Buildings and Infrastructure

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1. Introduction

Background

Population development, employment trends and mobility behaviour are important factors for the building and infrastructure sector. In the last decades, urbanisation has increased significantly in the midlands. Some agglomerations are not only growing but are joining with others. Mobility (kilometres travelled) has also considerably increased. The spatial separation of the home and working environment not only results in a steady increase in traffic but also increases the need for a functioning infrastructure. Housing space is extending to zones at the edge of or beyond the previous settlement areas, which are riskier with regard to extreme weather events. All together, these developments have resulted in a complex system that is becoming increasingly vulnerable. At the same time, costs rise if system elements collapse or fail. In order to reduce or prevent damage, the risks of climate change need to be estimated and considered early enough. Due to the long lifetime of buildings and infrastructure, it is important to adapt decisions regarding architecture, land use planning, building concepts and building services engineering to current and future climatic changes at an early stage. Firstly, additional costs for later measures may be thereby avoided. Secondly, adapted construction methods will reduce potential damage due to weather and climate. Thirdly, security and comfort of the living and working environment, as well as operational reliability of transportation will be improved.

The settlement elements examined in this chapter include the buildings of the living and working environment, road and rail networks, and urban water management (fig. 1, blue background). The remaining aspects of water, such as natural water bodies, water as a natural hazard, water supply and demand, and water usage are covered in the Water Management chapter. The energy sector is discussed in a separate chapter. As an overarching concept, settlement as a whole is also covered in the Buildings and infrastructure chapter, although only urban settlements are discussed.

The following aspects of climate change are of particular importance with regard to the buildings and infrastructure sector:

- Temperature rise / increase in heat waves
- Changes in water balance
- Increase in heavy winter precipitation
- Increase in winter storms
- Increase in thunderstorms with hail, heavy precipitation and wind gusts

In considering the effects on settlement elements and settlements as a whole, the emphasis is on two aspects: (1) quality of life and work, (2) stability and conservation of value of buildings and infrastructure.

Overview

Settlement elements: buildings

Indoor environment

Newer buildings normally have good heat insulation, which reduces the heating demand during the cold season. In summer, the heat penetrates indoors slightly more slowly but is also released outwards more poorly. Cooling can become necessary due to sunlight, and additional heat produced by machines, lighting and people, in

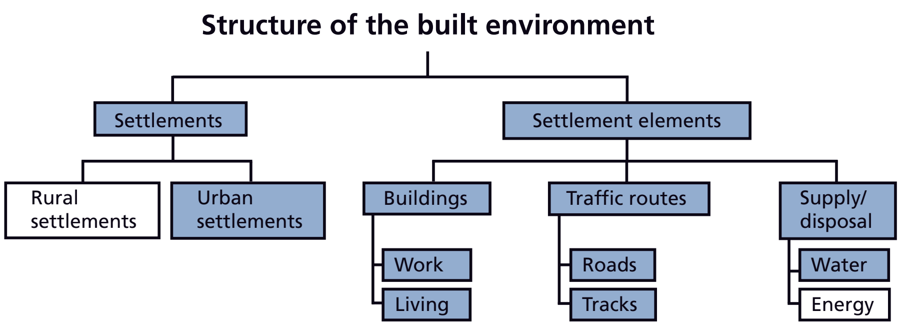

Figure 1: Overview of the areas dealt with in the Building and infrastructure chapter (blue background). The structure of the built environment is discussed as a synthesis aspect due to its strong interconnectedness with other topics (see Urban Switzerland chapter). Rural settlements are not specifically addressed, the energy sector is dealt with in a separate chapter.

particular for offices and other service company buildings, and industrial plants. With climate change, the cooling period will get longer and the probability of heat waves will increase. Anticipatory measures, such as the use of energy-efficient devices, automatically controlled lighting and sun screens, good (window) ventilation and highly efficient building cooling systems can contribute to improved room climate.

Building shells and entire buildings
For building shells, an early adaptation of building norms is particularly important. These norms are currently based on mean values of past observation periods but urgently need to be adjusted to the future climate.
The risk for entire buildings primarily results from the expected increase in extreme weather events. Such events may result in great financial damage, which, however, cannot entirely be attributed to climate change. Other important factors are the increasing concentration of assets, the growing risk vulnerability and the extension of residential buildings into areas that used to be considered too risky. Town planning therefore also has an important role to play. In areas at risk, zone planning and protective measures need to complement one another optimally in order to minimise the costs.

Rail and road network
With regard to the effects of climate change on the rail and road network, the largest problems are expected due to changes in the terrain, in particular as a result of the increase in heavy precipitation. Mudflows, avalanches and landslides can cause heavy damage to infrastructure. It is important to consider in this context the fact that natural hazards increase over the years independent of climatic changes, purely due to increasingly valuable infrastructure. In many cases, solution strategies are at hand and need to be adequately applied on a broader scale. Especially where road traffic is concerned, judging the necessity of measures also requires comparison with other risks, in particular that of traffic accidents.

Urban water management
The impact of climate change on urban water management is only partly assessable. Water supply will very likely be secure in spite of a changing demand (e.g. increased demand in summer) through optimised water management. With sewage disposal, rising temperatures, dry spells but also heavy precipitation may require adaptations in the operation of sewage plants.

Urban settlements
The temperature increase, as well as the increased frequency of heat waves or hot spells will particularly increase the heat load. In view of the health implications, consideration of this fact is imperative in spatial planning. Adequate measures to reduce the heat load can, as an additional positive effect, improve air quality.

Links to other topics
Energy
The savings in heating energy will be partly compensated by an increased demand for electricity for air conditioning.

Health
Particularly in urban areas, the increased heat load can cause health problems.

Agriculture
The increased water demand for agriculture and households can cause conflicts.

Tourism
Tourism strongly depends on a reliably functioning infrastructure.

Insurance
Natural hazards may result in increasing damages. Adaptation strategies to cope with climate change can reduce risk vulnerability (e.g. shatter-proof roof glazing) or increase it (e.g. sun protection).

2. Buildings

Room climate

With global warming, the demand for air conditioning will increase. Appropriate construction methods for new buildings and adequate renovation of existing buildings make it possible to cool buildings energy-efficiently and thereby minimise the costs.

Today, new and renovated residential and office buildings have good or very good insulation, which in winter reduces the heat requirement for room heating. At the same time, the improved insulation of the building shells reduces the outward transport of the heat that enters the building or is produced within the building in summer. In the case of large heat sources within the building and large amounts of incoming sunlight, this results in heat accumulation and therefore a cooling demand, in particular for utility buildings (see Energy chapter, section 2). Global warming will extend the annual cooling period and during hot spells, the room temperature may become a burden. As a result of this but also due to rising comfort demands, the importance of air conditioning will increase.

Office and other utility buildings

Thermal load and labour productivity

In office buildings, high outdoor temperatures, interior heat loads and sunlight often result in particularly unpleasant conditions. Many buildings have large glass panels through which light and solar energy can enter. In the room and within the glazing, the light is partly transformed into heat. Electronic equipment such as computers, copiers and printers produce additional heat. A high concentration of people in office buildings and lighting likewise add to the heat load. Good heat insulation, which is indispensable for low heating demand and for reasons of comfort even in a warmer climate, makes it almost impossible for the heat to escape through the windows or the rest of the building shell. On sunny and warm days, this results in high room temperatures, which are not only unpleasant but also reduce labour productivity. Studies have shown that for office work, labour productivity in summer decreases at temperatures above 26 °C.[1,2,3] In the heat-wave summer of 2003, the temperature in an average, non-air conditioned office space reached more than 26 °C (fig. 2) on 22 days within a time period of four weeks, despite the use of night cooling. In an average summer, this is the case for seven days. For office buildings without night cooling, which is still the norm today, the comfort threshold will be exceeded much more frequently.[4] Consequently, the cooling demand is not limited to extraordinary heat periods but also arises in the course of an average summer.

Adaptation of existing buildings

In existing buildings, the problem of heat load can be resolved by good sun protection, energy-efficient and automatically controlled (e.g. daylight- and movement-based) devices and lighting, the possibility of opening the windows, and the installation of cooling systems. Through technical optimisation and by making use of synergy effects with the heating supply, investment and running costs can be minimised. In new buildings, appropriate construction methods can make the installation of air-conditioners superfluous. So-called free cooling systems or highly efficient air conditioners use a fraction of the energy of today's standard of air conditioners and cooling systems.[6] Such systems use outdoor coolness as much as possible (e.g. low outdoor temperatures during the nighttime, evaporation, heat pump ground probes) to cool ceilings, floors and walls, which can again absorb warmth from the ambient air the next day. Architectural measures can make a considerable contribution, for instance sun protection (although an increase in the danger of hail and storms must be taken into consideration, in particular for high buildings; see Building shells section), room depth, window size and orientation, and architectural landscape elements, such as trees, lawns and water features.

Efficiency and energy demand

Provided that the critical points mentioned are taken into consideration in future building, overall the savings in heating energy are expected to be larger than the additional energy

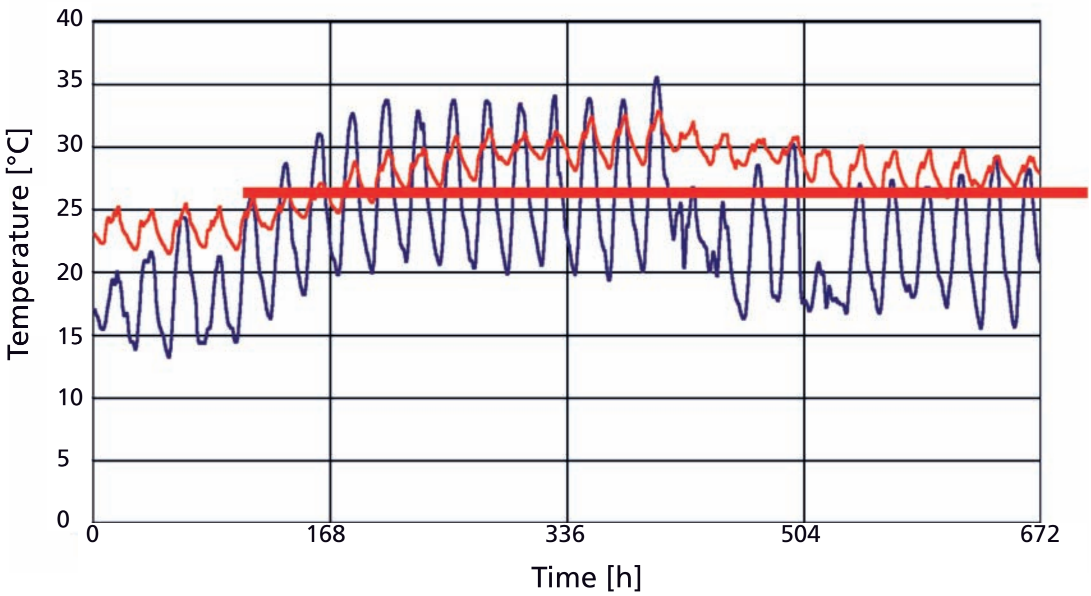

Figure 2: Calculated temperature profile for four weeks during the heat-wave summer of 2003, location MeteoSwiss Zurich. Outdoor (blue) and indoor (red) temperature in an office building with a large proportion of glass (80%), good sun protection (g=0.10), moderate internal loads (15W/m^2), comfort cooling during the day and intensive night cooling (nL=0.3h^{-1}). The comfort threshold of 26 °C (red bar) is exceeded on several days. Above this threshold, workplace productivity decreases rapidly. (Source: Frank 2006)[5]

demand for cooling. However, this change means a shift in the energy demand from fuels to electricity (see Energy chapter, section 2). There are economic and resource policy reasons for cooling buildings as efficiently as possible (see Energy chapter, section 5), in particular also in view of the enormous energy savings in comparison to inefficient cooling measures. A particular challenge in this respect is the fact that efficient building cooling requires the careful coordination of different elements (e.g. insulation, ventilation, shading, windows). Such integrated conception and planning is still the exception today. On every level, it is primarily the investment costs rather than the life cycle costs that are minimised, which prevents the realisation of carefully coordinated systems. Therefore, an urgent need for action exists in energy policy at the legislative level in the sectors concerned, as well as for builders, and building owners, operators and users.

Adaptation costs

Additional costs must be expected for the adaptation of existing office buildings and other utility buildings, such as shopping centres, hospitals, homes and schools, where air conditioning, air conditioning refurbishment and improved sun protection will account for the largest proportion of the costs. According to a study on behalf of the Swiss Federal Office of Energy[7], protection against overheating alone will cause costs of 10 Swiss francs per square metre a year. Today, office space amounts to about 40 million m^2, altogether the heated and lit area of the service sector amounts to more than 150 million m^2. Cooling two thirds of this area would cost 1 billion Swiss francs per annum. However, the benefit gained by higher labour productivity and workplace attractiveness is estimated to be even higher, which is why cooling of buildings will become an important topic in the coming years.

Residential buildings

In residential buildings, adequate construction usually avoids the need for cooling devices, in particular because of the nighttime cooling through opening the windows. Good and possibly also automatically controlled sun protection reduces the external heat load. Adequate ventilation, e.g. by means of earth tubes, as well as window and nighttime cooling through appropriate ventilation flaps and vents, dissipates the heat. Both measures – reduction of the heat load and dissipation of existing heat – contribute to a comfortable indoor climate. The effect of nighttime cooling can be enhanced by using the indoor storage capacity, for instance by means of exposed concrete ceilings, carpet-free flooring and plasterboard-reinforced attics. The use of ground probes as a relatively energy-efficient cooling source is also worth mentioning.

Building shell

The expected increase in intensity and frequency of extreme weather events endangers damageable elements of the building shell. Today's construction standards, which are based on the mean climatic values of past observation periods, need to be adapted to the future climate.

The vulnerability of structural elements on the outside of buildings could possibly increase in the future. Firstly, the frequency and/or intensity of extreme weather events is expected to increase (e.g. heavy precipitation, winter storms) and secondly, the number of constructions easily susceptible to damage will likely increase. These can be shade devices for protection against the warming climate, insulation or devices for energy saving and generation (e.g. solar panels). The variety of materials used for roofs and facades has increased. With office and industrial buildings in particular, materials with inadequate hail resistance are often used. These are translucent synthetic materials, steel sheets and sun screens (fig. 3).

Up to now, the requirements for the security of structural elements on the outside of buildings have been based on the mean values of past climate observation periods. These requirements are codified in construction standards. Not only technical installations (e.g. masts and towers, long-span bridges, greenhouses) and buildings at extreme locations (e.g. in the high mountains, in the vicinity of rivers), but also ordinary buildings are affected by more severe weather impacts. The anchorage of light facades and roof coverings, shatter resistance of roof glazing, weatherability of shading equipment and solar panels need to be examined for existing buildings, and adjusted to the future climate for new buildings.

Figure 3: Hail damage in facade made of synthetic material, Wetzikon 2004.
(Source: Thomas Egli)

Extreme events and threats to entire buildings

The possible increase in floods, heavy precipitation, storms and hail events can endanger buildings and lead to great financial damage. The changing risks require the adaptation of building regulations.

Floods

When floods occur today, they usually cause great financial damage in the area of infrastructure. This cannot be attributed to climate change but to the concentration of assets, that is, the risk of damage increases with the continuous expansion of the road and railway networks and the building of bridges and houses. Furthermore, in comparison to the past, building activities have extended into areas that used to be considered too risky and were therefore avoided.

The question of whether floods will become more frequent with climate change cannot be answered conclusively by the scientific community (see Water management chapter, section 3). An increase in frequency seems probable, in particular in winter and the transitional seasons. The midlands, the foothills of the Alps and Ticino would presumably be primarily affected. In order to prevent an increase in the extent of flood damage with climate change, flood protection needs to be reassessed regularly. The flexible strategy that Switzerland currently pursues (see Water management chapter, section 3) aims primarily at preventing damage and not necessarily at avoiding floods.[8]

Storms

Buildings that are particularly exposed, such as aerial towers, are strained close to the stability limit by storms as intense as Lothar (December 1999). If the number of such storms increases, this will require the tightening of building regulations.

Heavy rain

The expected increase in heavy precipitation is to be considered in the dimensioning of property drainage. This affects ground floors and cellars of buildings that border on slopes and hollows. In city centres, the risk may also increase, since drainage is often dimensioned for less heavy precipitation.[9]

Hail

Between 1983 and 2003, the number of large hailstorm tracks (track length > 100 km) doubled in Switzerland.[10,11] The large hailstorm tracks cause hailstones of large diameter. They damage sensitive roof and facade materials, such as synthetics, steel sheets and external insulation. Shading equipment is generally very susceptible to the effects of hail.[9]

Figure 4: Snow pressure caused the collapse of a hall roof, Waldstatt 2006.
(Source: Thomas Egli)

Snow load

The expected increase in winter precipitation may cause static problems for roofs at elevations where precipitation falls as snow. Too high snow loads can result in extensive damage or, in the worst case, even the collapse of the roof. Halls with large spans of lighter building materials, such as wood or steel, are particularly at risk. In such cases, the snow load is large in comparison to the self-weight. Flat roofs are also at risk, in particular if the previously fallen snow has turned to ice due to bad insulation and the new snowfall further increases the load. In order to minimise the risk of roof collapse, the possible future increase in snow load must be considered in the planning of private and public buildings.

Avalanches

The risk of avalanches may change with global warming but it is unclear whether they will become more or less frequent. Independent of a change in the overall number of avalanches, their frequency may also change for certain regions. In any case, minimising the costs requires risk analysis and adequate measures (zone planning, protection measures).[8] The avalanche winter of 1999 showed the possible extent of damage due to snow masses.

Uncertainties/Open questions

To estimate the temperature and humidity behaviour of rooms, as well as their impact on comfort and productivity requires improved models. Furthermore, the question of thermal comfort should not be considered separately but should be integrated with microclimatic and energetic issues.

3. Transport networks

Rail network

The effects of climate change on the rail network can be attributed primarily to the possible increase in extreme weather events. Heavy precipitation events put line stability at risk, and storms and heat waves can cause damage to overhead contact wires and rails. Appropriate countermeasures prevent an exponential increase in loss amount.

Line stability and security

Already today, railway lines are regularly exposed to natural hazards, primarily due to extreme weather events such as long rain periods or strong snowfall. Thus, numerous railway stations were flooded in connection with the floods of August 2005 (fig. 5). Heavy precipitation may not only result in floods but can also cause landslides and mudflows. Build up of water and waterlogging within the vicinity of the tracks, as well as bank erosion and mudflows from drainage channels, are further possible outcomes.

Figure 5: August 2005 flood, Dornibach/SZ
(Source: SBB)

Precipitation

The threat to line stability will increase with the predicted increase in winter precipitation, which will increasingly fall as rain at lower elevations, and with the expected increase in heavy winter precipitation In particular, the stability of embankments and slopes will be increasingly called into question. Heavy precipitation may also cause the undermining of lines.

The future frequency of instabilities and drainage problems will not only depend on precipitation amounts and intensity. The soil water content and water storage capacity of soil and loose rock, as well as water from nearby drainage channels, will also be important factors. This particularly applies to summer, in which total rainfall tends to decrease but the rain increasingly falls on parched soil.

It seems probable that the instability of embankments and slopes will rise with increasing precipitation. Apart from railway lines in the vicinity of slopes, the possibility that railway stretches built on artificially cut-out slopes in the midlands and the foothills of the Alps will slide away should not be underestimated. There, heavy precipitation may also lead to water logging, instability and hence to landslides.

Above the snow line, larger winter precipitation amounts may result in an increase in the danger of avalanches or blocking of infrastructure (switch blocking, restricted visibility, snow piles on the lines). With regard to avalanches, the railways have a land register of the relevant avalanche tracks. Already today, critical areas are secured with protective galleries or are closely monitored during heavy snowfall. The safeguarding of further avalanche tracks could be realised relatively straightforwardly in the event that such a need arises.

Temperature
The consequences of the mean temperature increase and the presumably more frequently occurring heat waves on line stability and security will primarily be of an indirect nature. The effects may result from the melting permafrost as well as possibly from the changes in thaw and frost processes.
The heat-wave summer of 2003 showed the consequences of high temperatures on slope stability. In the course of that hot summer, a great number of rockfalls and rock avalanches were observed in the entire alpine region, in particular at higher elevations and on north facing slopes. This extraordinary rockfall frequency can be interpreted as a sign that the destabilisation due to extreme heat occurs as an almost immediate reaction. As areas with permafrost are very often located outside of settlement and infrastructure areas, the future risk is also limited. In critical areas, risks and damages can be minimised by the expansion of protective measures (e.g. safety nets, protective walls, monitoring).
At lower elevations, which will be exposed to positive temperatures more frequently due to the temperature increase, a reduction in the number of rockfalls is imaginable.

Engineering works
Engineering works, such as bridges, tunnels and passages, are not expected to be affected by constructional problems in connection with global warming. The magnitude of the temperature increase will normally be able to be absorbed by the works without consequence. Storms are not expected to cause structural problems either. An increase in potholes and flow problems near bridges and passages as a result of larger floodwater amounts is possible.

Contact wires and tracks
Winter storms
Based on the expected increase in winter storms, an increase in falling trees is to be anticipated (fig. 6). When trees fall on contact wires or tracks, this normally causes delays and the interruption of railway services, as well as damage to infrastructure. About one third of the 300-km-route network of the SBB is forested on one or two sides.
The SBB aims at a defined forest profile along all forested route sections. In the vicinity of the tracks, small bushes and scrubs are preferred, and with increasing distance more highly growing trees, so that a clear profile is generated. Thus, falling trees can rarely cause damage anymore. This procedure is beneficial with regard to availability and safety in case of storms but less favourable with regard to the shading of train embankments in the event of heat waves (microclimate of embankments).

Temperature trend/Extreme heat
The increase in summer temperatures affects the railway system. High temperatures lasting for days can result in lateral displacement of the tracks. This happens because expansion of the tracks due to the heat is blocked by the seamless welding. The resulting compressive forces can lead to lateral displacement of the tracks. When the tracks are laid, measures are taken in order to reduce these compressive forces and to increase the lateral resistance of the tracks.
During the heat-wave summer of 2003, lateral displacements occurred about 50% more frequently than is the case during an average summer. In order to avoid the risk of derailing, trains need to reduce speed in the event of lateral displacement or, in extreme cases, are no longer able to ride the tracks concerned. Since heat waves will have become considerably more likely by the year 2050, railway companies need to prevent more frequent lateral displacements. Construction methods can be adapted with some extra costs, so that the tracks withstand higher temperatures without damage. Thus, the requirements for Ticino are already more strict today. The tracks are exposed to higher

Figure 6: Tree over the trackway, Wiggen
(Photo: SBB)

temperatures during laying in order to prevent any later deformation.

Increase in summer storms?
Summer heat-storms also present a potential risk to contact wires because lightning strikes can lead to operational disturbances and damage to contact wire systems. Since there have been no forecasts with regard to summer storms up to now, it is hard to estimate whether this risk will change.

Development of loss amount
According to a study by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), which shows the development of loss amounts from 1972–2005, the cumulative cost of damage due to floods, landslides and mudflows have risen almost linearly with time over the past 30 years (fig. 7). The report shows that the increase in the cumulated loss amount is clearly sub-proportional in comparison to population growth, increase in settlement area and value concentration. Therefore, the extent of loss due to natural hazards is smaller than one would actually expect from the development of value concentration. This trend is not least attributable to the effects of the protective measures. In view of the expected changes, it seems probable that an exponential increase in loss amounts due to property damage can be largely avoided by anticipatory planning and the implementation of corresponding measures.

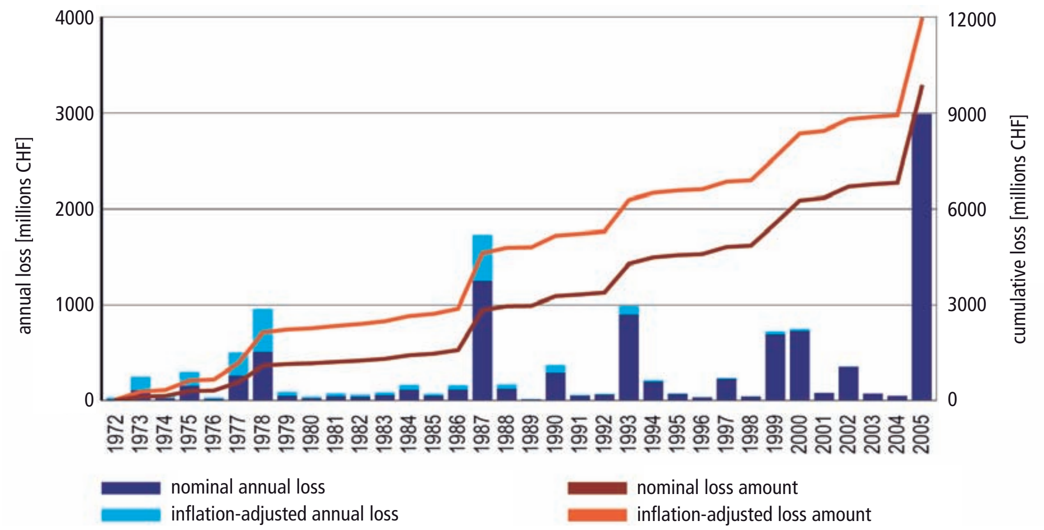

Figure 7: Loss amounts 1972–2005. Floods. Landslides. Mudflows.
(Source: Swiss Federal Institute for Forest, Snow and Landscape Research, 2007)

Road network

Similar to the railway system, the road network is also primarily at risk from extreme events. With preventive measures for new hazards and with adaptations in road making, disturbances and risks to road traffic will be kept largely constant.

Climate change will affect the road network in a similar way to the railway system. Fundamentally, it is expected that the extent of the effects on roads will be smaller because the road network is generally less sensitive as far as construction is concerned. Other factors, such as a further increase in the maximum weight of lorries or a distinct increase in the number of heavy vehicles, would in all likelihood have more severe effects than the expected climate change. Furthermore, the very dense road network has the advantage of being more flexible in comparison to the railway system; when a section of road is at risk or not passable anymore, alternative routes often exist.

Road making will adapt to changed conditions where necessary in relation to materials used and the construction of roadways. The most important climatic impacts on the road network will be floods and slope instabilities. In addition, avalanches, winter storms and hail may have adverse effects on road traffic.

Heavy precipitation/Floods

Floods can affect sections of roads in a similar way to railway lines. If rivers and lakes burst their banks, excessive volumes of water may cause undercutting or, in flatter areas, floods (fig. 8). In mountain areas, heavy precipitation often results in landslides and mudflows. On the other hand, low-snow winters may have a positive effect on road traffic, with a decrease in accident risk and costs for road maintenance.

Slope instabilities

Just as with rail traffic, there is a risk of mudflows and rockfalls for road traffic. Roads at higher elevations and in exposed positions are particularly at risk. Rockfalls are not necessarily attributable to climate change but can have various causes. Trigger factors include: rock weathering, larger water masses that act as a lubricant, frost/thaw effects that lead to the loosening of the rock formation, and the melting of permafrost due to increasing temperatures (see Line stability and security). A combination of different factors is also possible. Already today, the vulnerability of the traffic system to disturbances is great due to the large volume of traffic and people's expectation of almost unlimited mobility.

Avalanches

Just like the railway system, the road network may be affected by avalanches or avalanche risk. In conjunction with climate change, the risk will possibly increase at higher elevations, where larger precipitation amounts may fall as snow in winter.

Winter storms

Due to the expected increase in winter storms, falling trees will be more common. If these trees fall on the street, this puts drivers directly at risk and can lead to interruptions in road traffic. However, the risk is currently small and should not increase substantially in the future.

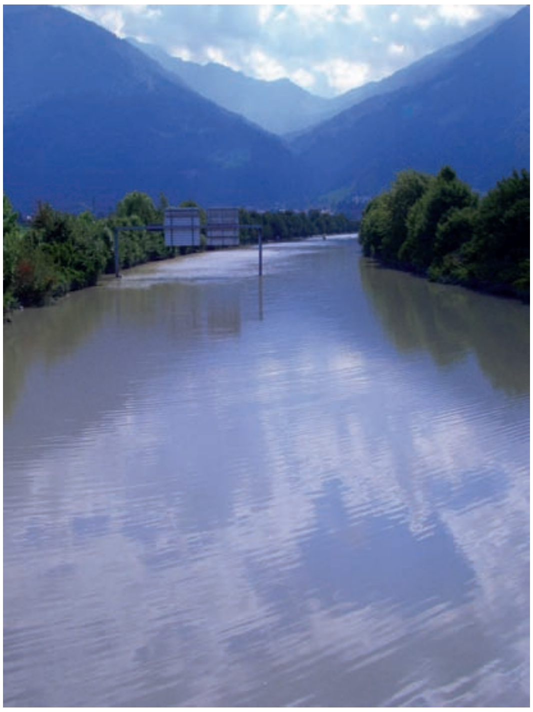

Figure 8: August 2005, N8, between East Interlaken and West Interlaken.
(Source: Muriel Kleist)

4. Urban water management

In order to ensure the water supply, warmer and drier summers on the one hand, and changes in water demand on the other, require that water management be optimised. Sewage disposal has to be adapted to the changing requirements due to higher temperatures, as well as more frequent dry spells and heavy precipitation events.

Water supply

With climate change, the demand for premium quality water (drinking water quality) will increase. This will require that water management be improved, in particular because there will be an increase in the variation of consumption. Additional peak consumptions could occur if more people spend their holidays in Switzerland in the summer months instead of going to the south, where it will be hotter in the future.

Dry summers will strongly increase the water demand for watering gardens. Water of lower quality can be used for this purpose, although appropriate infrastructure does not currently exist. The heat-wave summer of 2003 gave an indication of the extent of the expected demand. Since groundwater is rarely used to capacity today in Switzerland, and because there are sufficient water reserves in the lakes, it should be possible to cover additional peak consumptions, provided water supply infrastructure is adequately linked. However, temporarily falling groundwater levels are expected to occur regionally. Groundwater contamination due to the discharge of pre-cleaned surface water into the subsoil will become more frequent. Groundwater protection zones may need to be enlarged. This will mean considerable financial expense, since the setting aside of protection zones involves expropriation procedures.

Water provision from springs is critical in rural, poorly linked karst areas (Jura, Alp foothills) if springs with small catchment areas fed by surface water run dry during prolonged dry periods. In order to ensure water supply here as well, a stronger linked network is necessary, which will be associated with high costs.

With higher temperatures, water temperatures will also increase. This could possibly become uncomfortable in Switzerland but still not critical. The quality of raw water, of which 20% comes from lakes and 80% from groundwater and springs, could worsen in certain cases. A change in algae population and therefore in oxygen content would require new preparation processes. The danger of microbial recontamination in distribution pipelines will increase.

Sewage disposal

Sewer system

Higher temperatures in the sewer system due to higher outside temperatures will lead to increased concrete corrosion and therefore increase the need for maintenance. This problem can be avoided by choosing appropriate materials. Odour problems may possibly occur more often.

If the groundwater level falls during dry periods, the infiltration of groundwater decreases. At the same time, the exfiltration of sewage water increases. This increases the sedimentation in sewers and possibly pollutes the groundwater as well. Dry phases also affect the treatment of mixed water, that is, rainwater mixed with sewage water, which cannot be taken up by sewage plants due to capacity constraints. If dilution can no longer be ensured in small rivers due to low water flow or drying-up, the demand for treating mixed water may increase. Additionally, tractive forces in sewer lines decline with a decreasing proportion of foreign water, which increases the risk of blockages and requires adaptations in the operation of sewage plants.

On the other hand, heavy precipitation can lead to backwater in sewers and thus to flooding of cellars or entire neighbourhoods. With the expected increase in heavy precipitation, this problem will occur more often and, in critical cases, require the laying of larger dimensioned sewer pipes and installation of backwater valves.

Wastewater treatment

Climate change poses little threat to the wastewater treatment operation, however, certain adaptations will be necessary. Biological processes accelerate with increasing temperatures and oxygen demand rises as a result. Since oxygenation will be hindered at the same time, facilities will need to be upgraded.

Higher temperatures of waterbodies, low water due to increasing aridity and the greater demand for irrigation water will result in additional demands on wastewater treatment. Such investments may also be required by the demand for higher standards of water for bathing.

Private house connections

With both sewer systems and water supply, problems primarily occur at the house connections. In Zurich, this is the case for 50% of water pipe ruptures. If the groundwater level falls as a result of climate change, this may result in settling, which, in turn can cause more frequent pipeline ruptures.

Uncertainties/Open questions

The effects of climate change on urban water management can only partly be assessed. In order to assess more precisely where there is indeed a need for action, additional hydrological information is required, in particular on the development of groundwater levels, the frequency of short and heavy precipitation events, future water supply, the frequency of extremes and the seasonal cycle.

5. Urban settlements

In cities, the heat load is larger than in the surrounding area due to the larger proportion of sealed surfaces, less numerous green areas, waste heat from buildings, industry and traffic, and poor air circulation. With climate change, the problem of urban heat islands will increase.

Cities are often cooler during the day than the surrounding area but significantly warmer during the night. Different factors contribute to the so-called “heat island” effect and therefore to the generally higher heat load in cities. Buildings and sealed surfaces absorb more heat than ground that is not covered. The heat input during the day is stored by roads and buildings, and the cooling effect due to evapotranspiration is small in comparison to the surrounding rural area because green spaces and plants are rare. Additional heat comes from the emission of waste heat by buildings, industry and traffic. Finally, air circulation in cities is worse than in the surrounding area due to the reduced wind speed.

Temperature increase and more frequent heat waves or heat periods worsen the problem of urban heat islands. Thus, the effects of the heat wave summer of 2003 were distinctly more serious in cities than in rural areas.[12] Temperatures reached particularly high values, which meant that the mortality rate amongst inhabitants of cities was especially high.[13] With regard to health effects, it is not only the maximum daily values but also the high nighttime temperatures that are relevant. In view of the expected development that with climate change there will be a stronger increase in nighttime than daytime temperatures, countermeasures are particularly important. Since nighttime temperatures in cities are already generally higher today, the negative health effects will worsen with climate change.

In Switzerland, the increased heat load in cities has been neglected so far in urban development. This aspect needs to be considered in spatial planning in order to prevent the heat load resulting from climate change from increasing further for urban dwellers. Thus, for instance, greening and shading of pavements and pedestrian zones can reduce the heat load.

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