A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the Degree of Master of Science

Changes in the hydrological regime of the Ural River and challenges for transboundary cooperation within the UNECE Water Convention

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Due to low water availability Kazakhstan's environmental security and social development can be potentially jeopardized by water scarcity. Deficit and worsening quality is complicated by severe dependence on the water inflow from neighbouring countries as seven of eight basins in Kazakhstan are transboundary.

This thesis focuses on the Ural River Basin. Being the major water source in the region, the transboundary Ural River is of a great significance to both Russia and Kazakhstan, providing water supply for industrial, agricultural, and drinking needs. Since it is the only water source in the downstream Western Kazakhstan and Atyrau oblast (region), the population of the Ural-Caspian basin is heavily dependent on adequate quantity and rational distribution with upstream Russia.

The aim of this thesis is to explore hydrological changes in the Ural River Basin, those potentially undermining water security in the region. It further provides overview of corresponding challenges and prospects in building sustainable transboundary cooperation between Russia and Kazakhstan within the UNECE Water Convention framework.

Hydrological changes in the Ural River Basin, those potentially undermining water security in the region were explored, including climate change, water reservoirs in the upstream and agricultural activities. As analyzed, the climate change effects have been altering river's flow by changes in precipitation and temperature, the impact is done by construction of major Iriklinskoye and other upstream water reservoirs, and finally agricultural activities have had little effect on river's hydrology. Corresponding challenges and prospects in building sustainable transboundary cooperation between Russia and Kazakhstan within the UNECE Water Convention framework were analyzed. Based on the three principles, including "equitable and reasonable distribution", "precautionary principle" and "no significant harm", the Convention can contribute to dealing with both river hydrology issues and transboundary pollution.

Keywords: Hydrological regime, Ural River Basin, Remote Sensing, transboundary cooperation, UNECE Water Convention

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Thank you!

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List of Abbreviations

CEU	Central European University
CFSR	Climate Forecast System Reanalysis
FASRB	Framework Agreement on the Sava River Basin
GLDAS	Global Land Data Assimilation System
GRDC	Global Runoff Data Center
GSFC	Goddard Space Flight Center
IWRM	Integrated water resources management
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NGO	Non-governmental organization
RosNIIVKh	Russian Research Institute for Integrated Water Management and Protection
RS	Remote Sensing
SRB	Sava River Basin
SRBMP	Sava River Basin Management Plan
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WS	Weather Station
ZKO	Western Kazakhstan Oblast

1. INTRODUCTION

1.1. Problem definition and background

Water resource is one of the factors that can boost social development of the country, contribute to economic growth and serve to eradicate poverty. Access to drinking water has been recognized as a basic right in the 2010 UN General Assembly Resolution 64/292 on the human right to water and sanitation, highlighting the importance of water security throughout the globe. Water security is defined as the "*capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability*" (Bigas 2013).

Historically, there has always been a mismatch between drinking water availability and human needs and consumption, which resulted in the realization of the need to rational management of the scarce resource. Tensions over diminishing resources have appeared throughout the history and providing access to freshwater has always been important for country's social and political stability. As the population grows and exploitation of water supplies increases, securing both adequate quantity and quality of water is becoming a critical issue, which is complicated by the transboundary character of many water basins.

Water management challenge is most often addressed within the concept of "water security". While the term security is often associated with armed or violent conflict evoking negative connotation, nowadays water conflicts and security are rather viewed from a different perspective. Water security indicates access of people to scarce resources of adequate quantity and acceptable quality, which is often undermined by many external factors, such as climate change, outdated management practices, inability of governments to come to consensus on water distribution and many others. Water questions in Central Asia challenge sustainable development of the region and changes in hydrological regime undermine the ability to provide reliable and sufficient water supplies for the population.

Water scarcity is of a particular concern for Kazakhstan – a country with 90% of the territory related to arid zone with low humidity and limited water resources (Sarsenbekov et al. 2016) (Figure 1). Due to low water availability Kazakhstan's environmental security and social development can be potentially jeopardized by water scarcity (Ryabtsev 2008). Deficit and worsening quality is complicated by severe dependence on the water inflow from neighbouring countries as seven of eight basins in Kazakhstan are transboundary.

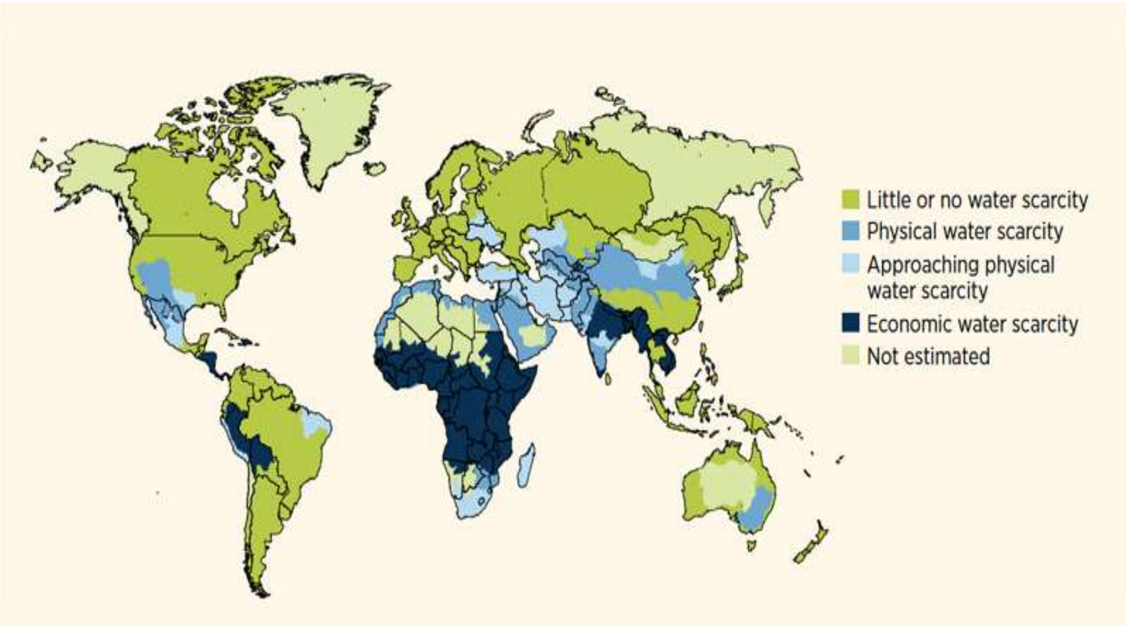


Figure 1 Global physical and economic water scarcity.
Source: World Water Development Report 4. World Water Assessment Programme (WWAP), March 2012.

This thesis will focus on the Ural River, which plays an important role in the transboundary Ural-Caspian basin. Being the major water source in the region, the transboundary Ural River is of a great significance to both Russia and Kazakhstan, providing water supply for industrial, agricultural, and drinking needs. It is the only free-flowing river in the region with unregulated mid- and downstream (Lagutov 2008), and since it is the only water source in the downstream Western Kazakhstan and Atyrau oblast (region), the population of the Ural-Caspian basin is heavily dependent on adequate quantity and rational distribution with upstream Russia.

Kazakhstan is concerned with environmental conditions of the Ural River, which have been showing alarming trends (UNDP 2004). Diminishing water resources have been affected by decreasing water level, growing water demand exceeding supply capabilities and deteriorating water quality. In-depth analysis is required to identify the extent of factors affecting hydrological regime of the Ural River in order to provide tailored policy response and achieve long-term water security in the region.

1.2.Research aim

This thesis aims to explore hydrological changes in the Ural River Basin, those potentially undermining water security in the region. It will further provide overview of corresponding challenges and prospects in building sustainable transboundary cooperation between Russia and Kazakhstan within the UNECE Water Convention framework. Addressing existing factors affecting hydrological regime of the river is a matter of great importance as the Ural River is the only source of water in the Western Kazakhstan and Atyrau oblast establishing water security in the region.

1.3.Research questions and objectives

This thesis sets out 4 research questions and relevant objectives, which are as follows:

RQ 1: What are the trends in water level in the Ural River Basin?

- Explore water flow and discharge rate in the Ural River;

- Study flow patterns in Kushum gauging station.

RQ 2: What is climate change and other factors' effect on the Ural River flow and discharge?

- Collect data on precipitation and temperature changes along the Ural River;
- Develop maps of snow depth for two periods of 1948-1980 and 1981-2010;
- Analyze relation between climate change and water level in the Kushum gauging station;
- Analyze effect of upstream water reservoirs, mainly Iriklinskoye;
- Identify extent of irrigated croplands that consume water in Orenburg and Western Kazakhstan oblast.

RQ 3: Has the UNECE Water Convention been successful in managing transboundary Ural River Basin?

- Assess the existing legal frameworks for managing and regulating resources on the transboundary Ural River;
- Identify current status of the UNECE Water Convention implementation;
- Identify how the UNECE Water Convention can help resolve dispute between two countries on managing the Ural River Basin.

RQ 4: What are the potential areas of improvement?

- Based on the analysis of major causes of the Ural River deterioration and existing legal framework between Russia and Kazakhstan, propose policy recommendations.

1.4. Thesis outline

The following 3 chapters (Chapter 2-4) provide literature review on the issues set out in the research questions. Chapter 2 defines the study area of the Ural River and identifies its significance in the region. Chapter 3 provides overview of climate change factor viewed to alter hydrological regime of the river and undermining people's access to drinking water. It also identifies application of remote sensing in studying the effects of climate change. Chapter 4 describes transboundary cooperation in basins within the UNECE Water Convention, using the example of the Sava River Basin. Research methodology is covered in Chapter 5, identifying required research data, its collection and techniques used to analyze the dynamics of temperature, precipitation, snow depth, assessment of alteration by water reservoirs. The chapter further discusses how the interviews were prepared and conducted, existing ethical considerations and limitations of the research. The following Chapters 6 and 7 discuss overall results of the research. Chapter 8 provides the summary of the research and short overview of the results and followed by recommendations based on the analysis conducted. If no reference is provided, tables, maps, figures and graphs were created by the author.

2. STUDY AREA

This chapter establishes the significance of the study area and identifies where the research can contribute. Geographical and hydrological characteristics of the Ural River are presented below.

2.1.The Ural River

Figure 2 Territory of the Ural River Basin
Source: Safronov A.V.

The total river length is 2428 km and total catchment area is 237 000 km^2. Around 1084 km of the Ural River is located within Kazakhstan territory, with 761 km flowing through Western Kazakhstan oblast (Kurmangaliyev 2008). The Ural River originates in the slopes of Kruglaya Sopka of the South Ural Mountains at 637 m above sea on the territory of Russia and ends at the Caspian Sea at 27 m below sea level in Kazakhstan (Figure 2). It is the only free-flowing river in the region with unregulated mid- and downstream (Lagutov 2008).

One of the specific features of the Ural River is extreme fluctuations in the total annual flow and uneven flow distribution (Lagutov 2008). During summer and winter periods, 9-10 months per year, the river is relatively small. However, in spring the Ural River is highly prone to flooding. Drastic water level rise downstream typically occurs in March-April and the width reaches 35 km, and in the upstream in April-May, with average width of 18-20 km (Lagutov 2008;Chibilev 2008).

The Ural River is fed by the melting snow, which comprises 60-80% of the annual total flow. Some is contributed by precipitation, around 2-12%, and 13-38% is fed by the underground waters. Major inflow is received in the upper mountainous part of the basin and between the cities of Orsk and Uralsk. Flowing through the Caspian Lowland it loses water through evaporation and infiltration into the ground (Chibilev 2008). Annually around 8 km^3 flows to Caspian Sea from the Ural River, with ¼ of the total flow being lost within the Caspian semi-desert and desert area.

Unimpaired runoff entering the territory of the Western Kazakhstan from Orenburg oblast of Russia accounts to 9.3 km^3. Of this amount, 1.4 km^3 is formed within Kazakhstan (rivers Or, Ilek, Bolshaya Hobda), and 7.9 km^3 formed within Russia.

2.2. Significance of the Ural River

The issue of environmental degradation of the Ural River has been brought up by many experts. It is the third longest river in Europe and the only water source for the downstream Kazakhstan in Western and Atyrau oblast (region). The Ural River plays an important role and is of a great significance for both Russia and Kazakhstan as it provides water supply for industrial, agricultural, and household needs.

A lot of settlements were built along the Ural River attributed to the convenience of having water supply nearby. It is a water source for cities and villages of the Republic of Bashkortostan, Chelyabinskaya and Orenburgskaya oblast of Russian Federation, as well as Kazakhstan. Major cities along the river include Verhneuralsk, Magnitogorsk, Orsk, Novotroitsk, Orenburg, Uralsk and Atyrau (Lagutov 2008).

With the Ural River being the only water source in the downstream Western Kazakhstan and Atyrau oblast (region), it puts population of the Ural-Caspian basin under heavy dependence on upstream Russia. Availability of water discharge from the upstream water reservoirs and reasonable allocation ensures social and economic well-being of the population living in the basin, thus, resulting in environmental stability and security.

The necessity of constructing water reservoirs was determined by the problem of providing water access for industrial and agricultural needs in the regions, as well as uneven distribution of the river's flow. Year 1932 has marked the beginning of the development of strategy on the use of Ural River basin water resources by Gidroprovod. It included questions of flow regulation, especially to provide water for industrial centres and emerging ore fields in Trans-Urals. Apart from the existing reservoirs, it was planned to construct additional Guberlinskoe water reservoir (0.055 km^3) on the Ural River, however, the plan was never implemented. At the moment 42 water reservoirs are functioning within the territory of Kazakhstan, with total volume of 1.1 km^3 (Chibilev 2008).

3. STUDYING HYDROLOGICAL REGIME CHANGES

3.1. Climate change impact

Climate change is one of the alarming factors determining balance of the water. It is mostly associated with high concentrations of greenhouse gases in the atmosphere, which causes rise in average temperature around the world and disturbs natural precipitation patterns, causing adverse effects. As defined by the UNFCCC the adverse effects of climate change means "*changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare*" (UNFCCC 1992).

Global warming caused by enhanced greenhouse gas accumulation has a significant effect on water resources. Climate change disturbs hydrological cycle with increased evaporation, rising temperature and unequal distribution of precipitation around the world (Figure 3). Major alterations of ecosystems may be caused by rise in temperature, significant reductions in precipitations, increased evaporation, as well as shift in the timing of wet and dry seasons (Arnell 1999). Evidence of climate change impacts is seen in hydrological systems disturbance, affecting water resources in terms of quantity and quality (Pachauri et al. 2015).

Climate change might have a long-term and catastrophic consequences with profound water security implications, requiring countries to urgently address this issue. The security implications are most pronounced in places where climate change effect hits the hardest, affecting states vulnerable to environmental destabilization. By displacing population and causing water shortages it will exacerbate already difficult water issues with eruption of low-level regional conflicts (Parsons et al. 2009).

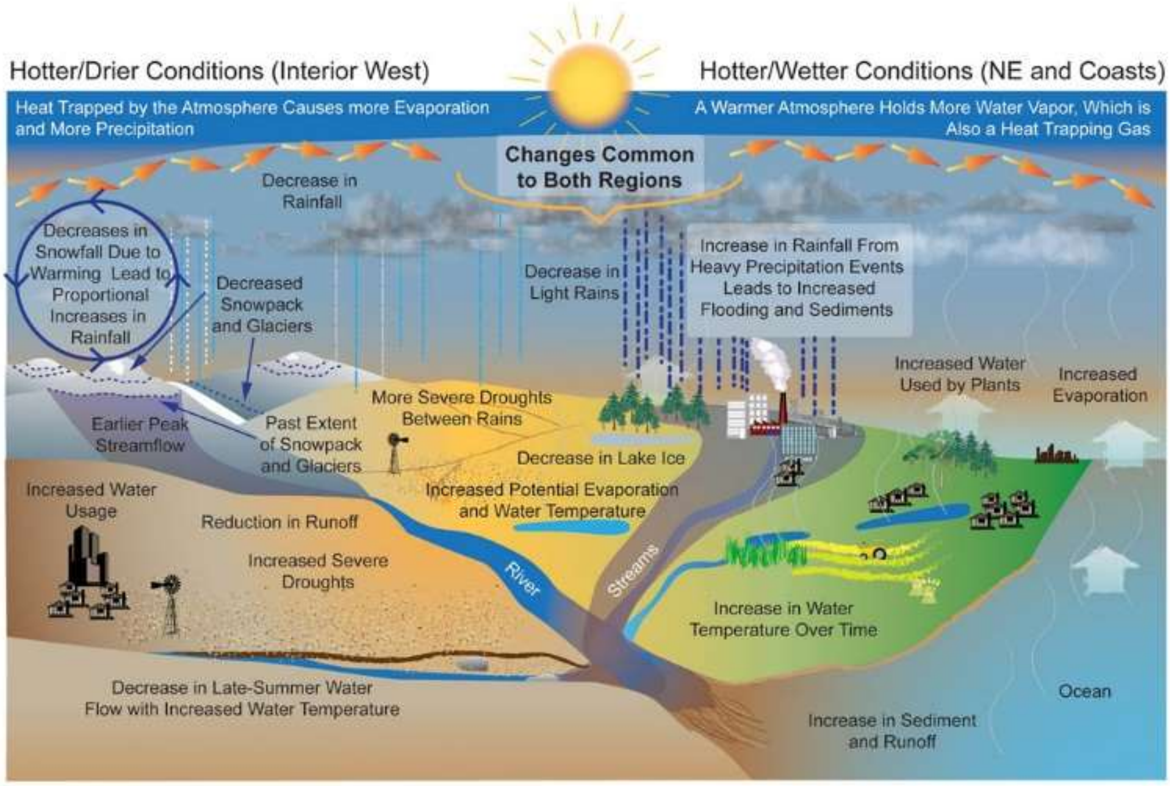


Figure 3 Climate change effects on water cycle
Source: US EPA (US Environmental Protection Agency)

The assessment of climate change impact on the water resource base is frequently conducted, as many aspects of social, economic and environmental development depend on the scarce resource. Water availability is pressured by both supply and demand. Supply is affected by external factors, such as pollution and degradation of water available for people. Demand on the other side, is pressured by population growth and increased consumption. Water stress is further exacerbated by climate change, which is likely to drive upsurge demand and shrink water resources (Arnell 1999).

Climate change negative impact can be seen all over the globe. One of the brightest examples in the Amazon River basin, where changes in temperature and precipitation altered water regime, affecting quantity, quality and timing. For the last decade, monthly mean air temperature has been showing a warming of 0.5-0.8°C (Quintana-Gomez 1999). Being home to many species, the effects hit habitat and behaviour of many plant and animal species (Hare

2003). Changes in climatic conditions threat freshwater in Amazonian region through warming water temperature, decreased precipitation and drier conditions, changes in nutrient input and more extreme events (Case n.d.).

The Ural River has been diminished over the years with climate change affecting the formation of the river flow. Most of the water – 72% of total flow is formed within Russian territory (KamUralRybVod 2007). The assessment of climate change impact on the Ural River is important in order to realize the factors that might undermine water security by limiting access of people to water resources in the region. As discussed by Lagutov (2008), the air temperature has increased by 0.21-0.61°C within the territory of the Ural River basin (Figure 4) and the effect of precipitation is considered to have a big impact on river's formation and total annual flow. Rising in the South-Eastern slope of the Ural Mountains, the river is mostly fed by melting snow, thus depending on the precipitation. The author indicates increase in precipitation up to 43mm/year between two periods of time 1970-1986 and 1987-2002, which contradicts the conclusion on the decreasing flow in the Ural River. However, as discussed by the author, direct relation between precipitation and water level is not clear, and a number of other factors should be taken into account while estimating changes in hydrological regime, such as agricultural activities, increase water intake, etc.

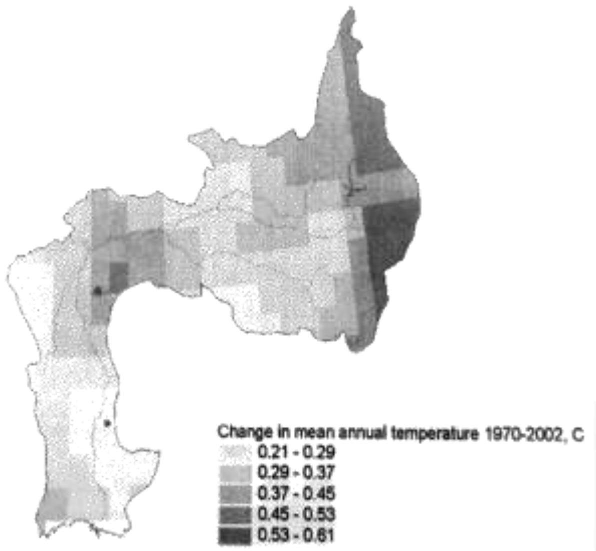


Figure 4 Change in mean annual temperature over the Ural River Basin for the period 1970-2002. Source: Lagutov, 2008

The author presents a concern by attempting to address negative impacts of climate change in the region. However, he suggests that further detailed analysis is required to draw clear connection between temperature and precipitation changes and their effect on the hydrological regime of the Ural River Basin (Lagutov 2008). A number of other factors in sum may determine changes in the hydrological regime. They include not only human impact of disturbing river flow by constructing water reservoirs or dams, but also the physiographic conditions of the catchment area within the basin. Thus, landscape specifics of the catchment area also determine uneven distribution of the stream flow with semi-desert and desert zones in downstream basin, compared to forest and steppe zones in the upper basin area (Sivokhip 2014).

3.2.Remote sensing in climate change studies

Use of remote sensing technologies is one of the efficient ways to conduct geographic data analysis using boundaries of a given water basin. Giovanni mapping gives opportunity to visualize, analyze and access great amounts of remote sensing data. Satellite remote sensing has provided major advances in understanding and analysing the climate system and its changes as it quantifies processes and spatial patterns of water bodies, atmosphere, and land (Yang et al. 2013).

Remote sensed data varies in its method of collection and can be applied in different ways to study the effects of climate change. For example, Global Land Data Assimilation System (GLDAS), which was developed by scientists at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) and the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) (Rodell et al. 2004).

GLDAS-2 provides satellite and ground-based observational data products by using advanced land surface modelling and data analysis techniques. It is based on high-resolution estimates of water and energy storage and serves as an effective tool to predict climate change, weather conditions, flooding (Rodell et al. 2004). GLDAS-2 is based on a 3-hourly temporal resolution. However, monthly products can be accessed through Giovanni maps, which are generated through temporal averaging of the 3-hourly products.

Satellite data of GLDAS-2 offers actual depth of snow cover for the period of 1948-2010, which is measured in meters. By using this data Giovanni mapping tool allows to create from the selected area *maps* that shows data for each grid cell, and *area-averaged time series* which represent a plot produced by computing spatial averages (Giovanni 2016).

4. TRANSBOUNDARY COOPERATION IN RIVER BASINS THROUGH THE UNECE WATER CONVENTION

Transboundary basins create political, economic and hydrological interdependency between countries. Water security while serving as a source of potential conflict and discourse, provides a lot of opportunities for mutual cooperation and establishment of peace and regional security. This was argued by Homer-Dixon, who put forward that "interstate scarcity wars- is the least probably", but can rather stimulate cooperation between countries and institutional change (Homer-Dixon 1999).

Transboundary water cooperation is recognized to generate many benefits for involved countries, including political stability, environmental sustainability, economic growth and social well-being. The United Nations Economic Commission for Europe Convention on the Protection and Use of Transboundary Watercourses and International Lakes, also known as Water Convention, has proved to be efficient in contributing to water security and establishing platform for capacity building, experience exchange and strengthening cooperation.

The UNECE Water Convention was adopted in Helsinki in 1992, entering into force in 1996. The Convention can be applied in various conditions and since it's based on principles of equality and reciprocity, it's an effective framework for both upstream and downstream countries. The three central pillars of the Water Convention include: 1- prevention, control and reduction of transboundary impacts; 2 – reasonable and equitable use; 3- cooperation through agreements and joint bodies (UNECE 2016).

The effectiveness of the Water Convention lies within its promotion of sound environmental water basins management, fostering principles of IWRM and offers holistic approach for transboundary cooperation (UNECE 2015). It acts as a framework agreement, which does not replace any bilateral or multilateral agreements between countries of the same basin, but rather fosters their establishment, implementation and development. The Water Convention requires equal and reasonable distribution between upstream and downstream countries, and focuses on many other transboundary issues, such as transboundary water pollution, information disclosure, research and development, joint monitoring and warning systems. The implementation of the Water Convention has proved to be successful in establishing peaceful transboundary cooperation in many regions, including the Sava River Basin.

After the Yugoslav conflicts in 1991-1995 Sava River, formerly national, became international flowing through Slovenia, Croatia, Bosnia and Herzegovina, and Serbia. Post-conflict situation created major disruption to river's ecosystem. Many industrial facilities in the Sava River Basin were poorly maintained, resulting in high levels of pollution flowing throughout the river. Lack of investment made it impossible to improve environmental conditions. Intensive agriculture and refugees put additional pressure on water resources through illegal dumping along the river (REC 1999).

Major improvements in Sava River Basin management had been made after efforts were joined to promote cooperation within the Water Convention (Weinthal et al. 2013). The main principles were implemented in the FASRB and the Convention served as a model for integrated management approach using three pillars of sustainability – economic, social and environmental. Within the framework of the Convention, the assessment of the SRB was conducted in order to identify pressures and negative impacts, as well as indicate adaptation and response measures, reflected in the Sava River Basin Management Plan (SRBMP).

Thus, apart from the political will for cooperation, the establishment of dialogue between two countries can be attributed to the commitment to the 1992 UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes. In relation to the Ural River Basin, both Kazakhstan and Russia recognize that sustainable transboundary water practices and management "*contribute to peace and security"* (UNECE 1992). However, the inability to come to a consensus on such issues as water quality, equitable distribution and little specific actions being taken to improve water management, resulted in the diminishment of the Ural River and degradation of the whole ecosystem (Kurmangaliyev 2008). Analysis and identification of issues within the current bilateral agreements between Kazakhstan and Russia, as well as the areas for improvement that the UNECE Water Convention could contribute to is required. The Ural River Basin will benefit greatly from the implementation of the convention principles.

5. RESEARCH METHODOLOGY

The methodology used in the thesis is discussed below to provide better understanding of undertaken steps to achieve objectives set out for the research. Research has been carried out to collect qualitative and quantitative data. Consultations were carried out with representatives of international organizations and NGO focusing on water resources in Central Asia and transboundary cooperation.

5.1. Research design

Below table summarizes methods that were used for thesis:

Research question	Objective	Methods
1. **What are the trends in water level in the Ural River Basin?**	Explore water flow and discharge rate in the Ural River;	• Literature review • Data collection (annual flow and discharge rate in Kushum gauging station, archives, online sources) • Statistics analysis
	Study flow patterns in Kushum gauging station.	
2. **What is climate change and other factors' effect on the Ural River flow and discharge?**	Collect data on precipitation and temperature changes along the Ural River;	• Data collection • Statistics analysis • Giovanni mapping • ArcGIS
	Develop maps of snow depth for two periods of 1948-1980 and 1981-2010;	
	Analyze relation between climate change and water level in the Kushum gauging station.	
	Identify alterations resulted from upstream water reservoirs, mainly Iriklinskoye;	

	Identify extent of irrigated croplands that consume water in Orenburg and Western Kazakhstan oblast.	
3. **Has the UNECE Water Convention been successful in managing transboundary Ural River Basin?**	Assess the existing legal frameworks for managing and regulating resources on the transboundary Ural River;	• Data collection • Analysis of legislative acts, legal frameworks from online resources • Consultations and interviews
	Identify current status of the UNECE Water Convention implementation;	
	Identify how the UNECE Water Convention can help resolve dispute between two countries on managing the Ural River Basin.	
4. **What are the potential areas of improvement?**	Based on the analysis of major causes of the Ural River deterioration and existing legal framework between Russia and Kazakhstan, propose policy recommendations.	

5.2. Assessment of hydrological changes

Quantitative and qualitative data was collected from various sources, including:

- Online databases to assess climate change trends;
- Statistical information from local authorities;
- Satellite products from Giovanni;
- National scientific libraries;
- Articles from mass media;
- Interviews with water experts in Kazakhstan.

5.2.1. Statistical data

In order to define and assess hydrological regime on the Ural River, the data was obtained from the GRDC, which is the digital repository of historic river discharge data from gauging stations located worldwide. The GRDC operated as a facilitator between users and providers of river discharge data within the United Nations projects and programmes. The provider of data on the Ural River gauging station was the republican state-owned enterprise “Kazhydromet”.

The data for a long-term period of 1915-1984 was obtained and provides information on daily discharge rate recorded in the Kushum gauging station (Figure 5). All the data was firstly classified according to years and analyzed through statistics analysis tools. Data Subtotal in Excel was applied and such functions as Sum to count total annual discharge and Average for mean annual discharge.

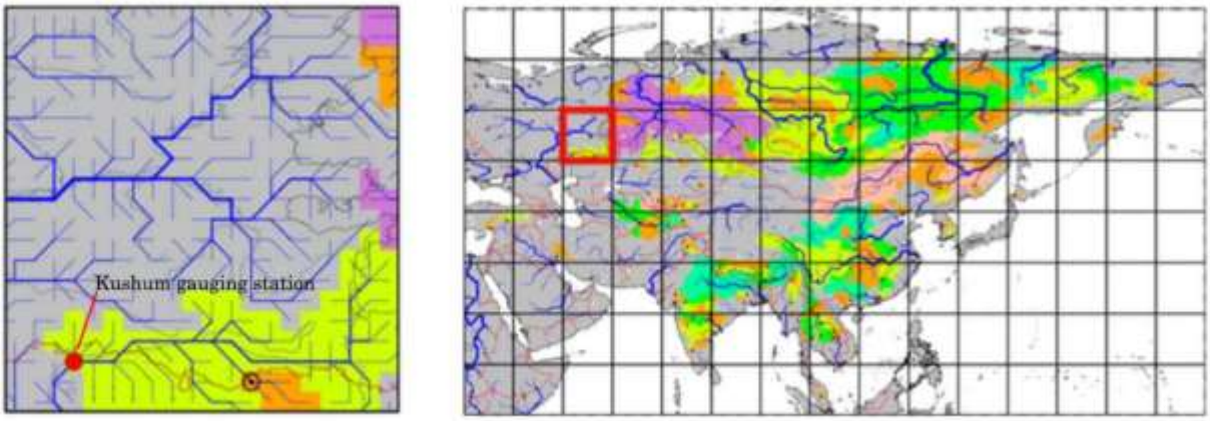


Figure 5 Location of Kushum gauging station on the territory of Kazakhstan
Source: GRDC

Data for the period of 1995-2007 on the Kushum station was obtained from the Western Kazakhstan hydrometeorological center -ZKO Hydromet. It provides information on the mean annual water level, discharge rate and annual flow. The analysis of the changes in hydrological regime was made by calculating mean annual discharge.

In order to define and assess impacts of climate change on the Ural River basin in the Western part of Kazakhstan, quantitative data was collected. The data offered daily data on minimum and maximum temperature, as well as daily precipitation. The analysis of changes in temperature was made by calculating average monthly minimum, maximum and mean indicators and drawing trendline over the given period of 1979-2014. Precipitation trend was completed by calculating total annual amount and analysing changes. The results are presented in Chapter 6. All the collected data on precipitation and temperature is summarized in Appendices 2-5.

5.2.2. Remotely sensed data

In the absence of necessary and reliable information, which was the case in this research, RS techniques serve as an efficient way to analyze the situation in the region. Giovanni maps were used to analyze snow depth in the Ural River Basin. Visualization of snow depth based on the data of GLDAS Model was done by creating time averaged map. Two periods were compared 1948-1980 and 1981-2010 with monthly temporal resolution. RS data on snow depth was processed through ESRI ArcGIS 10.4 software package.

5.3. Evaluation of transboundary cooperation in the URB

Interviews were used as a tool to identify issues of transboundary cooperation between Kazakhstan and Russia. In order to allow for open conversation on the sensitive topic of water security in Kazakhstan, semi-structured interviews were designed. This type of interviews is a good method to identify people's attitude towards existing water problems in Kazakhstan. Semi-structured interviews allow for research and planning, in which interviewee's responses can't be predicted in advance, and improvisation allows to reveal new information (Wengraf 2011). Questionnaire (see Appendix 6) was sent out to respondents in advance, as per their request in order to arrange the meeting.

Semi-structured interviews were conducted during research visit to Kazakhstan to enhance understanding of the water security issue in the Ural River basin. Total 5 interviews were conducted, however, all preferred to remain anonymous. Interviewees were members of international organizations and local NGOs in Kazakhstan. The questionnaire meant to explore major factors affecting water level decrease, barriers to transboundary cooperation with Russia, current programmes that deal with water security and status of implementation of the UNECE Water Convention in establishing rational water management based on the IWRM principles.

5.3.1. Ethical considerations during interviews

As the research touched upon sensitive topic of water resources in Kazakhstan and transboundary cooperation with Russia, the researcher followed the CEU ethical research guidelines, departmental protocol and interviews were based on the following principles:

- Providing questionnaire in advance by email and making sure that participation was voluntary;
- Making sure that interview procedures were unbiased and fair to all participants;
- Offering participants confidential anonymity by not using their names and title of organization;
- Making sure that the research procedures do not pose harm in any way to participants and that they will not suffer adverse consequences in their professional life as a result of participating in the interview.

5.4.Limitations

Some of the complications impacted the interpretation and analysis of the findings in the thesis, those pertaining to methodological limitations and limitations of the researcher.

- *Lack of available data and access to information.* Finding data on the water flow, discharge rate, population dynamics within a particular period of time was a significant obstacle, which required to limit the scope of the research. A lot of information on water resources is usually being sold in Kazakhstan. A number of attempts were made to contact

Kazhydromet Center in Kazakhstan requesting available data, however, no reply was ever received.

- *Time and financial constraints.* Limited time to investigate a research problem, conduct a thorough field work in the Ural River basin and track changes over time was constrained by the deadline of the thesis research. Financial constraints made it impossible to include additional stages of research, such as field work and purchase of data, resulting in condensed research.
- *Limited number of interviewees.* At the stage of arranging meetings many potential interviewees among the professional groups declined to participate in the interview. They were reluctant to provide information on the strategic water resources of Kazakhstan, even though they were informed in advance of the possibility to remain anonymous.

6. HYDROLOGICAL REGIME OF THE URAL RIVER

6.1.Changes in hydrological regime in Kushum

This chapter will answer the following research question 1: *What are the trends in water level in the Ural River Basin?* Results of water flow and discharge rate analysis in Kushum gauging station are presented below.

The analysis of hydrological regime in the Ural River on the territory of Kazakhstan was based on the data received from the Kushum gauging station. Initial river discharge was calculated by using rating curve relating height of the water level to discharge. It is generally believed that river gauging offers reliable information and has an accuracy of 5-10%.

Choice of the gauging station was determined by data availability within a substantial period of time and also because Kushum gauging station is the major functioning station on the territory of Western Kazakhstan along the Ural River. The station is located 1078 km downstream near Kushum village (Figure 6). Historically it has served as the main observation point to analyze hydrological characteristics and assess water level flowing from Russia to Kazakhstan.

Figure 6 Location of Kushum gauging station in the Ural River Basin

The catchment area of Kushum is 190 000 km^2. The average water discharge in the upstream near Orenburg is 104 m^3/sec and increases to 400 m^3/sec at the Kushum village, indicating great fluctuations in discharge rate. Average total flow in Kushum is 10.56 km^3, but in the 95% dry year it falls to 3,09 km^3.

As discussed in previous chapters, one of the major characteristics of the Ural River basin is significant fluctuation in the flow. Based on the data analyzed from the Kushum gauging station, within the period of 1915-2007 average mean annual discharge rate accounted to 298 m3/sec. Maximum discharge rate reached 800 m3/sec in 1946 and minimum 48 m3/sec in 1975 (Figure 7).

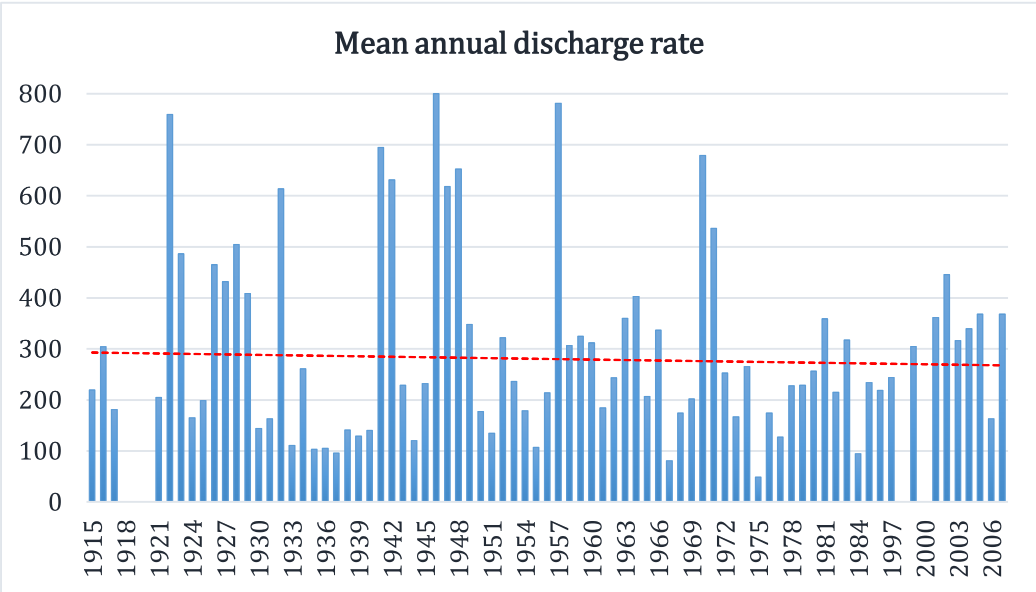


Figure 7 Mean annual discharge rate in Kushum gauging station, 1915-2007. Data source: (Vorosmarty 1998, ZKO Hydromet)

Based on the data analyzed, it can be assumed that wet year occurs frequently, approximately once every 10 years. However, from the period of 1972 the pattern changes indicating absence of extremely wet years. Trend of mean annual discharge rate shows gradual, but not drastic decrease.

Mean annual flow in the Ural River basin has been showing gradual decrease compared to long-term mean annual of 12.3 km^3/year. By 1995 the mean annual has decreased to 9.5

km^3/year falling by 23% of the long-term mean annual, by 2001 it accounted to 7.25 km^3/year indicating rapid decrease by 41%. By 2008 mean annual flow has improved to 10.63 km^3/year, however, still falling behind by 14% of the required minimum to pass.

Figure 8 presents the data from the Kushum gauging station.

The mean annual for 7 years of observation within 2001-2007 has shown overall improvement, increasing to 10.63 km3/year compared to 7.25 km3/year of previous 6-years-period 1995-2000 (

Figure 8). However, even within this time annual flow has been falling to abnormally low level of 5.14 km^3/year, which is by 58% below the long-term annual of 12.3 km^3/year.

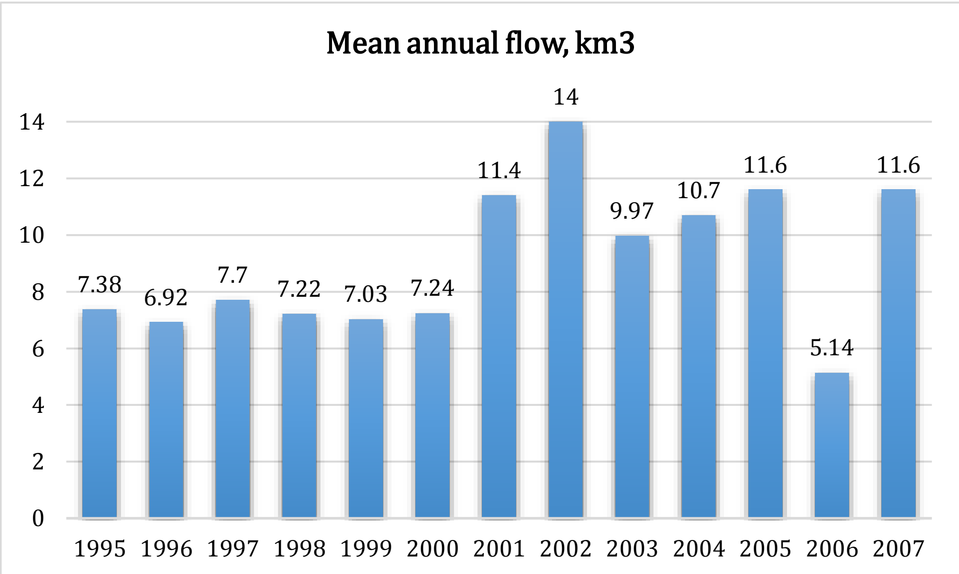


Figure 8 Mean annual flow of the Ural River in Kushum village, 1995-2007. Data source: (ZKO Hydromet)

Currently, the volume of passing flow from Russia to Kazakhstan is regulated by the Protocol of the working group on the Ural River Basin from 19.06.1996 (hereinafter – Protocol). According to it, around 7.8 km^3 is obliged to pass through the Ural River to the territory of the Western Kazakhstan, which is 1.5 km^3 less than unimpaired runoff. Based on the Protocol, during wet year at least 3.742 billion cubic meters should pass in April, 1.742 billion cubic meters accounts for May and 622 million cubic meters for June. However, Kazakhstan has been getting less than indicated volume, which has dropped down to around 5 km^3/year. Country has been attributing decrease in river flow to climate change effects, upstream water reservoirs in Russia and increased intake in the basin.

6.2. Climate change effect

This part will focus on the second research question: *What is climate change and other factors' effect on the Ural River flow and discharge?* The results of analyzed precipitation, temperature and snow depth within the Ural River Basin are described below.

Figure 9 Location of weather station 1-3 near Mountain Kruglaya Sopka in South Ural Mountains

The Ural River is mostly fed by melting snow, which accounts to 60-80% of total flow. Thus, the initial 3 weather stations (WS 1-3) to analyze precipitation in this region were chosen near the Mountain Kruglaya Sopka in the South Ural Mountains, where the river begins its formation (Figure 9).

The analysis of climate change was based on the amount of precipitation (mm) and temperature (C) over the 36-years period. For the purpose, the Global Weather Data for SWAT was collected, offered by the NCEP Climate Forecast System Reanalysis (CFSR) over the period of 1979 through 2014.

Despite the fact the Ural River mostly feeds on the melting snow, climate change effects were analyzed within the whole basin. Weather stations 4-7 located along the river on the territory of Russia were chosen to study changes in climate conditions that can potentially alter hydrological regime of the river (Figure 10). Analysis of four stations is intended to provide understanding on whether there was a shift in seasonality, amount of precipitation, which would indicate the effects of climate change across the whole Ural River Basin.

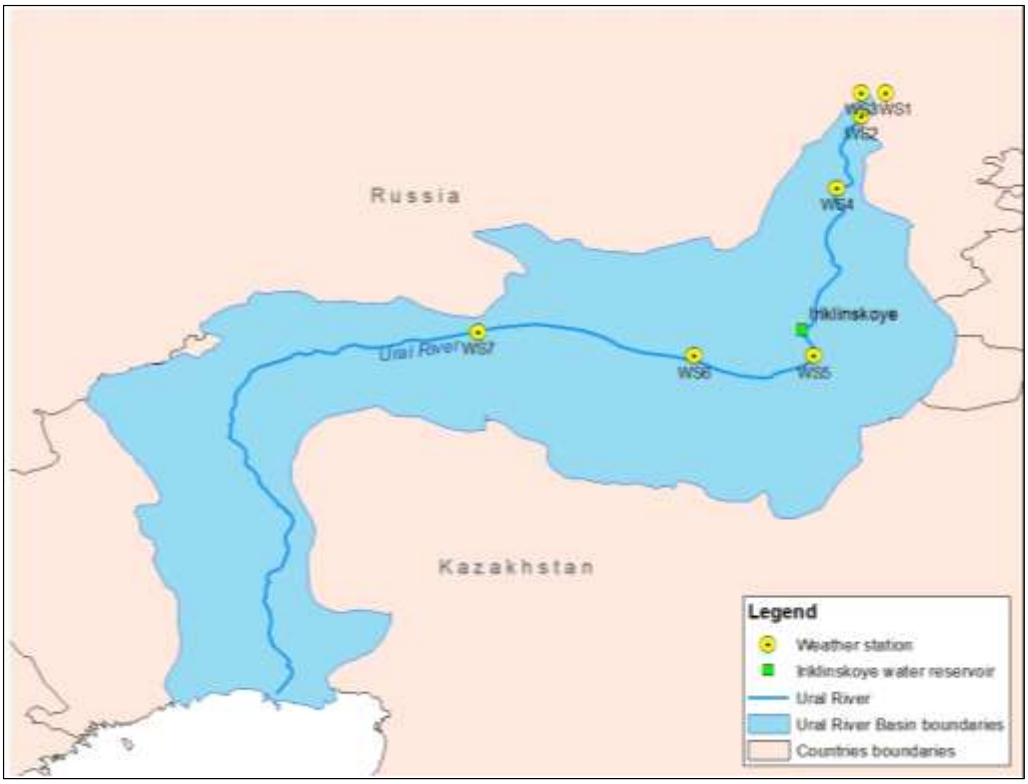


Figure 10 Analyzed weather stations within Ural River Basin

Climate change impact causes decrease of the amount of land covered by snow throughout the Northern Hemisphere. Warming affects the amount of snowfall and lengthens snow-free seasons. Decreasing precipitation and snowpack is a big concern in the Ural River basin as melting snow serves as a major source to fill the river and support annual flow.

Changes in the amount of precipitation provide evidence of changing water cycle in the basin. Based on the data from three weather stations (WS 1-3), located in the South Ural Mountains, it can be concluded that the region has been experiencing the effects of climate change. Total annual precipitation assessed through 1979-2014 has decreased by approximately 30% from 1000-1200mm/year to 700-900mm/year in recent years (Figure 11). Such decrease in precipitation potentially alters the streamflow of the Ural River. However, as the river mostly feeds on the melting snow from the mountains, the analysis of snow depth was conducted to study whether significant changes and decrease in snow formation affects the hydrological regime of the river.

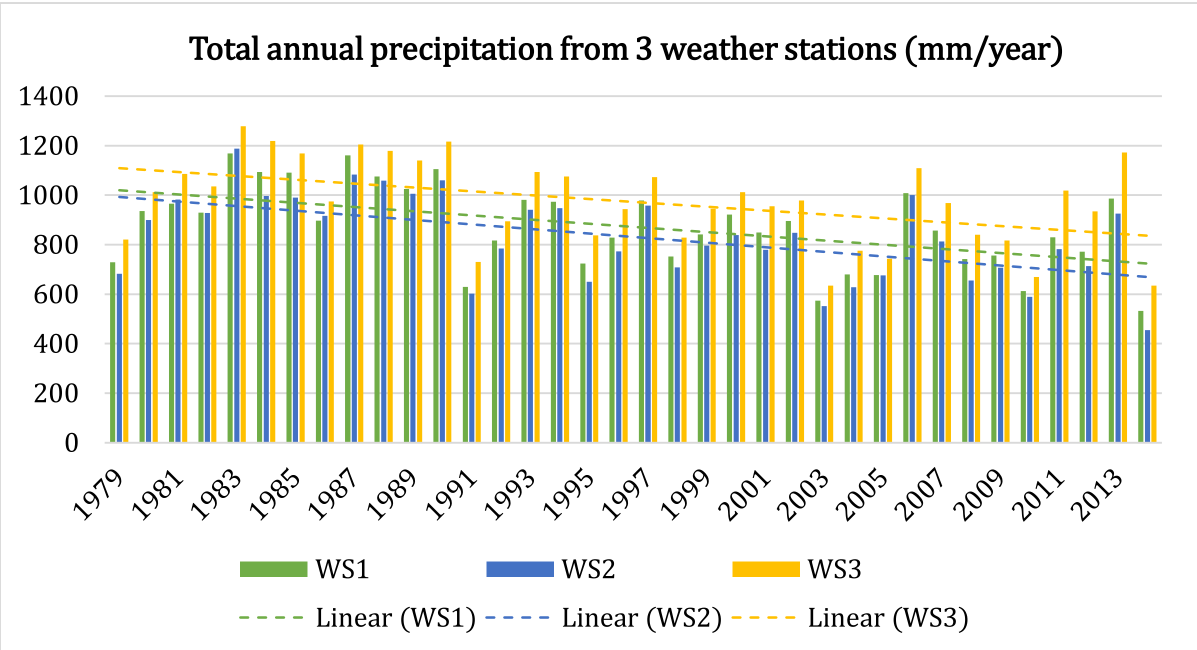


Figure 11 Total annual precipitation from WS 1-3 (mm/year)
Data source: NCEP CFSR

The comparative analysis of the average snow depth for two periods 1948-1980 (Figure 12) and 1981-2010 (Figure 13) based on the Giovanni maps indicates only a slight decrease throughout the whole territory of the Ural River basin. Decreasing melt water from mountain glaciers is a serious problem, which has a potential to undermine the Ural River's ability to maintain its system and causes decline in the annual flow. However, it is obvious from Giovanni maps that only slight changes occurred in the central part of the basin, but in the area that determines formation of the Ural River no drastic decrease in snow depth is indicated. Thus, the amount of snow that the river feeds on has not undergone serious changes throughout the period of 1948-2010, and does not have much effect on hydrological regime of the river.

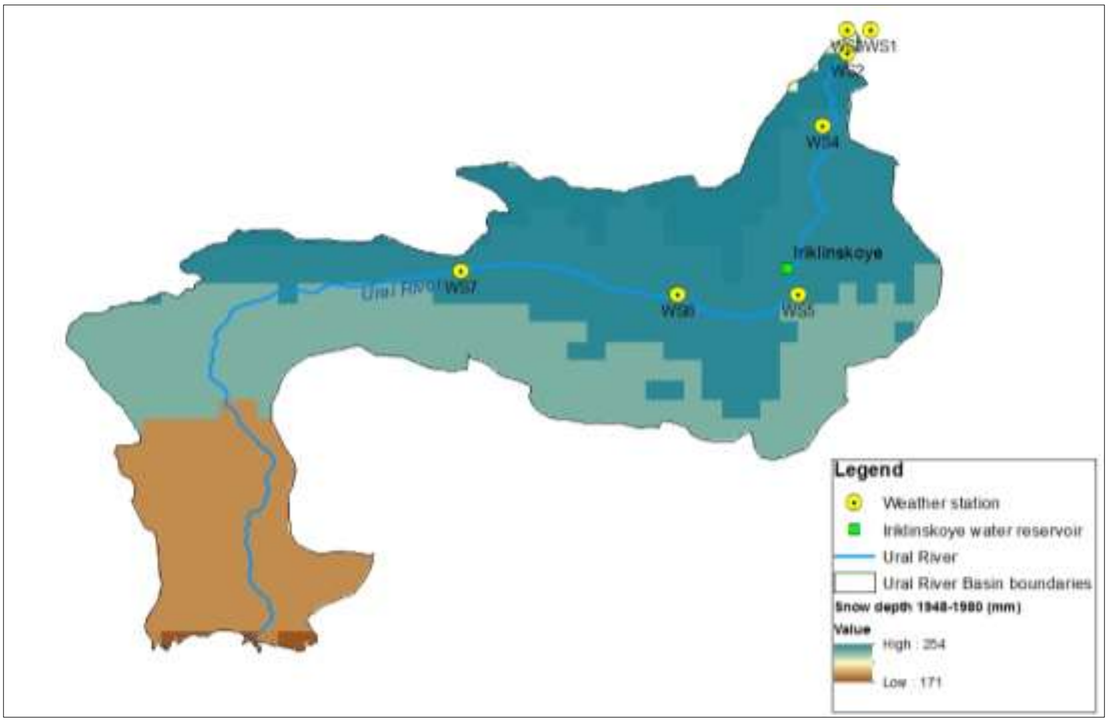


Figure 12 Average snow depth in the Ural River Basin throughout 1948-1980 (mm)

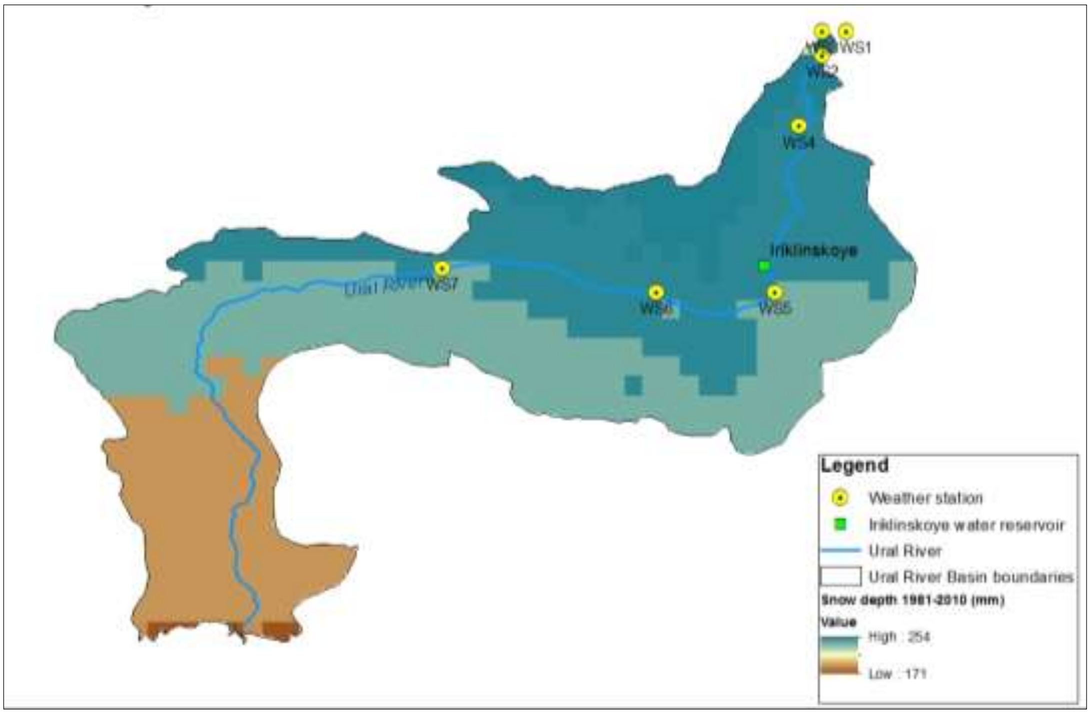


Figure 13 Average snow depth in the Ural River Basin throughout 1981-2010 (mm)

In order to understand the effects of climate change and at which locations Ural River is mostly affected by decreasing precipitation, total 7 weather stations were analyzed, including 3 located in South Ural Mountains and 4 more located along the river.

The results indicate that most precipitation occurs starting from May to August. Within the period of 1979-2005 the amount of precipitation has been decreasing in weather stations 1-3 (Figure 14, Figure 15, Figure 16), which supports common trend of total precipitation falling, indicated above. While snow depth has not been affected by climate change, this analysis indicates that summers have become drier and amount of rainfall has decreased significantly. Though it improved for the period of 2006-2013, the number still falls behind initial period of 1979-2000.

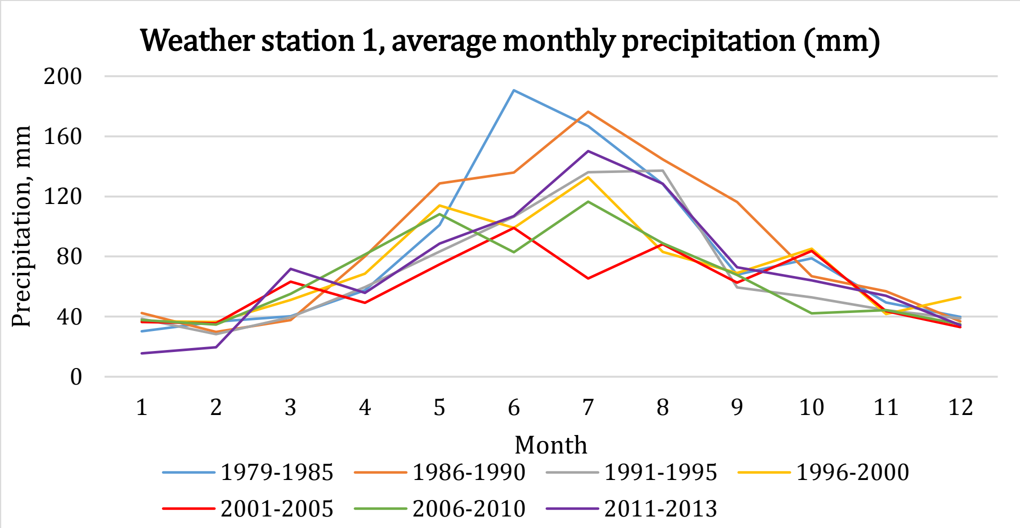


Figure 14 Average monthly precipitation from WS1 (mm). Data source: NCEP CFSR

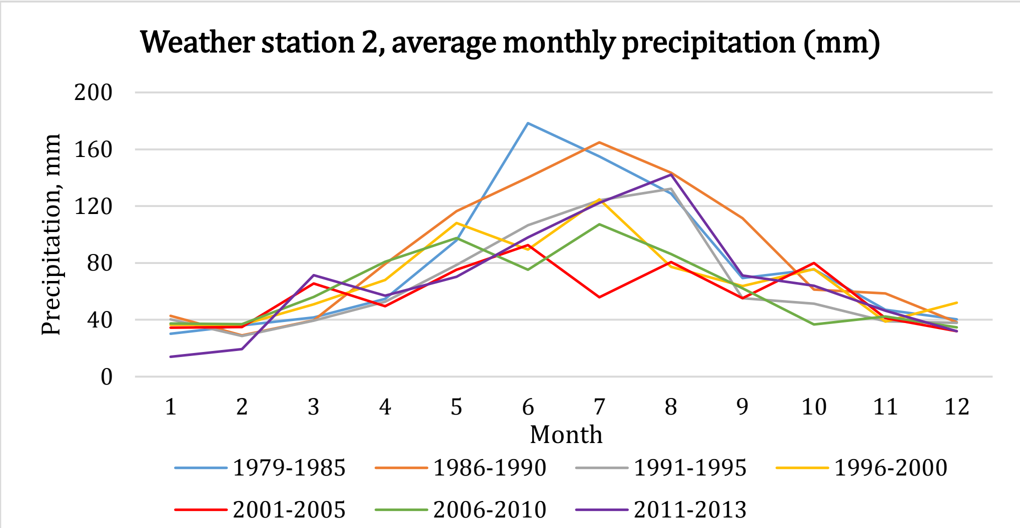


Figure 15 Average monthly precipitation from WS2 (mm). Data source: NCEP CFSR

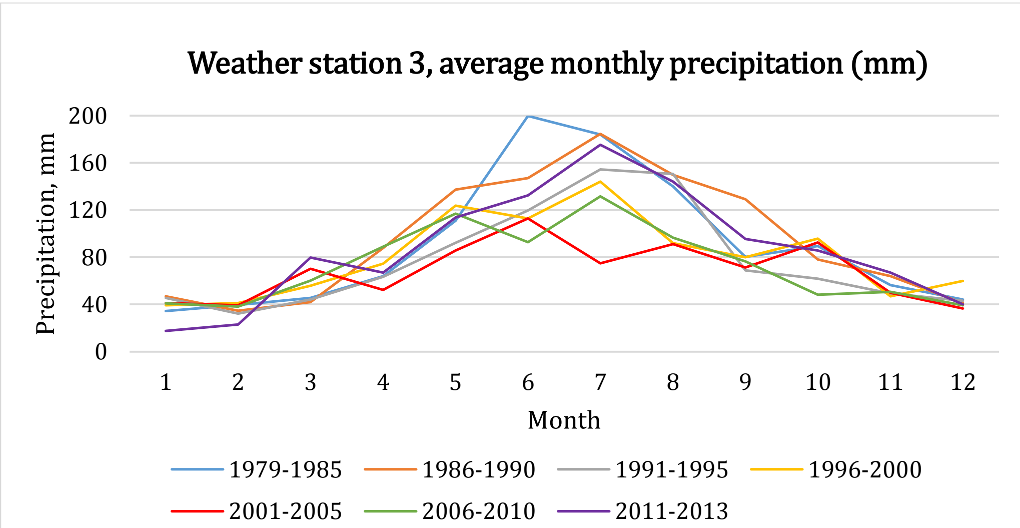


Figure 16 Average monthly precipitation from WS3 (mm). Data source: NCEP CFSR

The results from 4 additional weather stations, located along the Ural River have shown similar pattern of changes in precipitation. Weather station 4 shows similar patterns to previously mentioned 3 stations, as it is located 140 km South from WS3 and 20 km away from Magnitogorsk. The amount in total precipitation falls as it is not a mountainous area. Precipitation has been decreasing to a record fall within 2001-2005, but the period of 2006-2013 shows slight improvements by increased rainfall during May-July.

Analysis of WS 5-7 shows lower total amount of rainfall as the stations are distant from mountainous region of South Ural. Average monthly precipitation have gradually decreased for the whole period of 1979-2013 with less rains occurring during summer month. All results from stations 4-7 are summarized in Appendix 3.

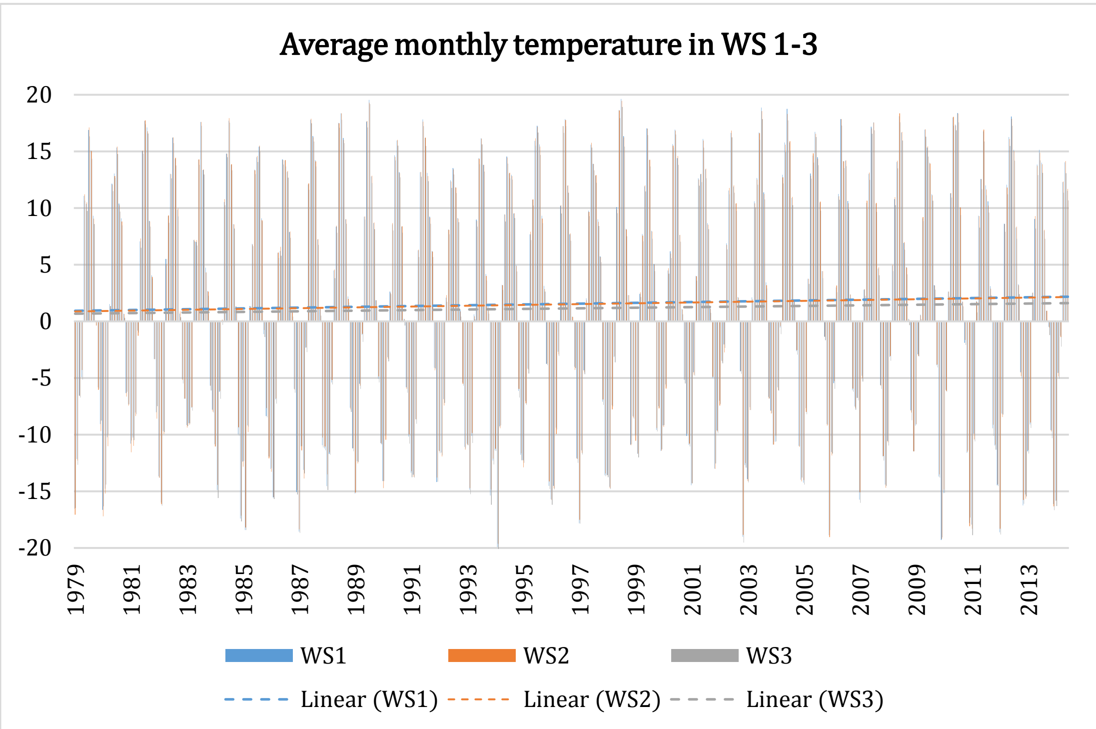


Figure 17 Average monthly temperature from WS 1-3

In terms of temperature, average monthly temperature at the North of the river basin has been showing gradual increase within the 35-years-period of observation. The estimates show the increase by approximately 1°C (Figure 17). Warmer air is associated with diminishing accumulation of precipitation. Analysis of temperature from weather stations 4-7 located along the Ural River on the territory of Russia also indicate overall trend of rising temperature within the basin (Figure 18). All the results are summarized in Appendix 5.

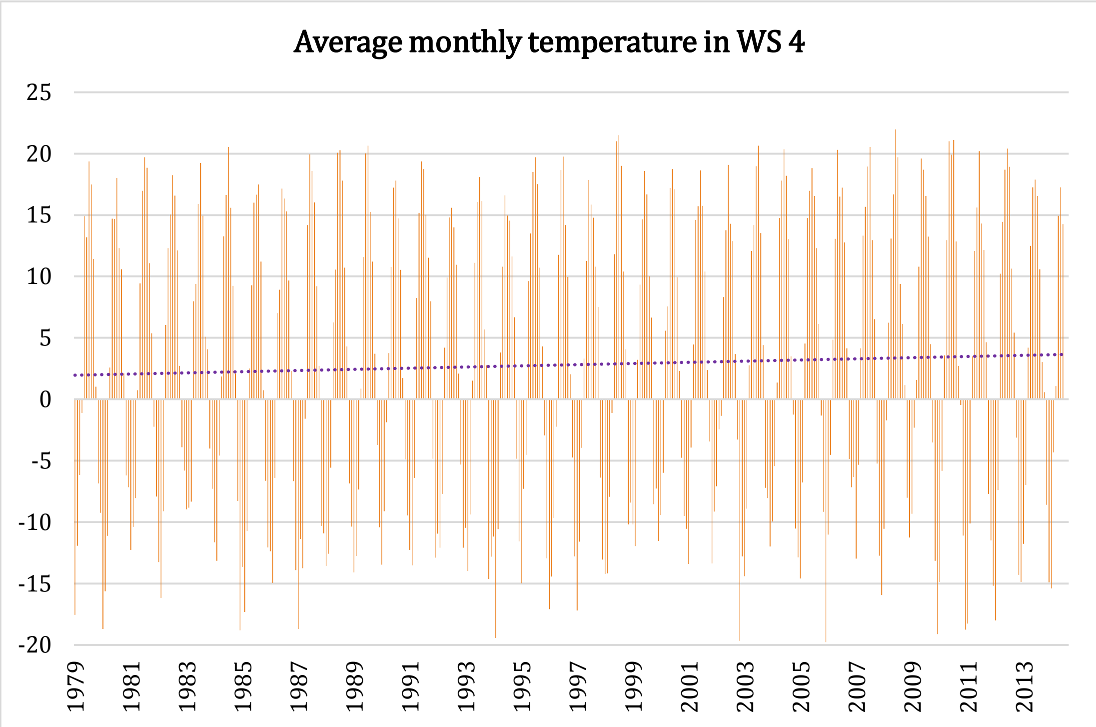


Figure 18 Average monthly temperature from WS 4 (mm)

The final results indicate that throughout the whole territory of the Ural River Basin amount of precipitation has decreased, caused by the effects of climate change. Snow depth has not been affected to the extent able to alter hydrological regime significantly, except for slight depth decrease within central part of the basin. Average temperature increasing trend also supports the idea of climate change impact in the region.

While snow depth has not changed significantly, the decreasing precipitation trends might pose a threat to river's hydrological regime. The relationship between snow depth and decreased precipitation exists in soil-moisture content. Adequate and frequent precipitation within the year provides high levels of soil-moisture quantities, recharging ground water. As the rainfall in the Ural River Basin decreases, it causes soil to dry up faster, not being able to return to moisture conditions within the normal range. The rate of melting snow soaking into the ground increases, limiting the ability of the river to feed on it and contributing to keeping soil moisture rather than filling up the river flow.

6.1. Hydrological regime changes by water reservoirs and agricultural activities

As was analyzed previously, climate change impacts hydrological regime of the Ural River. However, while accounting for changes along the river other factors cannot be omitted. As every single factor requires conducting in-depth analysis to evaluate full extent of its impact, it does not seem feasible within the scope of this research. This part of thesis gives brief overview of findings of such factors as water reservoirs and agricultural activities.

While primarily task of the research was to investigate the effects of climate change in the Ural River Basin, it was also important to account for other factors that are often blamed for decreasing flow of the river. As addressed by many experts on the Ural River great changes in hydrological regime are attributed to the construction of water reservoirs in the upstream Russia and increased agricultural activities on the territory of Kazakhstan, which puts pressure on limited freshwater resources.

Thus, the impact on stream flow is worsened by a number of other factors in combination with the effects of climate change. The analysis of water reservoirs focuses on Iriklinskoye water reservoir, as it is the biggest in the Ural River Basin with volume of 3260 mln m^3. Located in Orenburg oblast of Russia, the reservoir is claimed to have the major effect on the stream flow. The construction was initiated in 1949 and completed in 1957, followed by filling of the reservoir throughout 1958-1966.

Particularly in Bashkortostan a lot of small scale reservoirs have been constructed in the past years in order to satisfy unmet demands of water resources. The analysis was determined by the fact that the number of reservoirs within this region is rapidly increasing. The construction takes place on the tributaries of Sakmara river (Figure 19) - major tributary of the Ural River, where regulation of the stream flow results in decreasing water level.

Figure 19 Sakmara river. Source: Newell et al. 2007

Assessment of agricultural activities was initiated due to the fact that irrigation is the biggest consumer of water. Agriculture is well developed along the Ural River in Bashkortostan, Orenburg oblast and Western Kazakhstan. Among sown areas the biggest share is occupied by crops and fodder.

6.1.1. Water reservoir

Three major water reservoirs are located on the upstream Russian territory – Verhneuralskoe, Magnitogorskoe, Iriklinskoe with total volume of 0.60, 0.19 and 3.26 km3 respectively, which comprise 96% of all water reservoirs in the Ural River basin (Pavleychik *et al*. 2012). Despite benefits water reservoirs bring, they are proved to disturb aquatic ecosystems and increase water loss.

The construction in the upstream and regulation of the river flow has a negative impact in downstream, where flow is gradually decreasing. The construction of the biggest Iriklinskoye water reservoir, located in the upstream on the Russian territory, has had a major impact on river's hydrology (Figure 20) The analysis of river flow on the territory of Kazakhstan before and after construction of Iriklinskoye water reservoir indicates changes in distribution of discharge. As measured in Kushum gauging station, water level has decreased by 0.5-1.5 times since 1957 (Figure 21).

Figure 20 Location of Iriklinskoye water reservoir on the Ural River

The regulation in upstream after the construction of Iriklinskoye water reservoir has had an effect on the downstream, as the level of discharge has fell significantly. Negative effect is seen through altering hydrological regime and gradual decrease in the total discharge rate. Compared to the 30-years periods of 1930-1957 (Figure 22), before the construction of Iriklinskoye water reservoir, and 1958-1984 (Figure 21), when the reservoir was already functioning, the discharge as measured in Kushum gauging station has decreased by 17%.

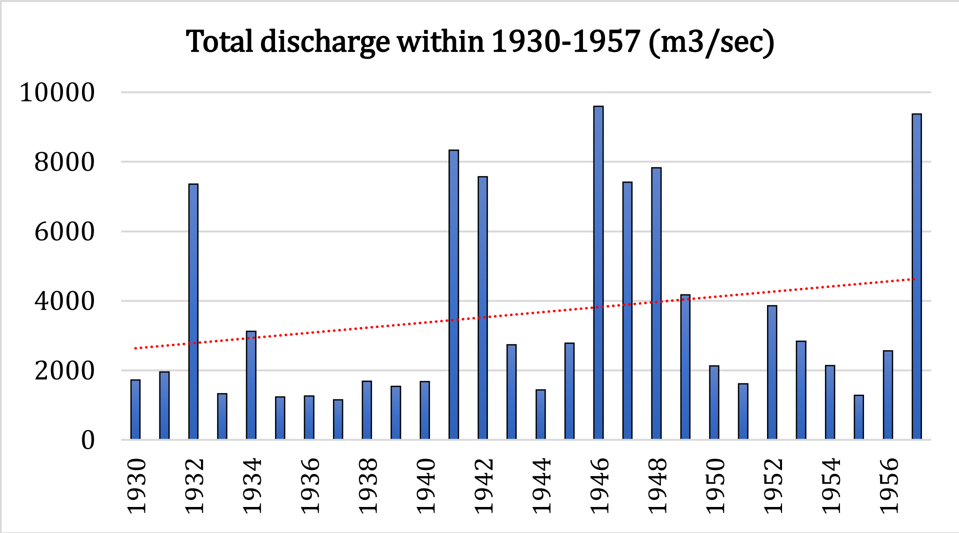


Figure 22 Changing trend in total annual discharge within 1930-1957 in Kushum gauging station
Source: GRDC

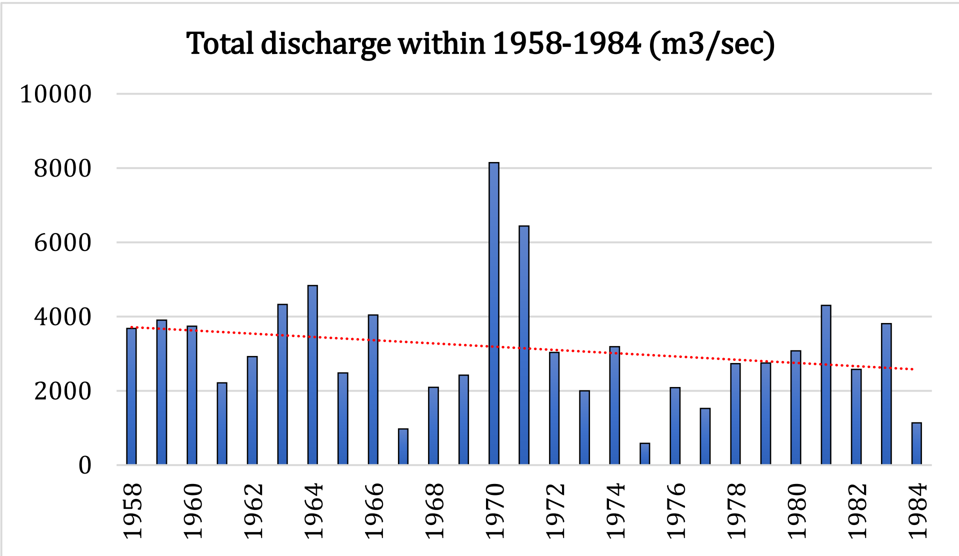


Figure 21 Changing trend in total annual discharge within 1958-1984 in Kushum gauging station
Source: GRDC

Transboundary character of the Ural River foresees agreed regional and intergovernmental cooperation on the use of water resources. However, some regions have been actively implementing policy on flow regulation to deal with water deficit problem. Such is the case with the Republic of Bashkortostan, where a number of significant water reservoirs were constructed on river tributaries for the last 20 years, including Sakmarskoe, Akyarskoe, Tanalikskoe and Makanskoe (Table 1).

Water reservoir	Completion year	River	Square, km2	Volume, mln m3
Sakmarskoe	2005	Sakmara	5.8	30.7
Akyarskoe	2002	Tashla	7.8	49.4
Tanalikskoe	1998	Tanalyk	2.01	14.2
Makanskoe	1998	Makan	4.41	15.5

Table 1 Water reservoirs constructed within the last 20 years in Bashkortostan

According to the Plan on the use and protection of water bodies in the Ural River Basin, developed by the Russian Research Institute for Integrated Water Management and Protection (RosNIIVKh), it is planned to expand number of water reservoirs in the upstream within 2016-2020 in order to provide the region with required volume of water. Construction will take place on Sakmara tributaries, which in turn is the largest tributary of the Ural River. While water reservoirs serve to ensure sufficient amount for various needs in the upstream, they inevitably alter hydrological regime downstream limiting access to water resources in other regions, including the territory of Kazakhstan.

6.1.2. Agricultural activities

Agriculture is proved to be one of the world's largest water consumers. In the Ural River Basin agricultural activities have been blamed for increased water intake, especially on the territory of Kazakhstan, where 44% of total water consumption is attributed to irrigation, while in Russia irrigation accounts to 2%. (Frolova 2016).

Based on statistics information offered by local authorities in both Kazakhstan and Russia, the analysis was conducted to identify whether agricultural activities have increased, putting pressure on water resources by large demand for irrigation. As summarized in Figure 23 area of irrigated crop lands within the last years (2008-2014) has not changed dramatically to alter significant variations in stream flow. In Orenburg oblast, slight increase by 7% from 4009.4 to 4303.4 thousand ha has occurred in 2013 compared to previous year, followed by drop to 4248.3 thousand ha in 2014.

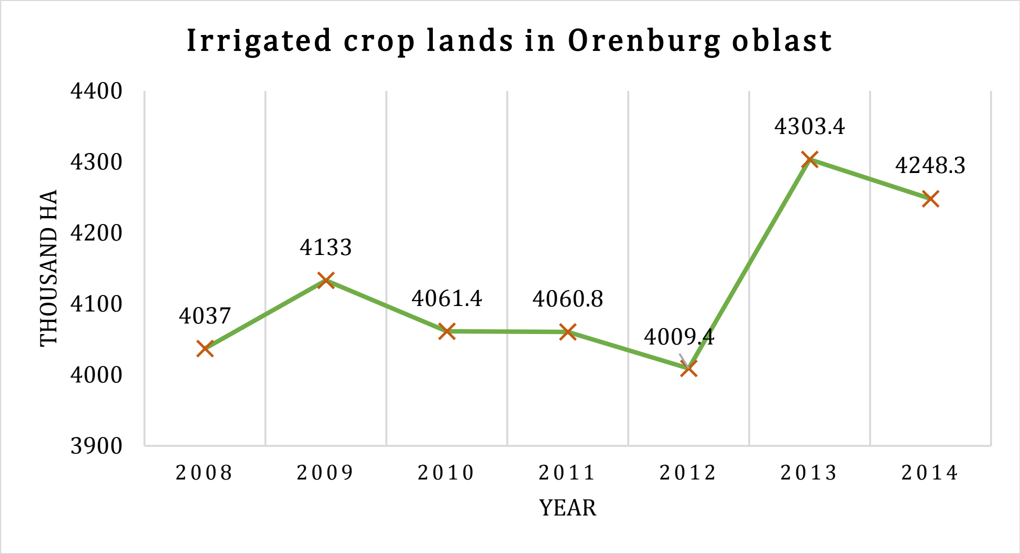


Figure 23 Irrigated crop lands in Orenburg oblast 2008-2014

As put by Russia, decrease in water level within Kazakhstan is caused by increased irrigation and agricultural production output. However, based on the analysis of irrigated crop lands within 2004-2015, the area of agricultural lands has been on a constant decline. Compared to 742.7 thousand ha in 2004, it has decreased by 35% to 484.7 in 2015 (Figure 24). It should be mentioned that the water intake from the Ural River for agricultural activities cannot be attributed only to irrigated croplands and further in-depth analysis is required to assess full extent of agricultural impact on the hydrological regime of the river.

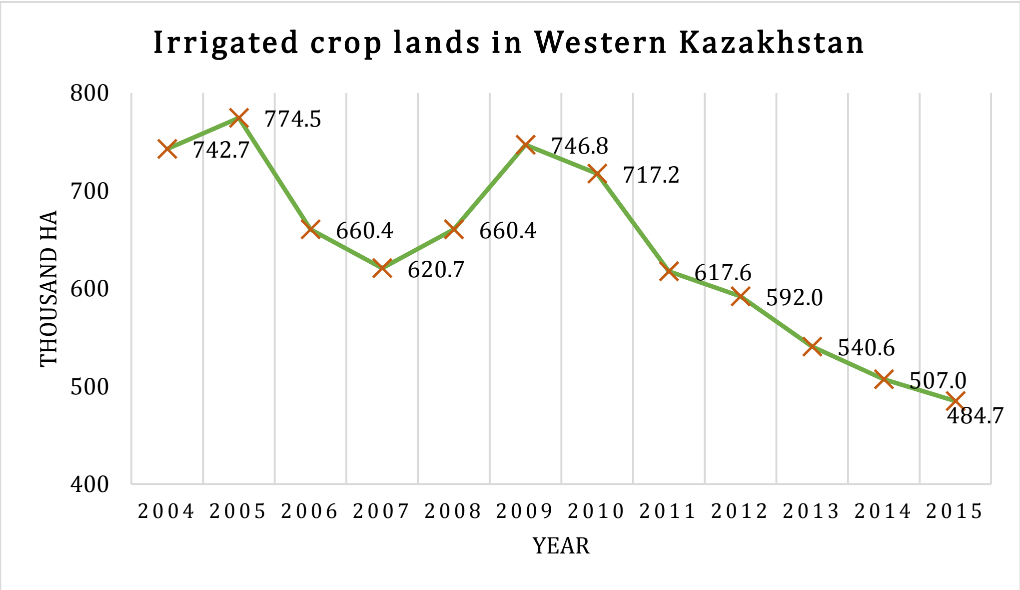


Figure 24 Irrigated crop lands in Western Kazakhstan oblast 2004-2015

The results indicate that throughout the last years in the Ural River Basin within territories of both countries area of irrigated croplands have not been drastically expanded, and on the contrary decreased in Kazakhstan. Little can be attributed to increased irrigation which would significantly challenge hydrological regime of the Ural River. However, in order to identify the extent of irrigation impact on water level changes in the river, in-depth analysis is required that will assess consumption of water by agriculture, and how much loss occurs due to irrational water management and outdated technologies for irrigation.

As a result, river's hydrological has been diminishing, dropping to as low as 5.14 km^3/year in 2006 compared to mean annual of 12.3 km^3/year. The drop in water level can be attributed to climate change effects, which is proved by the analysis of data from measured weather stations along the river. Precipitation has decreased and temperature has increased within the basin. However, though 80% of the river feeds on the snow melting in South Ural Mountains, satellite products do not indicate drastic changes those could affect hydrological regime of the Ural River. The analysis indicates that rather overall decrease and decreased soil moisture affect the changes in hydrological regime. Other factor – construction of water reservoirs in the upstream, especially visible on the example of major Iriklinskoye water reservoir, indicates negative effect on river's hydrology as the discharge has dropped significantly, marking increased intake of freshwater reserves for population. Irrigation in Kazakhstan and Russia did not affect Ural River's water level to a significant extent, as blamed by many experts, however, further analysis is required to assess ploughed lands, intake for agricultural activities in order to identify consumption from the Ural River. These factors show that a transboundary cooperation is required for countries to come to a consensus on the regulation of the flow and distribution of scarce water resources in the region.

7. TRANSBOUNDARY COOPERATION IN THE URAL RIVER BASIN

This part will provide information on possible cooperation within the UNECE Water Convention, trying to address research questions 3: *Has the UNECE Water Convention been successful in managing transboundary Ural River Basin?*

Complex character of hydropolitics presents one of the most challenging areas of transboundary cooperation. International river basins disputes brought countries to concern over allocation of water resources leading to conflicts. However, importance of the Ural River waters has rather served as an incentive for both Kazakhstan and Russia to address their problems in a peaceful and cooperative manner. While transboundary cooperation has improved after ratification of the UNECE Water Convention, the ongoing alterations of hydrological regime of the Ural River stem from disagreement of both countries on the actual factors that affect water level decrease and water distribution between upstream and downstream countries.

Consensus on climate change effect in the Ural River Basin is unequivocal. Two sides agree on shift in precipitation amount and temperature having negative effect on river's hydrology. The dispute arises as Kazakhstan blames Russia for excessive use of water in upstream through water reservoirs, diversion of river, pollution problems that undermine water security in downstream. In 2013 the question of diverting part of Volga River's flow into Ural to replenish water resources was raised again at that time by Environment Vice-Minister Erlan Nysanbayev during discussions of existing problems within transboundary Ural River Basin. The idea was attacked by Russian side, claiming that Kazakhstan should be held responsible for shallowing Ural River on its territory as the main problems are rooted in underinvestment and poor management system.

As the analysis indicates, climate change does take place in the region being one of the factors for altering hydrological regime of the Ural River. Construction of water reservoirs has affected river's flow, but little changes can be attributed to agricultural activities and increased irrigation. Too much time is being spent on blaming each other and arguing who gets a bigger piece of pie. The realization of the basin's issues and discussion of recommendation to overcome current critical situation was somewhat delayed, and undertaken policy is unsystematic with lack of coordination. Alarming state of the Ural River provides evidence that both countries have to come to a consensus and implement Integrated River Basin Management principles. Instead of blaming each other for diminishment of the river, countries should take holistic approach to build intergovernmental cooperation with involvement of all stakeholders. Solid foundation of the basin's problems should be established, that will guide actions and strategy with integration of policies and costs across interests of all stakeholders, including urban population, industries, agriculture.

As anthropogenic climate change and water consumption continue to exacerbate, the Ural River Basin will be more prone to its effects, experiencing extreme events. The transboundary character of the river will create even more interdependency between Russia and Kazakhstan, calling for increased cooperation. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes has proved to be efficient in many regions and can serve as an effective tool to create transboundary dialogue on water resources. Although the 1992 Water Convention does not explicitly cover climate change issues, it is one of the most important frameworks that sets out cooperation on transboundary impact of and adaptation to climate change.

By becoming party to the UNECE Water Convention in 2001, Kazakhstan has showed its commitment to enhanced cooperation and the need to strengthen national and international measures over *protection and use of transboundary watercourses*, such as Ural River basin. The UNECE Water Convention has contributed to establishing effective platform for addressing such issues as equitable distribution, adaptation to climate change, information disclosure, prevention of pollution and others. It has served as a basis for bilateral agreements between two countries following its ratification.

After ratifying the convention the 1992 bilateral agreement with Russia was reviewed and replaced with the **Agreement between Government of Kazakhstan and Government of Russian Federation on joint use and protection of transboundary water bodies** (Bilateral Agreement 2010). Up until now the Joint Kazakh-Russian Commission has held over 20 meetings and established working groups on 6 major transboundary river basins, including Ural, Ertis, Tobol, Kigach, Kara and Sary Uzen. (Akhmetov 2016). The newly adopted 2010 Agreement has expanded the scope of provisions, guided by the 1992 Water Convention, and included new terms, such as *"transboundary impact"* and *"critical situation"*.

Despite long-term cooperation between Russia and Kazakhstan many issues still exist, requiring effective dialogues to address questions of equitable distribution or pollution. As the problems evolve, the decision-making has proved to lack institutional coordination. Thus, despite knowledge and experience in the problems of the Ural River, lack of power given to the Russian-Kazakh Commission on joint use and protection of transboundary water bodies of the Ural River Basin and Zhayik-Caspian Basin Inspection, results in inefficient work conducted by them and inability to take decision that would improve the condition in the Ural River Basin. Other problems, include lack of investment for better capacity building and exchange of knowledge and technologies, that would help regulate hydrological regime and pollution levels in the river, as well as provide adequate response to arising problems. While countries continue blaming each other for increased intake, it is important to provide timely response in order to prevent further degradation of the Ural River ecosystem affected by climate change or anthropogenic alteration.

7.1.1. Equitable and reasonable distribution

Climate change in the Ural River Basin leaves a lot of uncertainties on the magnitude of its impact with countries failing to agree on joint actions. Hydrological regime has been changing due to decreased precipitation and growing temperature, which put Kazakhstan in the alarming state. For the last years Kazakhstan has been trying to negotiate transfer of water resources from the Volga River to increase freshwater flow in the Ural River. However, the implementation of such project would catastrophically impact Volga River Basin leading to increased loss of water and bioresources.

It is hard to predict timing, magnitude and nature of climate change effect in the Ural River basin. Consequences may alter existing water management system and governments should be ready to adapt to these uncertainties. As climate change puts pressure on water resources, principle of equitable and reasonable distribution between countries remains a challenge for both Kazakhstan and Russia. Effective cooperation should be ensured beforehand at all stages of planning and decision-making.

Management of transboundary Ural River requires reasonable and equitable distribution of water between Kazakhstan and Russia, which goes along with the Article 2, General Provisions of the Water Convention. As the water resources diminish due to climate change or increased intake and deteriorate due to excessive pollution both Parties to this Convention should take appropriate measures to provide equal rights to people of accessing drinking water.

Flexible water allocation is of a particular issue these days. Since 2008 the Ural River has been vulnerable to drier seasons, which impacted environmental conditions in the region. Though within 2001-2007, the mean annual flow has increased compared to previous 6-years period, the data shows low levels of water in Kushum.

The issue of decreased flow in the Ural River has been addressed on many international forums, where Kazakhstan associated decrease in water level not only with climate conditions but also with upstream flow regulation by water reservoirs, while Russia claimed that hydrological changes on the territory of Kazakhstan occur due to increased water intake. During the last years Kazakhstan has been trying to encourage to revise the operation and working regime of the Iriklinskoye reservoir in order to increase water discharge during dry years. However, both parties did not come to mutually beneficial agreement.

The inability of both governments to come to a consensus causes the Ural River to diminish and undermines water security in the region. *Reasonable and equitable* water use in the framework of the UNECE Water Convention will allow to find a rational way for sustainable water practices. Commitment to non-binding instruments, including recommendations and guidelines, will make it easier to apply the provisions of the Convention and will also serve as clear parameters in solving water distribution issues between both Kazakhstan and Russia.

The Water Convention provides a comprehensive framework and encourages countries "*to ensure that transboundary waters are used in a reasonable and equitable way, taking into particular account their transboundary character, in the case of activities which cause or are likely to cause transboundary impact*". However, good water governance requires not only soft law, but sound fundamental legal framework. Transboundary water cooperation in the Ural River basin lacks concrete agreements that would set out flexible water distribution mechanism and set mutual response during extreme events. If included in legislation, principle of equitable and reasonable use of water resources can help countries of the Ural River Basin to ensure that needs for drinking, agriculture, industries are equally taken into account and every country's interests are satisfied even when the region is affected by changes in climatic conditions.

7.1.2. Precautionary principle

As Parties to the Convention, Kazakhstan and Russia should be guided by the precautionary principle, which is especially applicable to water management practices. Precautionary principle is considered while accounting for climate change, when possible catastrophic, irreversible effects are identified, but potential damage lacks scientific proof (UNECE 2009). While link between transboundary impact and changes in precipitation and temperature are not fully proven, Kazakhstan and Russia should not postpone any actions associated with preventing potential adverse effects resulting from climate change, water reservoirs, agricultural activities and inadequate management system.

Both countries addressed issues of various factors that change hydrological regime and negatively impact water quality of the Ural River. Lately a lot of importance has been assigned to improving water quality and preventing further pollution to not only ensure access of population to clean drinking water, but also to create favourable conditions for conservation of a sturgeon population, which is now at the verge of extinction.

Precautionary principle of the UNECE Water Convention is especially applicable in the Ural River basin, where governments should aim to prevent potential water-related negative effects on human health, environment or political stability. As water is a complex element with complex biogeochemical processes, a lot of uncertainties arise, which cannot be backed up by sound scientific evidence. For Ural River Basin countries jeopardized by water scarcity, precautionary principle in policy-making will allow to mitigate likely harm on the water quantity and quality, basing its decision on the idea of "better safe than sorry".

7.1.3. “No significant harm” principle

As water security presumes not only rational distribution between countries, it requires cooperation on such issues as transboundary pollution and preservation of the ecosystem, which would grant access of people to good quality drinking water. “No significant harm” principle requires States to prevent and control pollution of transboundary waters, as well as use the watercourse in a way that will not cause transboundary impact across territories. It is especially important for countries striving to establish water security in the region through improved cooperation on such issues as water quality in upstream and downstream. General Provisions of Article 2 of the UNECE Water Convention establishes that the Parties shall take all appropriate measures “*to prevent, control and reduce pollution of waters causing or likely to cause transboundary impact*”.

Under Article 3 of the 2010 Agreement, Kazakhstan and Russia are “*to refrain from actions or omissions of the cases, which may lead to deterioration of the hydrological and hydrochemical regime of transboundary water bodies and related ecosystems*”. The obligation requires Parties to not only deal with pollution within its territory, but mitigate negative impact on transboundary rivers from water contamination resulting from floods, infections, coastal erosions, water discharges, liquid waste, and outdated hydraulic structures.

The implementation of this principle has remained challenging, as both Parties lacked coordination and cooperation to resolve transboundary pollution issues. With many industries and hydraulic structures, intensified by agricultural activities and changes in climatic conditions, water quality in the Ural River has been degrading and countries are still arguing on who is responsible for pollution. Establishing water security in the region means including principle of “no significant harm”, which will allow to achieve sustainable and integrated river basin management.

8. CONCLUSION AND RECOMMENDATIONS

The main goals of thesis were to explore hydrological changes in the Ural River Basin, those potentially undermining water security in the region. The research further provides overview of corresponding challenges and prospects in building sustainable transboundary cooperation between Russia and Kazakhstan within the UNECE Water Convention framework. Addressing existing factors affecting hydrological regime of the river is a matter of great importance as the Ural River is the only source of water in the Western Kazakhstan and Atyrau oblast establishing water security in the region. Four research questions were formulated:

RQ 1: What are the trends in water level in the Ural River Basin?

RQ 2: What is climate change and other factors' effect on the Ural River flow and discharge?

RQ 3: Has the UNECE Water Convention been successful in managing transboundary Ural River Basin?

RQ 4: What are the potential areas of improvement?

It was found out that annual flow in the Ural River Basin has been showing deteriorating trends compared to long-term mean annual of 12.3 km^3/year. Even during improvement years within 2001-2007, the annual flow has fallen to abnormally low level. The overall picture shows decreased water level in the river.

The evaluation of climate change implications establishes that precipitation has mainly decreased throughout the river basin, with minor impact on the snow cover in the South Ural Mountains, where the river feeds on. Temperature has been gradually increasing on the territory of the whole basin based on the analysis of 7 weather stations. Other factors show that the river hydrology is also affected by upstream water reservoirs, that increase water intake to support population in the Orenburg oblast. Lately a lot of newly established water reservoirs have marked increased intake by the Republic of Bashkortostan. Agricultural activities affect river hydrological regime to a lesser extent, however, further in-depth analysis is required to evaluate water consumption for irrigation.

Although the UNECE Water Convention has served to increase transboundary cooperation between Russia and Kazakhstan, two countries still fail to implement its principles to a full extent, which creates obstacles for rational river basin management. The implementation of the UNECE Water Convention can serve as an important framework for Kazakhstan and Russia to cooperate on the issues of the Ural River. Based on the three principles, including "equitable and reasonable distribution", "precautionary principle" and "no significant harm", the Convention can contribute to dealing with both river hydrology issues and transboundary pollution.

An important conclusion of this study is that the existing legal transboundary framework on managing water resources is sound. However, the Ural River Basin countries are required to make some adaptations to this framework in order to meet challenges of transboundary water management and uncertain future of diminishing water resources. Adaptations can be made within transboundary and national levels:

1. **Adapting to climate change**. Understanding of climate change effects, its extent on water resources and its changing character should result in effective adaptation mechanisms, agreed upon by both countries. Flexible mechanisms should be enabled in managing water resources of the Ural River between Kazakhstan and Russia.
2. **Existing legal mechanisms**. Existing bilateral agreements between Kazakhstan and Russia play a weak role in dealing with the issue of water allocation between upstream and downstream. Effective monitoring and control mechanism equitable and reasonable water distribution should be integrated into international and national legal laws.

3. **Building institutional capacity**. Existing institutions with specific focus on the Ural River might be more influential in establishing transboundary cooperation and coordination than other external organizations. The role and responsibilities should be expanded for the Russian-Kazakh Commission on joint use and protection of transboundary water bodies of the Ural River Basin and Zhayik-Caspian Basin Inspection.
4. **Funding mechanism**. Effective funding mechanism and attraction of foreign investment have a noticeable effect on transboundary cooperation, serving as an incentive for countries. Increased investment will allow for better exchange of experience, best practices, data, and technical knowledge, and will also attract environmentally sound technologies for rational water management.
5. **Encouraging scientific research**. As the regions suffers from lack of scientific research and absence of data, encouraging scientific research will allow assess transboundary impacts and will provide new knowledge about the region's issues. Understanding of factors altering hydrological regime and water quality in the basin will bring about effective dialogue between both countries.

References

Akhmetov, S. 2016. Implementing the Water Convention: country experience from Kazakhstan. Paper read at The UNECE Convention for the protection and use of transboundary watercourses and international lakes: key aspects and opportunities for Iraq, 14 January, 2016, Jordan. Accessed March 28, 2016. URL: https://www.unece.org/fileadmin/DAM/env/documents/2016/wat/01Jan__13-14_Iraq_Workshop_Convention/presentations/4.1_Akhmetov_Kazakhstanrev.pdf.

Arnell, N. 1999. Climate change and global water resources. *Global Environmental Change* 9 (October): S31–49. doi:10.1016/S0959-3780(99)00017-5.

Bigas, H. 2013. *Water security and the global water agenda a UN-Water analytical brief.* Hamilton: United Nations University - Institute for Water, Environment and Health. Accessed May 30, 2016. URL: http://public.eblib.com/choice/publicfullrecord.aspx?p=3286309.

Bilateral Agreement. 2010. Agreement between Government of Kazakhstan and Government of Russian Federation on joint use and protection of transboundary water bodies. Accessed March 28, 2016. URL: http://www.cawater-info.net/bk/water_law/pdf/kazakhstan_russia_2010_r.pdf.

Case, M. n.d. *Climate change impacts in the Amazon. review of scientific literature*. WWF Climate Change Programme. URL: https://wwf.fi/mediabank/1064.pdf.

Chibilev, A. 2008. *Basseyn Urala: istoriya, geografiya, ekologiya* [Ural river basin: history, geography, ecology]. Ekaterinburg: Izd. UrO RAN.

Frolova, N.L. 2016. Ural. *Popular science encyclopedia "Russia's Water."* Accessed March 25, 2016. URL: http://water-rf.ru/%D0%92%D0%BE%D0%B4%D0%BD%D1%8B%D0%B5_%D0%BE%D0%B1%D1%8A%D0%B5%D0%BA%D1%82%D1%8B/667/%D0%A3%D1%80%D0%B0%D0%BB.

Giovanni. 2016. Giovanni user manual 4.19. Accessed June 3, 2016. URL: http://disc.sci.gsfc.nasa.gov/giovanni/documents/ag/user-manual.

Hare, W. 2003. *Assessment of knowledge on impacts of climate change – contribution to the specification of article 2 of the UNFCCC: Impacts on ecosystems, food production, water and socio-economic systems*. Sondergutachten / WBGU. Berlin: WBGU, Geschäftsstelle. URL: http://www.wbgu.de/fileadmin/templates/dateien/veroeffentlichungen/sondergutachten/sn2003/wbgu_sn2003_ex01.pdf.

Homer-Dixon, T.F. 1999. *Environment, scarcity, and violence*. New Jersey: Princeton University Press.

KamUralRybVod. 2007. *Vozdeistvie godovogo stoka na vosstanovlenie osetrovih v reke Ural*. [Annual runoff impact on sturgeon population in the Ural River]. Orenburg: Orenburg Department of Federal State Agency "KamUralRybVod."

Kurmangaliyev, R. 2008. Ecologicheskiye problemi transgranichnogo vodotoka reki Ural i puti ih resheniya [Ecological problems of transboundary watercourse of Ural River and ways for its resolvement]. *Gilim zhane bilim* 3 (12): 91–96. URL: http://library.wkau.kz/index.php/en/elektronnaya-biblioteka1/stati/stati/kurmangaliev-r-m-ekologicheskie-problemy-transgranichnogo-vodotoka-reki-ural-i-puti-ikh-resheniya/download.

Lagutov, V., ed. 2008. *Rescue of sturgeon species in the Ural River Basin*. NATO Science for Peace and Security Series C: Environmental Security. Dordrecht: Springer Netherlands.

Pachauri, R.K., Mayer, L., and Intergovernmental Panel on Climate Change, eds. 2015. *Climate change 2014: Synthesis report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Parsons, R.J., Army War College (U.S.), and Strategic Studies Institute. 2009. *Taking up the security challenge of climate change*. Accessed June 1, 2016. URL: http://purl.access.gpo.gov/GPO/LPS115744.

Pavleychik, V.M., and Sivokhip, J.T. 2012. Vodno-khozyaystvennie i transgranichnie aspekty regulirovaniya stoka v basseyne reki Ural [Hydrological and transboundary aspects of regulation the Ural River Basin Flow]. *Proceedings of the Samara Scientific Center of the Russian Academy of Sciences* 14 (1(9)): 2367–71.

Quintana-Gomez, R.A. 1999. Trends of maximum and minimum temperatures in northern South America. *Journal of Climate* 12 (7): 2104–12. Accessed June 13, 2016. URL: http://journals.ametsoc.org/doi/pdf/10.1175/1520-0442(1999)012%3C2104%3ATOMAMT%3E2.0.CO%3B2.

Regional Environmental Center (REC). 1999. *Assessment of the environmental impact of military activities during the Yugoslavia conflict*. Accessed June 2, 2016. URL: http://reliefweb.int/sites/reliefweb.int/files/resources/Assessment%20of%20the%20Environmental%20Impact%20of%20Military%20Activities.pdf.

Rodell, M., Houser, P.R., Jambor, U., Gottschalck, J., Mitchell, K., Meng, C.-J., Arsenault, K., et al. 2004. The global land data assimilation system. *Bulletin of the American Meteorological Society* 85 (3): 381–94. doi:10.1175/BAMS-85-3-381.

Ryabtsev, A. 2008. Threats to water security in the Republic of Kazakhstan in the transboundary context and possible ways to eliminate them. Paper read at the Socio-economic stability and water productivity: Food and water security in Central Asia, in Tashkent. Accessed March 28, 2016. URL: http://www.icwc-aral.uz/workshop_march08/pdf/ryabtsev_en.pdf.

Sarsenbekov, T.T., and Ahmetov, S.K. 2016. *Report on the regional water partnership (Republic of Kazakhstan)*. Global Water Partnership. Accessed May 10, 2016. URL: http://www.gwp.org/Global/GWP-CACENA_Files/en/pdf/kazakhstan.pdf.

Sivokhip, J.T. 2014. Analiz ekologo-gidrologicheskoy spetsifiki transgranichnogo basseyna reki Ural v svyazi s regulirovaniyem stoka [Analysis of ecological and hydrological specifics of transboundary Ural river basin due to flow regulation]. *Vestnik VGU, Seriya: Geografiya. Geoekologiya* 3: 88–94.

United Nations Economic Commission for Europe (UNECE). 1992. Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Helsinki. Accessed March 24, 2016. URL: http://www.unece.org/fileadmin/DAM/env/water/pdf/watercon.pdf.

———. , ed. 2009. *Guidance on water and adaptation to climate change: Convention on the Protection and Use of Transboundary Watercourses and International Lakes*. United Nations Publication. New York: United Nations.

———. 2015. *Policy guidance note on the benefits of transboundary water cooperation. identification, assessment and communication*. Policy Guidance ECE/MP.WAT/47. Geneva, Switzerland: UNECE. Accessed June 2, 2016. URL: http://www.unece.org/fileadmin/DAM/env/water/publications/WAT_Benefits_of_Transboundary_Cooperation/ECE_MP.WAT_47_PolicyGuidanceNote_BenefitsCooperation_1522750_E_pdf_web.pdf.

———. 2016. The Water Convention: serving the planet. Accessed June 19, 2016. URL: https://www.unece.org/fileadmin/DAM/env/water/publications/brochure/Brochures_Leaflets/A4_trifold_en_web.pdf.

United Nations Framework Convention on Climate Change (UNFCCC). 1992. United Nations Framework Convention on Climate Change. URL: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf.

Weinthal, E., Troell, J., and Nakayama, M., eds. 2013. *Water and post-conflict peacebuilding*. Abingdon, Oxon ; New York, NY: Earthscan, from Routledge.

Wengraf, T. 2011. *Qualitative Research interviewing: biographic narrative and semi-structured methods*. Reprinted. London: Sage.

Yang, J., Gong, P., Fu, R., Zhang, M., Chen, J., Liang, S., Xu, B., Shi, J., and Dickinson, R. 2013. The role of satellite remote sensing in climate change studies. *Nature Climate Change* 3 (10): 875–83. doi:10.1038/nclimate1908.

Appendices

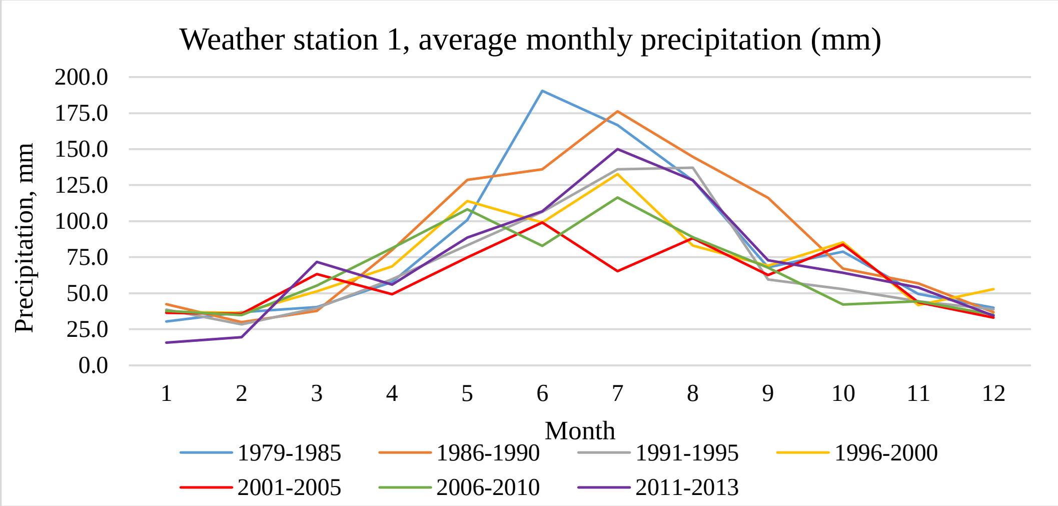
Appendix 1 Total annual discharge (m^3/sec)

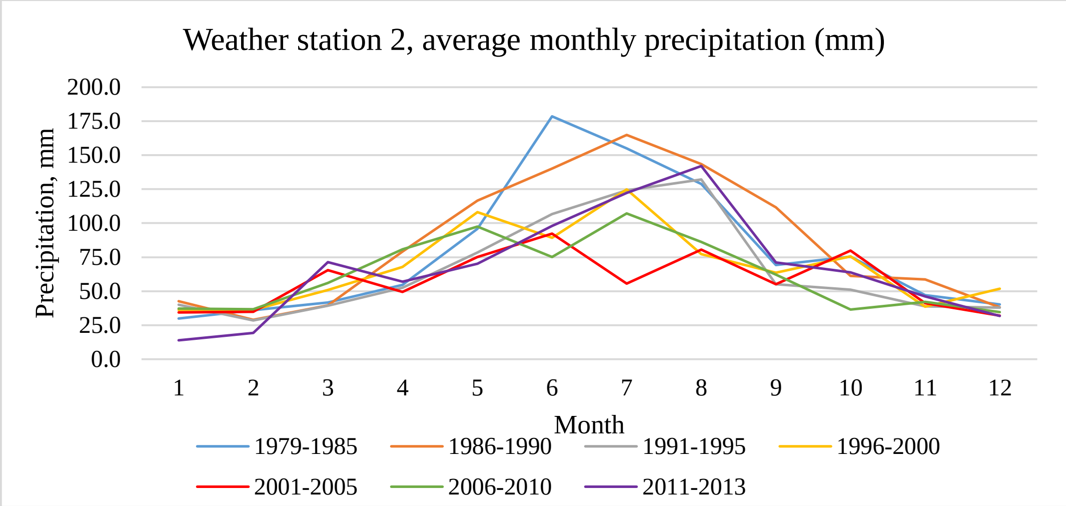
Year	**1915**	**1916**	**1917**	**1918**	**1919**
Discharge	2634	3647	2173	n/d	n/d
Year	**1920**	**1921**	**1922**	**1923**	**1924**
Discharge	0	2460.5	9107	5831.5	1979
Year	**1925**	**1926**	**1927**	**1928**	**1929**
Discharge	2386	5575	5180	6054.5	4901.5
Year	**1930**	**1931**	**1932**	**1933**	**1934**
Discharge	1729.5	1956.5	7360.5	1327	3125.5
Year	**1935**	**1936**	**1937**	**1938**	**1939**
Discharge	1240	1262	1151	1690	1544.5
Year	**1940**	**1941**	**1942**	**1943**	**1944**
Discharge	1683.5	8333.5	7569	2741.5	1442.5
Year	**1945**	**1946**	**1947**	**1948**	**1949**
Discharge	2784	9598.5	7415	7829	4175.5
Year	**1950**	**1951**	**1952**	**1953**	**1954**
Discharge	2126.5	1612.5	3857	2838	2144.5
Year	**1955**	**1956**	**1957**	**1958**	**1959**
Discharge	1285.5	2562	9371.5	3675.5	3899.5
Year	**1960**	**1961**	**1962**	**1963**	**1964**
Discharge	3736	2212	2917	4322	4833
Year	**1965**	**1966**	**1967**	**1968**	**1969**
Discharge	2481	4041	969	2088	2420.5
Year	**1970**	**1971**	**1972**	**1973**	**1974**
Discharge	8146	6434	3033.5	1997.5	3183.5
Year	**1975**	**1976**	**1977**	**1978**	**1979**
Discharge	585.5	2087	1525	2732.5	2746.5
Year	**1980**	**1981**	**1982**	**1983**	**1984**
Discharge	3076.5	4301.5	2578.5	3805	1134

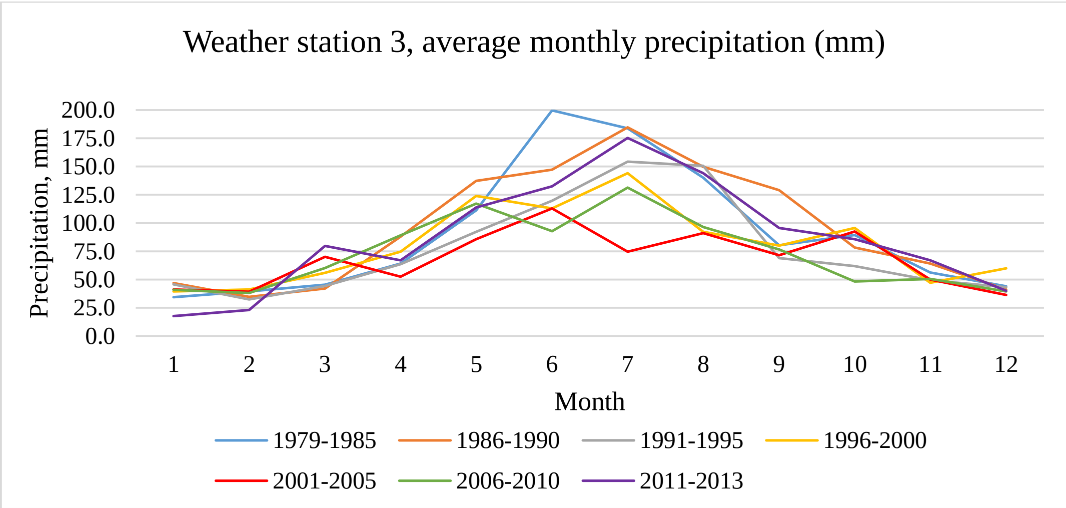
Appendix 2 Total precipitation as measured in 7 weather stations (WS) (mm/year)

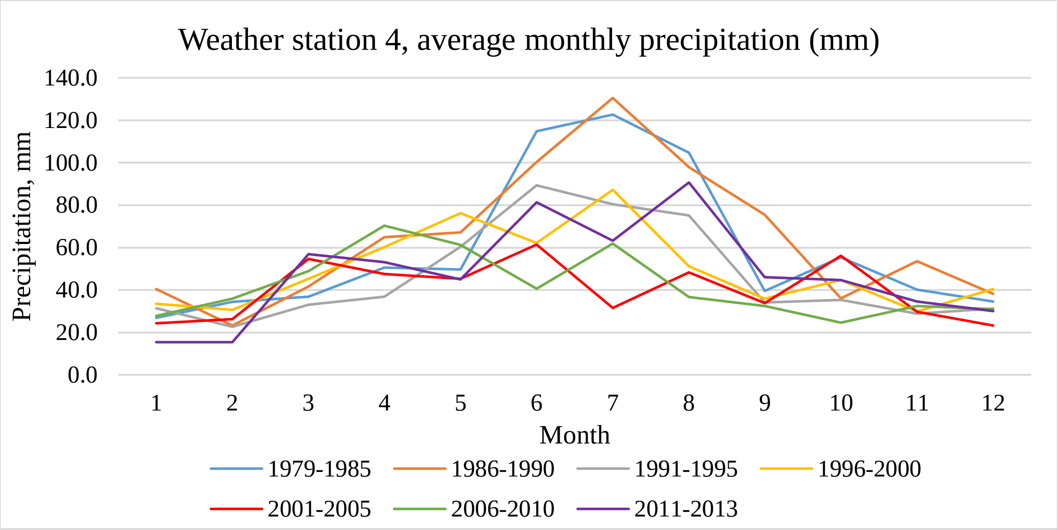
Year	WS 1	WS 2	WS 3	WS 4	WS 5	WS 6	WS 7
1979	729.1	682.7	820.9	511.7	614.6	584.8	757.8
1980	935.4	899.2	1011.8	693.5	675.4	597.9	642.9
1981	965.5	982.2	1086.3	727.3	791.5	837.2	709.3
1982	929.6	927.7	1035.4	666.5	850.1	875.6	826.1
1983	1168.3	1187.5	1278.7	1014.6	938.8	1042.7	959.1
1984	1093.9	996.4	1219.4	647.2	690.0	580.4	506.8
1985	1091.4	989.9	1168.0	713.7	717.5	755.0	686.5
1986	897.1	916.9	974.4	742.2	675.5	619.8	683.7
1987	1160.5	1083.3	1204.5	735.9	906.5	938.0	838.6
1988	1075.8	1059.2	1178.8	797.5	1241.9	973.4	799.9
1989	1024.9	1005.7	1140.7	840.1	796.9	821.1	631.2
1990	1104.8	1060.2	1216.7	732.9	786.6	983.7	775.4
1991	629.3	601.5	730.0	471.6	352.7	419.5	496.4
1992	816.6	785.1	895.0	588.6	598.4	614.7	787.4
1993	981.5	941.1	1093.1	670.3	794.8	934.0	895.9
1994	973.5	947.8	1074.9	633.3	497.9	646.7	636.3
1995	723.3	649.7	838.0	431.3	481.0	595.5	573.4
1996	828.2	772.7	943.0	597.8	480.2	496.7	495.0
1997	979.0	957.4	1072.8	686.6	645.2	920.3	822.5
1998	752.7	708.1	829.1	490.6	432.9	503.9	507.6
1999	841.2	795.6	944.6	550.2	571.5	567.1	602.6
2000	921.5	838.3	1011.6	631.1	540.4	600.6	747.5
2001	849.1	778.9	955.3	487.1	476.4	569.5	674.5
2002	895.3	847.9	978.8	534.9	473.5	569.3	618.9
2003	573.6	551.2	635.1	437.6	510.0	624.7	603.6
2004	679.6	627.4	775.7	463.7	537.9	795.6	861.4
2005	677.3	675.6	742.9	489.3	376.1	448.6	531.0
2006	1007.8	1000.0	1109.6	697.3	496.1	670.8	669.9
2007	856.4	812.4	968.4	474.3	385.4	563.9	642.7
2008	741.8	655.5	840.0	462.0	437.8	508.4	544.8
2009	755.6	707.1	817.1	445.5	435.3	516.1	586.7
2010	612.3	588.8	669.7	443.4	346.4	459.1	467.9
2011	829.4	782.2	1018.0	557.1	380.7	544.6	698.6
2012	771.9	713.6	933.9	523.7	443.2	495.0	588.7
2013	985.8	925.7	1172.2	649.9	502.6	659.2	861.3
2014	532.6	454.6	634.9	350.8	396.9	395.1	424.2

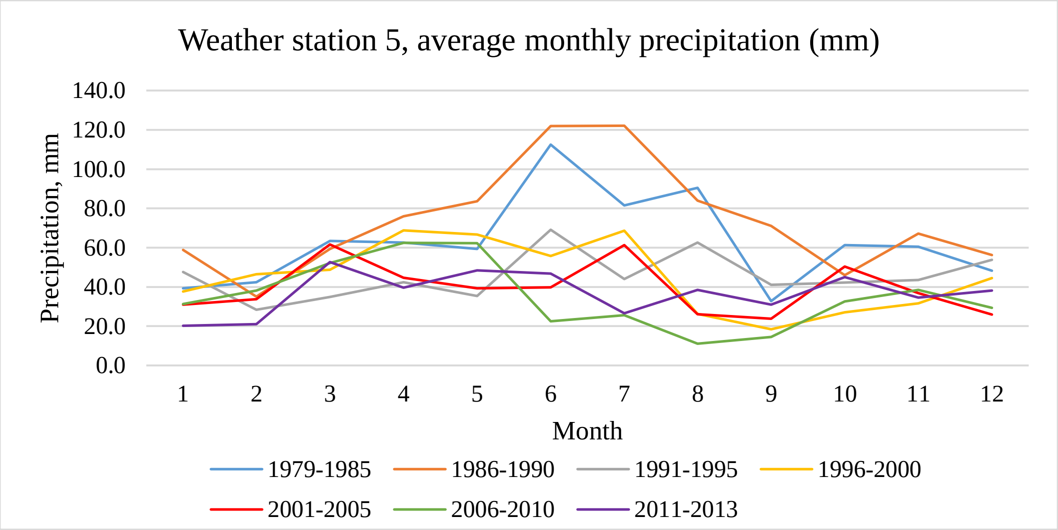
Appendix 3 Average monthly precipitation for different periods (mm)

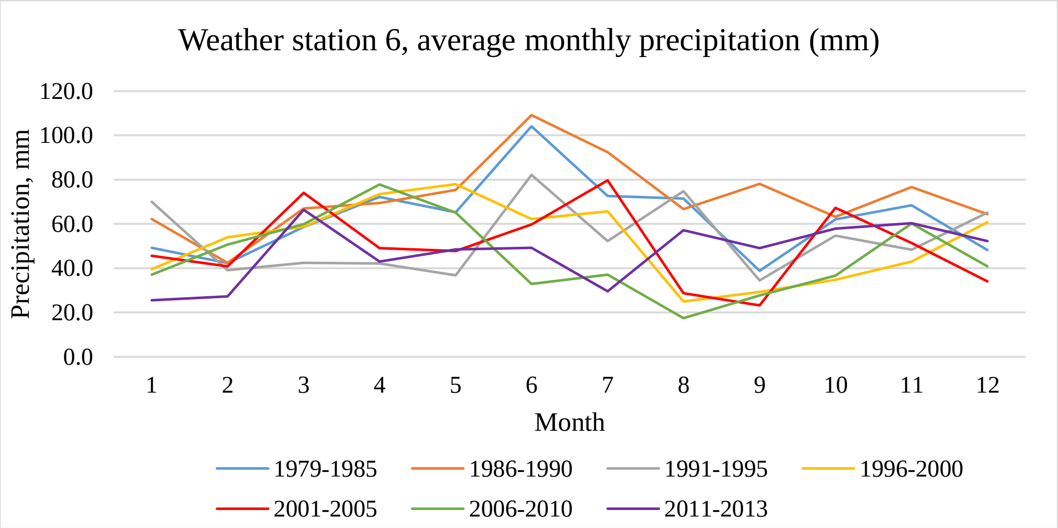


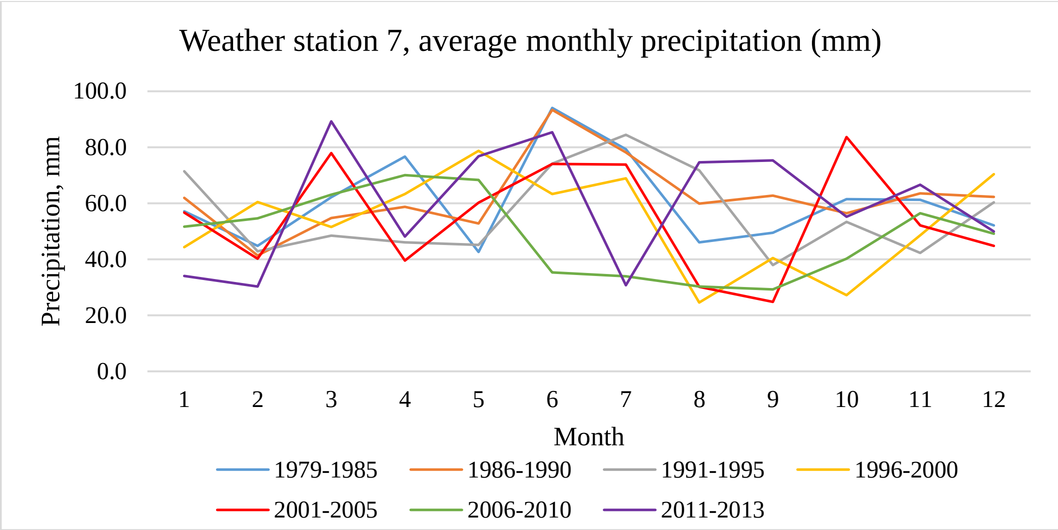





Weather station 4, average monthly precipitation (mm)
Precipitation, mm
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
1 2 3 4 5 6 7 8 9 10 11 12
Month
1979-1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-2010
2011-2013


Weather station 5, average monthly precipitation (mm)
Precipitation, mm
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
1 2 3 4 5 6 7 8 9 10 11 12
Month
1979-1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-2010
2011-2013


Weather station 6, average monthly precipitation (mm)
Precipitation, mm
0.0
20.0
40.0
60.0
80.0
100.0
120.0
1 2 3 4 5 6 7 8 9 10 11 12
Month
1979-1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-2010
2011-2013


Weather station 7, average monthly precipitation (mm)
100.0
80.0
60.0
40.0
20.0
0.0
Precipitation, mm
1
2
3
4
5
6
7
8
9
10
11
12
Month
1979-1985
1986-1990
1991-1995
1996-2000
2001-2005
2006-2010
2011-2013

Appendix 4 Average monthly temperature (°C)

Weather station 1

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-16.5	-12.1	-6.6	-4.9	11.1	10.4	16.9	15.1	9.3	0.0	-5.8	-9.1
1980	-16.7	-14.8	-10.2	1.5	12.1	13.1	15.4	10.4	9.1	0.7	-6.3	-7.3
1981	-10.8	-10.3	-8.1	-0.8	7.1	15.0	17.7	17.1	8.9	4.1	-3.3	-8.0
1982	-13.7	-16.0	-9.7	5.5	9.3	13.0	16.2	14.4	9.9	0.7	-5.1	-6.8
1983	-9.1	-9.0	-7.6	7.2	7.0	14.3	17.6	13.4	4.7	2.7	-5.7	-7.8
1984	-10.9	-14.9	-6.2	0.0	10.5	14.8	17.7	13.8	8.6	1.3	-10.0	-17.4
1985	-12.4	-18.4	-9.2	1.4	6.8	13.4	14.5	15.4	9.1	-1.1	-8.4	-11.9
1986	-13.0	-15.6	-6.9	6.1	6.2	14.3	14.2	13.2	7.9	0.9	-6.0	-15.1
1987	-18.6	-11.0	-13.1	-2.3	12.1	17.8	16.4	14.3	7.2	1.1	-10.9	-11.2
1988	-14.6	-11.7	-5.4	4.5	8.4	17.5	18.4	16.2	9.0	2.2	-7.6	-11.2
1989	-15.2	-12.4	-5.5	-1.2	9.3	17.6	19.5	12.8	8.7	1.9	-5.1	-10.8
1990	-14.1	-10.1	-3.2	2.6	8.6	14.7	16.0	13.2	8.4	0.2	-5.8	-10.2
1991	-13.4	-13.5	-8.6	6.3	13.2	17.8	16.2	13.1	9.2	6.2	-4.1	-14.2
1992	-11.4	-11.6	-6.9	2.1	8.1	12.5	13.5	11.8	9.1	1.0	-5.4	-11.1
1993	-10.8	-14.9	-10.1	0.6	9.0	14.4	16.2	13.8	4.2	1.3	-15.4	-12.3
1994	-11.4	-19.9	-9.3	3.2	9.4	14.6	13.1	12.9	9.5	5.0	-6.1	-11.8
1995	-12.3	-7.1	-4.2	7.7	10.7	15.9	17.3	15.6	9.3	3.1	-3.8	-14.5
1996	-15.7	-14.5	-9.4	-2.7	10.2	17.2	17.9	12.0	7.7	0.4	-4.0	-12.1
1997	-17.8	-11.4	-4.3	2.0	9.8	15.6	13.9	12.8	9.0	5.7	-7.1	-13.6
1998	-13.6	-14.6	-7.4	-3.1	10.1	18.7	19.6	16.4	8.2	2.3	-10.9	-8.4
1999	n/d	-10.1	-11.7	2.4	7.7	11.9	17.0	14.2	8.0	5.1	-9.6	-7.5
2000	-11.4	-9.2	-5.6	4.5	6.2	15.7	16.9	14.4	7.6	1.1	-5.2	-10.1
2001	-10.9	-14.5	-4.5	4.0	12.6	13.0	16.1	13.4	8.7	1.2	-5.0	-13.0
2002	-9.6	-7.0	-3.5	-2.0	6.9	11.6	16.7	11.9	10.4	2.1	-4.4	-19.0
2003	-12.7	-13.9	-7.6	2.1	10.6	12.7	16.7	18.9	11.4	3.4	-6.7	-7.9
2004	-10.9	-10.6	-5.8	-0.5	13.0	15.8	18.8	15.8	10.9	1.8	-2.6	-11.0
2005	-14.0	-14.3	-7.7	3.8	13.1	14.6	16.7	14.5	10.5	4.4	-1.3	-9.1
2006	-18.9	-11.5	-5.5	3.0	11.2	17.9	14.2	14.2	10.6	2.4	-6.1	-7.5
2007	-6.7	-15.8	-4.8	2.8	10.5	13.0	17.2	17.6	10.4	4.7	-5.6	-11.9
2008	-14.4	-10.6	-3.1	4.9	10.8	14.1	18.1	16.7	6.9	4.8	0.2	-7.8
2009	-11.5	-9.2	-2.9	0.6	9.1	16.9	15.3	14.0	11.2	3.2	-3.9	-13.7
2010	-19.3	-15.2	-6.1	2.6	11.3	18.0	17.4	18.4	10.1	1.7	-1.9	-11.6
2011	-17.8	-18.0	-9.9	1.8	9.3	12.6	16.8	12.0	10.6	3.1	-9.4	-3.2
2012	-14.5	-18.6	-8.2	8.6	12.1	16.3	18.1	15.1	8.3	3.3	-4.5	-16.2
2013	-15.3	-11.5	-9.1	2.5	9.0	13.8	15.1	14.0	8.0	0.9	-0.5	-9.6
2014	-16.1	-15.9	-4.5	-1.3	12.3	14.1	11.5					

Weather station 2

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-17.1	-12.3	-6.6	-4.3	11.2	10.5	17.1	15.0	9.1	-0.4	-6.0	-9.7
1980	-17.2	-15.2	-11.0	1.3	12.1	12.8	15.4	10.2	8.8	0.7	-6.6	-7.4
1981	-11.6	-11.0	-8.4	-1.3	7.3	15.1	17.8	16.8	8.8	3.9	-3.3	-8.6
1982	-13.8	-16.1	-9.9	5.0	9.3	13.0	16.2	14.4	10.0	0.9	-5.2	-6.8
1983	-9.4	-9.1	-7.6	7.2	7.2	14.3	17.6	13.4	4.3	2.6	-5.7	-8.0
1984	-11.1	-14.4	-6.1	0.1	10.8	14.8	17.9	13.9	8.6	1.3	-9.4	-17.2
1985	-12.8	-18.2	-9.8	1.1	6.8	13.3	14.6	15.5	8.9	-0.8	-7.7	-12.1
1986	-13.3	-15.5	-6.8	6.1	6.6	14.2	14.2	13.3	8.0	0.9	-6.0	-14.9
1987	-18.4	-11.4	-13.9	-2.3	12.2	17.9	16.3	14.1	7.3	1.2	-10.3	-11.0
1988	-13.5	-11.6	-5.2	4.6	8.4	17.5	18.4	16.0	9.0	2.0	-7.8	-11.2
1989	-15.1	-12.6	-5.7	-1.1	9.3	17.7	19.3	12.9	8.7	1.9	-4.9	-10.8
1990	-14.7	-10.5	-3.3	2.5	8.7	14.5	16.0	13.1	8.4	0.2	-6.0	-10.0
1991	-13.2	-13.7	-8.6	6.3	13.2	17.6	16.2	12.8	9.2	6.1	-4.3	-13.8
1992	-11.5	-11.9	-7.4	2.3	8.1	12.3	13.4	11.8	9.1	0.9	-5.5	-11.3
1993	-10.9	-14.7	-9.9	0.4	8.9	14.4	16.1	13.8	4.0	1.1	-14.8	-12.1
1994	-11.2	-19.6	-9.4	3.2	9.4	14.5	13.1	12.8	9.6	4.9	-6.0	-11.7
1995	-12.9	-7.2	-4.3	7.9	10.8	16.2	17.2	15.4	9.1	2.8	-3.7	-14.1
1996	-15.8	-14.7	-10.0	-2.9	10.3	17.2	17.8	12.0	7.8	0.4	-4.3	-12.2
1997	-17.5	-11.6	-4.5	1.9	9.7	15.8	13.9	12.9	8.8	5.7	-6.9	-13.4
1998	-13.6	-14.7	-7.8	-3.1	9.9	18.6	19.5	16.3	8.1	2.3	-10.9	-8.5
1999	n/d	-10.6	-11.7	2.6	7.6	12.0	17.0	14.3	7.9	5.0	-9.4	-7.7
2000	-11.4	-9.3	-5.9	4.7	6.0	15.5	16.8	14.6	7.6	1.0	-5.1	-9.9
2001	-10.8	-14.3	-4.7	4.0	12.5	13.0	16.0	13.5	8.5	1.1	-4.9	-13.0
2002	-9.7	-7.4	-3.5	-2.7	6.8	11.8	16.8	12.0	10.4	2.1	-4.4	-18.9
2003	-12.5	-14.1	-7.8	2.0	10.4	12.5	16.6	18.6	11.2	3.2	-6.8	-8.2
2004	-10.9	-10.1	-6.1	-0.4	12.7	15.6	18.3	15.9	11.0	1.8	-2.6	-11.1
2005	-14.1	-14.0	-8.0	3.7	12.9	14.8	16.6	14.4	10.6	4.4	-1.4	-9.2
2006	-19.0	-11.8	-5.3	3.2	11.1	17.9	14.1	14.2	10.4	2.4	-5.9	-7.6
2007	-6.7	-15.1	-5.0	2.9	10.7	13.1	17.0	17.5	10.5	4.8	-5.7	-11.9
2008	-14.7	-10.7	-3.0	5.0	11.0	14.2	18.4	16.7	7.0	4.7	0.2	-8.1
2009	-11.5	-9.1	-3.1	0.5	9.2	17.0	15.5	13.9	11.1	3.1	-3.8	-13.5
2010	-19.2	-14.9	-6.1	2.6	11.3	18.1	17.3	18.3	10.1	1.7	-1.6	-11.5
2011	-18.1	-18.3	-10.4	1.7	9.3	12.6	16.9	11.7	10.2	2.9	-9.1	-10.9
2012	-14.4	-18.3	-8.5	8.6	11.8	16.1	17.9	15.0	8.4	3.2	-4.8	-15.8
2013	-15.7	-11.3	-8.9	2.6	9.3	13.7	14.9	13.9	8.1	0.9	-0.5	-9.7
2014	-16.3	-15.8	-4.9	-1.4	12.4	14.1	11.7					

Weather station 3

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-16.5	-12.7	-6.7	-5.1	10.7	9.7	16.3	14.4	8.6	-0.4	-5.9	-8.8
1980	-16.3	-14.4	-10	1.34	11.5	13	14.8	9.68	8.5	0.32	-6.2	-7.3
1981	-10.5	-10.5	-8.2	-1	6.49	15	17.4	16.6	8.4	3.79	-3.3	-7.5
1982	-13.8	-16.3	-9.8	5.51	8.7	13	15.7	13.7	9.3	0.38	-5.5	-6.8
1983	-9.23	-9.03	-7.9	7.05	6.69	14	17.3	13	4.3	2.25	-6.1	-8.1
1984	-11	-15.6	-6.8	-0.3	10.3	14	17.5	13.3	8.2	0.98	-10	-18
1985	-12.3	-18.4	-9.3	1.29	6.64	13	14.1	15	8.8	-1.4	-8.5	-12
1986	-12.9	-15.7	-7.3	5.59	5.8	14	13.7	12.7	7.4	0.43	-6.3	-15
1987	-18.7	-11	-13	-2.7	11.6	17	15.9	13.7	6.7	0.51	-11	-11
1988	-14.9	-11.8	-5.6	3.82	7.81	17	17.8	15.7	8.6	1.66	-8	-11
1989	-15.1	-12.4	-6	-1.8	8.98	17	19.2	12.2	8.2	1.32	-5.4	-11
1990	-14.1	-9.98	-3.5	2.4	8.03	14	15.5	12.7	7.8	-0.4	-6.3	-11
1991	-13.8	-13.8	-9.1	5.67	12.8	17	15.5	12.4	8.6	5.69	-4.2	-14
1992	-11.6	-11.8	-7.2	1.72	7.69	12	13	11.3	8.8	0.41	-5.7	-11
1993	-10.9	-15.3	-11	0.15	8.37	14	15.6	13.2	3.6	0.68	-16	-13
1994	-11.5	-20.1	-9.2	2.77	8.81	14	12.6	12.5	9.1	4.4	-6.7	-12
1995	-12.5	-7.37	-4.6	7.18	10.2	16	16.7	14.7	8.7	2.63	-3.9	-15
1996	-16.2	-14.9	-9.6	-3.1	9.52	17	17.2	11.4	7.1	-0.1	-4.1	-12
1997	-17.9	-11.8	-4.7	1.66	9.29	15	13.3	12.2	8.4	5.22	-7.4	-14
1998	-13.8	-14.8	-7.5	-3.6	9.55	18	18.9	15.4	7.5	1.8	-11	-8.6
1999	n/d	-10.1	-12	2.15	7.08	11	16.5	13.7	7.3	4.45	-9.7	-7.6
2000	-11.3	-9.15	-5.8	4.21	5.59	15	16.5	13.8	7	0.63	-5.5	-9.9
2001	-11	-14.3	-4.8	3.58	12	12	15.3	12.6	8.1	0.76	-5	-13
2002	-9.86	-7.29	-3.7	-2.4	6.35	11	16.3	11.4	9.8	1.65	-4.6	-20
2003	-12.9	-14.2	-7.8	1.72	10.1	12	16	17.9	11	2.9	-6.8	-8.1
2004	-10.6	-10.6	-6.1	-1.1	12.2	15	17.7	15.1	10	1.22	-2.9	-11
2005	-13.8	-14.4	-8.2	3.3	12.6	14	16.3	13.8	9.8	3.81	-1.7	-9.1
2006	-18.4	-11.7	-6	2.56	10.7	17	13.5	13.7	9.9	1.84	-6.2	-7.8
2007	-6.99	-16	-5.3	2.27	9.92	12	16.6	16.9	9.7	4.06	-6	-12
2008	-14.5	-11	-3.5	4.43	10.3	13	17.6	16	6.3	4.15	-0.3	-8.7
2009	-11.5	-9.11	-3.1	0.19	8.83	16	14.6	13.3	11	2.8	-4.1	-14
2010	-19.1	-15.1	-6.2	2.16	10.9	17	16.9	17.6	9.4	1.33	-2.1	-11
2011	-17.3	-18.9	-11	0.8	8.27	12	15.9	11.1	9.6	2.31	-10	-11
2012	-14.6	-18.8	-8.2	7.92	11.2	15	17.3	14.2	7.3	2.39	-5	-16
2013	-15.5	-11.7	-9.4	1.95	8.19	13	14.2	13.1	7.3	0.11	-1.2	-10
2014	-16.7	-16.3	-5.1	-2.2	11.4	13	10.7					

Weather station 4

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-17.6	-11.9	-6.2	-1.1	14.9	13.2	19.4	17.5	11.4	1.0	-6.8	-9.2
1980	-18.7	-15.6	-11.1	2.6	14.7	14.7	18.0	12.3	10.6	2.1	-6.2	-7.2
1981	-12.3	-10.4	-8.0	0.7	9.4	17.0	19.7	18.9	11.1	5.4	-2.2	-7.9
1982	-13.2	-16.2	-9.1	6.0	12.3	15.0	18.2	16.6	12.1	2.7	-3.9	-5.8
1983	-8.9	-8.8	-8.3	8.0	9.4	15.9	19.2	14.9	5.1	4.1	-4.0	-7.3
1984	-11.6	-13.1	-4.6	1.9	13.3	16.6	20.5	15.6	9.2	2.1	-8.3	-18.8
1985	-13.7	-17.3	-10.7	2.5	9.3	16.0	16.7	17.5	11.2	0.7	-6.6	-12.0
1986	-12.4	-14.9	-6.4	7.0	8.9	17.2	16.4	15.3	9.7	2.3	-6.7	-13.9
1987	-18.7	-11.4	-13.7	-1.6	14.2	19.9	18.6	16.0	9.2	2.7	-10.3	-10.9
1988	-13.6	-12.6	-5.6	6.3	10.6	20.1	20.3	17.8	10.7	4.3	-6.9	-10.4
1989	-14.1	-12.7	-7.3	0.9	11.6	20.0	20.6	15.2	11.2	3.7	-3.7	-10.4
1990	-13.5	-9.1	-1.9	3.8	10.8	17.2	17.8	14.7	10.5	1.7	-4.9	-9.5
1991	-12.3	-13.5	-6.4	8.3	15.2	19.4	18.7	15.0	11.5	8.0	-4.8	-12.9
1992	-10.9	-12.1	-7.7	4.2	9.9	14.8	15.6	14.0	10.9	2.1	-5.3	-12.1
1993	-10.5	-14.0	-9.4	1.5	11.1	16.0	18.1	16.1	5.7	2.8	-14.6	-12.8
1994	-11.2	-19.4	-10.6	3.8	10.8	16.6	15.0	14.6	11.6	6.7	-4.8	-11.6
1995	-15.0	-7.3	-4.5	9.6	13.5	18.5	19.7	17.5	10.7	4.3	-2.9	-12.9
1996	-17.1	-14.4	-9.7	-2.2	11.8	18.7	19.8	14.2	10.0	2.0	-4.7	-12.8
1997	-17.2	-11.6	-4.0	3.3	11.3	17.9	15.8	14.8	10.8	7.5	-6.4	-13.0
1998	-14.2	-14.2	-7.9	-1.1	11.8	21.0	21.5	19.0	10.4	4.1	-10.2	-8.4
1999	n/d	-10.2	-11.9	3.2	9.3	14.6	18.6	16.7	10.0	6.6	-8.5	-7.3
2000	-11.5	-9.4	-6.0	5.6	7.6	17.2	18.8	17.1	9.9	2.3	-4.8	-9.5
2001	-10.5	-13.4	-3.9	4.5	14.6	15.7	18.6	15.7	10.4	2.4	-3.4	-13.4
2002	-9.1	-7.1	-2.4	-1.4	8.3	13.8	19.1	14.3	12.9	3.7	-3.3	-19.7
2003	-12.8	-14.4	-8.9	2.8	12.1	14.2	19.0	20.7	13.5	4.4	-7.2	-8.1
2004	-12.0	-9.9	-5.4	1.4	14.8	17.8	20.4	18.2	13.0	3.5	-1.3	-10.5
2005	-12.9	-14.6	-6.8	4.5	14.8	17.0	18.8	16.6	12.3	6.1	-1.3	-9.2
2006	-19.8	-11.0	-4.5	4.8	13.0	20.3	16.5	17.2	12.8	4.2	-4.9	-7.1
2007	-6.3	-13.0	-5.3	4.1	13.3	15.7	18.9	20.5	13.0	6.5	-5.2	-12.7
2008	-15.9	-10.5	-1.7	6.2	13.1	16.7	22.0	19.7	9.4	6.1	1.2	-8.0
2009	-11.2	-9.3	-2.3	1.6	10.8	19.6	18.7	16.5	13.2	4.5	-3.5	-13.1
2010	-19.1	-14.9	-5.8	3.6	13.0	21.0	19.9	21.1	12.9	2.7	-0.5	-11.1
2011	-18.8	-18.2	-10.1	3.5	12.1	15.6	20.2	14.3	12.2	4.6	-7.7	-11.5
2012	-15.2	-18.0	-7.4	10.2	14.4	18.7	20.4	18.9	10.6	5.4	-3.1	-14.3
2013	-14.9	-11.8	-7.0	4.2	12.5	17.3	17.9	16.5	10.6	3.0	0.6	-8.6
2014	-14.9	-15.4	-4.3	1.1	14.9	17.3	14.3					

Weather station 5

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-16.8	-11.2	-5.7	-2.2	16.3	15.9	21.5	20.7	14.4	4.0	-6.2	-7.5
1980	-17.8	-15.8	-8.9	4.6	17.1	18.0	22.3	17.3	13.3	3.6	-4.1	-6.8
1981	-11.2	-9.6	-5.3	2.7	11.3	18.1	23.1	21.9	14.9	6.9	-1.4	-7.1
1982	-12.0	-16.0	-8.4	8.3	14.4	17.5	20.8	18.5	14.9	4.2	-3.5	-5.0
1983	-8.2	-7.1	-6.3	10.3	11.8	18.1	23.0	19.0	8.6	6.0	-2.2	-6.4
1984	-11.5	-15.5	-4.6	2.4	15.9	18.9	25.3	19.6	14.1	5.4	-5.3	-19.7
1985	-12.7	-13.0	-9.8	4.7	13.0	20.0	20.3	21.1	15.1	3.1	-4.4	-9.5
1986	-9.3	-13.8	-7.1	6.6	12.8	19.1	19.8	19.9	14.2	4.3	-4.3	-10.3
1987	-14.7	-10.2	-11.2	1.7	16.1	22.2	21.9	20.1	11.9	3.8	-7.1	-9.0
1988	-13.2	-13.4	-5.0	7.3	12.9	21.8	21.8	20.7	13.8	6.1	-3.9	-6.7
1989	-10.1	-10.3	-4.6	2.4	13.5	21.0	24.1	19.5	14.6	6.1	-1.8	-7.4
1990	-12.8	-9.0	0.0	6.8	13.3	20.6	20.2	18.0	13.6	4.0	-3.2	-8.0
1991	-11.1	-12.2	-5.3	9.7	16.7	21.5	22.2	18.2	15.2	10.3	-2.4	-11.7
1992	-9.3	-10.6	-6.9	5.8	12.2	17.4	18.7	17.6	14.4	3.7	-2.5	-11.4
1993	-8.6	-14.0	-8.3	2.6	12.7	18.2	21.0	19.7	8.9	4.9	-13.2	-12.1
1994	-12.5	-18.7	-10.2	4.9	13.4	18.8	16.8	18.1	15.1	8.2	-3.0	-10.0
1995	-14.5	-7.1	-4.2	11.9	15.5	21.8	23.2	20.7	13.3	6.4	-1.3	-11.4
1996	-17.4	-14.8	-8.9	-0.1	14.7	21.1	22.9	18.1	13.5	3.6	-5.0	-12.3
1997	-13.8	-10.7	-2.4	6.5	13.7	21.9	19.3	18.9	14.2	10.5	-4.9	-12.7
1998	-14.4	-12.3	-6.6	1.9	14.7	23.9	25.1	23.1	14.2	7.1	-7.0	-7.7
1999	n/d	-6.8	-10.7	4.7	11.5	17.4	20.3	22.1	12.9	8.4	-6.4	-6.2
2000	-10.7	-8.2	-5.5	8.3	10.3	20.1	22.1	21.5	12.7	3.6	-3.8	-7.6
2001	-9.3	-11.6	-3.3	6.3	17.1	18.5	21.3	19.5	12.9	4.1	-0.7	-11.6
2002	-7.9	-5.4	-0.9	2.1	10.3	17.3	21.8	18.5	17.0	6.0	-1.1	-18.6
2003	-12.3	-12.9	-8.7	3.5	14.9	17.0	21.3	23.1	16.0	6.6	-5.3	-6.8
2004	-11.3	-9.2	-4.2	5.4	16.5	20.4	22.0	21.4	16.8	6.5	0.2	-9.8
2005	-12.9	-16.2	-5.9	6.0	16.3	19.8	22.1	19.5	15.1	8.0	-1.0	-7.8
2006	-19.7	-9.2	-2.0	9.4	15.3	23.8	19.7	21.1	15.1	6.1	-2.7	-5.9
2007	-5.1	-10.4	-6.9	5.1	15.0	18.3	21.6	23.7	16.0	7.8	-4.2	-12.9
2008	-16.1	-10.4	0.7	9.4	15.0	19.2	25.1	23.6	13.2	7.6	1.9	-7.5
2009	-11.3	-10.0	-1.5	2.8	12.9	21.6	21.7	19.7	16.2	6.2	-2.9	-11.9
2010	-17.6	-14.4	-4.9	4.6	15.7	23.4	23.1	25.4	16.0	3.9	0.8	-7.7
2011	-17.4	-16.9	-9.0	5.9	14.7	18.1	23.9	19.4	15.3	5.9	-7.3	-14.0
2012	-15.3	-18.9	-6.0	13.8	16.9	22.1	24.0	23.9	13.9	8.1	-1.3	-13.0
2013	-12.9	-11.5	-5.3	9.0	15.5	20.5	21.2	19.6	13.7	5.1	1.8	-7.6
2014	-14.5	-16.4	-3.9	2.3	17.0	20.1	17.5					

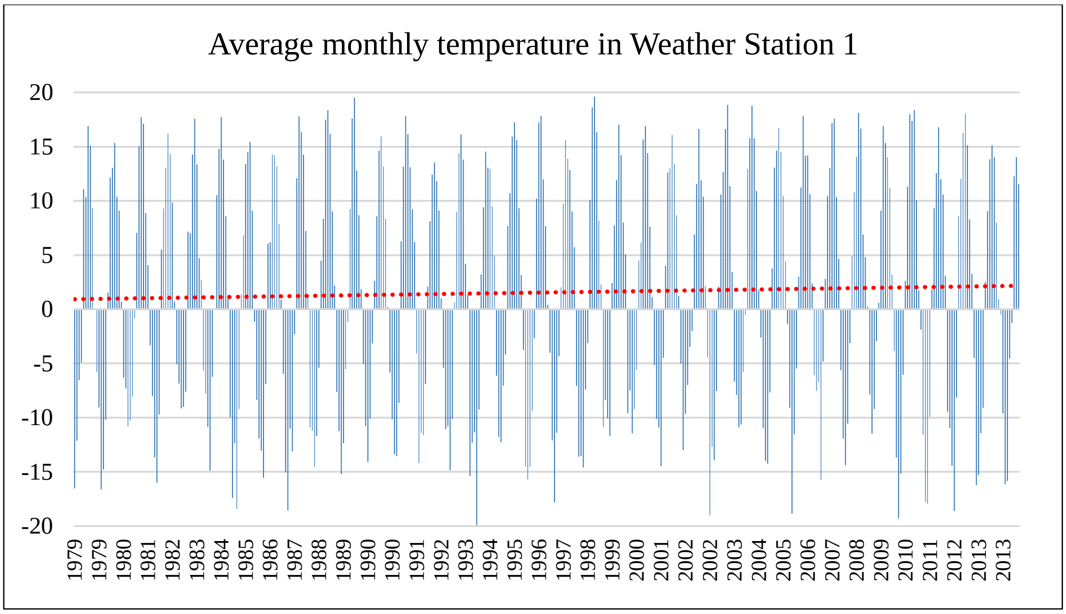
Weather station 6

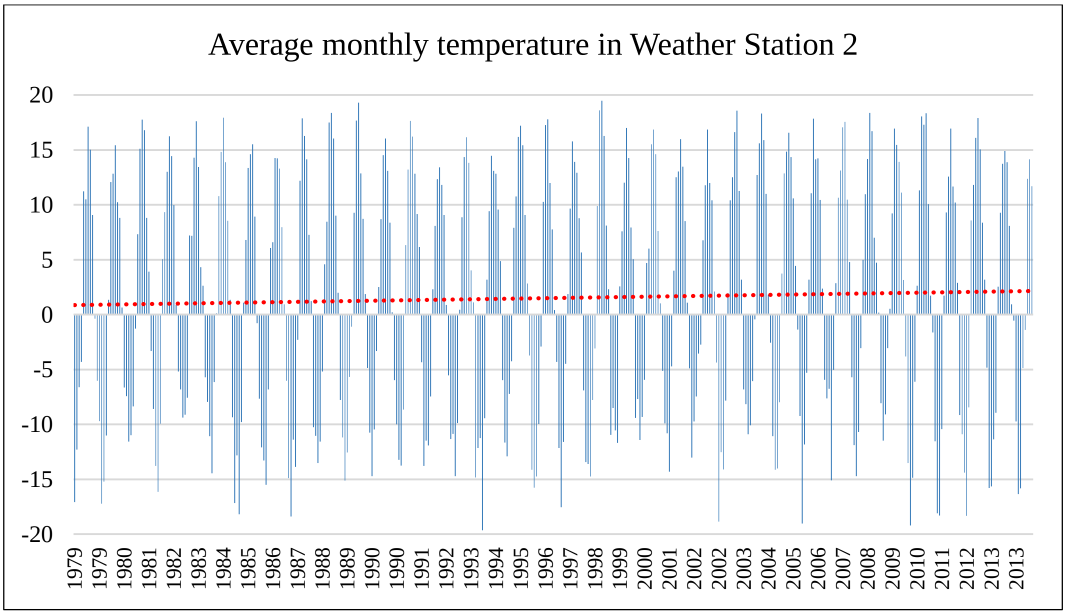
Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-16.5	-11.5	-5.3	-2.4	15.6	14.4	20.6	20.4	13.4	3.3	-5.3	-8.0
1980	-18.1	-14.8	-9.0	2.7	15.2	17.3	21.5	17.0	12.7	3.9	-4.7	-7.1
1981	-11.3	-9.4	-6.3	0.8	10.6	18.0	22.4	21.9	14.1	6.7	-0.7	-6.2
1982	-12.1	-17.2	-8.3	6.6	12.9	16.0	20.2	18.6	14.9	3.8	-4.6	-6.4
1983	-8.2	-7.6	-7.2	9.4	11.6	16.5	21.8	17.8	6.1	3.8	-2.9	-7.8
1984	-10.3	-15.6	-5.3	2.5	15.0	18.2	25.0	18.9	13.4	5.0	-5.3	-17.9
1985	-12.5	-13.1	-9.5	3.4	12.4	19.0	19.2	20.3	14.7	2.5	-5.6	-10.5
1986	-9.6	-14.3	-7.2	6.2	11.5	18.5	18.9	19.2	13.3	3.7	-4.7	-11.0
1987	-15.5	-11.2	-10.6	-1.8	14.5	20.7	20.4	19.1	11.0	3.3	-7.9	-10.8
1988	-14.5	-14.2	-5.8	6.2	12.1	21.3	21.6	20.9	13.4	5.2	-5.9	-8.6
1989	-11.8	-10.8	-4.9	1.4	13.1	20.4	23.2	18.8	14.2	5.3	-2.5	-8.6
1990	-14.0	-9.7	-1.5	4.3	11.7	18.4	19.1	17.0	12.9	2.5	-3.3	-9.4
1991	-12.0	-13.9	-8.3	8.5	15.9	19.9	21.1	17.8	14.3	10.4	-2.7	-12.1
1992	-9.8	-11.4	-7.4	5.3	11.6	16.9	18.0	16.3	14.5	3.0	-2.7	-9.7
1993	-8.5	-14.0	-7.8	2.2	11.9	16.7	19.5	18.7	8.2	4.1	-13.5	-11.0
1994	-10.5	-20.3	-9.9	4.5	12.5	17.3	15.6	16.7	14.4	7.6	-3.8	-10.5
1995	-13.5	-7.3	-4.2	10.2	14.8	20.6	22.3	19.7	13.3	6.1	-1.1	-12.0
1996	-17.3	-13.5	-9.3	-0.4	14.5	20.0	22.0	17.5	13.0	3.1	-3.8	-12.5
1997	-14.8	-11.8	-2.4	5.7	12.5	20.2	18.2	17.5	12.6	9.5	-5.8	-13.0
1998	-14.8	-13.0	-6.2	0.9	13.5	22.6	24.2	22.0	13.3	6.4	-7.3	-8.6
1999	n/d	-7.7	-10.9	4.7	10.9	16.8	20.7	21.8	11.7	7.7	-7.1	-6.0
2000	-10.7	-8.1	-5.6	8.2	9.2	18.9	21.3	20.4	12.1	3.2	-3.9	-7.3
2001	-9.5	-11.8	-3.6	6.1	15.5	17.0	21.0	18.3	12.6	3.5	-1.2	-11.0
2002	-8.1	-5.1	-1.3	1.9	9.0	16.1	21.4	17.5	16.2	5.3	-1.5	-19.3
2003	-12.7	-13.4	-9.0	3.3	13.8	15.1	19.8	22.0	15.3	6.6	-5.2	-7.3
2004	-11.0	-8.7	-3.2	4.6	15.0	18.7	20.4	20.3	15.7	5.8	0.2	-10.4
2005	-13.4	-16.5	-6.3	5.7	16.1	18.8	21.5	18.9	15.1	7.9	-1.2	-6.9
2006	-18.8	-9.2	-1.6	8.8	14.4	22.5	18.7	20.7	14.2	5.6	-3.3	-6.0
2007	-4.7	-11.4	-6.1	4.9	13.9	16.5	20.3	23.4	15.1	6.8	-4.5	-13.5
2008	-15.9	-10.8	0.3	9.5	14.3	17.9	23.8	22.3	12.0	7.2	1.0	-7.5
2009	-11.8	-9.3	-1.6	2.6	12.0	20.1	20.8	18.9	15.9	5.8	-2.6	-11.5
2010	-17.6	-13.8	-5.0	4.3	14.8	22.2	23.6	24.8	15.4	3.7	0.6	-7.0
2011	-16.1	-17.9	-8.9	5.3	13.8	16.8	23.4	19.2	14.3	5.7	-7.5	-13.1
2012	-13.5	-18.0	-5.9	13.9	16.3	21.4	23.5	23.4	13.5	8.0	-1.4	-12.1
2013	-13.4	-10.8	-4.8	8.6	14.6	19.7	20.2	19.5	13.7	4.9	1.4	-8.3
2014	-14.1	-17.2	-3.8	3.4	16.1	18.6	17.0					

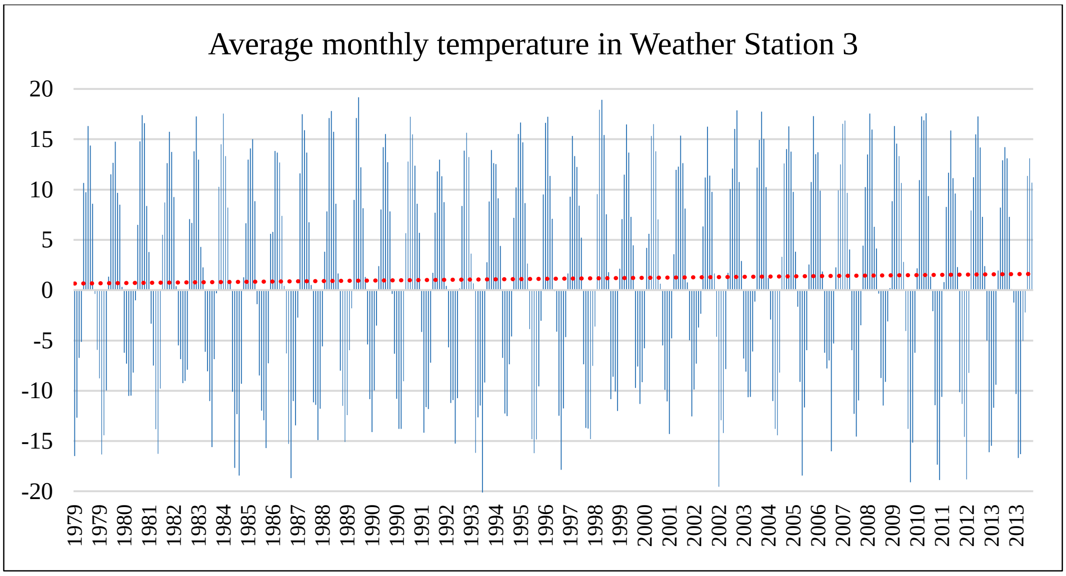
Weather station 7

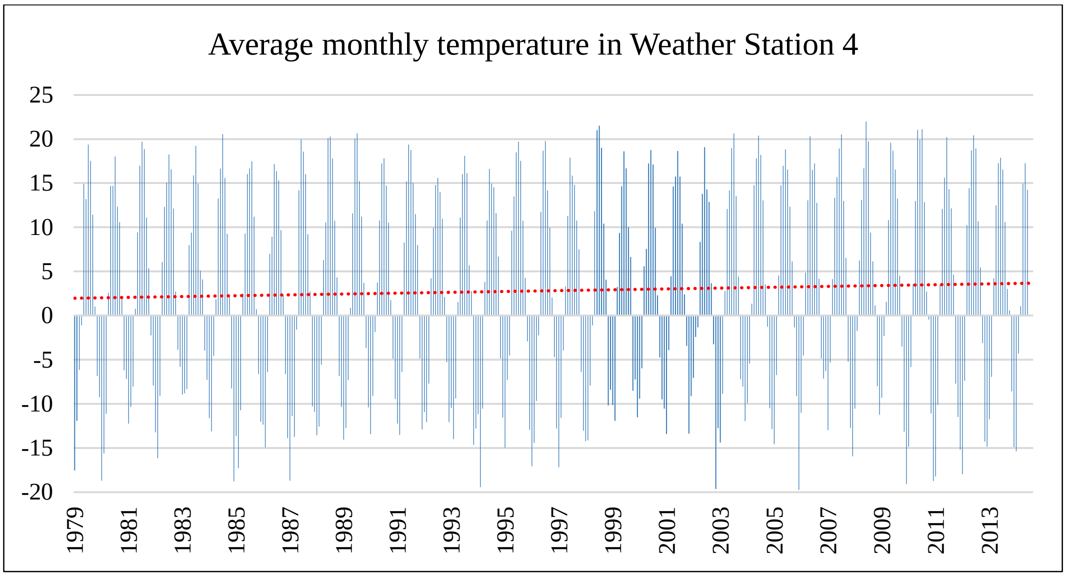
Year/Month	1	2	3	4	5	6	7	8	9	10	11	12
1979	-13.7	-10.2	-4.3	2.2	17.4	15.2	21.3	21.1	14.9	4.1	-3.2	-5.1
1980	-14.7	-13.9	-8.0	5.9	15.7	18.2	21.8	17.6	13.3	4.8	-3.0	-5.1
1981	-9.8	-8.0	-5.7	3.2	12.8	20.5	24.2	23.2	14.0	7.7	0.0	-4.5
1982	-11.1	-15.7	-6.9	8.6	14.3	17.1	21.9	20.0	15.8	3.9	-2.9	-4.1
1983	-6.9	-6.2	-6.1	10.1	13.1	17.0	22.1	18.7	7.8	6.0	-2.1	-7.4
1984	-8.7	-14.8	-3.5	3.2	16.8	19.7	25.9	19.3	14.8	5.9	-3.5	-16.2
1985	-12.0	-12.0	-7.9	4.5	14.0	19.9	20.0	21.9	15.4	3.5	-3.2	-9.6
1986	-10.1	-13.6	-6.2	5.9	12.2	19.7	19.8	20.0	13.5	4.5	-5.3	-9.9
1987	-16.4	-10.5	-10.1	1.4	16.0	22.0	21.3	19.0	11.5	4.1	-7.0	-10.6
1988	-14.0	-13.6	-4.9	5.3	13.3	22.2	23.0	22.2	14.1	5.8	-5.7	-8.6
1989	-11.2	-10.1	-4.3	3.9	14.1	22.3	23.7	20.0	15.3	6.3	-1.7	-7.8
1990	-13.3	-8.7	-0.6	7.6	12.5	18.9	20.3	17.9	13.8	4.6	-2.0	-8.1
1991	-11.1	-11.6	-7.7	9.8	16.3	21.0	21.9	19.0	14.7	10.7	-2.3	-11.0
1992	-8.6	-10.5	-6.2	5.2	12.2	17.8	18.8	16.7	15.1	3.7	-1.5	-9.8
1993	-7.7	-12.9	-7.2	4.5	13.1	17.3	20.3	18.9	9.1	4.7	-12.1	-9.8
1994	-10.3	-19.6	-8.9	5.4	13.1	17.5	16.5	18.1	15.6	8.2	-2.7	-9.8
1995	-12.7	-5.9	-2.9	13.8	16.7	21.9	22.5	20.2	14.9	7.1	-0.3	-12.6
1996	-16.9	-12.7	-8.0	0.7	16.4	21.1	23.3	18.7	14.0	3.8	-1.6	-10.8
1997	-15.3	-10.7	-2.1	6.0	13.5	21.1	18.9	18.3	13.0	9.2	-4.9	-12.4
1998	-13.0	-13.0	-4.7	2.1	14.1	23.4	25.3	22.0	14.1	7.2	-6.4	-7.5
1999	n/d	-5.6	-8.7	5.8	11.9	18.4	22.4	22.4	12.7	8.3	-6.7	-4.7
2000	-8.6	-6.7	-5.1	7.7	9.7	18.8	22.0	21.1	12.8	4.1	-3.4	-6.4
2001	-7.8	-10.9	-2.5	7.4	15.5	18.0	22.1	19.3	13.4	4.2	-0.5	-10.1
2002	-7.1	-4.2	-0.4	3.8	9.9	16.9	23.1	18.4	17.0	5.8	-0.2	-19.1
2003	-11.2	-13.0	-7.7	4.7	13.8	15.1	20.6	23.0	16.0	7.6	-3.5	-5.8
2004	-9.7	-8.5	-1.8	5.3	15.3	20.1	21.4	21.4	16.2	6.2	0.6	-8.2
2005	-11.4	-15.4	-6.4	5.8	17.4	19.4	21.5	19.5	15.8	8.5	-0.2	-5.8
2006	-18.7	-9.4	-1.6	8.5	15.1	23.4	19.9	22.6	14.8	6.1	-2.3	-5.0
2007	-2.9	-10.3	-3.6	5.7	15.1	17.6	21.1	24.5	16.1	7.3	-3.8	-12.1
2008	-14.0	-9.8	2.0	10.6	14.8	18.8	24.2	22.9	13.0	7.4	1.6	-6.9
2009	-11.3	-8.0	-1.0	4.3	13.9	22.4	22.3	19.9	16.7	6.4	-2.1	-9.8
2010	-16.4	-12.3	-4.3	5.6	16.7	23.1	25.6	25.8	16.2	4.4	1.9	-4.9
2011	-12.7	-15.8	-7.1	6.1	14.7	17.1	24.9	20.4	14.0	6.3	-6.4	-10.5
2012	-11.1	-16.7	-5.5	14.4	16.9	21.6	23.2	23.7	14.4	8.5	-0.2	-10.3
2013	-11.0	-9.2	-4.0	9.2	16.1	20.0	21.2	20.3	14.2	5.6	2.2	-6.3
2014	-13.0	-15.3	-3.2	4.8	17.0	18.8	18.5					

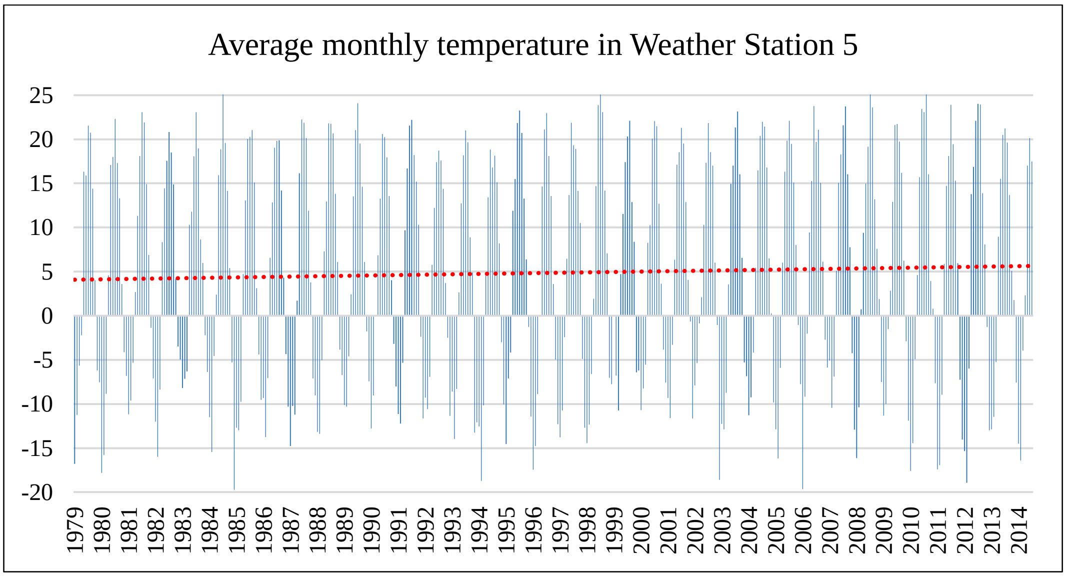
Appendix 5 Average monthly temperature trends (°C)

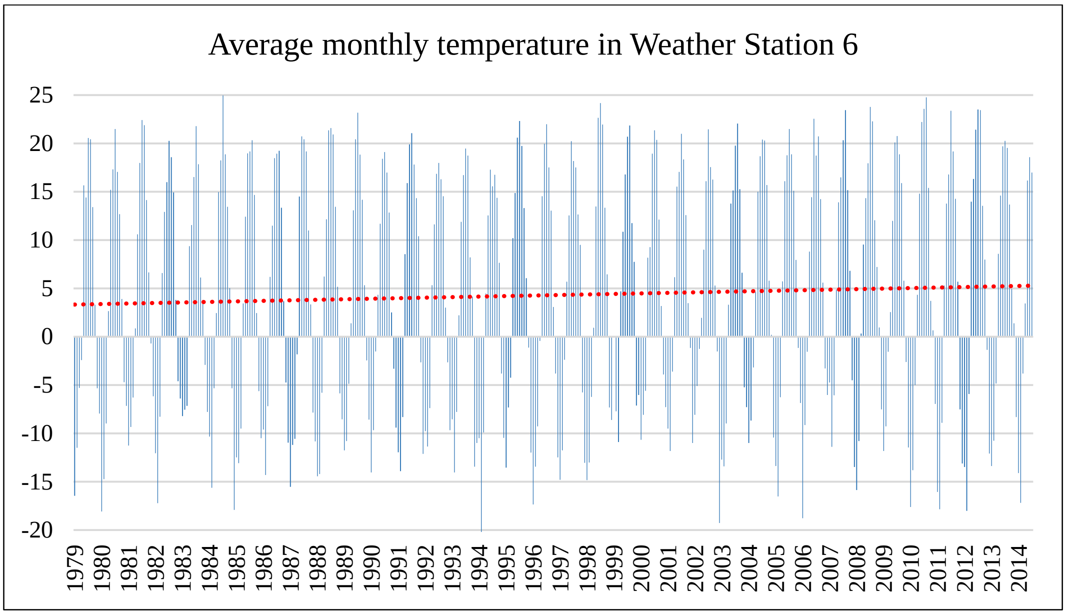





Average monthly temperature in Weather Station 3


Average monthly temperature in Weather Station 4


Average monthly temperature in Weather Station 5


Average monthly temperature in Weather Station 6
25
20
15
10
5
0
-5
-10
-15
-20
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
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2003
2004
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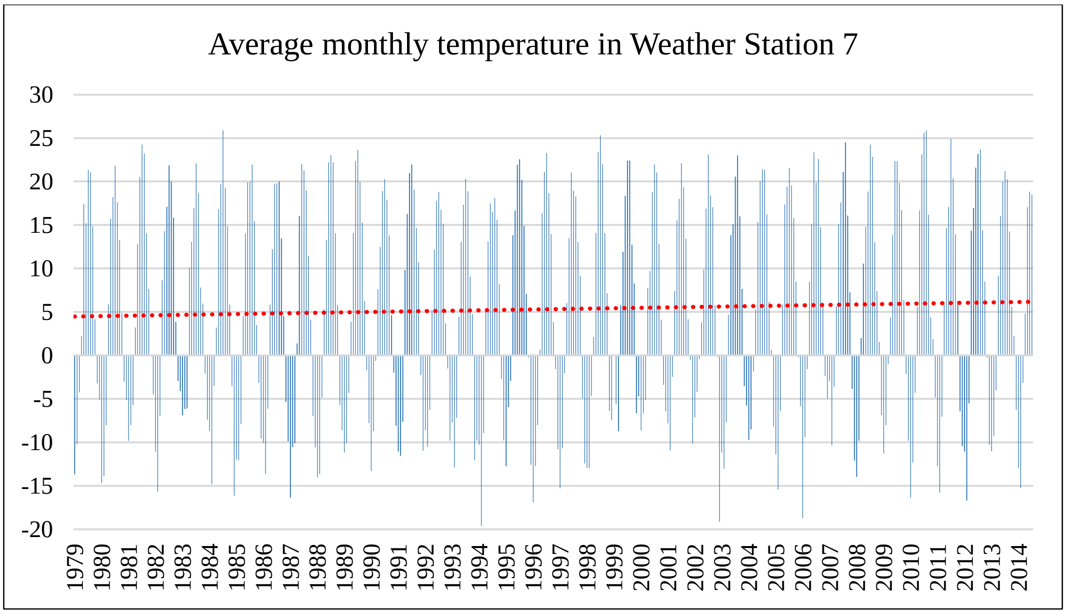
2007
2008
2009
2010
2011
2012
2013
2014


Average monthly temperature in Weather Station 7
30
25
20
15
10
5
0
-5
-10
-15
-20
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
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2012
2013
2014

Appendix 6 Questionnaire

The below questionnaire will contribute to the research on the Ural River Basin conducted at the Central European University as part of the Master's Thesis. The aim is to enhance understanding of such issue as water security in the region. The questions have been raised as a result of notable gaps in the literature relating to these issues.

Name___________________________ Organization___________________________

❑ *I would like to remain anonymous.*

Can you please describe how you and your organization contribute to establishing water security and biodiversity conservation in the region?

Water security:

What are the major factors affecting water level decrease in the URB?

What are the major sources of pollution in the URB? What has been done to eliminate them?

How successful was the UNECE Water Convention in establishing rational water management (based on the IWRM principles) in the URB?

What are the largest barriers to transboundary cooperation in the URB?

What water issues do you envision in future that could undermine water security in the URB?

What international programme/framework could help to achieve transboundary cooperation and biodiversity conservation in the URB?

What policy recommendations you would give for better management of the URB and its ecosystem?