February 1961.

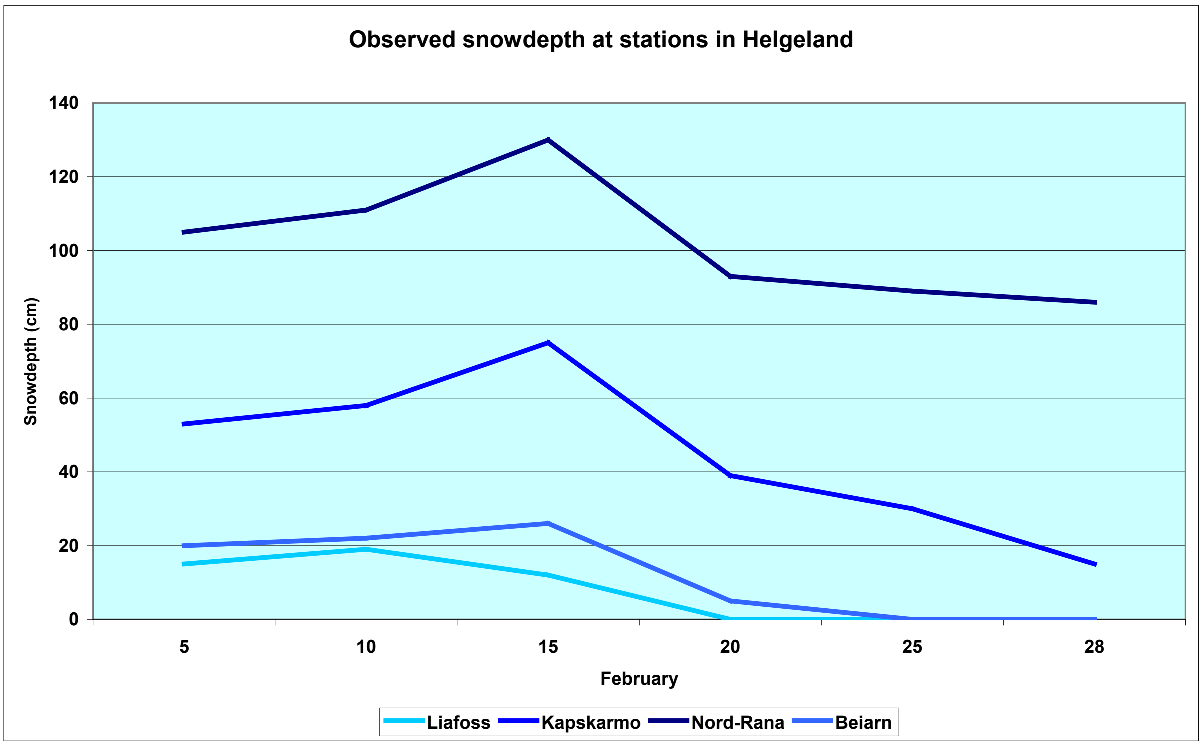


Figure 3.2.16.6. Observed snow depth in February 1961 at stations in Helgeland.

3.2.17 A large autumn rainfall flood at Helgeland in October 1962.

October 1962 was wet in most of Nordland. Heavy rainfall 21 and 22 October caused on of the larger autumn floods at Helgeland and Salten.

Initial conditions:

The development of the snow cover had not started within the region prior to the flood. Some rain fell between 16 to 20 October causing the discharge to increase in many rivers in Nordland.

The flood:

An anticyclone with a warm kernel was situated over Great Britain, forcing the polar front northwards. Warm air masses from the Norwegian Sea moved towards the Norwegian coast. The polar front was situated across Helgeland, and precipitation along the front penetrated from west-northwest. Oreographic lifting over the coastal mountains caused heavy preciptation from 20 to the morning of 22 October. The highest one and two-day rainfall was 144 mm and 275 mm, observed at Nordfjordnes. The weather type was **HM** (Grosswetterlagen) and **A** (Lamb/Jenkinson).

Figure 3.2.17.1 show observed daily rainfall at seven stations and observed daily discharge at six stations within the district.

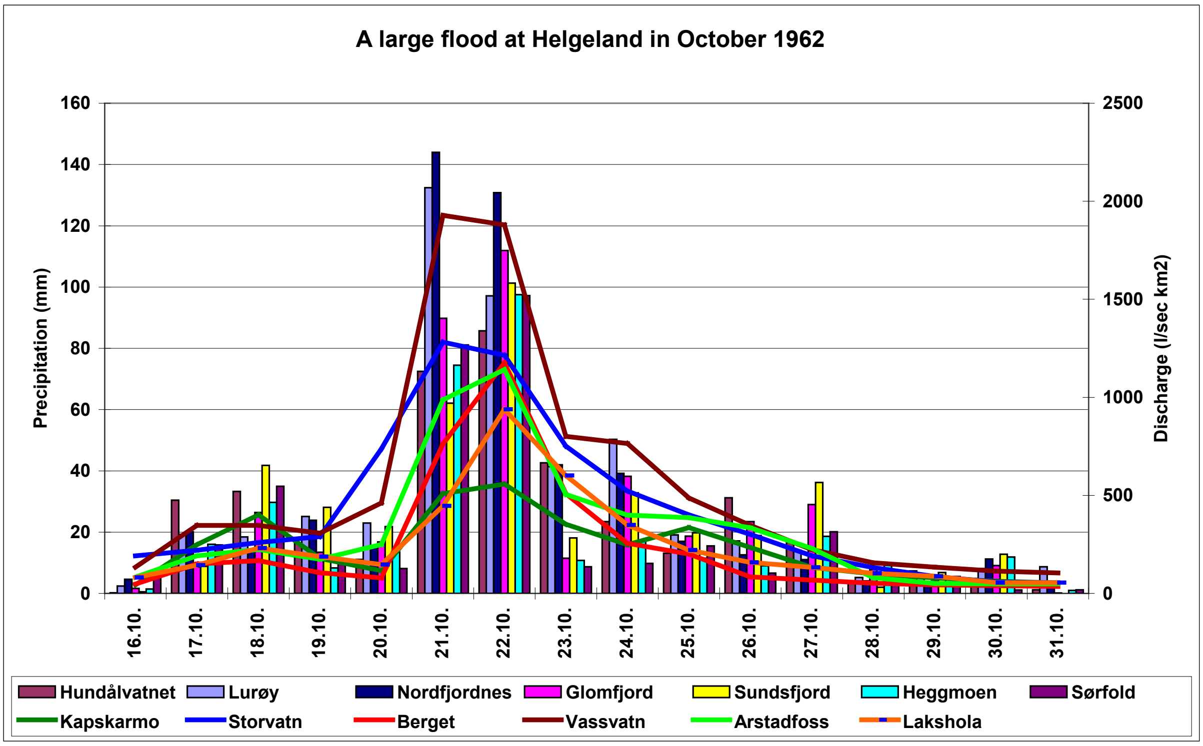


Figure 3.2.17.1 Observed precipitation and daily discharge at Helgeland during the rainstorm 21-22 October 1962.

Extension and ranks of the flood:

The flood was the third largest inflow flood at River Røssåga 1909-1967, the largest at River Rana at Berget since 1950, the eigth largest since 1916 at Lake Vassvatn, the largest at River Beiarelva since 1916, in River Saltdalselva since 1945, at Lakshola since 1916 and at River Kobbelv since 1916. It was the fourth largest at River Laksâ and the ninth largest at River Forsaelv. Figure 3.2.17.2 show the sum of rainfall and snow melt in Nordland 21- 22 October.

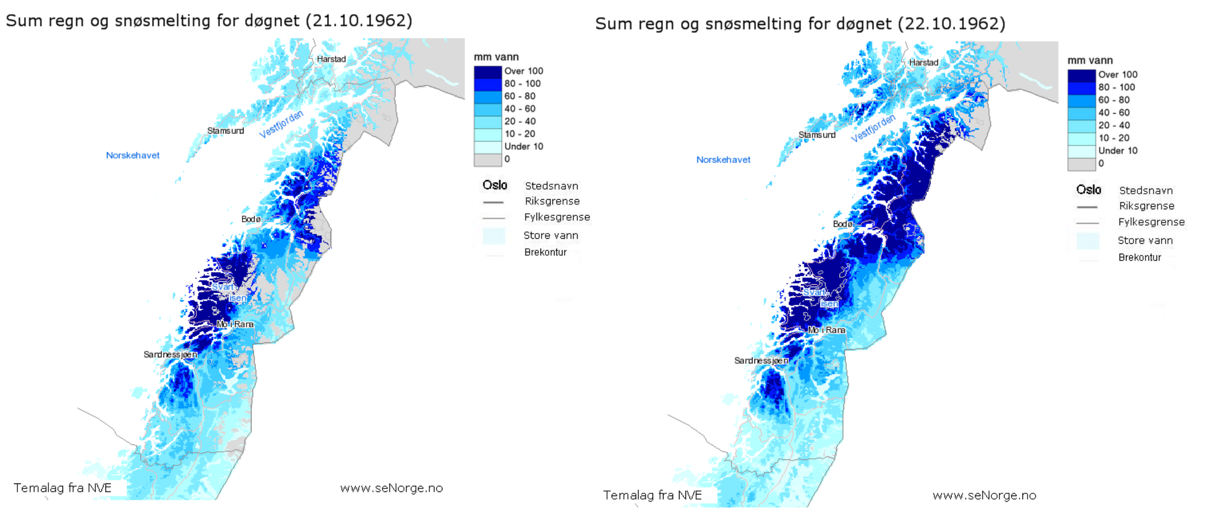


Figure 3.2.17.2. The distribution of the sum of rainfall and snowmelt 21 and 22 October 1962

3.2.18 A large winter flood in Nordland 9 January 1964.

Heavy rainfall caused a severe flood i Nordland in January 1964. Figure 3.2.18.1 show observed precipitation and discharge at a number of stations from Mo i Rana to Salten. The flood magnitude at Laksâ in Steigen is probably far too high because of an unreliable rating curve.

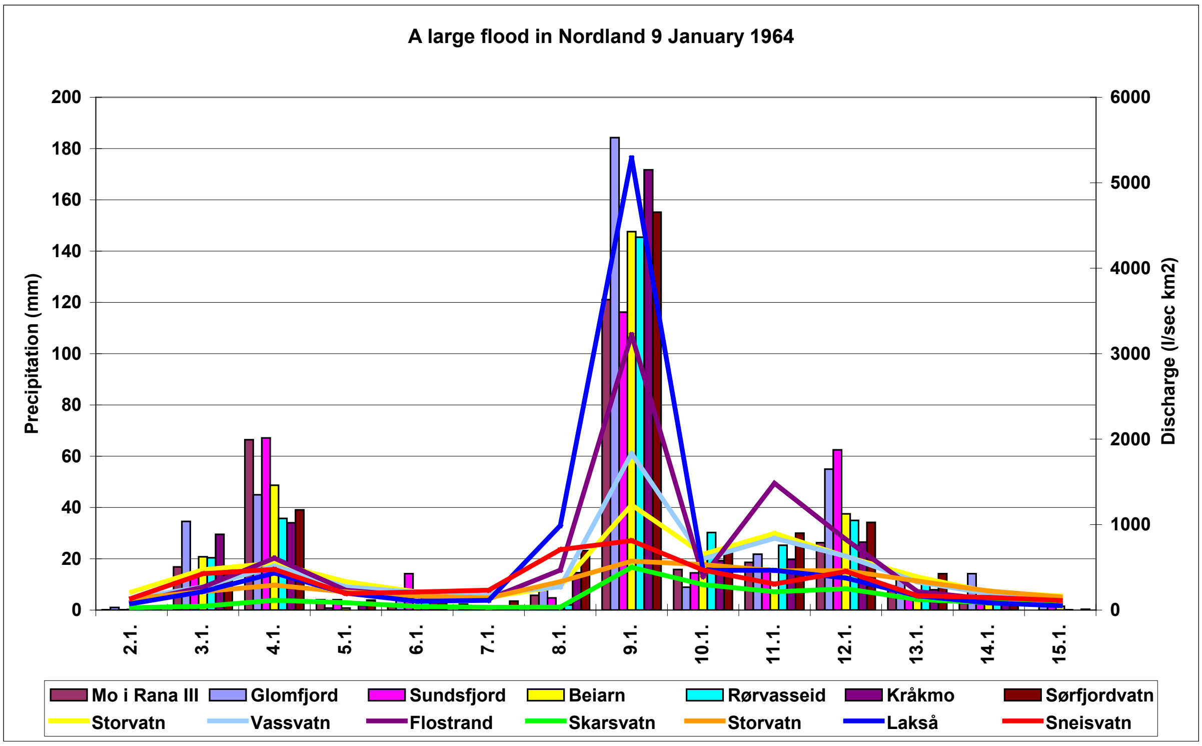


Figure 3.2.18.1 Observed precipitation and discharge during the flood in Nordland 9 January 1964

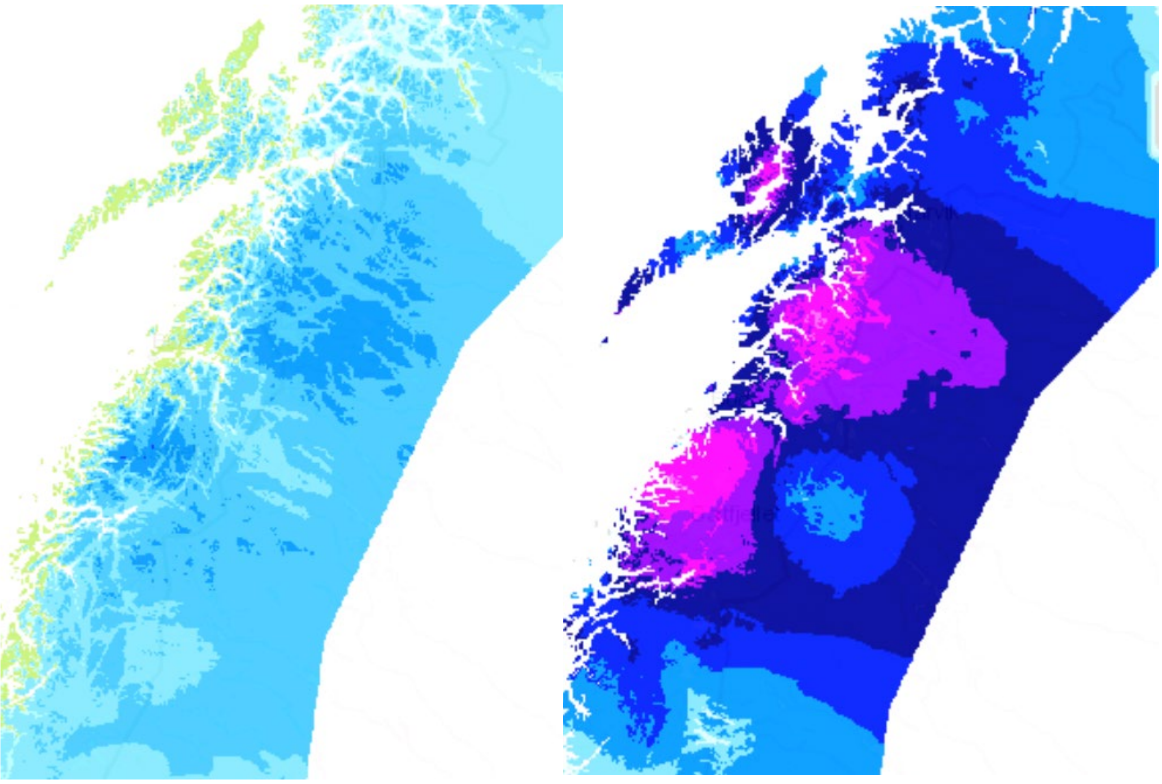


Figure 3.2.18.2 The distribution of the snow cover and the precipitation in Nordland and Troms 9 January 1964.

A major anticyclone embedded in mild airmasses was located across the European mainland. An intense low was located from south of Greenland extending over Iceland to Spitsbergen and further across Novaja Semlya into Siberia. An atmospheric river was flowing norteastward from far south in the Atlantic toward the Norwegian coast at Lofoten. The resulting rainfall is among the highest one-day rainfalls observed between Santen and southern Troms. Weather types 9 January were: **HM**(Grosswettwerlagen) and **A**(Lamb-Jenkinson).

3.2.19 Severe rainfall floods in Salten and Sør-Troms in 1964.

Three large floods occurred at Nordland and sør-Troms in October 1964. The first took place in Sør-Troms 4.-5 October, causing substantial damage in Tromsø. The second flood was a local rain flood at Hinnøya 22.-23 October. The one-day rainfall was among the largest observed in this district. The third flood occurred west and south of the Svartisen glacier 29 October. Another flood occurred at Forsbakk in Rana, but this flood was small.

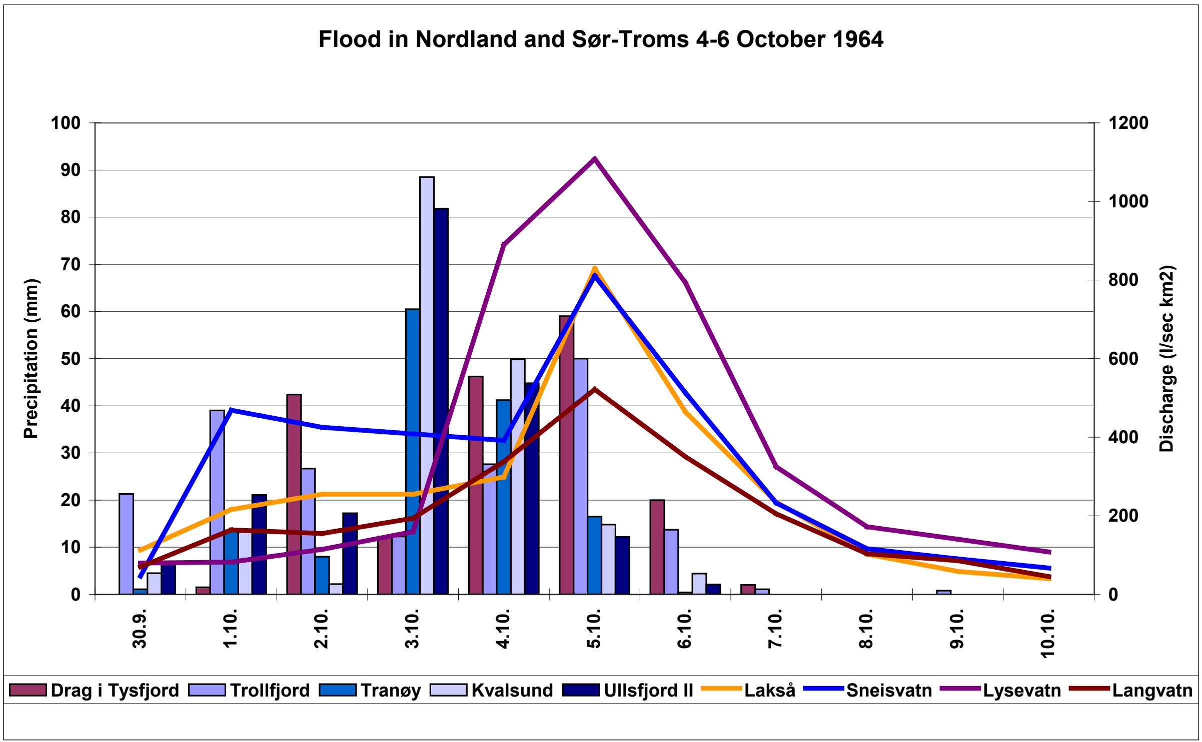


Figure 3.2.29.1 Observed precipitation and daily discharge in Salten and Sør-Troms 4-6 October 1964.

Extension and ranks of the flood:

The flood was among the largest in several smaller rivers in Troms. The flood was the largest observed at River Storelv at Kvaløya 1962-1977 and at Skogsfjordvatn at Ringvassøya since 1955. The flood was the second largest at Jægervatn since 1955. The flood was ranked as the 13th largest at Salangselva at Øvrevatn since 1916 and the 15th largest at Målselv at Malangsfoss since 1907.

Weather types 4-5 October were: **HM**(Grosswettwerlagen) and **SW**(Lamb-Jenkinson).

Weather types 22-23 October were **HM**(Grosswettwerlagen) and **SW**(Lamb-Jenkinson).
Weather types 29 October were **HM**(Grosswettwerlagen) and **SW**(Lamb-Jenkinson).

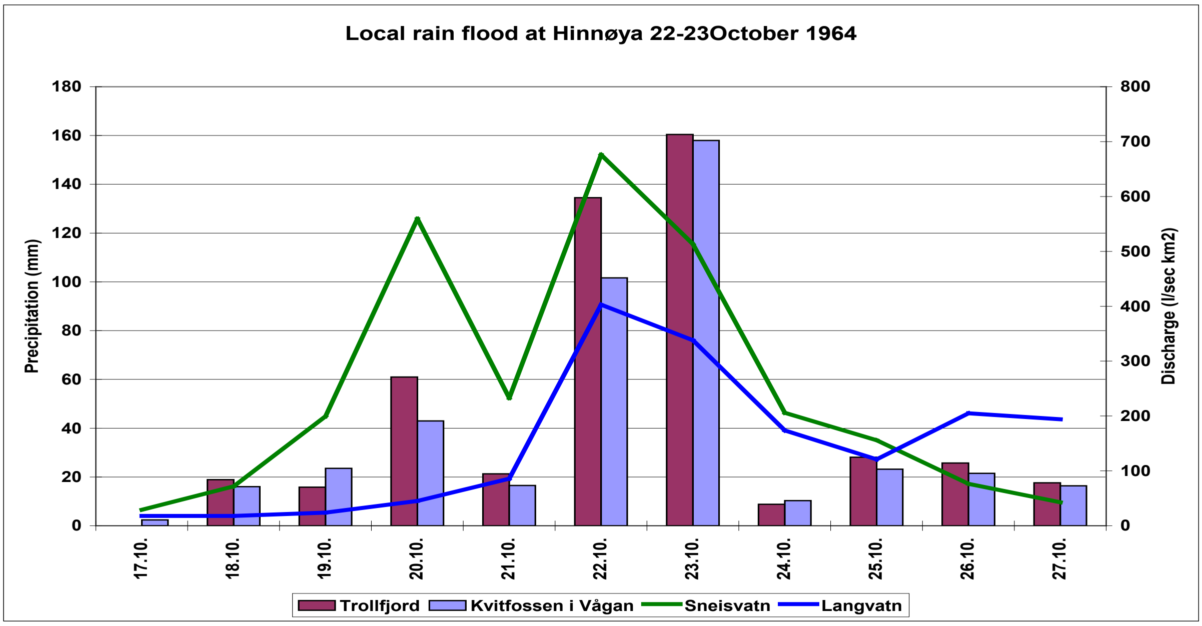


Figure 3.2.19.2 Observed precipitation and daily discharge at Hinnøya 22-23 October 1964.

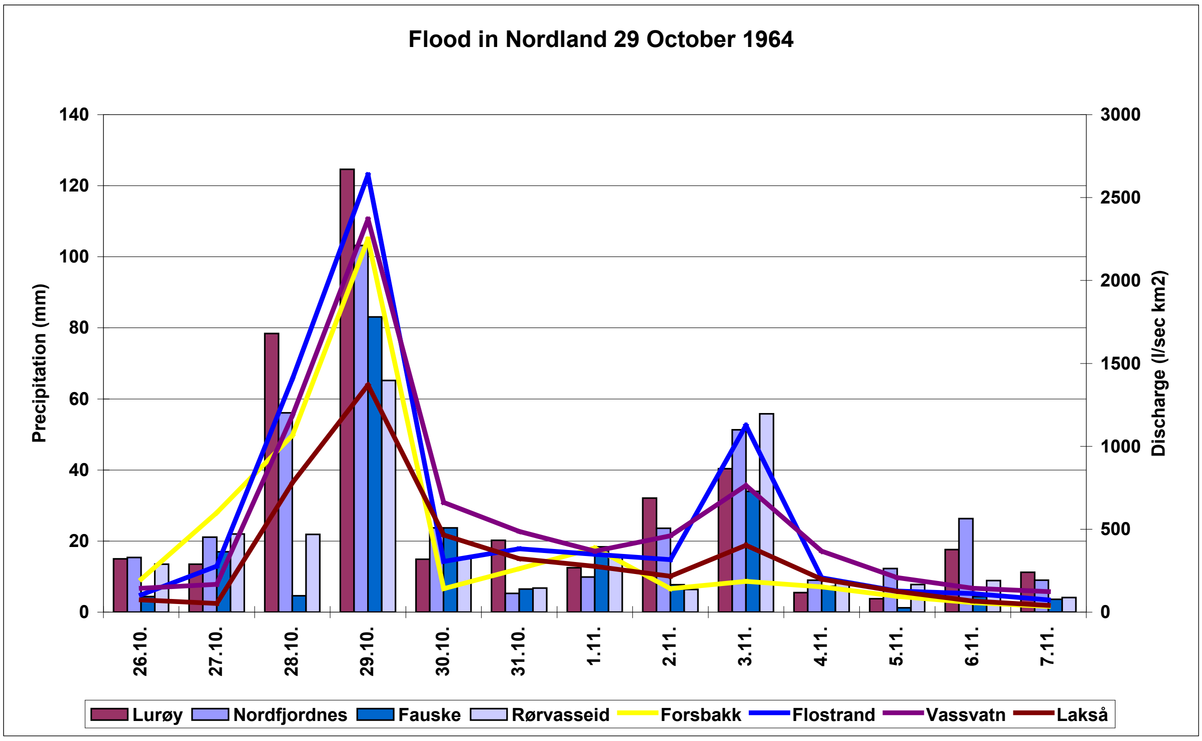


Figure 3.2.19.3 Observed precipitation and daily discharge during the flood in Nordland 29 October 1964.

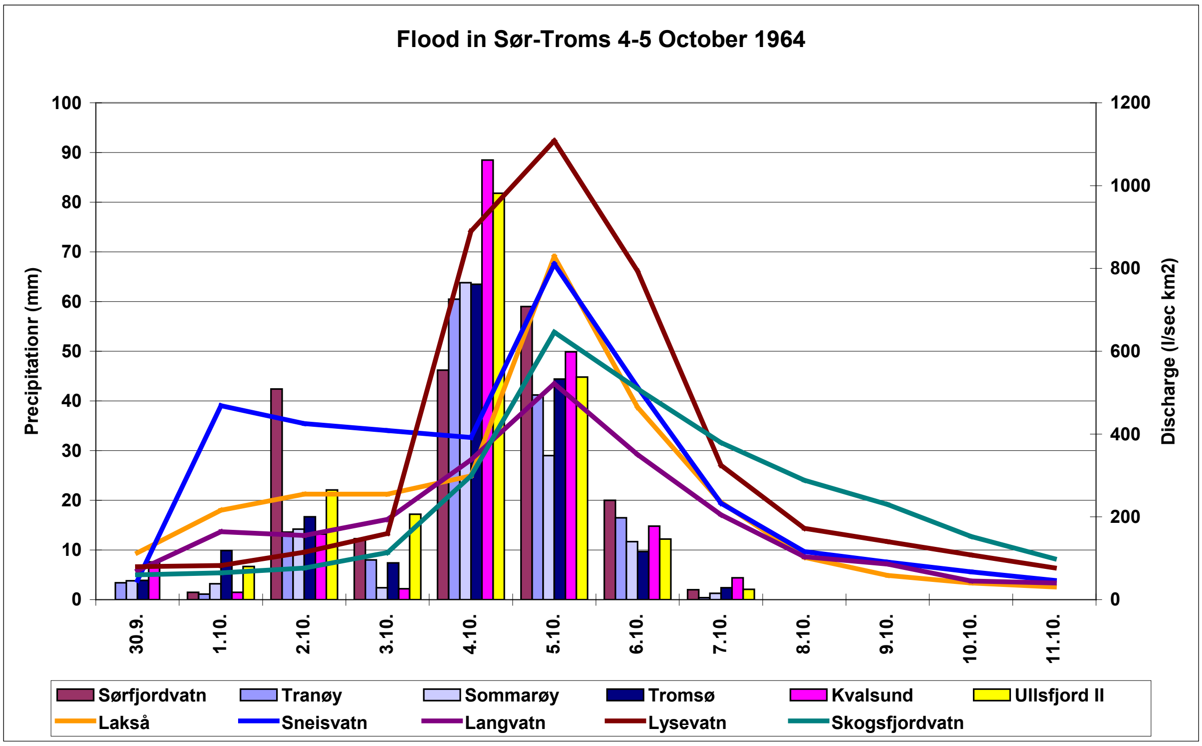


Figure 3.2.19.4 Observed precipitation and daily discharge in Sør-Troms in October 1964.

3.2.20 The spring flood in Finnmark in June 1968.

The spring flood in Finnmark in June 1968 was the largest occurring in the county since the major floods in 1917 and 1920, causing floods in the major rivers Alta, Tana, Neiden, Pasvik and Karpelv. There was also floods in some smaller rivers close to the coast in Finnmark and Troms, but these floods were smaller, and occurred later in the summer. Figure 3.2.20.1 show observed daily precipitation and discharge in rivers in Finnmark.

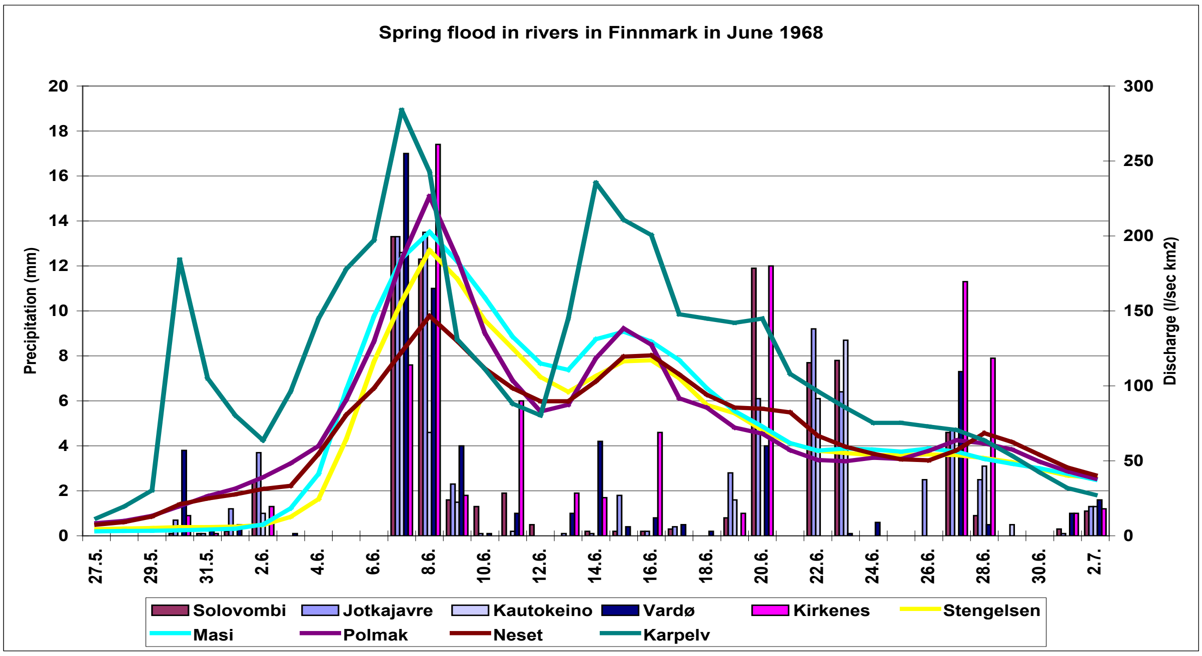


Figure 3.2.20.1 Observed precipitation and discharge in Finnmark during the spring flood in June 1968.

Extension and ranks of the flood:

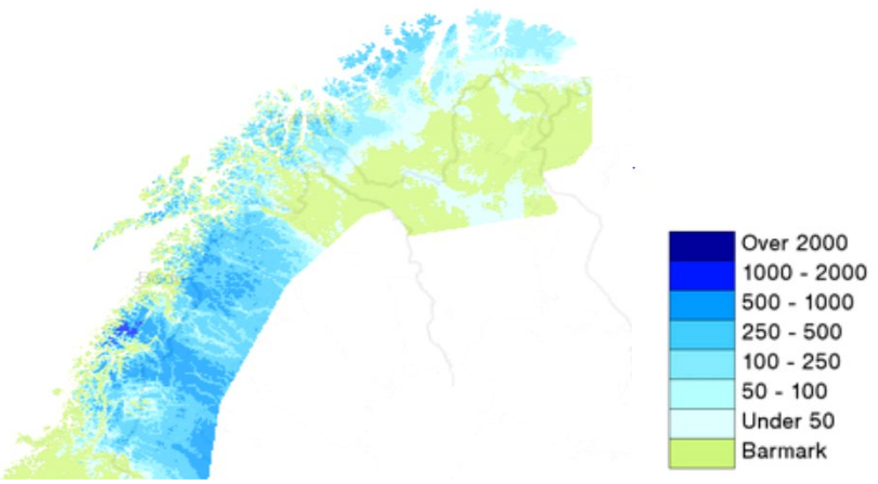
The flood in Finnmark was a combined snowmelt and rainfall flood.

The flood was the tenth largest at 196.36 Fosshaug and the third largest at 196.12 Lundberg, both in River Barduelv. It ranks as the ninth largest at 204.4 Skogsfjordvatn at Ringstadelv 1957-2014, and 203.2 Jægervatn at Jægerelv 1955-2014 and as the third highest in River Signaldalselv at 204.6 Kavlefoss 1928-1993.The flood does not rank among the ten largest in the other long term series in Troms, such as 196.1/2 Bardufoss, 196.3 Malangsfoss or 191.1/2 Vassås/Øvrevatn.

The flood ranks as the third highest 1915-1991 at 212.2 Stengelsen and the highest at 212.10 Masi 1967-2014 both in River Alta. It ranks as the second highest in River Leirbotnelv at 213.2 Leirbotnvatn. The flood was the fourth largest at 230.1 Normanset 1961-2014 and the second largest at 234.4 Smalfjord 1960-1986 two small coastal catchments in Finmark. In River Tana the flood ranks as the third highest at 234.18 Polmak 1911-2014. Further east the flood was the eight largest in River Neiden at 244.1/2 Neiden/Neset.

Initial conditions:

The snowmelt started 27 May and increased rapidly during a dry spell from 3 to 6 June. The distribution of the snow water equivalent from Salten in Nordland to Finnmark is shown in Figure 3.2.20.2. Most of the snow had melted in Finnmark, especially in the inland, but some snow remained in catchments closer to the coast. More snow remained in inland catchmemts in Troms and Nordland.



The flood:

A dry spell occurred 3-6 June preceeded by moderate rainfall and the discharge started to rise because of snowmelt from the 3. A widespread rainfall event caused the flood to peak 8 June. The flood was the third largest observed in River Alta at Stengelsen 1916-1968 and the largest at Masi 1966-2008. The flood was the third largest 1912-2000 in River Tana at Polmak and fourth largest in River Neiden at Neset 1911-2005.

The weather types 7-8 June were: **WZ** (Grosswetterlagen) and **W**, **CW** (Lamb Jenkinson).

3.2.21 Two passages of remnants of tropical cyclones occurred at Svartisen in August 1971.

Two extreme rainstorms occurred in the district close to the Svartisen Glacier 20 aqnd 25-26 August 1971. The flood was caused by high temperatures in combination with heavy rainfall. Figure 3.2.21.1 show observed daily rainfall and discharge at selected stations within the region. The flood was exceptionally large at Engabre and Høgtuvbre, where glaciolgical studies were going on. The water level in Lake Engabrevatn prevented the field assistents measuring the sediment transport were prevented from reaching the station.

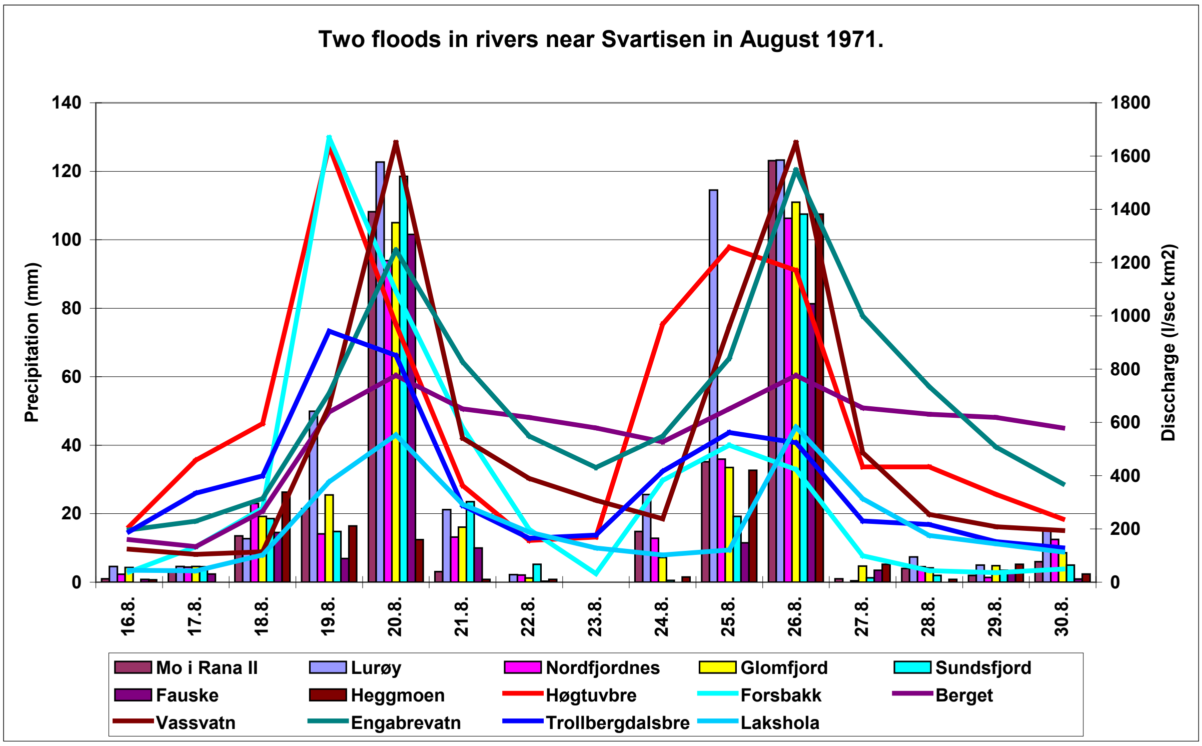


Figure 3.2.21.1 Observed daily rainfall and discharge at stations close to the Svartisen Glacier in August 1971.

Extension and ranks of the flood:

The flood was the largest on record at 153.1 Storvatn since the observations started in 1916 and at 156. Bjørnfoss in River Rana. The flood ranks only as the x largest in rivers without glaciers in the catchment, such as 157.3 Vassvatn where the flood was only the 11te largest.

Cause of the floods:

The rainfall was caused by transport of warm and humid air from the southwestern Atlantic Ocean. An extra-tropical depression moved eastwards from Nova Scotia 16 August. The depression amageted with remnants of the tropical hurrican Beth 17 August. Beth provided the extra-tropical depression with more energi and humidity. The high temperatures and strong wind caused extreme melting of glacier ice in addition to the rainfall. Remants of the tropical storm Cloe moved into the Atlantic 25 August north of an anticyclonic ridge and caused the second flood.

The distribution og the rainfall 20 and 25-26 August is shown in Figure 2 and 3. The weather type during the first flood was **BM** (Grosswetterlagen) or **ANW** (Lamb/Jenkinson). During the second flood, the weather type was TRW (Grosswetterlagen) or **SW** (Lamb Jenkinson)

3.2.22 The winter flood in Nordland in December 1989.

Mild weather and rainfall resulted in a flood in Nordland 3 December 1989. Figure 3.2.22.1 show observed daily rainfall and discharge at selected stations from Dundelandsdalen ro Lofoten.

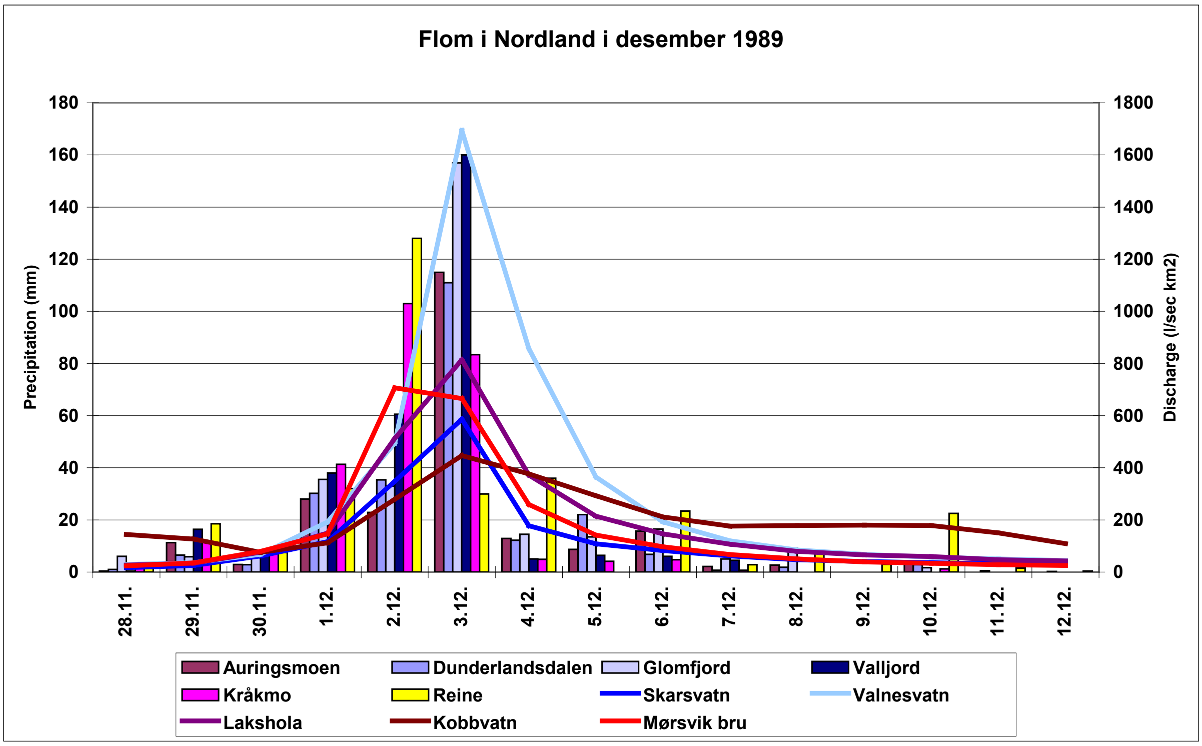


Figure 3.2.22.1 Observed precipitation and daily discharge during the floods at Fjordane in January 1989.

Extension and ranks of the flood:

The flood was the second largest at 156.15 Forsbakk 1963-2014, third largest in River Lakselv at 162.3 Skardsvatn 1916-2014 and second largest at 162.4 Valnesvatn 1912-2014 in the Salten district. The flood was the sixth largest naturalised flood in River Kobbelv at 167.3 Lake Kobbvatn 1916-2014, the fifth largest in River Lommerselv at 168.1 Storvatn 1917-1990, 2007-2014 and

Cause of the flood:

Prior to the flood most catchments were covered by snow, but the mild weather caused most of the snow to melt by 1 December as shown in Figure 2. The distribution of the snow cover and snowmelt the last day is shown in Figure 3 by 3 December when the flood peaked. The temperature was then above zero degrees in most of Nordland. The rainfall turned into snow as the temperature started to drop in some catchments late in the day on 3 December. The distribution of the precipitation 2 and 3 December is shown in Figure 4. Most of the precipitation on 2 December fell from Bodø and further north. The next day heavy precipitation also fell further south to the Røssåga catchment.

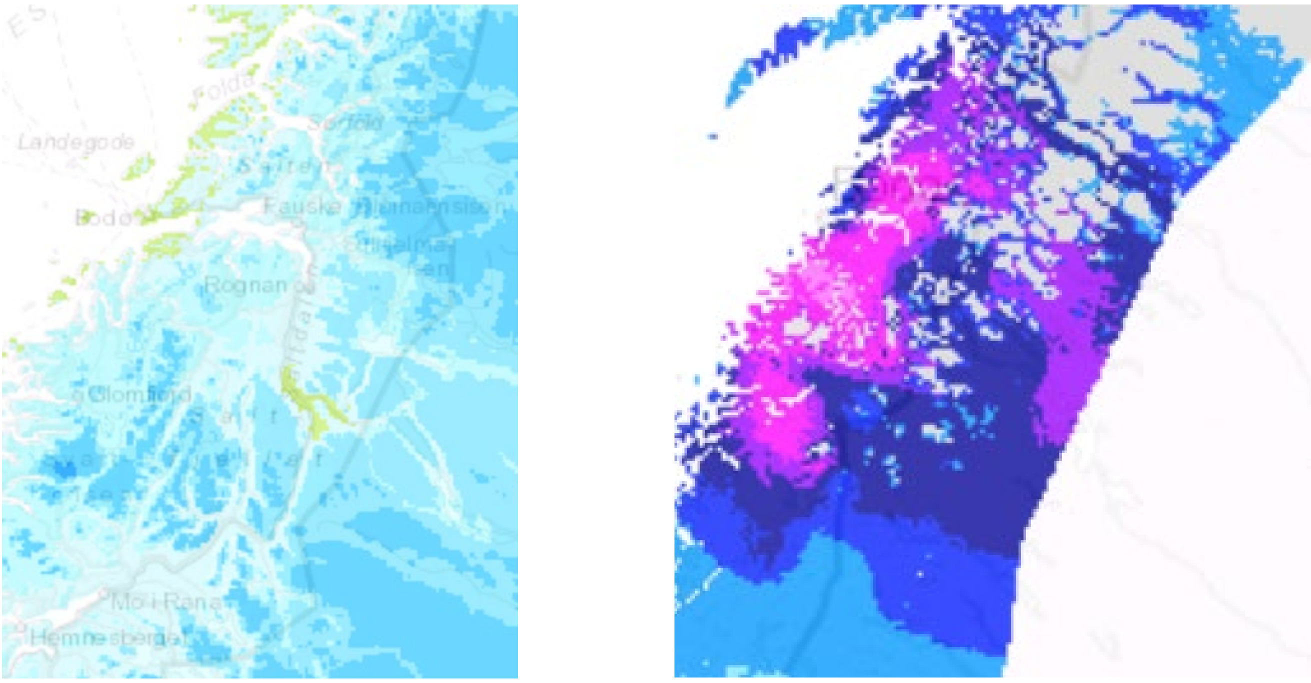


Figure *3.2.22.2* The distribution of the snow reservoir by 1/12 and the rain and snowmelt by 3/12-1989.

Between a strong anti-cyclone extending from the North Sea to Central Europe and a depression extending from the Denmark straith to north of Spitsbergen a heavy precipitation area reached the northern part of Nordland 2-3 December from southwest. The wind weered to northwest behind the front causing the temperatures to drop. The weather types were **HM** (Grosswetterlagen) and **A** (Lamb/Jenkinson).

3.2.23 The spring flood in Troms and West Finnmark July 1993.

The spring flood occurred in two separate peaks in July 1993 in Troms, first partly resulting from rainfall, with a second peak caused by snowmelt only. Figure 3.2.23.1 show daily rainfall and discharge at selected stations in Troms.

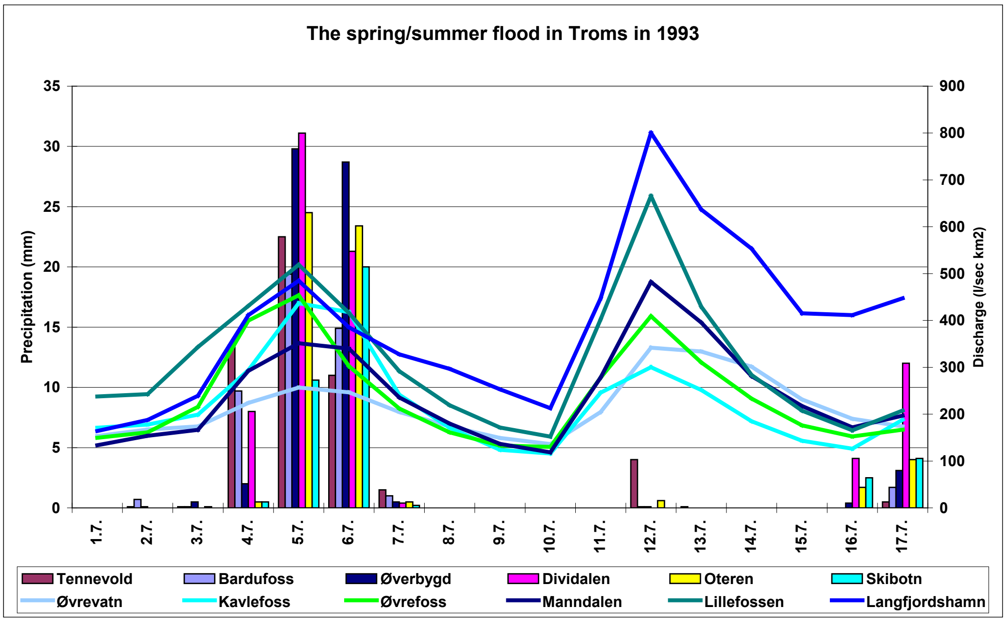


Figure 3.2.23.1 Observed daily precipitation and discharge during the spring flood in Troms and West Finnmark in July 1993.

Extension and ranks of the flood:

The flood peaking 5. July was third largest in River Signaldalselv at Kavlefoss 1917-1994, third largest in River Skibotnelv at Helligskogen 1982-2006, second largest in River Storelv at Øvrefoss 1961-1994. The flood peaking 11 - 12 July was the fourth largest in River Junkerdalselv 1937-2007, sixth largest in River Salangselv at Øvrevatn 1916-2008, x largest in River Kåfjordelv at Manndalen bru 1971-2007, third largest River Reisaelv at Lake Oksfjordvatn 1955-2007, second largest in River Kvænangselv at Lillefossen 1962-2006 and largest in River Langfjordelv 1980-2003.

Cause of the flood

Initial conditions:

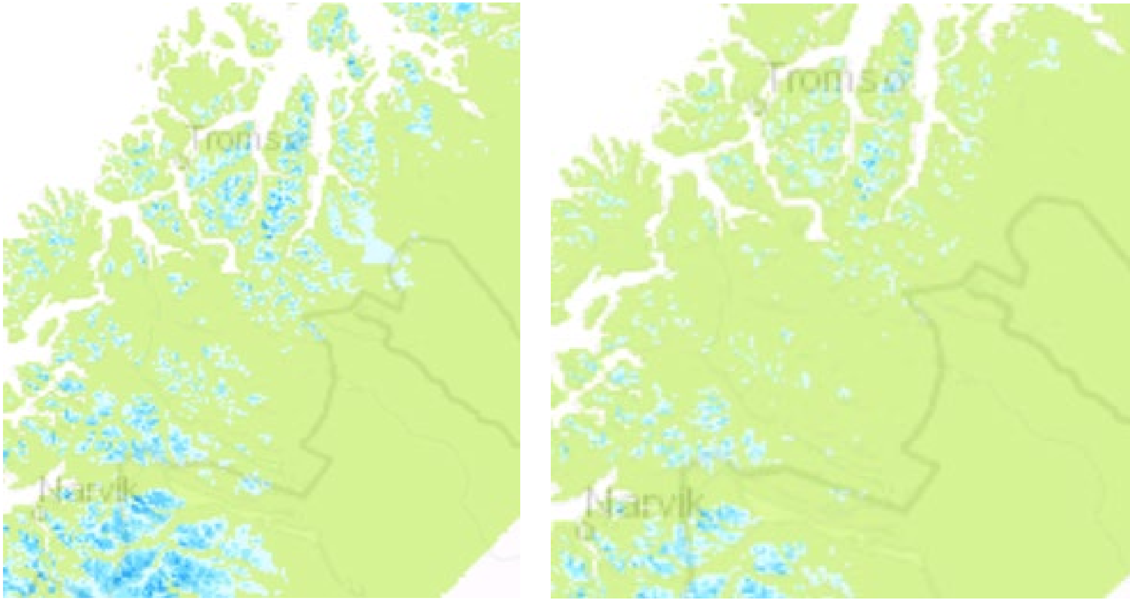


Figure 3.2.23.2 The distribution of the snow storage at 1 July and 10 July 1993.

Rainfall and snowmelt:

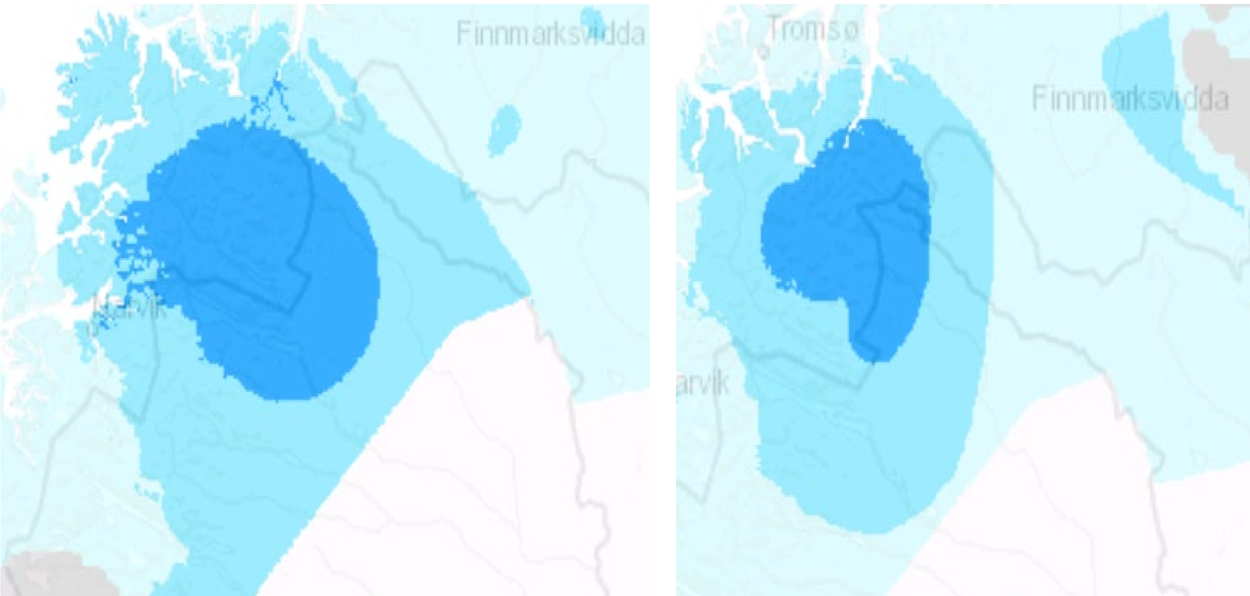


Figure 3.2.23.3 The distribution of the rainfall 5 July and 6 July 1993

The weather types 4-6 July were **NWA** (Grosswetterlagen) and **W**, **ANN**, **ANN** (Lamb-Jenkinson)

3.2.24 Vesleofsen extended to Troms in June 1995.

Figure 3.2.24.1 Observed daily precipitation and discharge during the spring flood in Troms in June 1995.

Extension and ranks of the flood:

The flood was seventh largest in River Salangselv at Øvrevatn 1916-2008, second largest in River Skibotnelv at Helligskogen 1982-2006, seventh largest in River Kåfjordelv at Manndalen bru 1971-2014, sixth largest in River Reisaelv at Lake Oksfjordvatn 1955-2007 and fifth largest 1962-2007 in River Kvænangselv at Lillefossen.

Cause of the flood

Rainfall and snowmelt:

The weather type was: **WZ** (Grosswetterlagen) and **C/C/NW/W** (Lamb-Jenkinson)

3.2.25 The spring flood in Finnmark in June 1996.

A large spring flood occurred in June 1996 in East Finnmark. Observed daily precipitation d discharge is shown at selected stations in Figure 3.2.25.1.

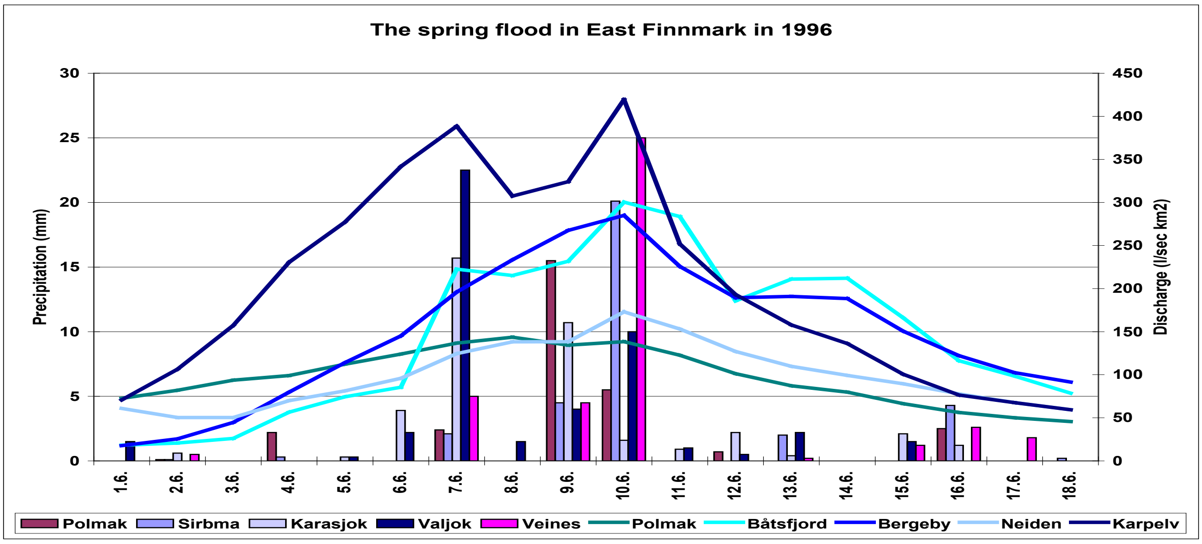


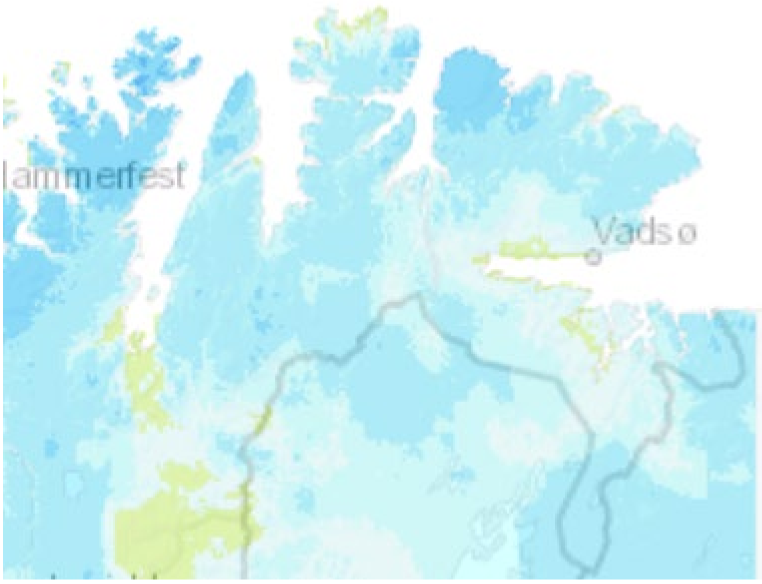
Figure 3.2.25.1 Observed daily precipitation and discharge during the spring flood in June 1996

Extension and ranks of the flood:

The flood was second largest observed at Neiden 1912-2002

Cause of the flood

Initial conditions:
Figure 3.2.25.2 show initial snow storage (mm) 5 June 1996.



Rainfall and snowmelt:
Figure 3.2.25.3 show the accumulated rainfall 5 - 11 June 1996.

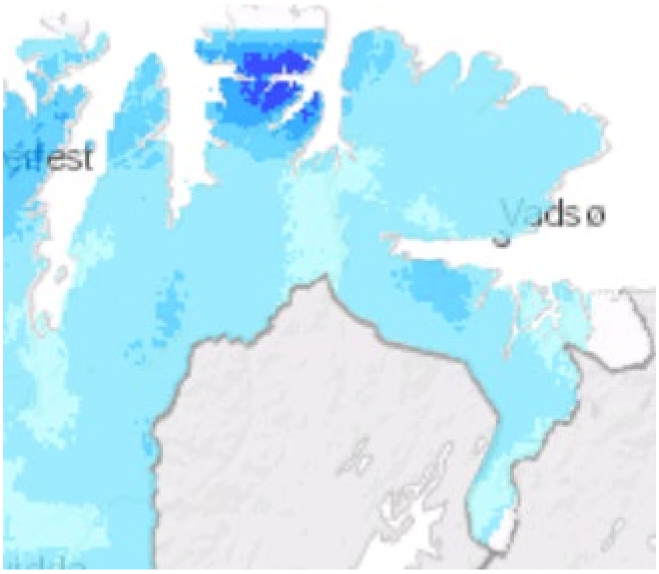


Figure 3.2.25.3 The accumulated rainfall 5 - 11 June 1996
The weather types 7-10 June were **BM** (Grosswetterlagen) and **AS**, **SW**, **AS**, **SW** (Lamb-Jenkinson)

3.2.26 The spring flood from Salten to Troms in June 1997

A large spring/summer flood occurred in several rivers from Saltdalen in Nordland to Kvænangen in Troms in June 1997. Observed floods in Nordland are shown in Figure 3.2.26.1 and in Figure 3.2.26.2 in Troms.

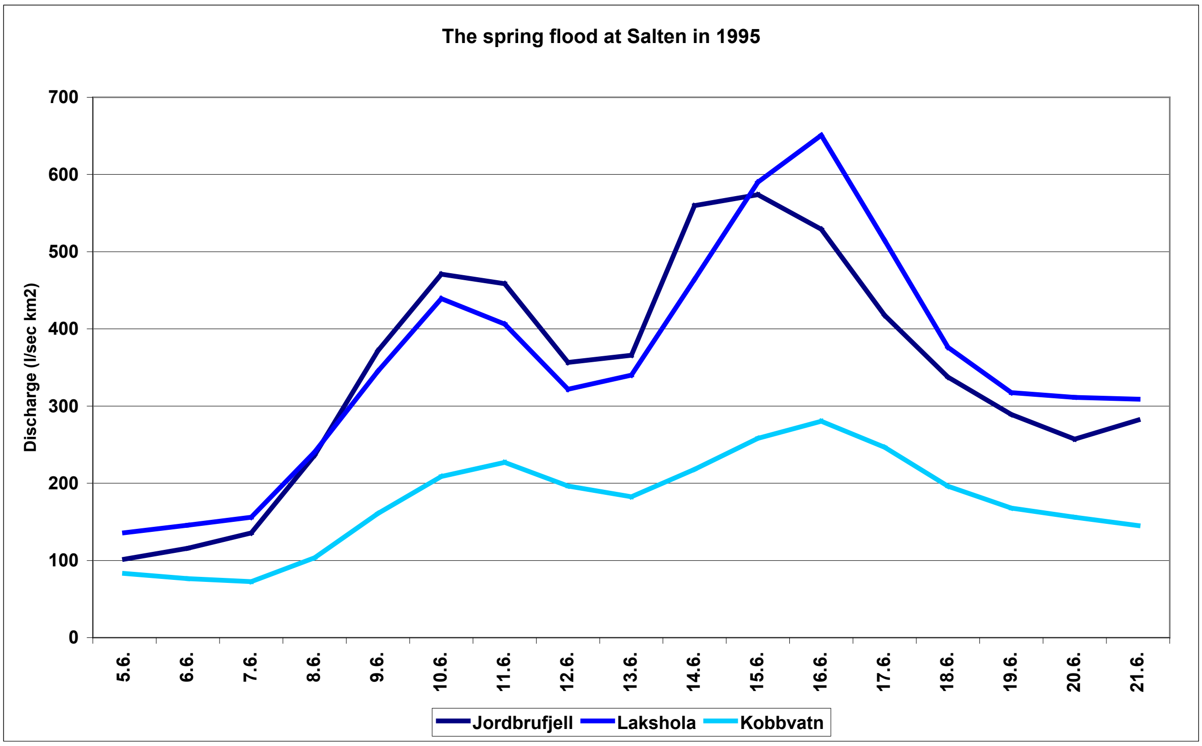


Figure 3.2.26.1 Observed daily discharge during the spring flood at Salten June 1997.

Figure 3.2.26.2 Observed daily discharge during the spring flood in Troms June 1997.

Extension and ranks of the flood:

The flood was fifth largest in River Saltdalselv at Jordbrufjell 1945-2006, eight largest in river Kobbelv at Lake Kobbvatn 1916-1997, second largest in River Salangselv at Lake Øvrevatn 1916-2008, largest at River Lakselv at Jægervatn 1955-2007 and in River Skibotnelv at Helligskogen 1982-2006, second largest at River Reisaelv at Lake Oksfjordvatn 1955-2007 and fourth largest at River Kvænangselv at Lillefossen.

Cause of the flood:

The winter temperatures were mild at most of Norway including the inland part of Nordland and close to the normal near the coast of Nord-Norge. The snowfall was heavy, especially in January, and a cold spring caused a large snow reservoir to develop. A snow depth of 12 meters was observed at Svartisen Glacier. The temperature rose in early June when a dry and warm period started lasting almost all of June. The distribution of the snow storage 5 June is shown in Figure 3.2.26.2. The temperature in June are shown in Figure 3.2.26.3.
This caused heavy snowmelt in several mountainous rivers in Nordland. The period from 6 - 21 June was completely dry, and the flood was therefore caused by snowmelt only.

This summer was extremely hot in Sør-Norge, Sweden and on the European mainland, co-inciding with the devastating flood in River Oder in Germany, Poland and Czech Republic.

The weather type was: **TRM/ NWZ**(Grosswetterlagen) and **NW/SW**(Lamb-Jenkinson)

3.2.27 The flood in November 1999 at Salten.

A rainfall flood occurred in coastal catchments at Salten 12-13 November 1999.

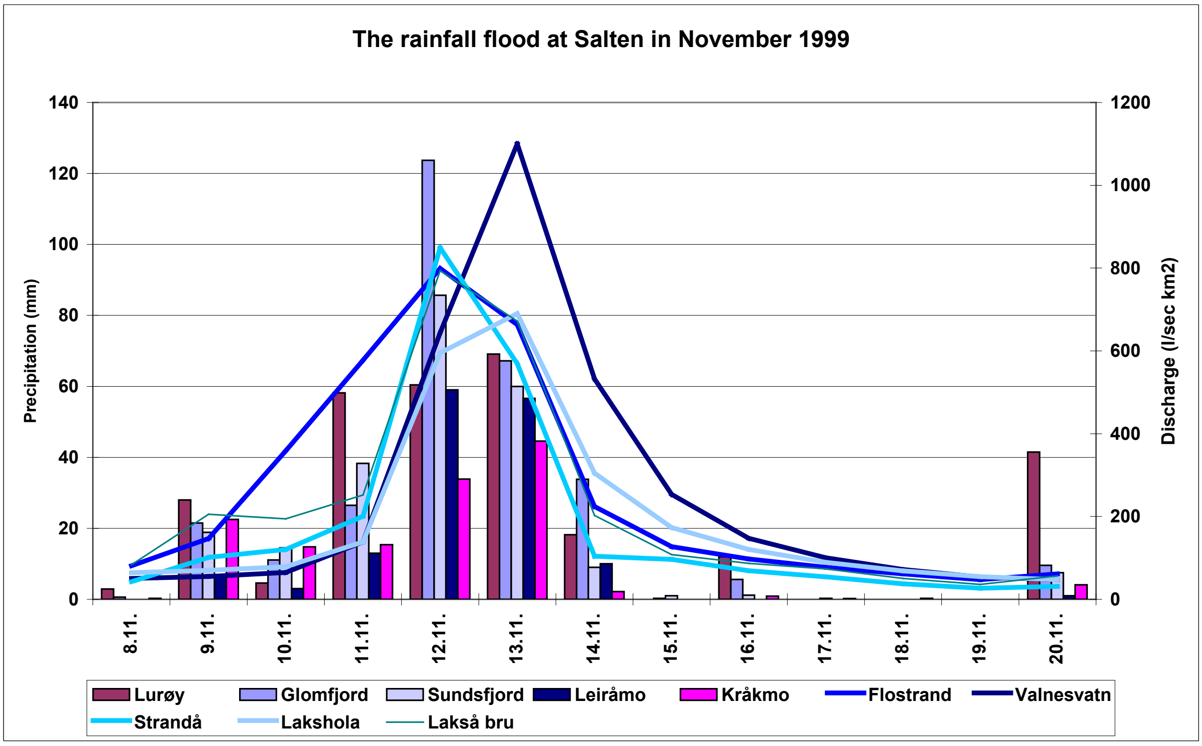


Figure 3.2.27.1 Observed daily precipitation and discharge during the rainfall flood in Salten 12- 13 November 1999.

Extension and ranks of the flood:

The flood was sixth largest in River Lakselv at Valnesvatn 1912-2007, fifth largest in River Strandå 1916-2008, seventh largest in River Lakså at Lakshola 1916-2007, fifth largest in River Kobbelv at Lake Kobbvattn 1916-2005 and fourth largest in River Lommerselv at Mørsvik bru 1985-2008.

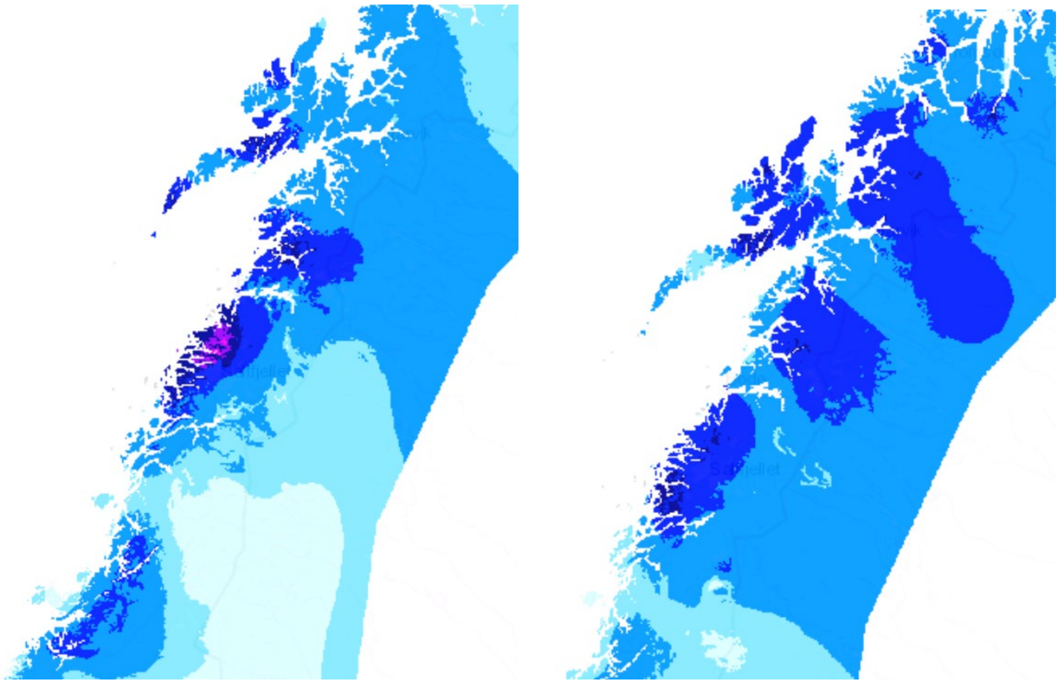


Figure 3.2.27.2 Distribution of the precipitation 12 and 13 July 1999 in Nordland and Troms.

Cause of the flood:

The weather types 11-15 November were **HB** (Grosswetterlagen) and **C**, **C, CNW**, **C** (Lamb-Jenkinson).

3.2.28 The spring flood in Neiden in May-June 2000

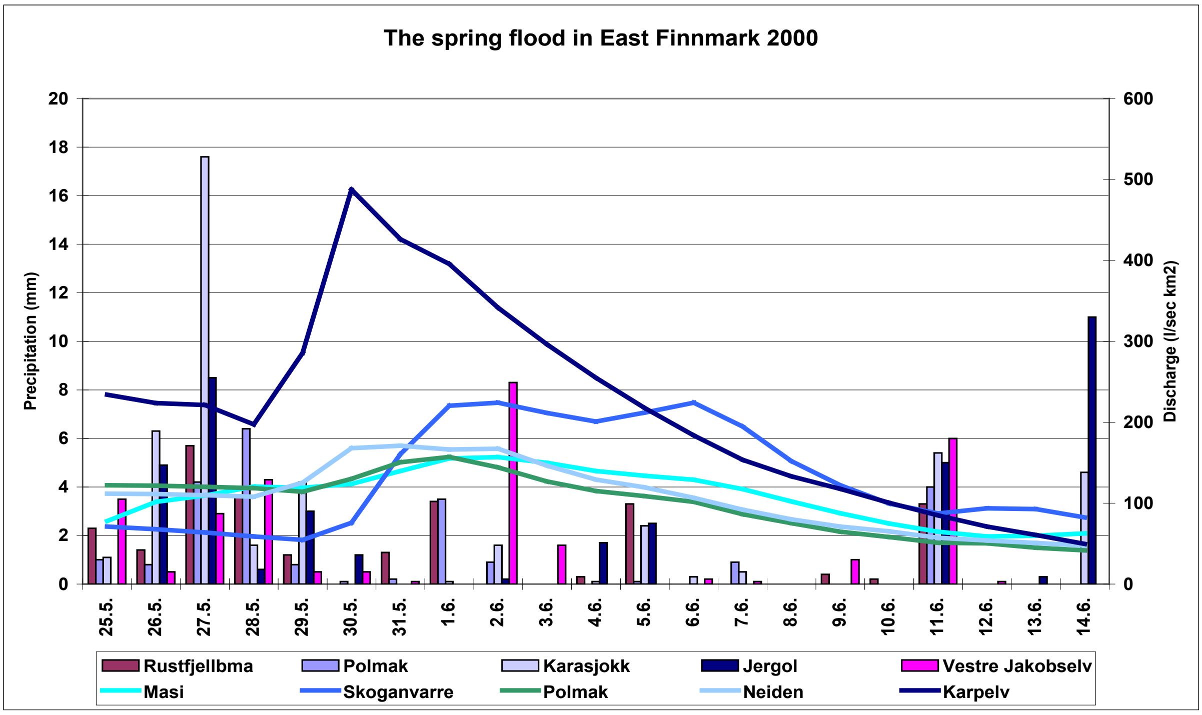


Figure 3.2.28.1 Observed daily precipitation and discharge during the spring flood in Finnmark in May-June 2000.

Extension and ranks of the flood:

The flood was fifth largest observed in River Altaelv at Masi 1966-2008, third largest in River Tana at Polmak 1912-2014 and third largest observed in River Neiden 1912-2002.

3.2.29 An example of a coastal rainfall flood where heavy rainfall did not cause an extreme flood 14-15 February 2001.

Locally heavy rainfall occurred at coastal stations at Fosen and Helgeland, causing moderate floods.

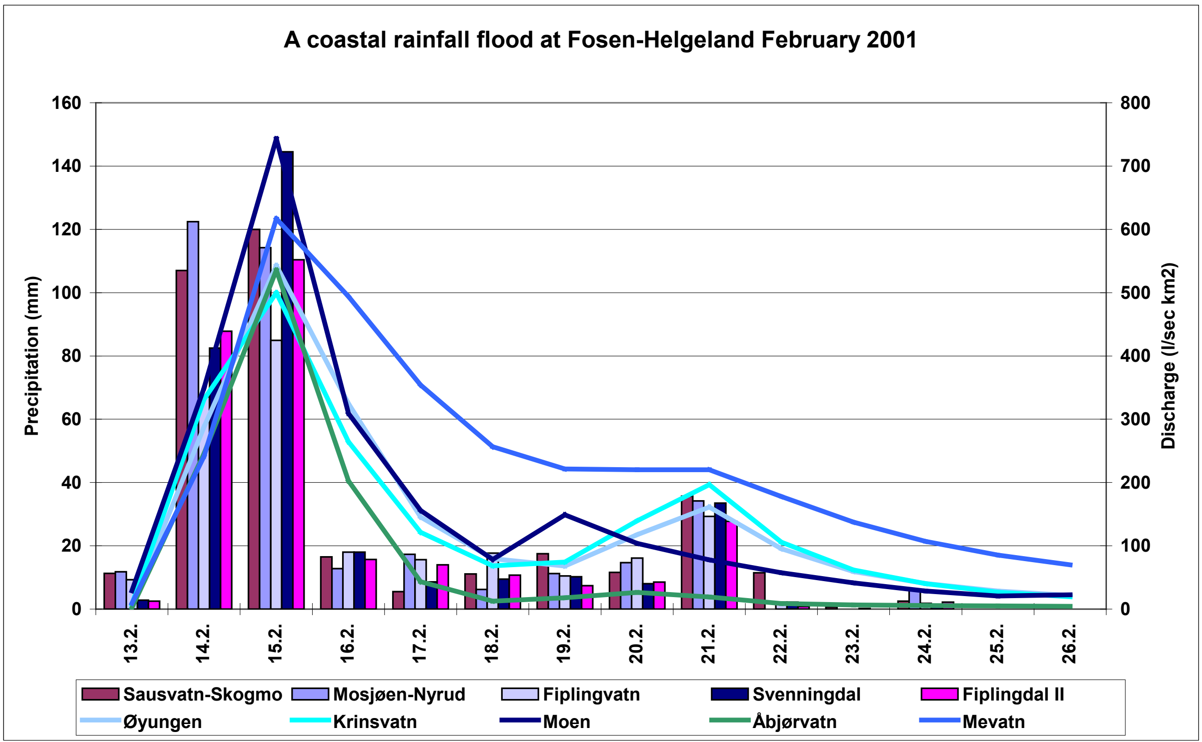


Figure 3.2.29.1 Observed precipitation and discharge at stations on the coast of the Fosen peninsula and Helgeland i Mid-February 2001.

The weather type 14-15/2 was: **BM** (Grosswetterlagen) and **A** and **AW** (Lamb-Jenkinson)

3.2.29 The large winter flood in Nordland 11 January 2002.

January 2002 had abundant precipitation in Nordland. The precipitation peaked 10-11 January, causing floods from River Fusta at Helgeland to River Ringstaselv in Vesterålen.

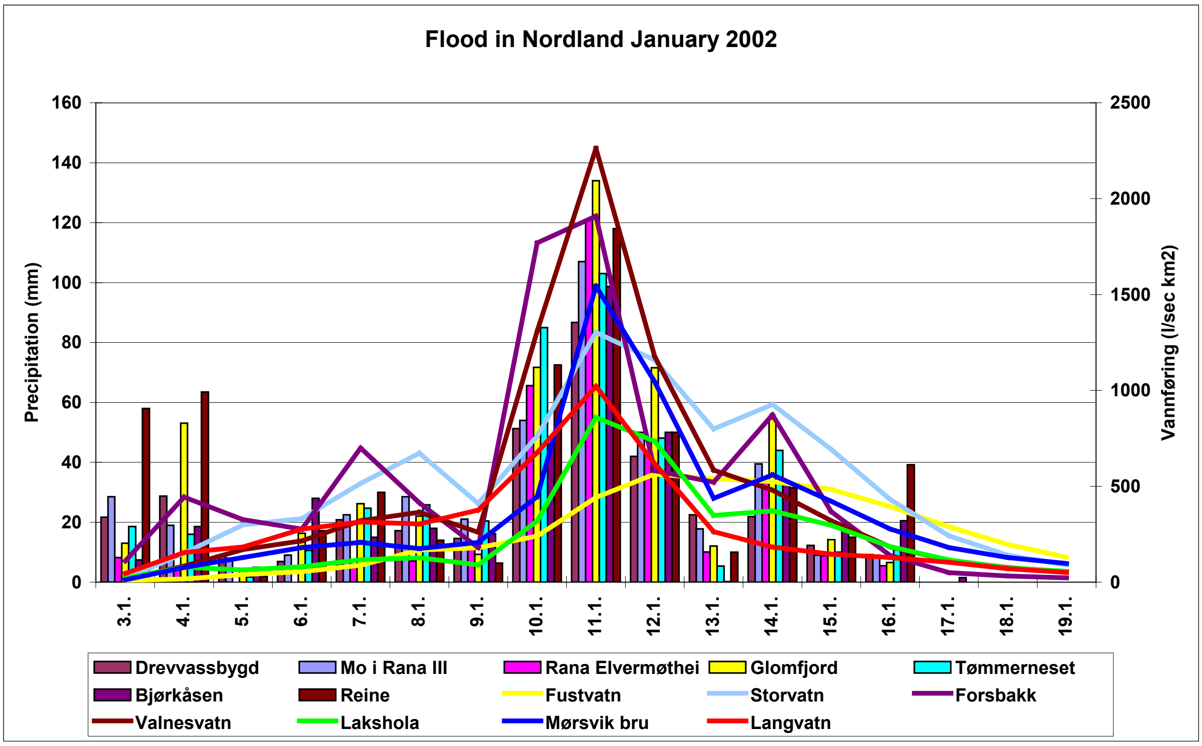


Figure 3.2.29.1 Observed precipitation and daily discharge during the winter flood in Nordland in January 2002.

Extension and ranks of the flood:

The flood was the largest observed in River Fusta at Lake Fustvatn since 1908, the fourth largest in River Leirelv at Storvatn since 1916, the second largest at River Rana at Forsbakk since 1963, the largest in River Lakselv at Lake Skardsvatn and in River Laksǻ at Lakshola since 1916. The flood was the largest observed in River Lommerelv at Mørsvik bru since 1985, at Laksǻ at Laksǻ bru since 1953, and at Forsǻ at Melkedal since 1939. The flood was second largest at River Ringstadelv at Lake Gǻslandsvatn since 1934.

Precipitation fell almost every day through the first half of January 2002. The precipitation fell as snow 1. January, but the temperature rose to 8-10°C 2-4. January at many locations. Most of Nordland was covered with snow as the flood started, as shown in Figure 3.2.29.2. (left), except on the coast and the lowlands next to the fjords. The ground was completely saturated as seen from the groundwater storage in Figure 3.2.29.2 (right). More than 100 mm rain fell at many locations 10-11 January causing the flood as shown the groundwater. The distribution of snowmelt 10. and 11. January is shown in Figure 3.2.29.3, the distribution of the precipitation in Figure 3.2.29.4 and the total inflow for meltwater and rain in Figure 3.2.29.5.

The weather type 10-12/1 was: **HM**, **BM** and **BM** (Grosswetterlagen) and **A**, **ASW** and **SW** (Lamb-Jenkinson).

Flood damages:

The flood caused extensive damages at Nordland. Around 30 roads were closed. Several landslides were released, and the railway line was blocked. Several houses were evacuated at Mo I Rana, and several bridges damaged. Many houses suffered damages in the basements because of the high groundwater levels. A dam failure occurred at Nervatn at Hinnøya, without any serious consequences.

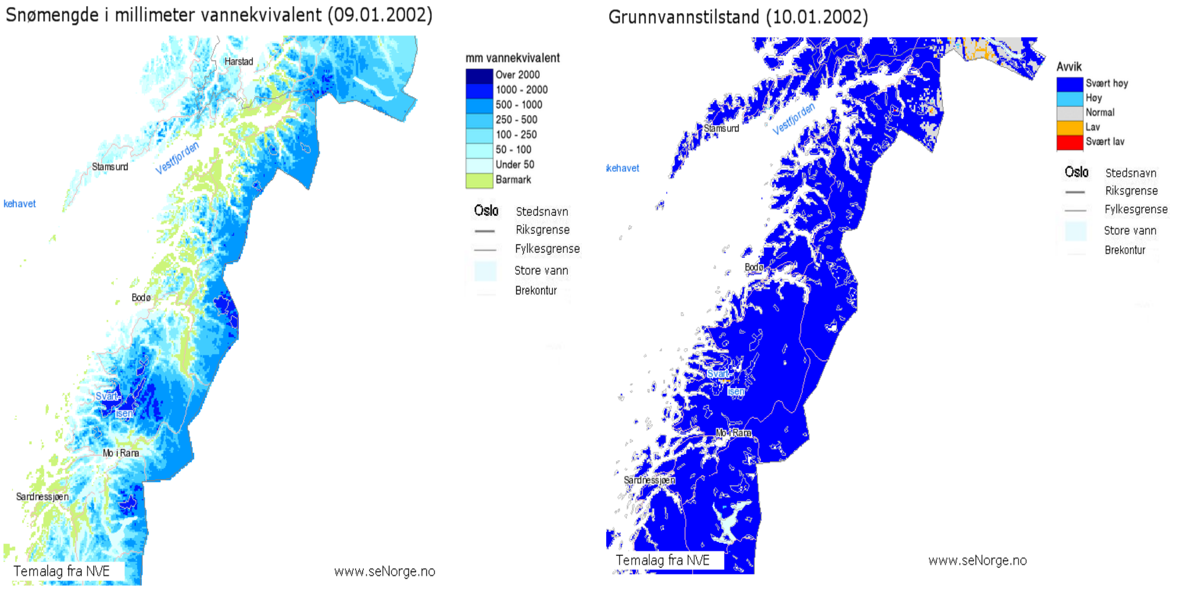


Figure 3.2.29.2 The state of the snow and groundwater reservoirs 9. January.

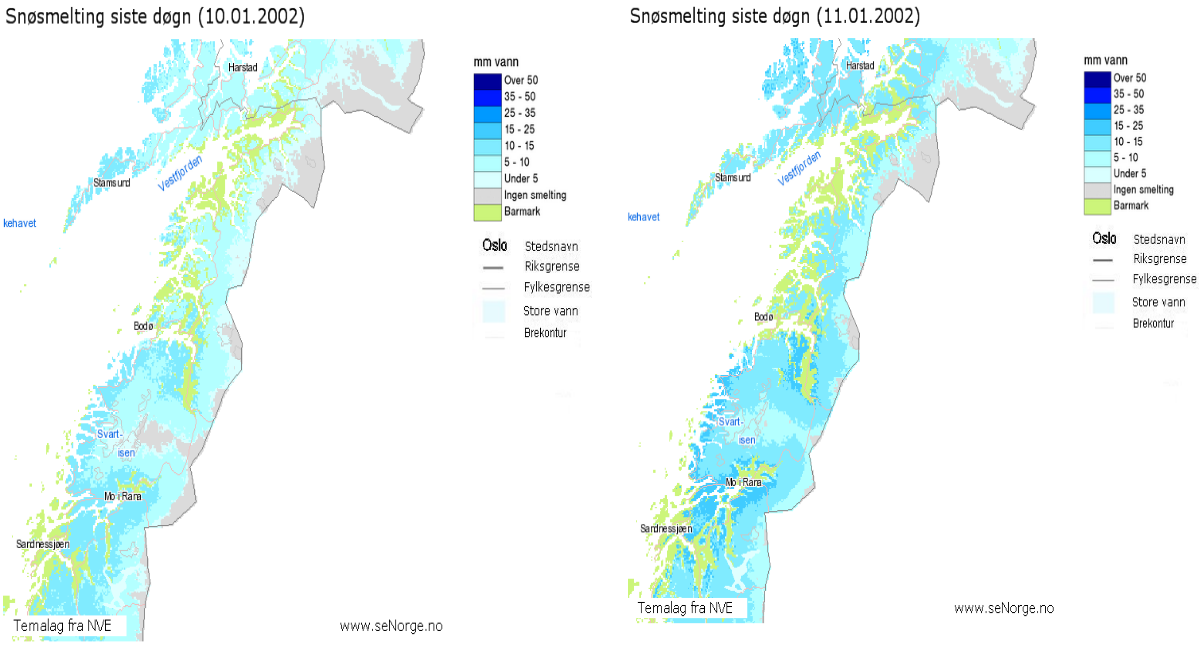


Figure 3.2.29.3 The snowmelt 10. and 11. January 2002.

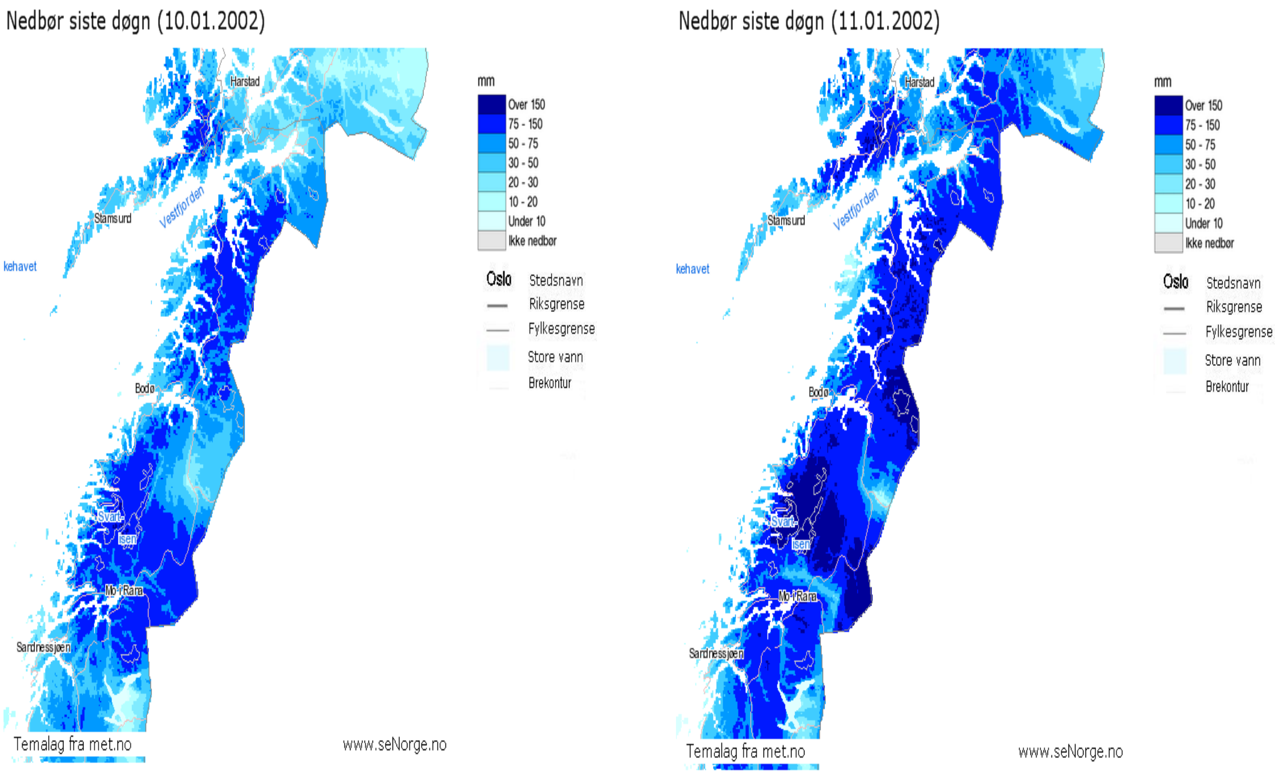
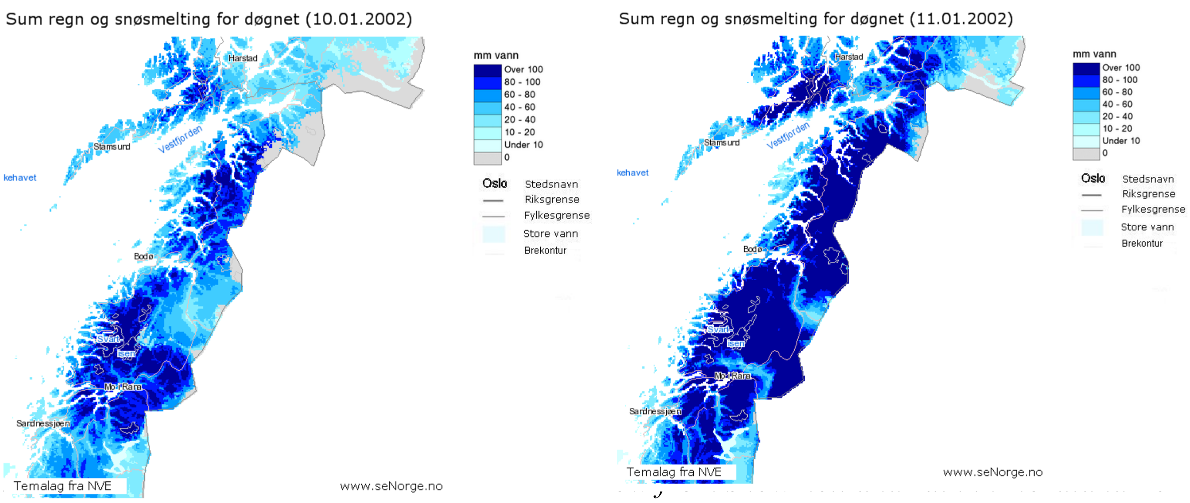


Figure 3.2.29.4 The distribution of the precipitation 10. and 11. January 2002.

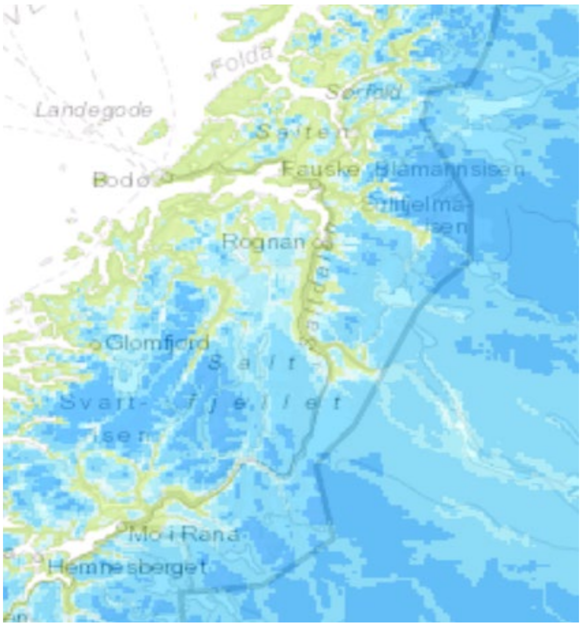


and 11 January 2002.

3.2.30 Flood and slush avalanches in May 2010 in Nordland, Troms and Finnmark.

Large spring floods occurred in North Norway 13-17 May 2010. Observed floods are shown in Figure 3.2.30.1.

Figure 3.2.30.1 Observed daily discharge and rainfall during the flood in rivers in North Norway in May 2010.



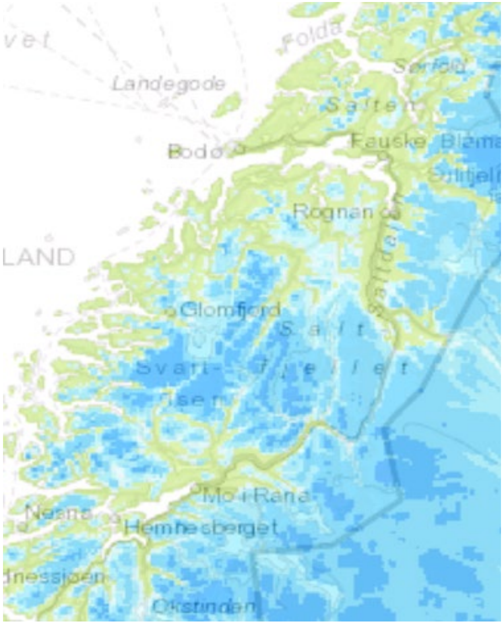


Figure 3.20.3.x Snow cover 15 May and remaining snow cover 18 May 2010

Extension and ranks of the flood:

Large floods occurred at stations from Helgeland to West Finnmark. In Nordland floods occurred in River Vefsna, Fusta, Leirelv and Junkerdalselv. The floods in several of these rivers was the third largest on record. In Troms the floods in River Salangselv, Jægerelv, Fiskelv and Reisaelv were the largest on record, while the flood ranks as the third or fourth largest in tributaries to River Målselv and in other smaller rivers in Troms. The flood in River Leirbotnvatn in Finnmark was also the largest on record and the flood caused also damages in River Altaelv where other larger floods has occurred.

Cause of the flood:

A series of Vb depressions moved toward South Norway and Sweden from Central Europe. A forecast Thursday 13 May indicated a rainfall in Oslo of 45 mm rainfall. The rain fell instead in Sweden, and the precipitation area penetrated to the water divide toward Nordland and Troms in Northern Norway. The temperature rose in the mountains from freezing temperature to 20^{0} C because of strong foehn. Ekstreme melting caused floods in many rivers in Nordland and Troms and many slush avalanches in the mountains.

The weather types were: **TRW** 13-15 May, **TRM** 16-18 May (Grosswetterlagen) and **SW/CW/ W/W/A /A** 13 – 18 May (Lamb/Jenkinsson).

Flood damages:

Quickly rising floods or slides caused closure of E6 at Herrenes, one state road and 9 county roads in Nordland in the evening Saturday 15 May. A large avalanche blocked the railway at Lønsdal in Saltdal. 21 persons were evacuated at Beisfjord in Narvik. Landslide at Manndalen in Troms took a car and an outhouse. Avalanche moved a cabin out on the ice of Store Sagelvvatn. Large avalanche threathened a village at Skibotn. Sunday 16 May the ice run flood in River Eibuelv in Alta moved two cars intoLake Leirbotnvatn. A slush avalanche took eight persons skiing, killing three persons at Jamtfjell in Vefsn.

3.2.31 The extreme flood in inner Troms 14 - 15 July 2012

Rainfall and warm air from southeast caused a local flood in Salangen and Målselv in mid July 2012. Observed rainfall and discharges are shown in Figure 3.2.31.1.

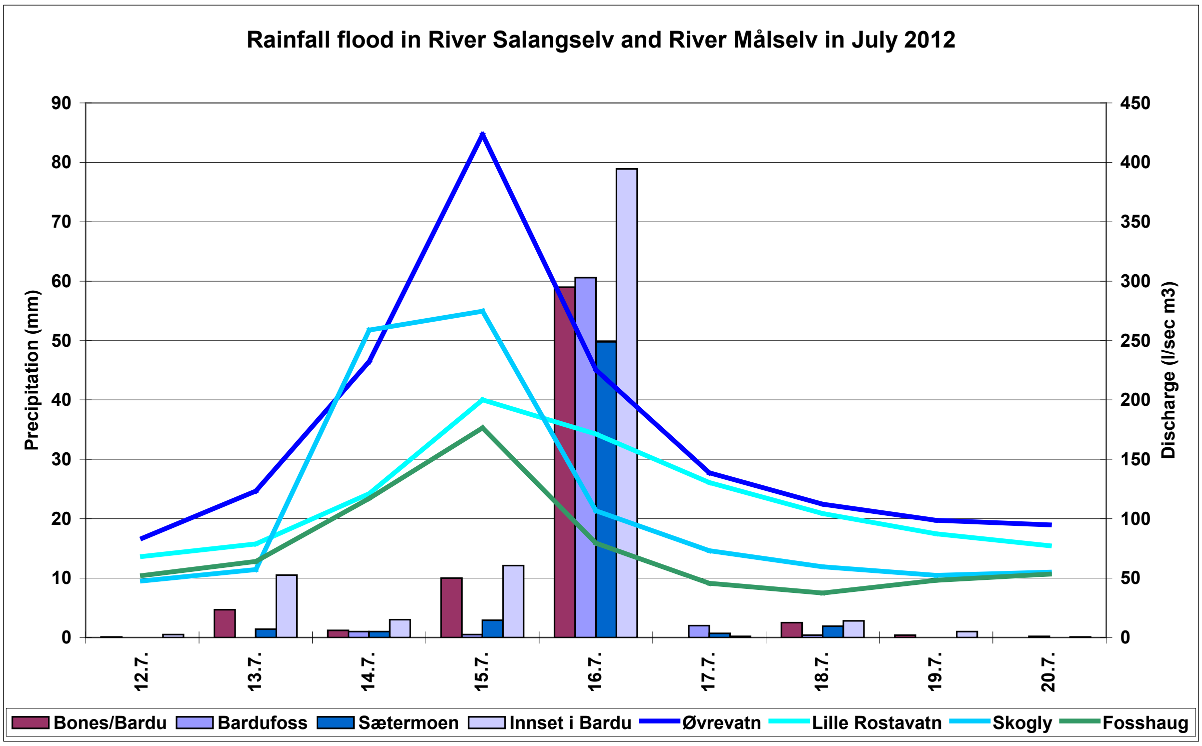


Figure 3.2.31.1 Observed rainfall and discharge (daily values) during the July flood in 2012 inner Troms.

Extension and ranks of the flood:

The flood occurred mostly in inner Troms, especially in River Målselv and River Salangselv. The flood was the eight largest on record in River Målselv at 196.3 Malangsfoss 1908-2014 and the third largest in River Salangselv at 191.1/2 Vassås/Øvrevatn 1913-2014. The return period was estimated to exceed the 100-year flood at four stations in River Målselv (Devoli, Engen, Hoseth & Pettersson (2013).

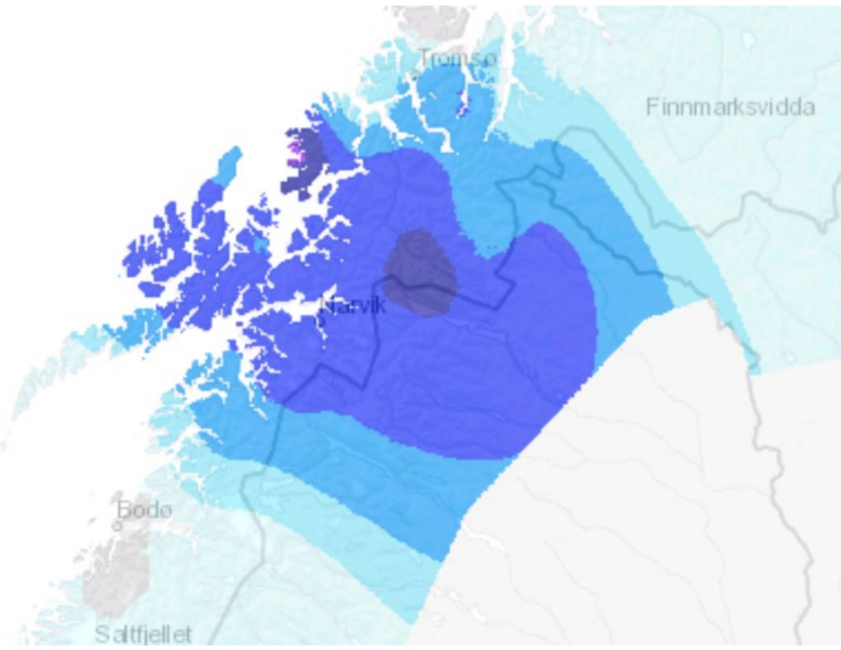


Figure 3.2.31.2 The distribution of the precipitation 15 July 2012.

Cause of the flood:

Intense rainfall occurred over the Ofoten district and the southern part of Troms County 14-15 July. A large anticyclone was extending from Ural to the Kola penninsula. Warm and humid air extended from the Black Sea to approx. 65 degrees north. Further to southwest a stationary low was located across Southern Scandinavia. The temperature was lower, and a quasistationary front occurred between the warm airmasses to the northeast and the cooler air masses toward southwest (Noer & Bøyum, 2012). The flood was caused by rainfall penetrating from Sweden with source further east in Finland. The synoptic situation shows similarities to the Vb-tief flood generation pattern with warm and humid air masses moving northwestward from the Mediterainian.

Weather types 13-17 July: **WZ** (Grosswetterlagen), **W/W/N/A/SE** (Lamb-Jenkinsson).

Snowmelt contributed also to the flood.

Flood damages:

Four municipalities, Målselv, Bardu, Storfjord and Balsfjord suffered damages from the flood. Heavy rainfall caused also many landslides. A total of 183 properties suffered damages. Some 5000 daa of farmland was inundated and covered by deposits of sand and gravel. Several rivers went bankful and damages local roads. The flood destroyed several bridges causing the local population in Østerdalen at Målselv and in Signaldalen to be insulated. The damages were estimated to 70 Mill. NOK. At least 10 Mill. of the damages was covered by the County.

3.2.32 The rainfall flood in coastal rivers at Helgeland in December 2013.

A large rainfall flood occurred in coastal rivers from Vefsna at Helgeland to Steigen at Salten 11-12 December 2013. Figure 3.32.1 show observed rainfall and discharges at selected stations at Helgeland.

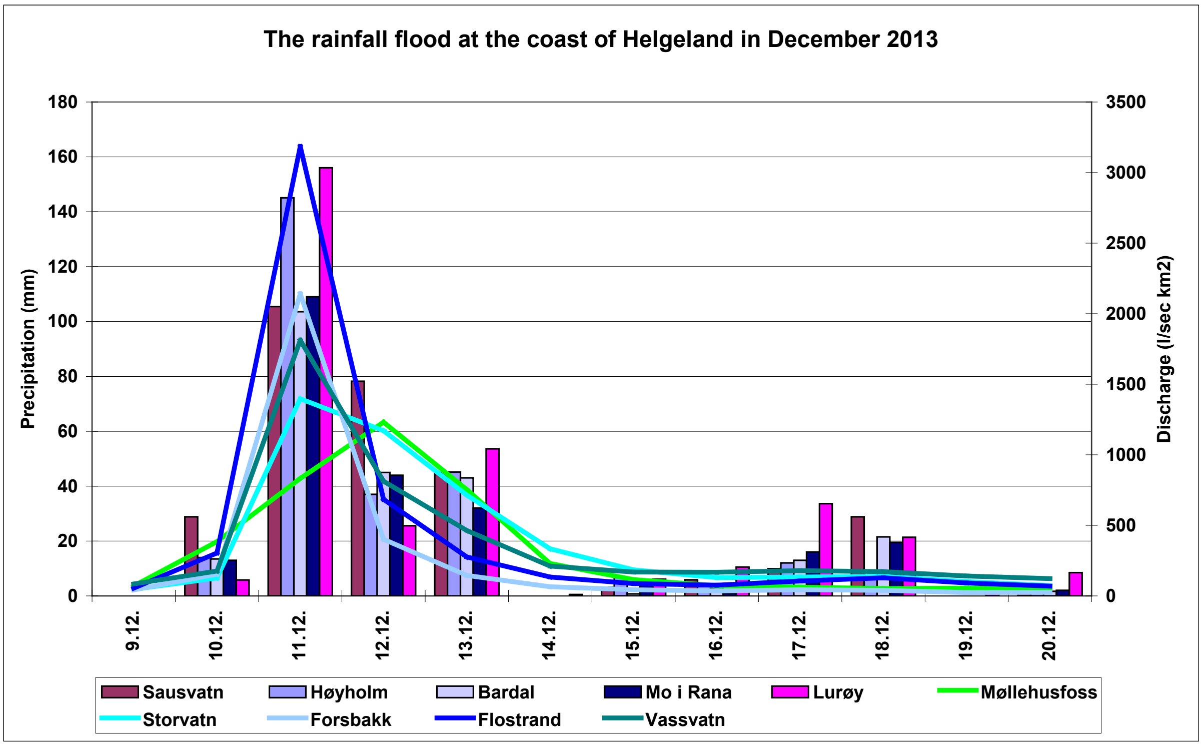


Figure 3.2.32.1 Observed rainfall and discharge (daily values) during the December flood at Helgeland 2013.

Extension and ranks of the flood:

The flood occurred in coastal catchments at Helgeland and Salten. The distribution of the precipitation is shown in Figure 3.2.32.2.

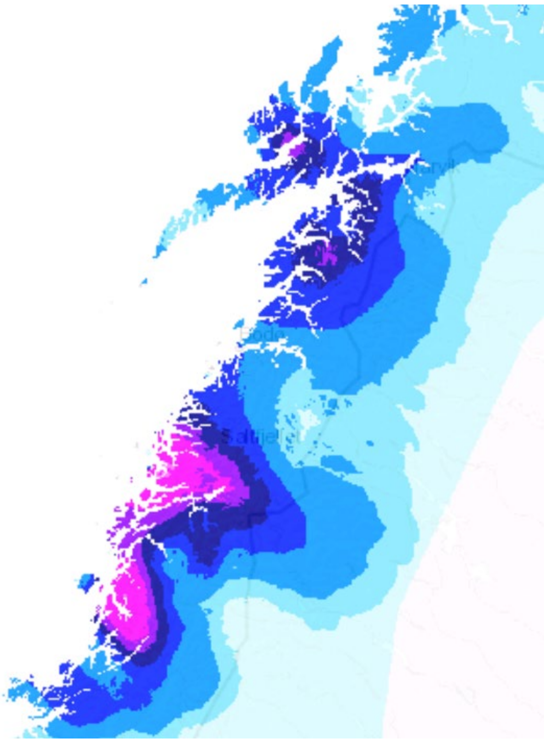


Figure 3.2.32.2 The distribution of the precipitation 11 December 2013.

The flood ranks as the largest at 157.4 Flostrand 1963-2014, the fourth largest at 157.3 Vassvatn 1917-2014 and the third largest at 165.6 Strandå 1971-2014, 156.15 Forsbakk 1963-2014 and 156.27 Leiråga 1974-2014.

Cause of the flood:

A large anticyclone was located over the European mainland from the Mediteranian to southern Scandinavia. An intense low was located between Iceland and Greenland extending northward of Norway. The polar front crossed over the coast of Norway at Helgeland producing heavy rainfall in coastal rivers. Weather types 10- 13/12 were: **HM** (Grosswetterlagen) and **SW** (Lamb/Jenkinsson).

NVE

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