CAMP4ASB
Climate Adaptation & Mitigation Program for Aral Sea Basin
CENTRAL ASIA

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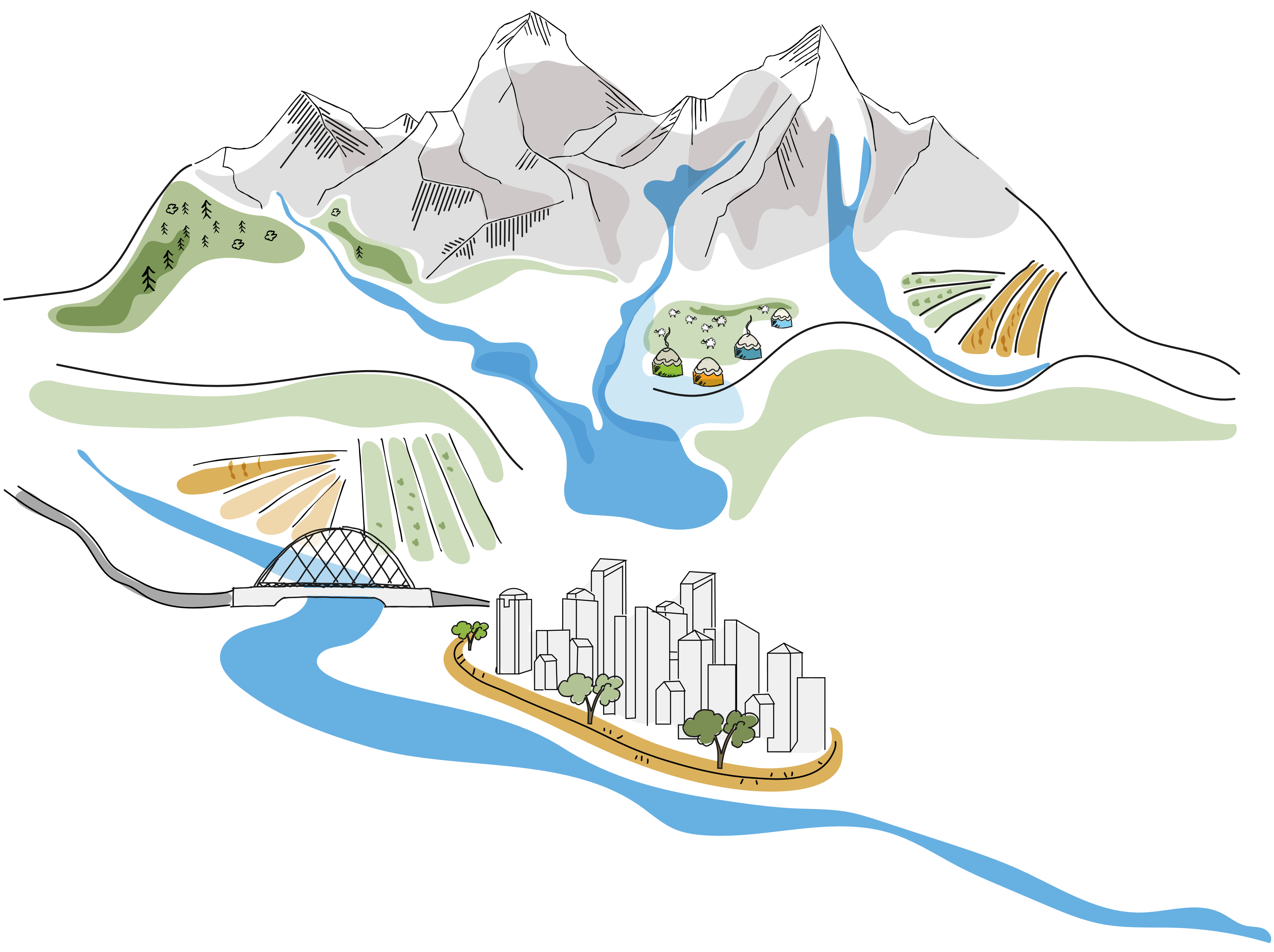
Climate Change and Hydrology in Central Asia

A Survey of Selected River Basins



Climate Change and Hydrology in Central Asia: A Survey of Selected River Basins

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This report is based on the research by the group of national experts:
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Climate Change and Hydrology in Central Asia

A Survey of Selected River Basins

Introduction

Selected river basins

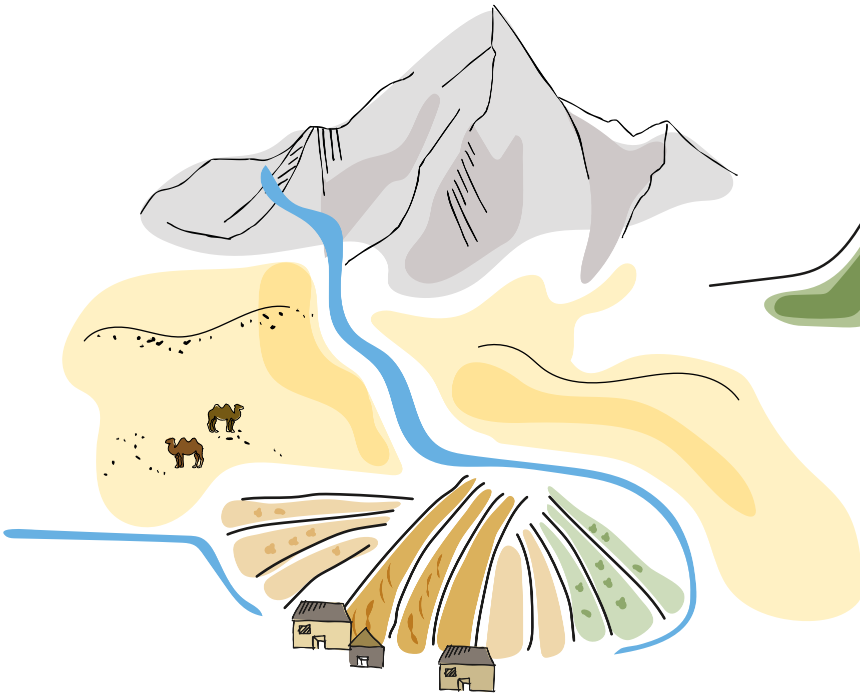
10 Esil and Zhabai
Representative of Central Asia's flatland climate and hydrology systems, these rivers originate in the vast northern grasslands of Kazakhstan. Their average flow is modest, but spring floods can be significant and water flow can vary from year to year.

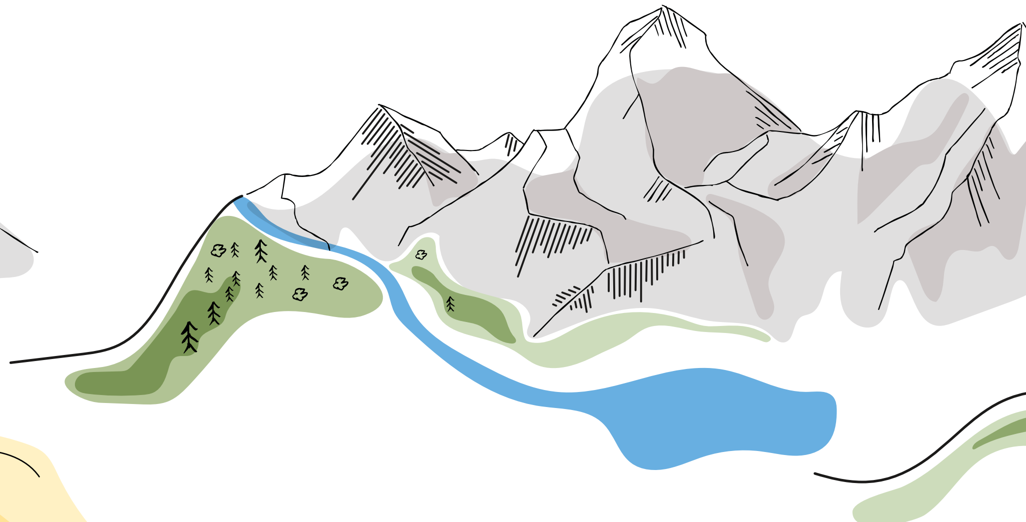
14 Bukhtarma
A powerful mountain river with sources in the Altai Mountains with whitewater rapids fed by glaciers and snow, the Bukhtarma's scenic environment makes it a popular tourist destination.

16 Zeravshan
With origins in glaciers in the Pamir-Alai Mountains of Tajikistan, the Zeravshan carries its waters to the ancient and densely populated areas of Samarkand and Bukhara, Uzbekistan, home to 6 million people.

18 Kofarnihon
Rising in the high snowy mountains of central Tajikistan, the Kofarnihon flows through highly contrasting climates from wet to dry and icy cold to desert hot, and boasts diverse water uses for irrigation, municipal needs and industries.

20 Murghab
Originating in the dry highlands of central Afghanistan, the Murghab flows into Turkmenistan and ends at an ancient oasis. Agriculture is the predominant water user in the basin.





Water flow in the rivers of Central Asia is defined by a multitude of factors – climate, terrain and soil types, and weather extremes. This report highlights key research findings on five important river basins across Central Asia, and presents the visual material with short annotations for a lay readership.

Temperature, precipitation, the extent of permanent snow cover in the basin and the amount of water and snow (melt water equivalent), along with sun radiation and evaporation are the key meteorological factors that define the hydrological conditions. Soil and vegetation cover, slopes, and geological factors as well as human regulation and diversions of water flow play a great role in mitigating or exaggerating flood intensity and the water distribution across a basin. The Soil and Water Integrated Model, applied in this analysis allows representation of a river basin as a system. It simulates the hydrological, biogeochemical and vegetation processes, and integrates the anthropogenic impacts of water storage, irrigation and water withdrawals into the modelling framework.

The national hydrometeorological services of the Central Asian countries are producing weather forecasts for 5–7 days that are 80–90 per cent accurate. Producing seasonal weather outlooks is a more difficult task. Hydrological forecasts rely on weather forecasts, and users are mainly interested in longer-term seasonal predictions and flood peak warnings – a daunting task associated with a high degree of responsibility for human lives, crops, energy production, water regulation and infrastructure. Climate change projections are inherently

uncertain, since they depend on estimates of global greenhouse emissions, global atmospheric processes and climate models. Medium and high emission scenarios were used in these studies.

None of the models can project precipitation amounts or type – rain or snow – with confidence for specific river basins, especially in the mountain areas. At the regional scale, however, the northern parts of Central Asia are expected to become somewhat wetter, while the southern parts become drier – a continuation of recently observed trends as monitored by the North Eurasian Climate Centre and portrayed in the recent national communications to UNFCCC. Mountain regions have their own climates, and may feature a mosaic of contrasting trends. All models show moderate-to-strong climate warming from 2°C to 6°C by the middle and end of this century, compared to the current climate.

The water flow projections were averaged for the periods up to 2040, 2041–2070 and 2071–2100, and compared with the baseline of 1981–2010. Little or no significant changes in hydrology could be seen before 2040 in any of the river basins. Beyond this point, changes are likely and their significance will grow over time.

Seasonal peaks of water flow are likely to shift to earlier in the year. Peak flow for the Esil River is likely to increase. Shrinking glaciers in the Bukhtarma and Zeravshan basins and faster snow melt in spring mean that less water will be available in summer – a troubling prospect in the densely populated middle and lower areas of the Zeravshan basin, which rely heavily on irrigation.

Flows in the Kofarnihon depend on the amount of snow in winter and the amount and intensity of rainfall in spring. Rising temperatures will melt snowpack earlier and add water management challenges.

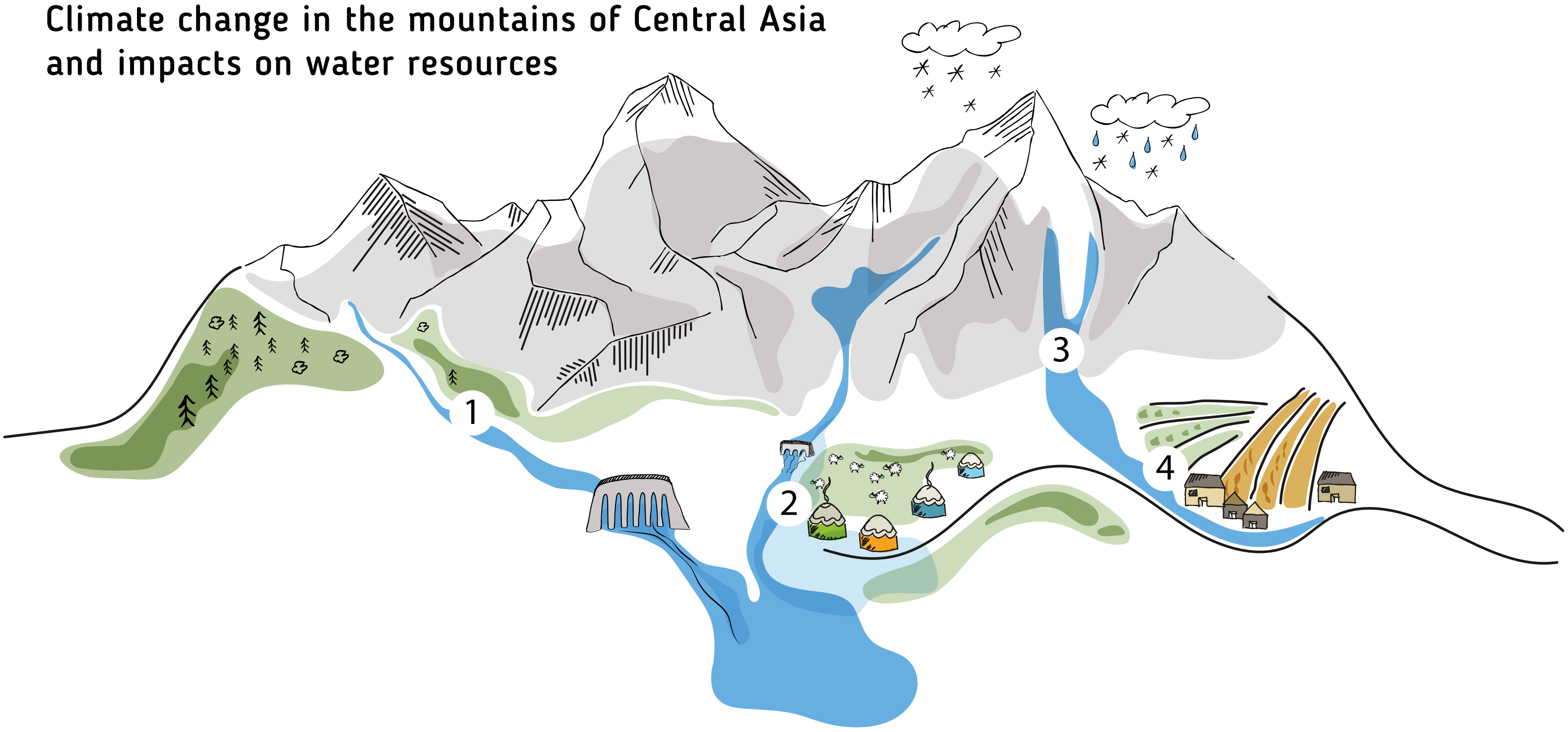
The Zeravshan and Kofarnihon play vital roles in irrigation and crop cultivation in Uzbekistan and Tajikistan. Water management efficiency in agriculture can be improved starting from water intakes, pumps and canals, down to the field and plant level – through drip irrigation, improved leveling and crop selection. Many farmers are already using these adaptation approaches to conserve water and protect the soil. Others are harvesting rainwater and guarding against extreme weather and climate variability with greenhouses and protective plantings. Authorities are improving coordination and preparedness measures, cleaning drainage systems and revising protections against flooding in the Esil and Bukhtarma.

Of the rivers in this survey, the Murghab is the most vulnerable to climate change, and is likely to experience significant reductions in water flow in the coming decades. The implications for water security, especially among downstream agricultural users, are serious.

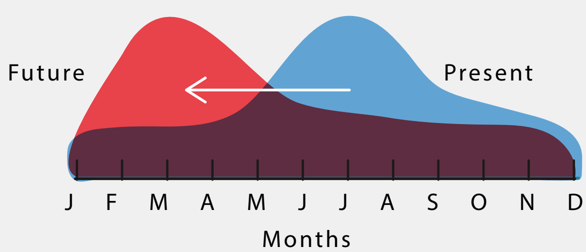
As temperatures rise more precipitation is likely to fall as rain instead of snow, and ice and snowpack are likely to decline due to less snow and higher temperatures. These changes will affect river flows in terms of both timing and amount of discharges. The discharge graphs for the rivers show projections under two climate scenarios based on selected greenhouse gas emission pathways – moderate (RCP 4.5) vs. strong (RCP 8.5) warming.

Hydrology of rivers

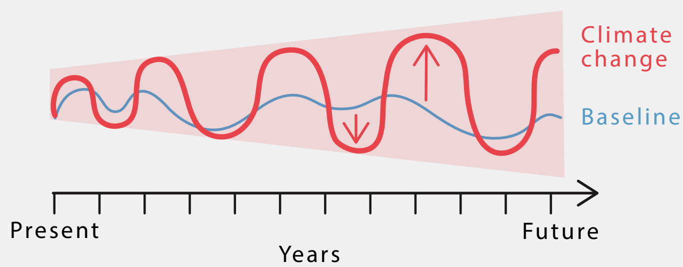
Climate change in the mountains of Central Asia and impacts on water resources



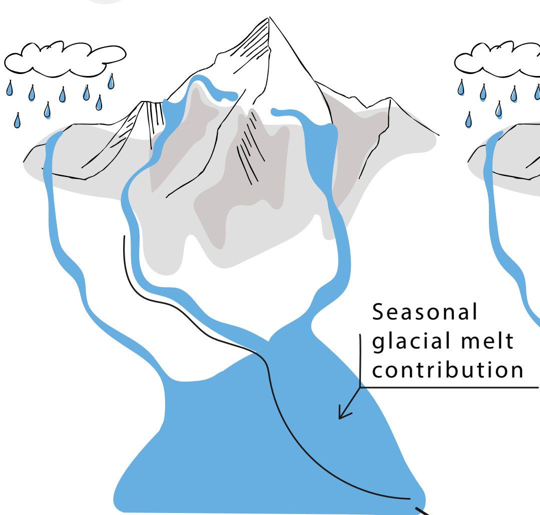
1 Seasonal shift in water availability



2 More pronounced inter-annual water fluctuations

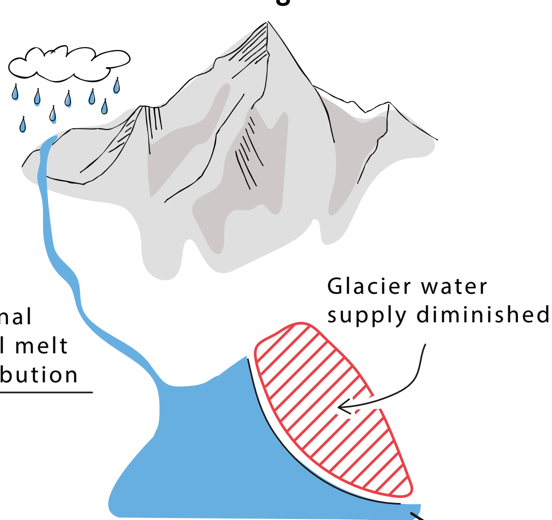


3 With glaciers



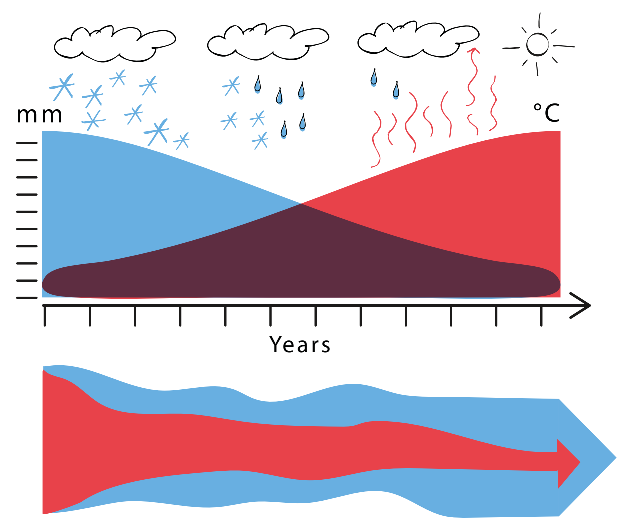
Present
Glaciers contribute important part of flow in hot and dry summer months

Without glaciers



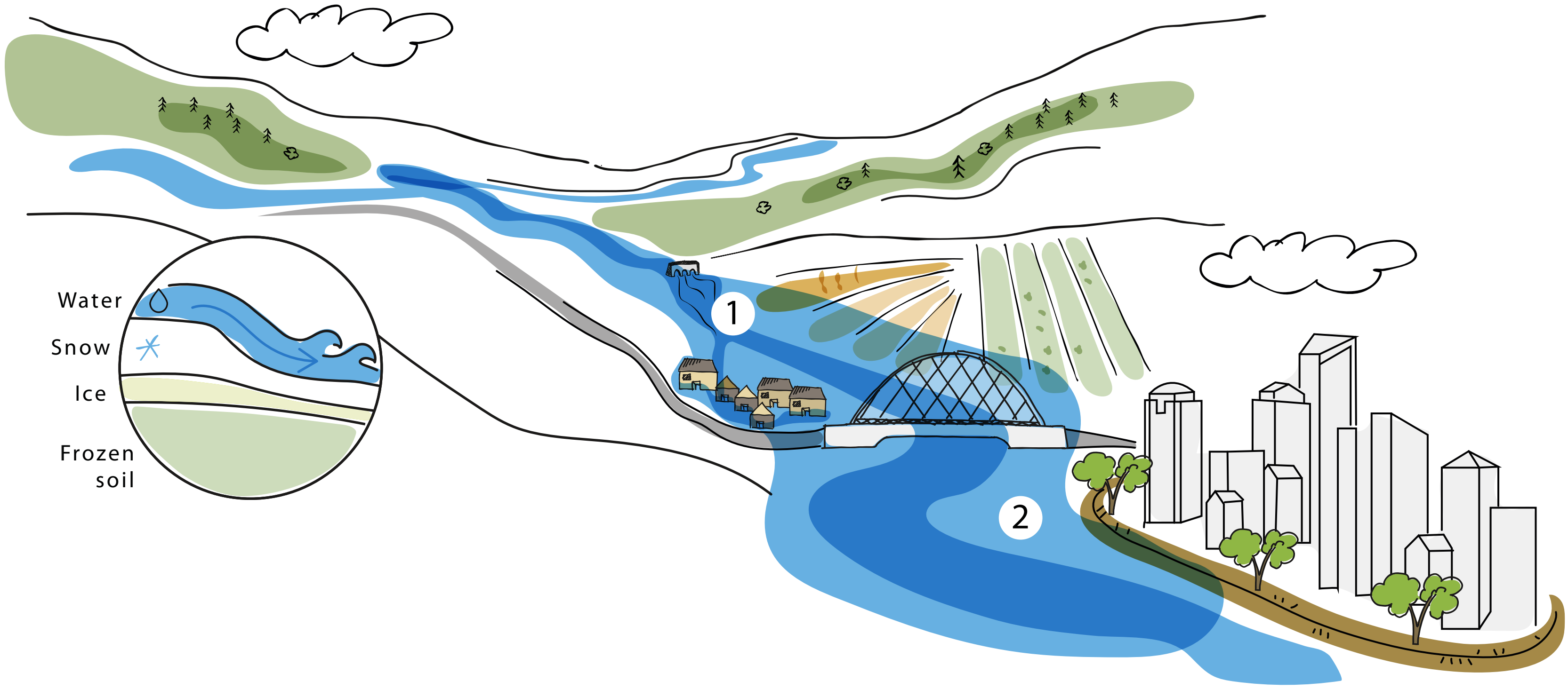
50-70 years from now
Less water security in hot and dry years

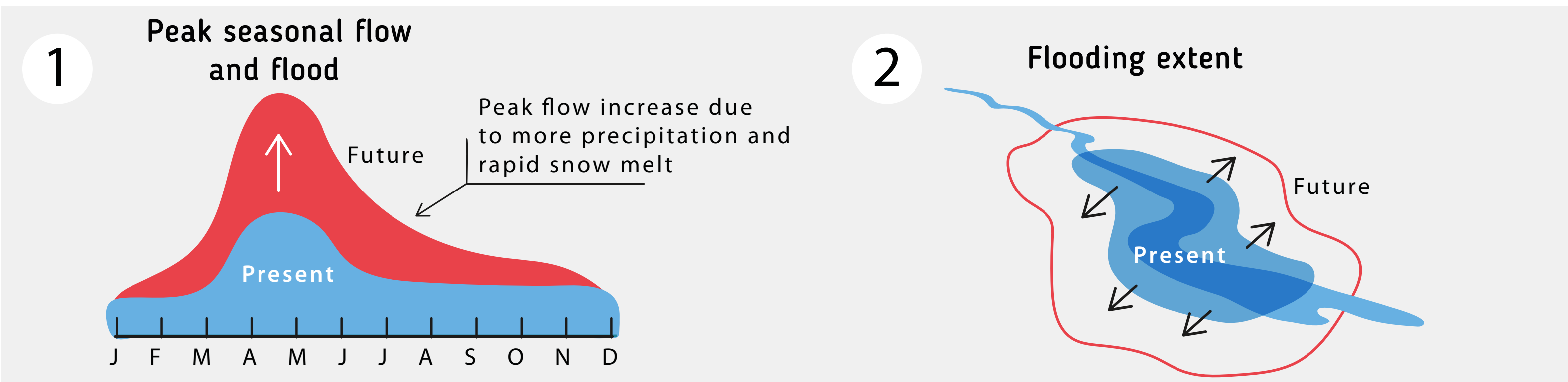
4 Snow pack declining due to warmer temperatures



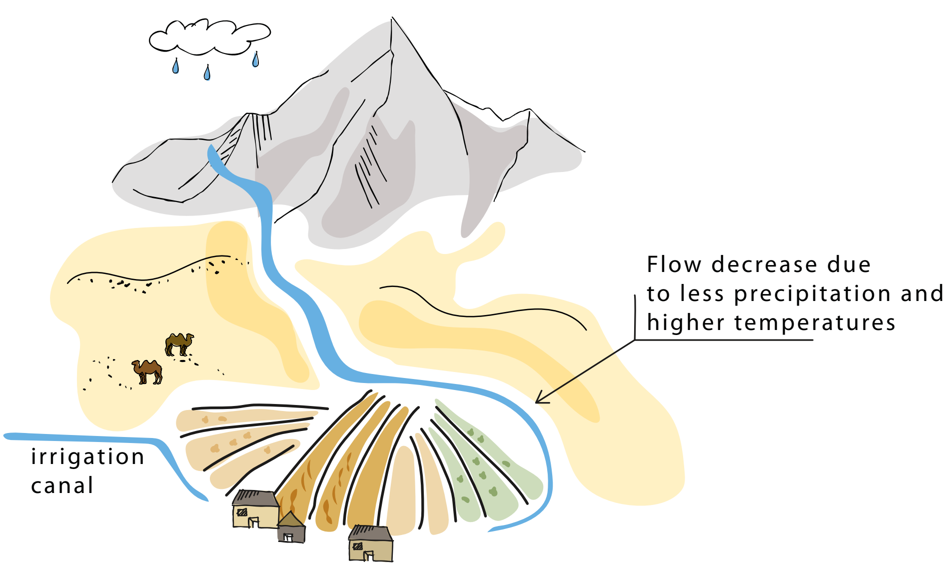
River flow declining due to increased evaporation

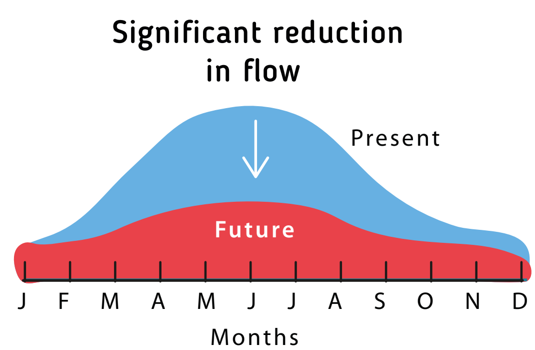
Climate change in the northern steppes of Central Asia and impacts on water resources





Climate change in southern deserts and highlands of Central Asia and impacts on water resources





Esil and Zhabai

The Esil starts as a typical small flatland river in Central Asia with an average flow of 4 m^3 of water per second at Astana, the major city in the basin. Further downstream, the Zhabai sub-basin drains an area of 8,800 km^2 and has an average flow of 8 m^3 per second. Together the basins cover an area of 177,000 km^2 and are the largest system in the survey. The model considered only 5,400 km^2 of the Esil basin – upstream of Astana – but considered the full extent of the Zhabai basin.

After the Esil River passes Astana and is joined by Zhabai and other streams, its flow strengthens to as much as 40–50 m^3 per second, doubling as it flows through Russia, where it changes its name to Ishim before joining the Irtysh River and draining into the Arctic Ocean. The total length of the Esil is 2,450 km, and the river is mostly fed by spring snowmelt. The climate across the basin is continental with moderate rainfall and a temperature range of -40°C to +35°C. Near Astana, a canal spans 20 km to connect the Esil to the Nura River to supply the capital with additional water.

The snow melts faster than the river ice, and the frozen soil channels the melt water into the river. For the 2–3 weeks of the snowmelt period, the river discharges 1,000 m^3 of water per second or more at Astana and 1,700 m^3 per second downstream at Zhabai-Atbasar where the river level may rise by 6 metres causing significant damage to infrastructure and property. When the area experiences sudden warming, floods can develop rapidly, and can complicate the forecasts for the timing and scale of the event. Weekly hydrological forecasts, along with field measurements can provide some indication of imminent flooding, but extreme flooding remains difficult to predict.

Agriculture in the basin uses Esil River water for cattle and some irrigation, but most of the basin's agriculture is rain-fed, and the main water uses are domestic and industrial. City water supplies are sufficient, but population growth comes with increased demand for water.

Overview

- - - - - River basin boundaries

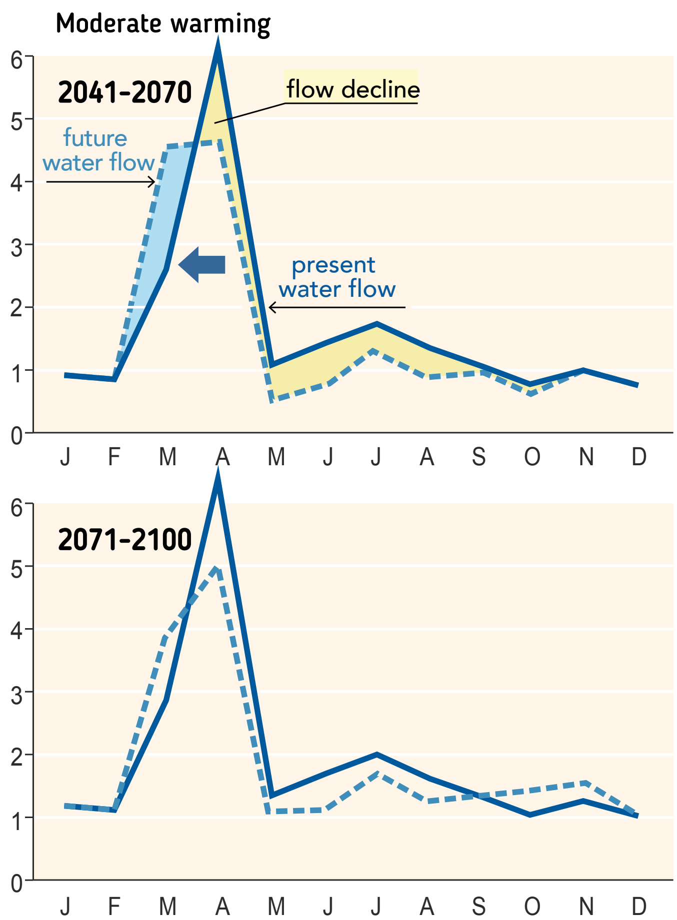
+++++ National boundaries

15 Average annual water flow per gauging station (m^3/s)

Under both warming scenarios (moderate and strong) for 2041–2070, the monthly peak flow of the Esil River might be lower than current levels, but it will occur over two months – March and April – as opposed to the current peak in April. The peak seasonal flow of the Zhabai River is expected to be higher than the current flow. An overall increase in the discharge of the Zhabai River by the end of the century under both warming scenarios is projected, with particularly strong increase of the peak flow in April.

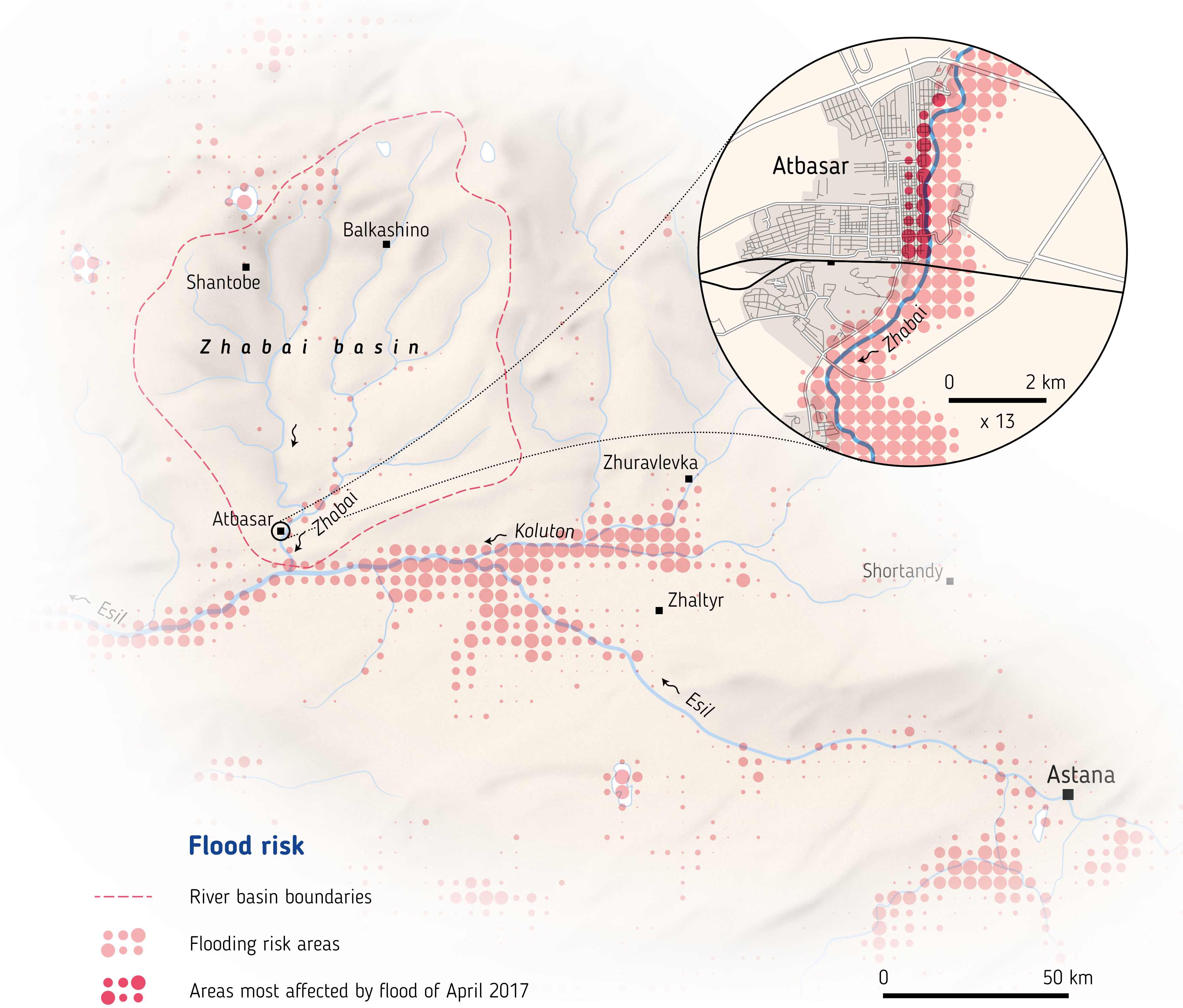
Esil River: Projected changes in hydrology

Average monthly water discharges, m³ per second



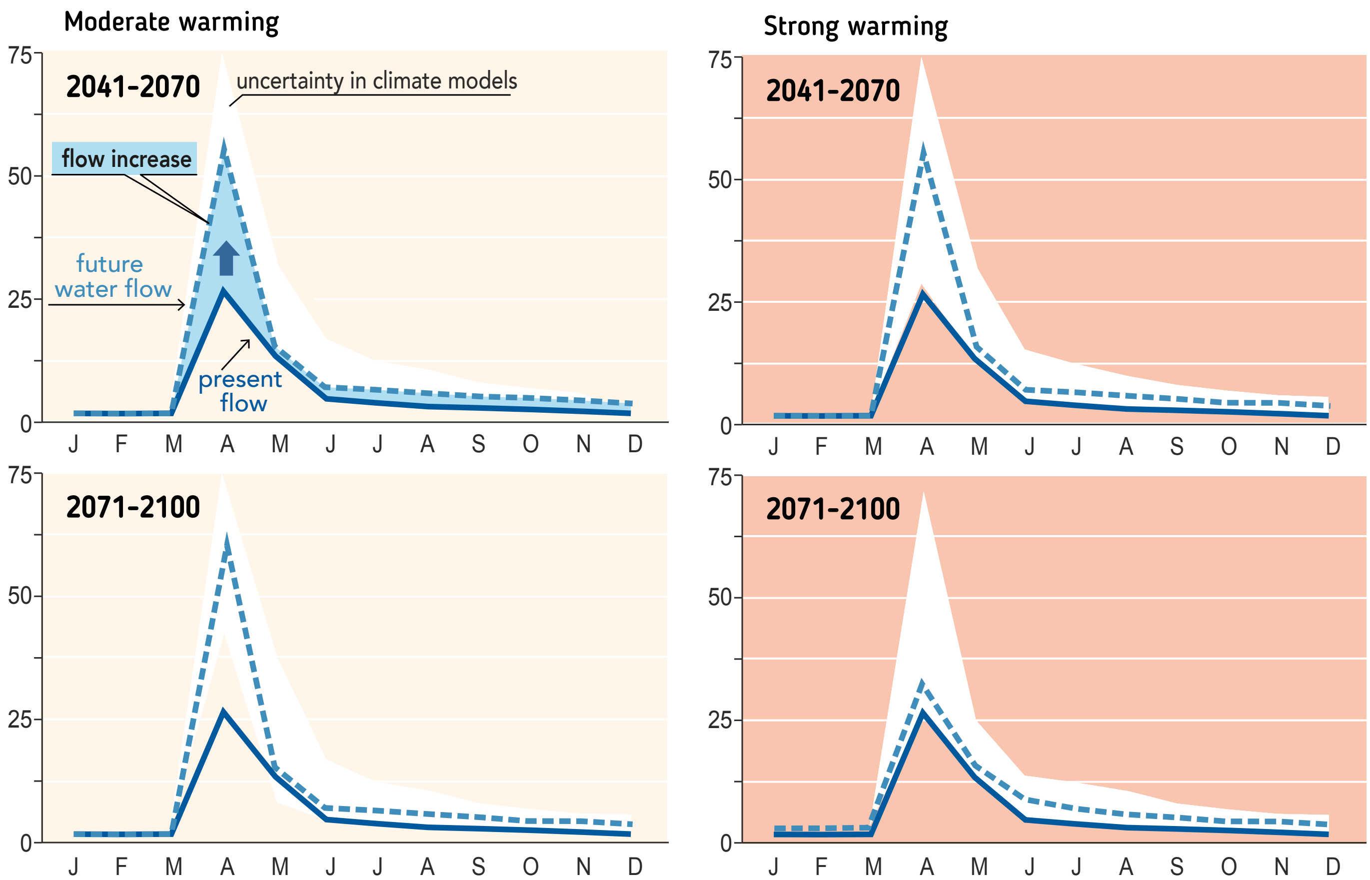
Projected climate change impacts on hydrology

- Increase in precipitation
- Water flow increase
- Increase in spring floods
- Shift in water peak to earlier dates
- Increase in temperature



The population and the authorities alike are growing more concerned about the increasing scale of spring floods in the lower Zhabai River and in the middle reaches of the Esil. As the floods grow, the riverbank reinforcements cannot keep up with the power of the water. A massive green belt supported by engineering and flood water diversion structures now surrounds Astana, the capital of Kazakhstan, to protect residents from sweeping winter storms and spring floods. Smaller towns are also investing in increased flood protection. Nevertheless, in April 2017 a dam at Atbasar ruptured and released a wave – amplified by wind and rain – that flooded more than 450 houses, displaced some 1,400 people and blocked roads. Modelling results show that such events may become more common and intense, if not routine in the future.

Zhabai River: Projected changes in hydrology
Average monthly water discharges in m³ per second



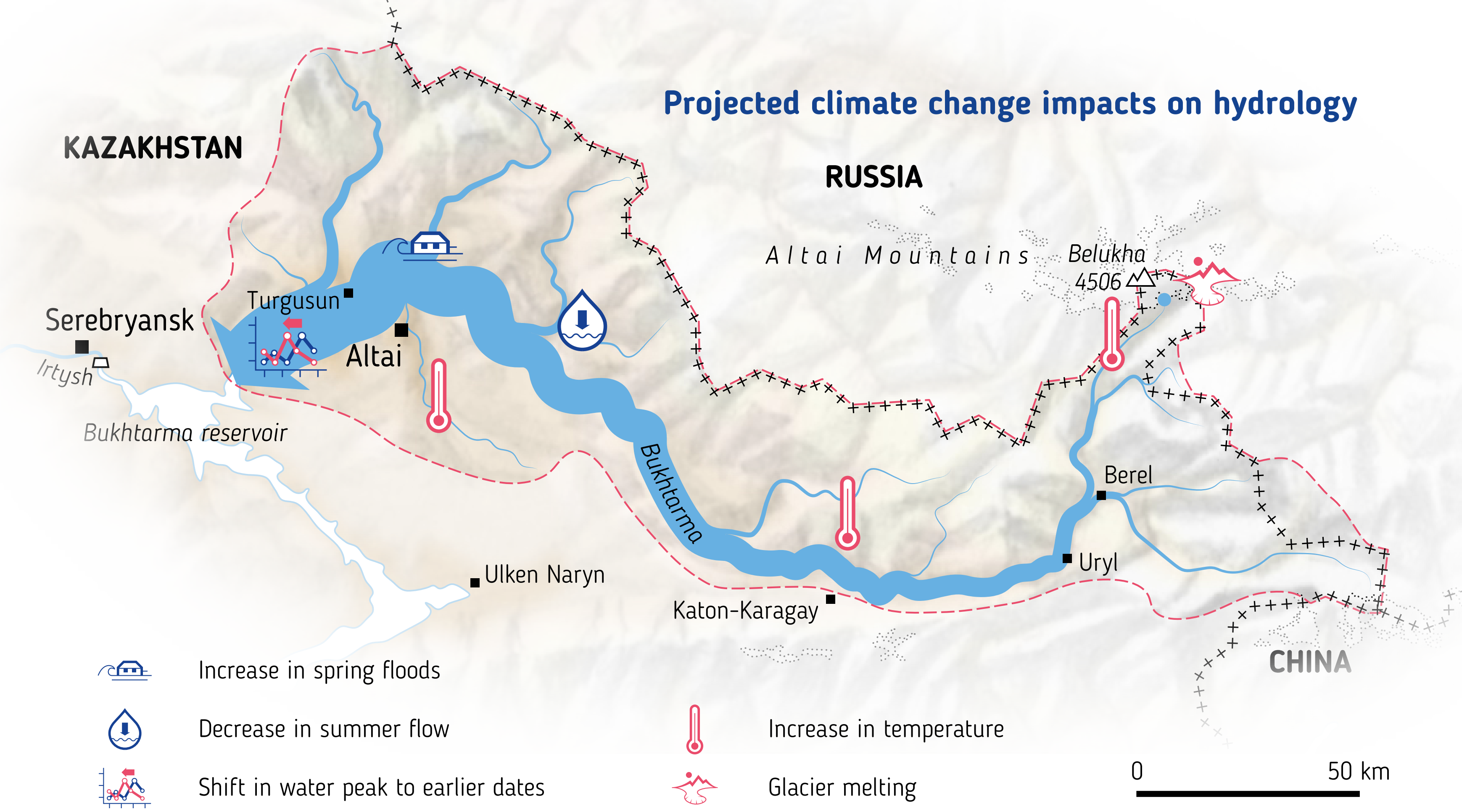
Bukhtarma

The glacier-fed Bukhtarma River originates in the Altai Mountains of eastern Kazakhstan, and flows from an elevation of 4,500 m down to 400 m at an average rate of 214 m^3 of water per second – a powerful river famous for its clean water. The minimum recorded flow occurred in 2004 at 40 m^3 of water per second, and the maximum recorded flow came in April 2015 at 2 700 m^3 of water per second.

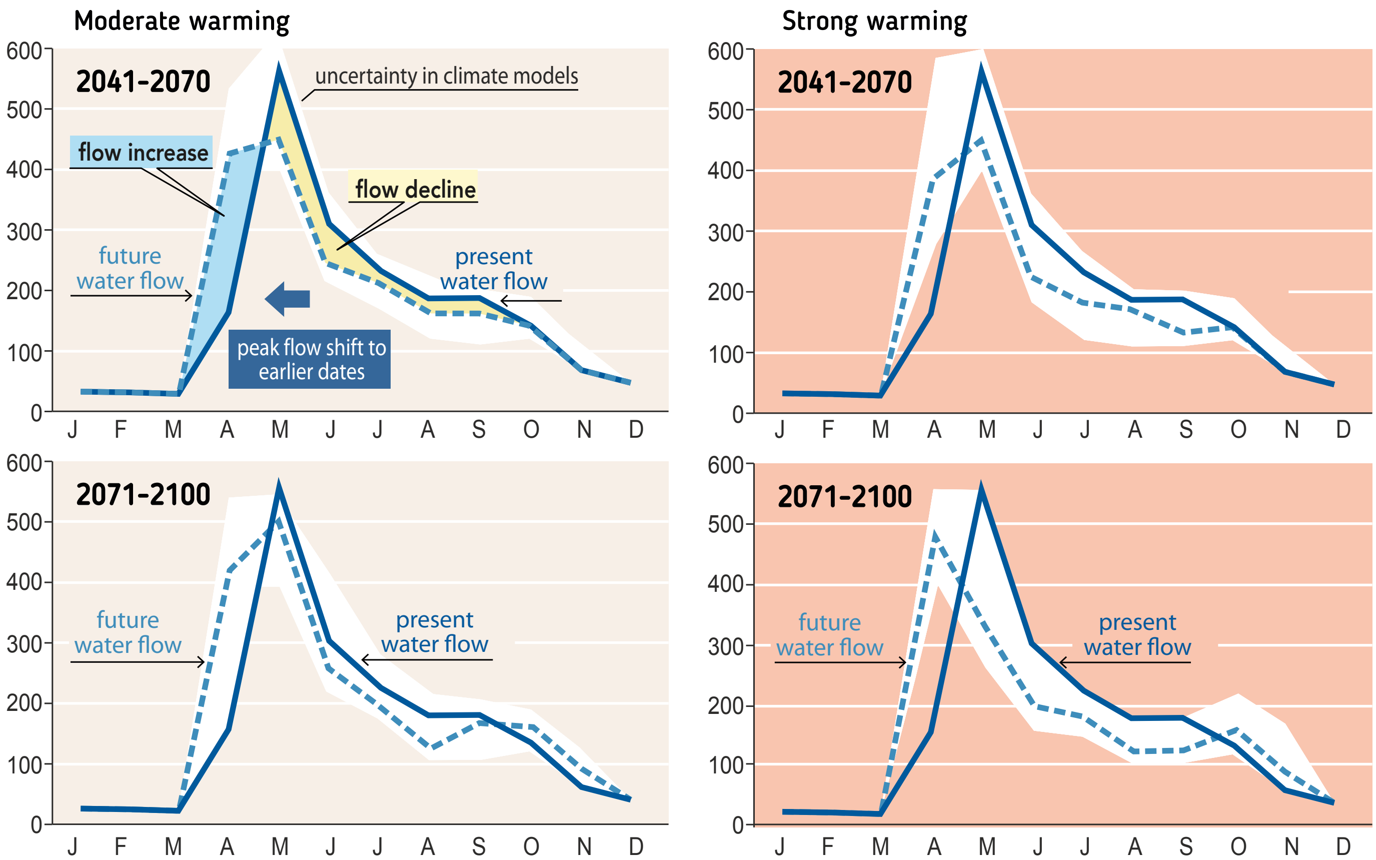
Agriculture in the basin is rain-fed and consists mostly of pastures for grazing. Some mining occurs in the basin, and small cities are scattered throughout. Hydropower plants operate on the Irtysh River in the cascade, but none are on Bukhtarma. The Bukhtarma's whitewater rapids and its scenic environment makes it a popular tourist destination.

Under both warming scenarios (moderate and strong) for 2041–2070, the peak flows of the Bukhtarma River shift to earlier in the year, with strong increase in April (doubling compared to the current levels) and some reduction in May. For 2071–2100, the changing patterns of flow under the moderate warming scenario are similar in spring to the same scenario for the earlier period, but with a marked reduction in summer flow.

Under the strong warming scenario in 2071–2100 the peak flow comes one month earlier (April is becoming a month of the peak flow instead of May), while river flow in summer months may decline by 50–100 m^3 of water per second.



Bukhtarma River: Projected changes in hydrology
Average monthly water discharges in m³ per second



Kofarnihon

The Kofarnihon River starts at an elevation of about 3 000 m in the mountains of central Tajikistan, and falls to a low of 300 m. The upper reaches of the river basin receive 1 000 mm of precipitation per year and more. The southern lower part of the basin is much hotter and drier, and gets virtually no snow. Some glaciers feed the river, but most of the flow comes from spring snowmelt. The upper reaches are home to important Tajik industries, the densely populated Hissar Valley and the city of Dushanbe and to spas and resorts that take advantage of the scenic beauty, mineral waters and hot springs in the area.

Total length of the river is 387 km with drainage area covering 11 000 km^2. Average annual flow is 164 m^3 of water per second, with flood peak discharges up to 1 200 m^3 per second. Suddenly rising temperatures in the mountains and heavy rains – as much as 30 mm in less than a day – can trigger significant flooding.

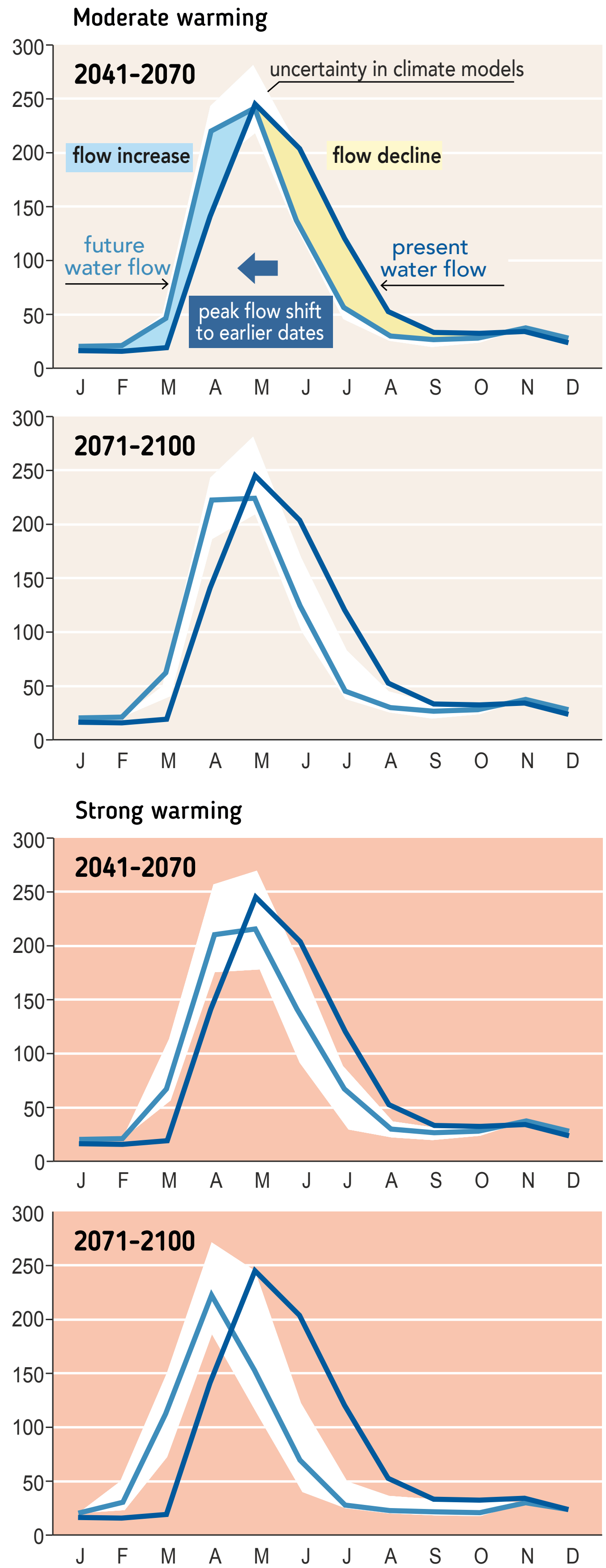
The Kofarnihon River is less dependent on glaciers for its water so the melting of glaciers will not affect it as much, but warming temperatures will result in higher river flows in the spring and lower flows in the summer. Population growth in the area puts more people and property in harm's way, and new housing and agricultural cultivation along the river adds to the risk.

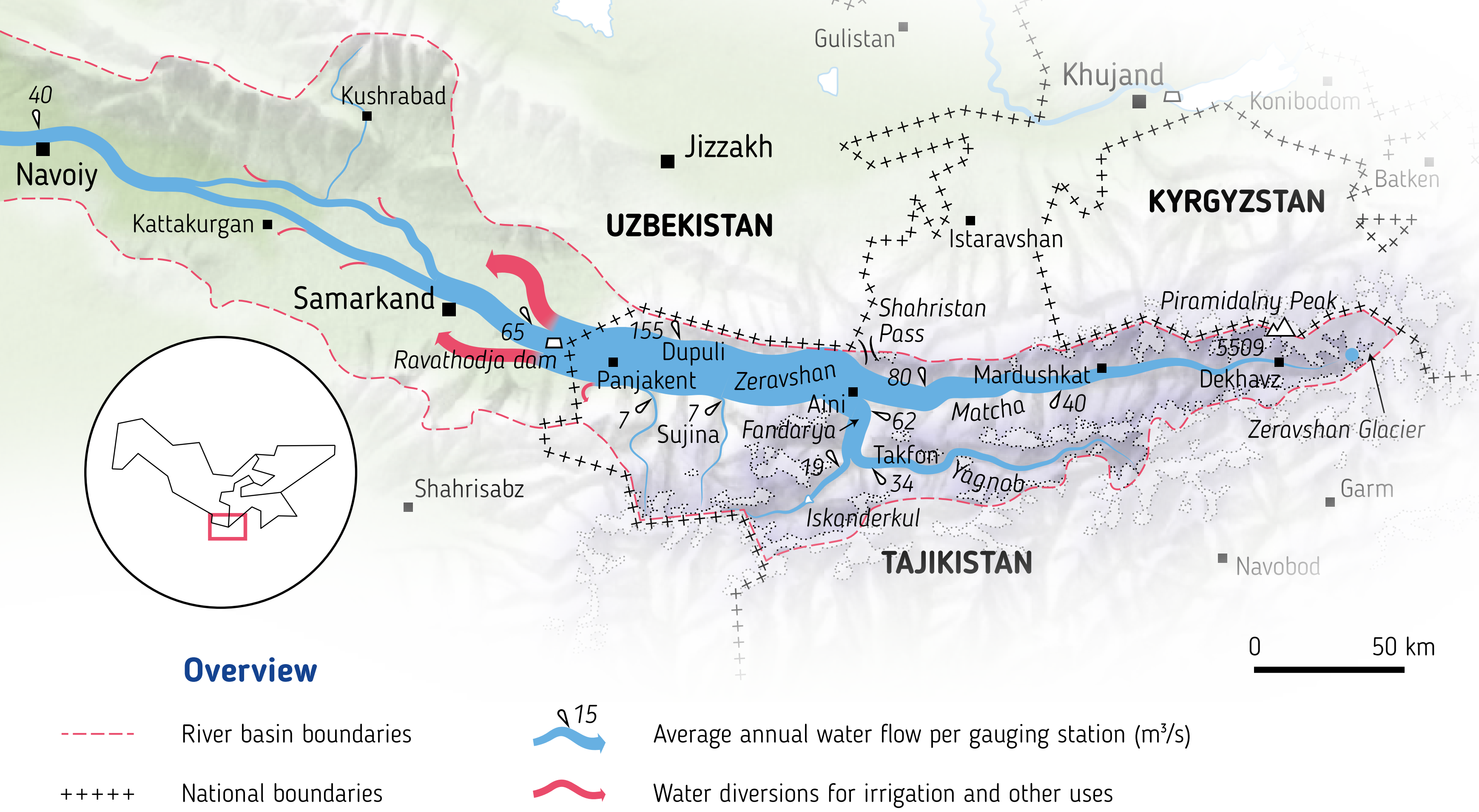
Under the moderate warming scenario for 2041–2070, the peak flow is similar to the current peak, but rises earlier in the year and declines more quickly after the peak. Under the strong warming scenario for 2071–2100, the peak occurs markedly earlier and remains below the current peak. Significant flow reduction is possible in summer months.

Projected climate change impacts on hydrology

- Increase in spring floods
- Shift in water peak to earlier dates
- Decrease in precipitation
- Glacier melting
- More rapid snow melt
- Increase in temperature
- Population growth
- Irrigated areas

Kofarnihon River: Projected changes in hydrology
Average monthly water discharges in m^3 per second





Zeravshan

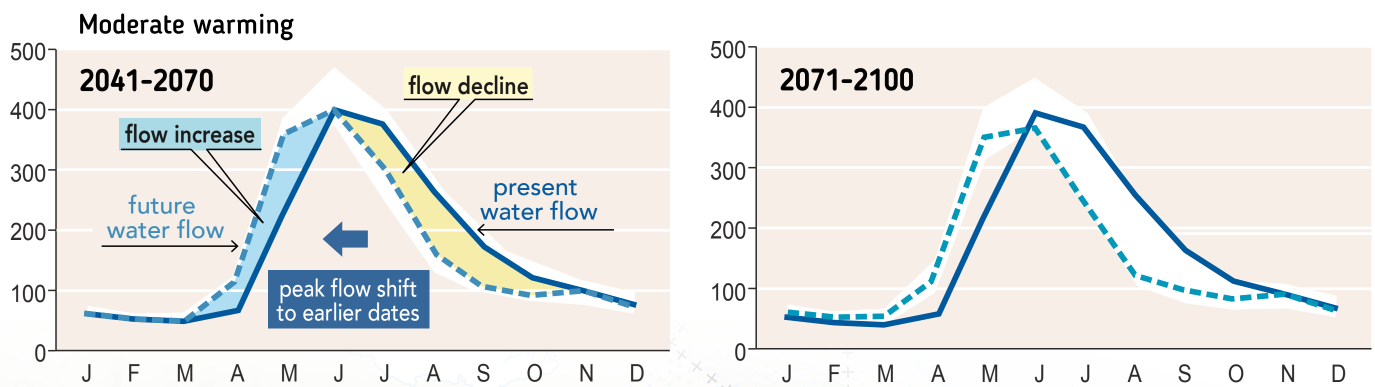
The Zeravshan glacier is an important source of the Zeravshan River, which rises in the mountains of Tajikistan at an elevation of 2 800 m and flows down to Uzbekistan. The Zeravshan basin is home to 6 million people, and the river serves the ancient cities of Samarkand and Bukhara and provides irrigation for 0.5 million ha. In Tajikistan, the Zeravshan flows naturally through the mountains with few water withdrawals, but in Uzbekistan water demand is high and the available water is fully used. According to estimates of the Hydrometeorological Service of Tajikistan, the Zeravshan glacier has been retreating, and has already lost significant size. Rising temperatures may increase the climate risks to agriculture in the lower part of the basin in the densely populated Samarkand and Bukhara provinces.

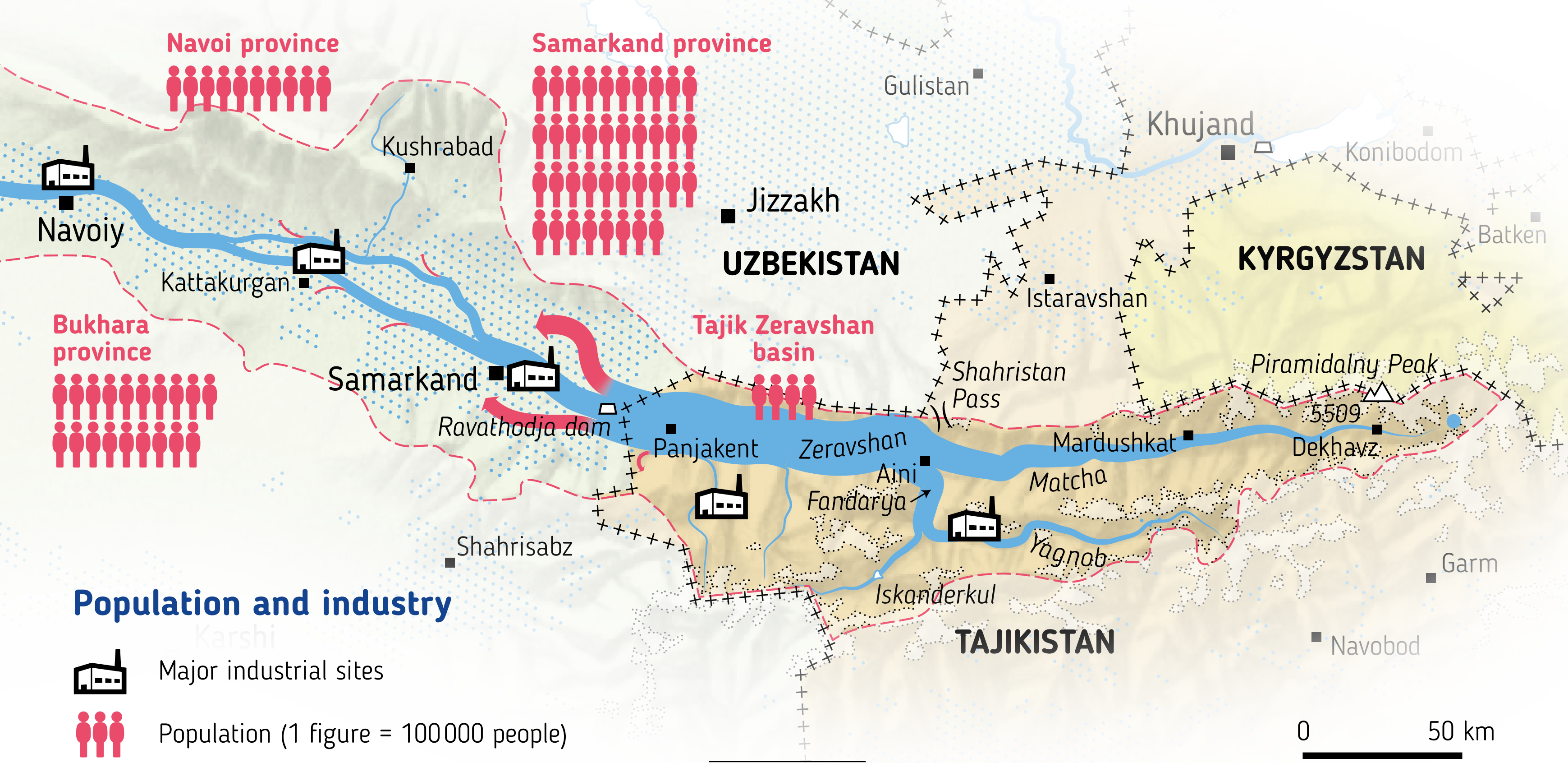
The Zeravshan drainage area is about 42 000 km^2, and the river's length is in excess of 800 km. The name of the river translates as "gold bearing", and while little extractable gold remains in the main riverbed, its tributaries and geological formations are indeed rich in gold, and this area hosts the largest gold mining enterprises in Tajikistan and Uzbekistan.

The average annual precipitation in the Zeravshan basin – 500 mm – is unlikely to change much, but the mix is likely to have less snow and more rain. The current annual average temperature of the river basin of 5°C is expected to grow to 8°C under moderate warming and to 10-12°C under the strong warming scenario. This significant warming will shrink glaciers and reduce the snow and ice cover in the basin. The consequent reductions in the amount of melt water that reaches the river will result in a declining river flow. At the same time, disruptions in the hydrological cycle will increase both the variability of river flows and the frequency of potentially more destructive flood events in the mountain areas. In the lower reaches of the basin, cotton yields are highly likely to decline unless water saving technologies and other adaptation measures are introduced.

Zeravshan River: Projected changes in hydrology

Average monthly water discharges in m³ per second





Overview

Murghab

The Murghab originates in the dry highlands of central Afghanistan at 2 600 m. The river flows north-west within Afghanistan and north in Turkmenistan, and stops at the ancient oasis of Merv, mingling its waters with those of the Karakum Canal. The total length of the river is 850 km (350 km in Turkmenistan), and the drainage area is 48 700 km².

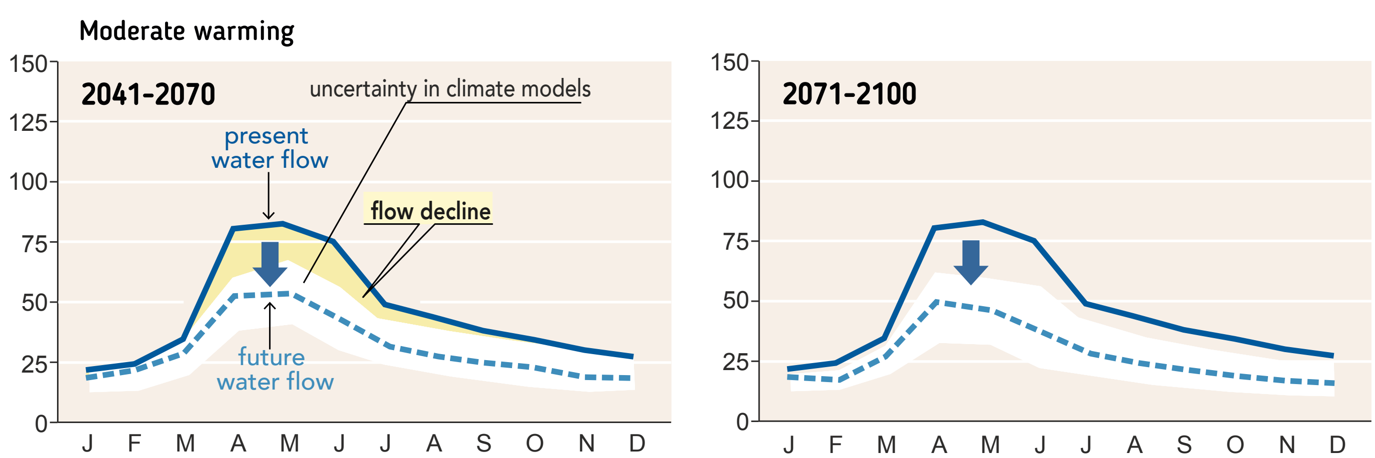
The river is fed mainly by snow and rain in the upper catchment in Afghanistan, and has a mean annual discharge of about 50 m³ of water per second when it enters Turkmenistan. In Turkmenistan it receives some small rivers and streams, but in view of the predominantly hot and dry climate, these do not influence the scale of the flow.

Agriculture is the predominant water user in the basin. The major cropland areas occur in the downstream section of the river in Turkmenistan and along the traditional irrigation areas in the basin.

Under both climate scenarios for both the 2041–2070 and 2071–2100 periods, overall flows and peak flows decline dramatically in the Murghab. The peak flows also tend to shift to earlier in the year. Neither of the scenarios takes into account changes that may occur in water use patterns in the Afghan part of the river, but if Afghanistan pursues developments that require Murghab water, the flow in the Turkmenistan part of the river might decline even further.

Projected climate change impacts on hydrology

Murghab River: Projected changes in hydrology
Average monthly water discharges in m³ per second



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Variations in selected geographic names

Name used in the report	Variations and alternatives
Altai (town) in Kazakhstan	Zyranovsk
Esil	Ishim
Gissar (mountains, valley) in Tajikistan	Hissar, Hissor
Kafirnigan	Kofarnikhon
Murghab	Murghob, Murgap, Margiana
Zeravshan	Zarafshan, Zerafshan, Matcha (upper part of the river)
Zhabai	Zhabay

Many geographic and local names are pronounced and spelled differently depending on the international or local usage, historical and modern style and other peculiarities. Some cities have been renamed recently, but the older versions are often still used. This report maintains a consistent spelling of names, and the table offers some variations or alternatives of selected names used in the report.

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