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Local Assessment of Vulnerability to Climate Change Impacts on Water Resources in the Upper Thukela River Basin, South Africa - Recommendations for Adaptation

Cover Photo: Phil Graham

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Report Summary

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Title
Local Assessment of Vulnerability to Climate Change Impacts on Water Resources in the Upper Thukela River Basin, South Africa – Recommendations for Adaptation

Abstract
This report originates from a project entitled Participatory Modelling for Assessment of Local Impacts of Climate Variability and Change on Water Resources (PAMO), financed by the Swedish Development Agency and Research Links cooperation (NRF and the Swedish Research Council).

The project is based on interactions between stakeholders in the Mhlwazini/Bergville area of the Thukela River basin, climate and water researchers from the University of KwaZulu-Natal (Pietermaritzburg Campus) and the Swedish Meteorological and Hydrological Institute (SMHI) during a series of workshops held in 2007-2009. Between the workshops, the researcher's compiled locally relevant climate change related information, based on requests from the workshop participants, as a basis for this adaptation plan.

The aim is to provide a local assessment of vulnerability to climate change impacts on water resources and adaptation strategies. The assessment identifies existing climate-water related problems, current adaptation strategies and recommendations for future action based on likelihoods for change and the severity if such changes will occur.

Sammanfattning
Denna rapport har sitt ursprung i projektet Deltagande modellering för bedömning av lokal inverkan av klimatvariabilitet och förändringar på vattenresurser (PAMO), finansierat av Sida och Research Links (NFR i Sydafrika, samt VR i Sverige).

Projektet baseras på interaktion mellan vattenintressenter i Mhlwazini/Bergville området av Thukelas avrinningsområde och klimat och vattenforskare från University of KwaZulu-Natal (Pietermaritzburg Campus) och SMHI under en serie av workshops under 2007-2009. Mellan workshops har forskarna tagit fram klimatförändringsrelaterad information med lokal relevans, baserat på önskemål från deltagarna i workshops. Denna information har sedan använts som ett underlag till framtagandet av en anpassningsplan.

Syftet är att tillhandahålla en lokal bedömning av sårbarhet relaterad till påverkan på vattenresurser av klimatförändringar, samt en lokalt föreslagen anpassningsstrategi. Existerande klimatrelaterade problem och nuvarande anpassningsstrategier har identifierats och rekommendationer för framtida aktioner, baserade på sannolikhet för förändringar och kännbarheten av konsekvenserna om dessa förändringar inträffar.

Key words
Climate change, water resources, vulnerability, adaptation, participatory modelling

Supplementary notes	Number of pages	Language
Appendix I: Contact information and more comprehensive information of the results from the modelling, including information of available model-generated information Appendix II: Complete tables from all three groups ranking all risks and the likelihood of their occurring more often in the future	47	English

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Contents

Impacts of and Adaptation to Climate Change in South Africa

South Africa lies in one of the regions of the world that is most vulnerable to climate variability and change. Impacts from a changing climate can be considerable, particularly in dry regions. However, different regions of the country will be affected in different ways and regional analyses are needed to assess this. In many parts of the world, more extremes are projected and both drier and wetter conditions may be expected. More information about the causes of climate change and its effects can be obtained from the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/)

Communities already cope and adapt to a variable climate. The key to enabling communities to deal with an uncertain future climate is to understand what makes them vulnerable and work towards reducing those factors. Helping them live sustainable lives will equip them with the resilience to weather a variety of stressors including present climate variability, globalization, urbanization, environmental degradation, disease outbreaks and market uncertainties, and in turn, future climate change.

1. The PAMO Project

This report originates from a project entitled Participatory Modelling for Assessment of Local Impacts of Climate Variability and Change on Water Resources (PAMO). The Swedish Development Agency and Research Links cooperation (South African NRF and the Swedish Research Council) financed the project.

The project is based on interactions between stakeholders in the Mhlwazini/Bergville area of the Thukela River basin, climate and water researchers from the University of KwaZulu-Natal (Pietermaritzburg Campus) and the Swedish Meteorological and Hydrological Institute (SMHI) during a series of workshops held in 2007-2009. Between the workshops, the researcher's compiled locally relevant climate change related information, based on requests from the workshop participants, as a basis for this adaptation plan.

The aim of this adaptation plan is to provide a local assessment of vulnerability to climate change impacts on water resources and adaptation strategies. The assessment identifies existing climate-water related problems, current adaptation strategies and recommendations for future action. The plan is a joint production of various stakeholder groups in water resource management, with water resource/climate experts acting as information providers/facilitators. The rationale behind the work is that (i) adaptation strategies should be ratified by local actors; (ii) knowledge and information should be multi-directional between stakeholders, planners and researchers; and (iii) the process will increase understanding between involved groups.

More information about the project can be obtained from:

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1.1. The Local Setting:

Bergville/Winterton area and Mhlwazini Community

In the upper reaches of the Thukela River basin are found the communities of Bergville, Winterton and Mhlwazini. These areas are prime farmland where both commercial and small-scale farms are found. Commercial farmers grow rainfed maize in the summer and irrigated wheat in the winter while the small-scale farmers only grow maize. Both also raise cattle though the commercial on a larger scale. Mhlwazini is located on the edge of the Cathedral Peak State Forest and has a community centre where crafts are made for sale to tourists.

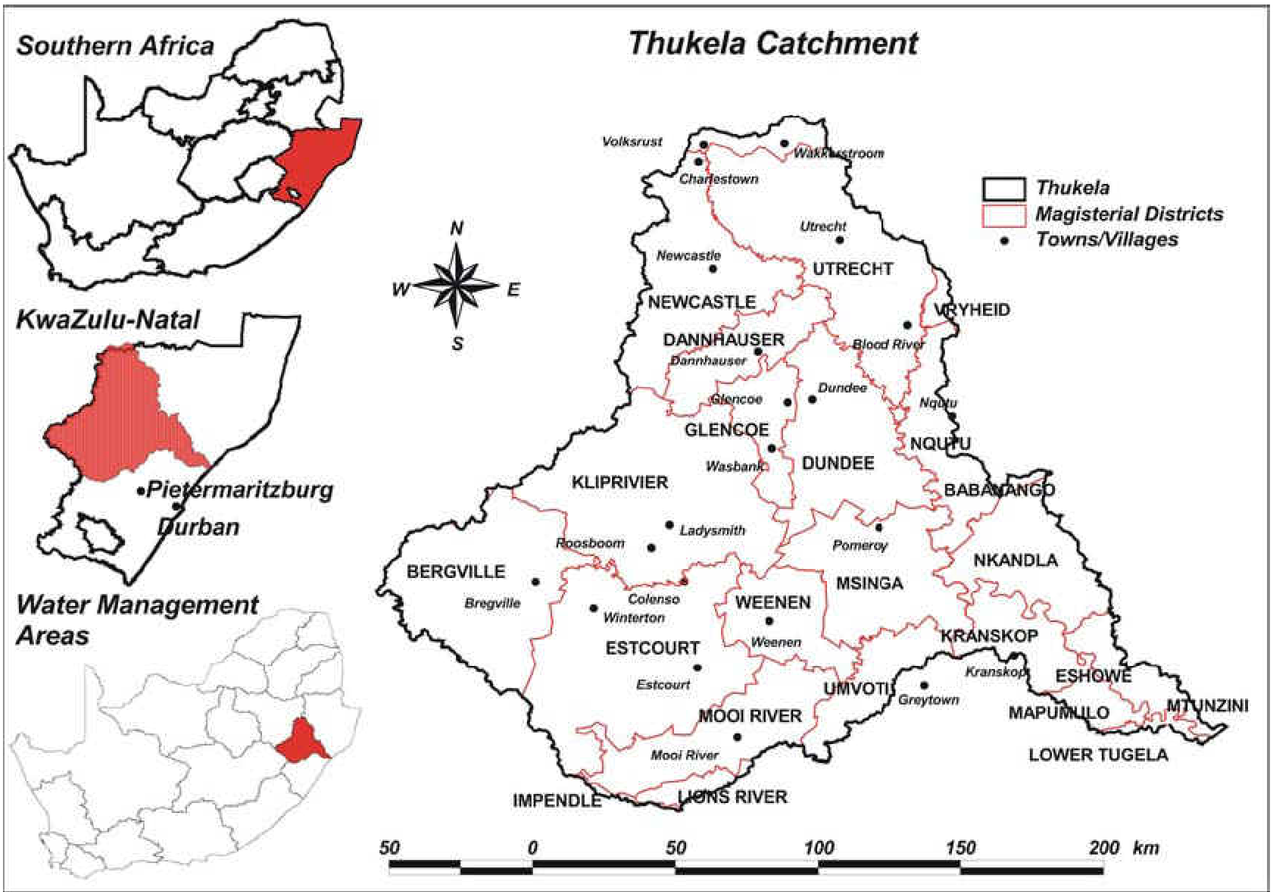


Figure 1. *Map of the Thukela catchment. The PAMO project focused on the Bergville area, situated in the western part.* [1]

[1] Schulze, R.E., Dlamini, D.J.M. and Horan, M.J.C. 2005. The Thukela Catchment: Physical and Socio-Economic Background. *In*: Schulze, R.E. (Ed) *Climate Change and Water Resources in Southern Africa: Studies on Scenarios, Impacts, Vulnerabilities and Adaptation*. Water Research Commission, Pretoria, RSA, WRC Report 1430/1/05. Chapter 10, 191 - 209.

1.2. Who has participated?

Representatives of three stakeholder groups met the project researchers in a series of three workshops (held in August 2007, March 2008 and September 2008). The groups are:

Authorities, NGOs, Water utilities, research organizations:

- KwaZulu-Natal Department of Agriculture *(contact: E.B. Msimanga, +27 36 4481164; +27 36 4386478)*
- Department of Water Affairs and Forestry (at local and regional level) (*contact: Keith Nuns, +27 82 8082744)*
- Ezemvelo KwaZulu-Natal Wildlife *(contact: Debbie Jewitt, +27 33 8451436)*
- Umgeni Water *(contact: Mark Summerton, +27 33 3411265)*
- Institute of Natural Resources
- Institute of Commercial Forestry Research

***Commercial farmers**:*

- Members of the Bergville and Winterton Farmer's Associations *(contact: Andrew Fyvie, tel: +27 36 4481280**;** +27 82 9253742)*

Small-scale farmers and other inhabitants in Mhlwazini community

- Contact: *E.B. Msimanga, +27 36 4481164; +27 36 4386478*

The draft version of this document was discussed in a joint meeting with representatives from the three groups in May 2009.

Discussion about climate change impacts on farming during an authority stakeholder group meeting.

During the first set of workshops (August 2007) challenges related to present climate variability that might be enhanced by climate change were identified for:

- Agriculture
- Water resources and infrastructure
- Wildlife, livestock and ecology.

These are presented in the Tables below. Both too much and too little water can cause serious effects within the three areas. The challenges were found to be different between the three stakeholder groups. In general, small-scale farmers were both concerned about the impacts of too much as well as too little water, whereas too little water was the main concern for commercial farmers. The high risk for increased occurrence of fires was stressed by all three groups.

In the tables the following abbreviations are used:

- **AU** Authorities, NGOs, Water utilities, Research organizations
- **CF** Commercial farmers
- **SSF** Small-scale farmers

2. Identified existing Climate and Water related Challenges

2.1.1. Climate related Challenges - Agriculture

Challenges related to droughts, low soil moisture or low dam storage

When?	***Effects:***	***Identified by:***
Summer crops		
October-November	*Poor yield due to too little rain during planting time*	*AU*
November-December	*More pest attacks (cutworm)*	*CF*
November-February	*Poor yield of soya drybeans and maize*	*CF*
December-February	*After three months without rain, nothing can be planted*	*SSF*
January-March	*More pest attacks (cutworm) for SSF*	*AU*
Winter crops		
June-October	*Poor yield of wheat if dam water storage is low at the end of wet season (most critical in Aug-Oct). Most severe after several consecutive years with low rainfall.*	*AU, CF*

Challenges related to high or intense rainfall		
When?	***Effects:***	***Identified by:***
Summer crops		
October-March	*Flooding causes poor yields*	*AU, SSF*
	Waterlogged fields make planting difficult	*AU*
October-December	*Flooding and surface runoff makes it difficult to plant*	*SSF*
November-March	*Too much rain causes waterlogging and plants become yellow; poor yield*	*SSF*

Challenges related to too few frost days		
When?	***Effects:***	***Identified by:***
Winter crops		
July-September	*Less frost days might increase the occurrence of pests (winter wheat)*	*CF*
June-July	*Increase risk for tillering - stooling on winter wheat*	*CF*

2.1.2. Climate related Challenges - Water Resources

Challenges related to drought		
When?	***Effects:***	***Identified by:***
June-August	*Decreased water supply and water quality*	*AU*
June-October	*Low water levels in springs and boreholes makes it difficult to wash clothes, make mud blocks for houses, cook food and irrigate home gardens*	*SSF*

Challenges related to flooding/high rainfall

When?	***Effects:***	***Identified by:***
November-March	*Decreased water quality*	*AU*
November-March	*Increased risk for dam breaks due to inappropriate spillway design*	*AU*
October-March	*House walls can fall down, flooding in houses, decreased drinking water quality*	*SSF*

Discussion of climate related challenges during a commercial farmers' workshop.

2.1.3. Climate related Challenges - Wildlife, Livestock and Ecology

Challenges related to drought and/or high temperatures (low river flow and low soil moisture)

When?	***Effects:***	***Identified by:***
July-October	*Loss of grass (and other vegetation) for grazing due to veld fires during dry and hot winters, especially if combined with Berg winds*	*AU, CF, SSF*
	Loss of animals due to lack of riverine drinking water	*SSF*
July-October	*Extended low flows/ many days per year with low river flows cause decline of aquatic species*	*AU*
August-October	*Fish become stressed or die due to change in the onset of spring rains, higher temperatures and low flows*	*AU*
July-October	*Domestic animals and wildlife become stressed or die if river flows are low*	*SSF*
July-October	*Dry soils increase wind erosion*	*SSF*
September	*Change in timing of flows will stress/alter behaviour of aquatic ecosystems*	*AU*

Challenges related to flooding and/or increased flow variability		
When?	***Effects:***	***Identified by:***
Jan-March	*More frequent flooding and higher magnitude will affect biodiversity, especially riparian vegetation*	*AU*
Jan-March	*More frequent large flood events will cause soils and gully erosion*	*AU, SSF*
Feb-March	*Livestock and wildlife may become diseased*	*SSF*

Identification of climate variability challenges during a workshop in Mhlwazini.

2.2. *Identified future Challenges related to Climate and Water*

The regional climate in South Africa is dependant on global climate, both today and in the future. No one knows exactly how the future global climate will develop and what the corresponding changes in South Africa will be. The major authority on information related to climate change and its effects is The Intergovernmental Panel on Climate Change (IPCC), a scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP). Hundreds of scientists all over the world contribute to the work of the IPCC as authors, contributors and reviewers. The main activity of the Panel is to provide Assessment Reports of the state of knowledge on climate change in regular intervals. The latest one is "**Climate Change 2007**", the Fourth IPCC Assessment Report and can be found at http://www.ipcc.ch/ipccreports/assessments-reports.htm.

Through the work of the IPCC, scenarios have been made that take into account different paths for worldwide economic and population development. These development scenarios lead to estimates of how the greenhouse gases that affect the atmosphere will increase (for example, carbon dioxide from petrol exhausts and from burning coal). Using these development scenarios, simulations were made for how the future climate may change within the coming century.

The assessment of climate change used in the workshops originated from regionally downscaled climate simulations coupled to an agro-hydrological model (ACRU developed at UKZN). Three dynamically downscaled climate simulations produced at SMHI using the RCA regional climate model (RCM) were used to assess projected changes in future climate. Input from two different global climate models (GCMs) were used in the regional climate model to perform the downscaling at a horizontal resolution of 50 km. The simulations covered the period 1961-2050 and were based on two separate IPCC emissions scenarios (SRES-A2, SRES-B2). In total three climate simulations were produced, ECHAM4: A2 and B2 and CCSM3 B2.

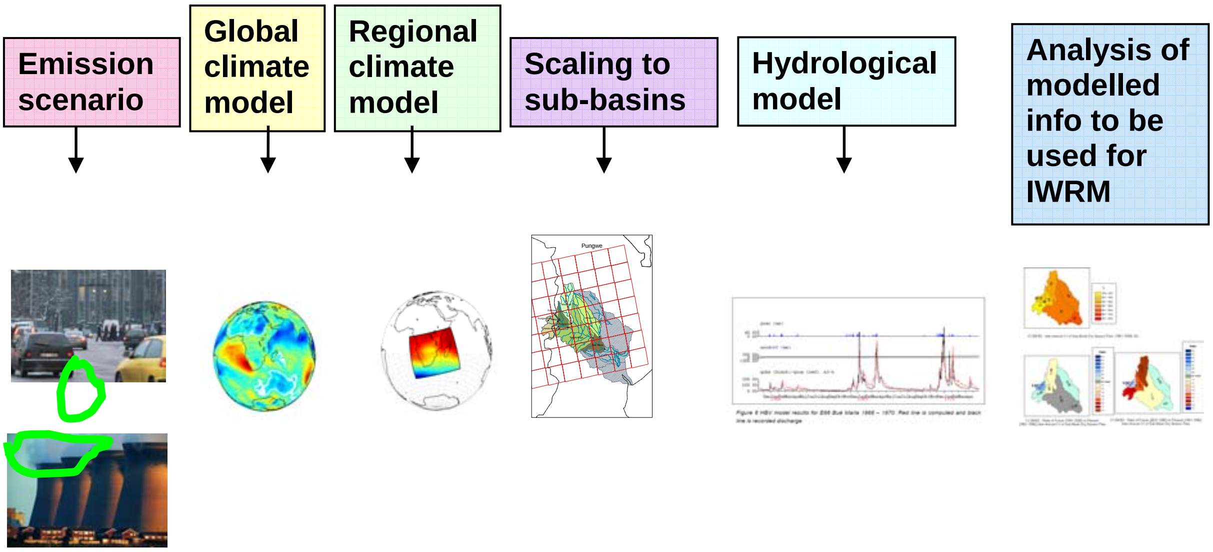


Figure 2. *The chain of modelling used in the project to assess future water resources.*

The climate simulations were used as inputs to the ACRU Agro-hydrological model to obtain local scale results on climate change impacts to the hydrological regime. Due to biases in the climate model, precipitation and temperature outputs from the RCM were first corrected using scaling methods before being entered into the ACRU model. A number of key variables describing changes in water resources and related processes were compiled from the ACRU model results for presentation and discussion in the participatory modelling process.

Although there was general consensus between the three simulations regarding projected increase in temperature, change in rainfall, as well as streamflow and other hydrological factors (see examples below and Appendix I) varied between the simulations. Two of three simulations showed fewer days with low river flow and higher average rainfall, annually and in summer.

Below are examples of information, based on this modelling, that was presented for discussion during the second workshop (March 2008, shown for Mhlwazini). The numbers show the comparison between the reference period (1961-2005) and the future period (2006-2050). A number greater than one indicates an increase; less than one indicates a decrease. It can be noted that changes of extreme events are more pronounced than changes of averages.

In Appendix I, more comprehensive information of results from the modelling is given, including a summary table of available model-generated information. This information is available for non commercial use. Contact information is provided in Appendix I.

Washing of clothes in a tributary to the Thukela River.

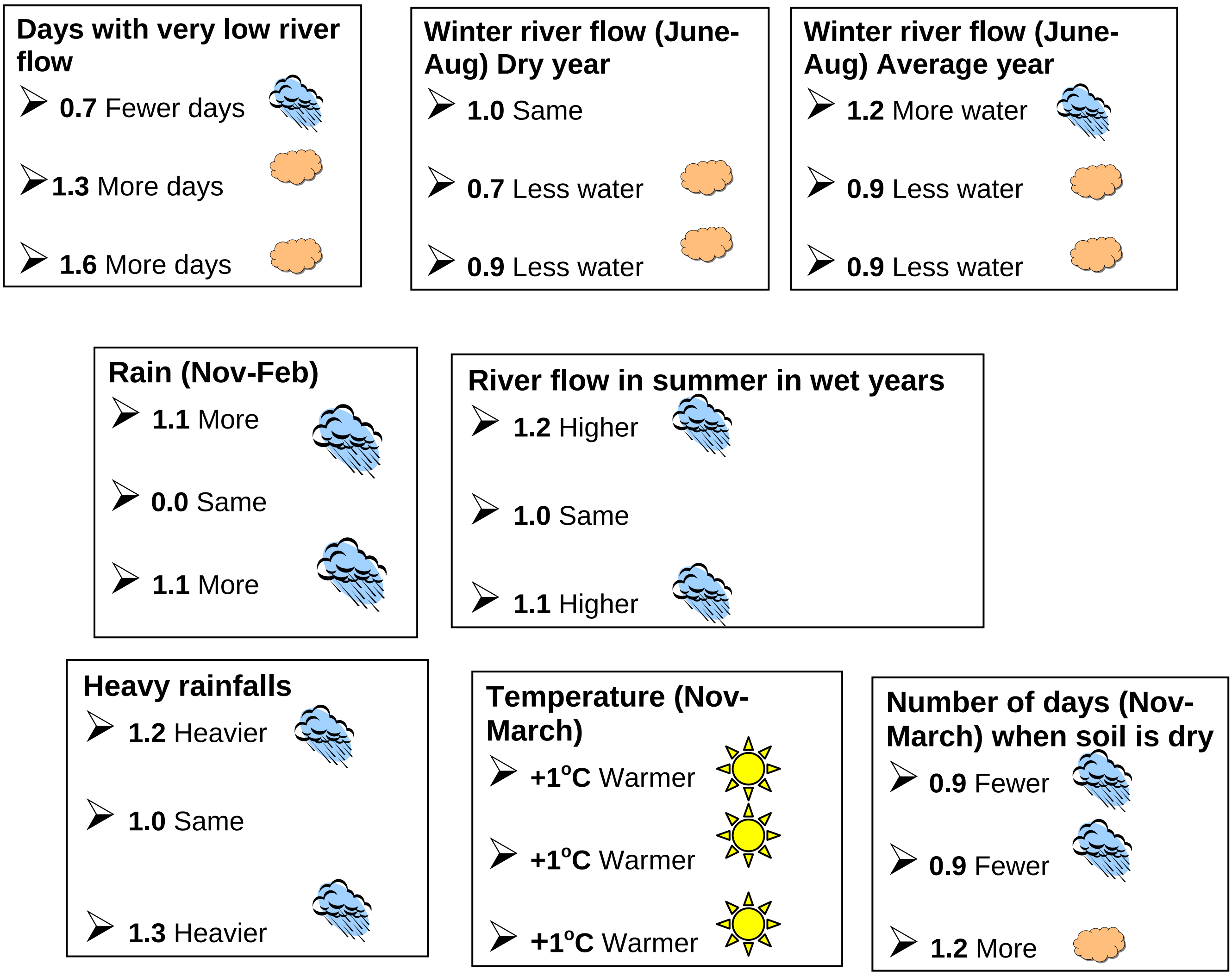


Figure 3. *Mhlwazini: Comparison of averages for 1961-2005 and for 2006-2050 with results from three model setups. The upper is based on CCSM B2, the middle on ECHAM B2, the lower on ECHAM A2. Heavy rainfall is defined as the average rainfall from the 20 highest events during the rainfall season.*

The differences shown represent averages over long periods of time and changes become more pronounced as time progresses. However, just as the climate varies considerably for today's conditions, it will continue to do so even in the future. This means that we can expect both warm and cool years in the future even if the average trend indicates increasing temperatures. Rainfall in the region is highly variable today and will also continue to be so in the future. Although the change of averages sometimes was small, the results indicated a more pronounced increase of extremes.

2.3. Meeting the challenges ahead

During the second and third workshops (March and September 2008) the previously identified problems were ranked according to severity as well as their likelihood of being more or less frequent in the future in order to compile severity-likelihood matrixes.

Participants first ranked the ***severity*** of the identified problems according to if an increased occurrence would have an impact on society/and or environment that is:

Insignificant (1), Minor (2), Moderate (3), Significant (4) or Catastrophic (5)

Then they, based on the compiled climate change information (see examples in Section 2.2), estimated the ***likelihood*** of the different events occurring more often in the period 2006-2050 as compared to 1961 – 2005 as:

Remote (1), Unlikely (2), Possible (3), Likely (4), or Certain (5)

Below, only risks that were identified as Catastrophic (5) or Significant (4) and at the same time identified as Certain (5) or Likely (4) to occur more often in the 2006-2050 period compared to the 1961-2005 period are presented. Main challenges are those that are identified as Catastrophic **and** Certain to occur more often in the future. Additional challenges are those identified as Catastrophic **or** Significant **and** Likely to occur more often in the future. In Appendix II, the complete tables from all three groups ranking all risks (from Insignificant to Catastrophic) and the likelihood of their occurring more often in the future (from Remote to Certain) are presented.

2.3.1. Agriculture

The Bergville/Mhlwazini area is seen by farmers and authorities alike as a highly productive area with abundant natural resources and good climate. There is a huge potential for utilizing good conservation practices and for sustainable water resources through dams and irrigation. The reality for the commercial farmers and the small-scale farmers is of course highly different and greatly affects how they farm now and what opportunities they have to progress and adapt for the future. Though concern for climate- and water-related problems is acute among farmers and agricultural governmental workers, other problems related to agriculture are also of great concern and affect future planning strategies. From the standpoint of commercial farmers, adapting for the future is about staying ahead and being progressive. This includes increasing and stabilizing water availability through increased irrigation and good conservation measures. The small-scale farmers are generally in need of better opportunities to finance equipment for farming and controlling fires. They are more optimistic about aid from government regarding finance, schooling, electricity, subsidized housing and household water. They deemed the problem of climate change at par with high food costs but lower than HIV and poor opportunities for higher education.

__Table 1.__ Identified risks for agriculture with high severity as well as the likelihood that it will happen more often in the future (2006-2050) compared to in 1961-2005. When relevant, it is indicated if small-scale farmers (SSF) or commercial farmers (CF) would be affected.

	Severity (Importance)	
Will this happen more often in the future? (based on climate change scenarios)	***Significant***	***Catastrophic***
Yes, it seems certain	Loss of yields due to pests and diseases (CF and SSF) Reduced winter yields due to more frequent hot days (above 32°C) (CF)	
Yes, it seems likely	Loss of yields due to over-grazing and increased ero-sion (more surface runoff during summer) (SSF)	

Agriculture: Main challenges

Identified by stakeholder participants as Catastrophic or Likely to occur more often in the future with impacts that are Catastrophic or Significant.

- **Loss of crop yields due to increased pests and diseases and more frequent hot days (> 32°C) (CF and SSF)**

Problems arising from increased crop pests and diseases and higher temperatures will entail heavy financial and food losses for farmers. This will challenge biologists as well as agricultural extension officers and advisors to keep up to date with the latest knowledge on new and suitable crop varieties and pesticides. Some natural remedies are already in use and should be promoted such as using hot chillies on cabbages to control pests. Commercial farmers get much of their new knowledge about new pesticides from sales representatives, but small-scale farmers rely on the Dept. of Agricultural Extension. Even today, they get less information and advice because of the heavy demand on few officers. Many agricultural programs and information are initiated at high levels in government and are not always adapted to local conditions.

Recommendations:

- Promotion of already tested natural remedies of pest control
- Strengthen the number and increase the capacity of agricultural extension officers, especially in relation to impacts of climate change
- Increase cooperation and promote information sharing between commercial farmers, small-scale farmers and the agricultural extension office
- Adapt all agricultural programs and planning strategies to local conditions

- **Loss of yields due to overgrazing and increased erosion especially during summer**

External stressors such as higher input costs of fuel and machinery might have the positive side-effect that more commercial farmers move to conservation agriculture including no-till and the use of environmentally friendly chemicals. For the commercial farmers, the problem of soil erosion due to heavy surface runoff has diminished as many now exercise no-till as a soil conservation measure and follow conservation laws and polices. However, many small-scale farmers have limited resources and pressing needs and priorities that constrain their possibilities and motivation to put efforts into soil conservation. Though they are aware of policies concerning e.g. field burning, overgrazing, plowing up and down slopes they do not always prioritize them, as they choose short-term benefits over long-term sustainability. Improved soil conservation as an adaptation measure to climate change will probably only become realized as more pressing short-term needs and priorities are fulfilled. Land distribution policies have resulted in small fields that are generally unprofitable and farmers might be unmotivated to use the land in a sustainable way. The culture of maintaining a large number of cattle also puts heavy pressure on the land and increases risk for soil erosion.

- Law enforcement needs to be strengthened and education increased to get people to follow conservation policies
- Re-evaluate land distribution policies to encourage sustainable farming
- Encourage soil conservation practices especially to small-scale farmers

Agriculture: Additional Challenges for Commercial Farmers

Identified by stakeholder participants as Possible to occur more often in the future with impacts that are Significant.

- **Dry soils in winter**
- **Loss of winter yields due to lower dam storage (increased frequency of years with < 650 mm rainfal**l)

Commercial farmers mention slow response from authorities as one of the major obstacles that inhibits sustainability, expansion and progress. It is difficult for example to get permits to increase irrigation.

Recommendations:

- Facilitate the handling of applications
- Increase communication and trust between commercial farmers and government authorities to improve possibilities to prepare for climate change.

Agriculture: Additional challenges for Small-scale Farmers

- **Drought during the summer planting and growing season**
- **Loss of yields due to high intensity rainfall**

Small-scale farmers need agricultural extension services to provide advice on how to adapt for climate variability and change, and on finding means to finance and use current and new technology and practices. This includes procedures and implements for soil sampling, ploughing, planting, etc. Equipment especially targeted towards small-scale farmers is available, e.g. single row planters from Brazil but needs to be promoted. Water harvesting to capture rain in the wet season, growing cover crops during the dry season, and stone packing and other means to decrease water loss should also be encouraged and supported. Economic resources and knowledge dissemination is needed to make this process possible. Again, this can only be accomplished with a strong extension service and good communication and trust between local government and the entire farming community (commercial and small-scale) to bring about concrete changes, and thus facilitate preparedness for climate change.

Recommendations:
- Targeted financial programs for new technology and practices e.g. water harvesting, soil sampling

Discussions of adaptation strategies during a workshop in Mhlvazini.

2.3.2. Water Resources and Infrastructure

Water resources are relatively abundant in the upper reaches of the Thukela River basin and many large reservoirs are located in the region to provide hydropower and irrigation water. However, irrigation infrastructure is unevenly distributed. Most of the commercial farmers have access to irrigation in the winter season while few small-scale farmers grow irrigated crops. The same is true for household water. In Mhlwazini, water is collected from nearby springs and quantity and quality are not guaranteed throughout the year.

Table 2. *Identified risks for water resources with high severity as well as the likelihood that it will happen more often in the future (2006-2050) compared to 1961-2005.*

	Severity (Importance)	
Will this happen more often in the future? (based on climate change scenarios)	***Significant***	***Catastrophic***
Yes, it seems likely	Difficulties to supply water in winter due to increased number of single years with insufficient streamflow generation. Increased water temperature changes water quality, which increases the difficulty of adhering to drinking water standards Increased rainfall could increase runoff and sedimentation which could impact on dam yield used for water supply	Insufficient household water in winter/dry periods (SSF) Too much water causes houses to fall down and makes it wet and cold inside houses causing diseases (SSF) Dams run dry due to a prolonged period of low rainfall (CF)

Water allocation: main challenges

Identified by stakeholder participants as Likely to occur more often in the future with impacts that are Significant or Catastrophic.

- **Dams run dry due to low rainfall over a prolonged period**
- **Increased number of single years with insufficient streamflow generation cause difficulties to supply water in winter**
- **Increased water temperature changes water quality, affects possibility to adhere to drinking water standards**
- **Increased rainfall could increase runoff and sedimentation which could impact on dam yield used for water supply**

In a future scenario of less water availability, water demand management will be very important. Infrastructure reforms will also be required to get water to areas where it is needed. More water may have to be impounded to cope with an increased variability, possibly upsetting the seasonal balance of water resources distribution and potentially leading to undesirable biodiversity consequences. Attitude change is vital to improve individual awareness of the problem and one's part in the solution. Population growth should also be kept within the limit of available water resources.

For water authorities, challenges include improving the skills and knowledge of employees about the effects of climate change. A sustainable vision for the future must be created by understanding the larger picture. An increasing demand from small communities for household water must be put into perspective with the effects of climate change. Learning to cope with water shortages and inter-connected water quality problems is paramount.

Recommendations:

- Water use efficiency must be promoted e.g. through education programs
- Bylaw reforms need to be changed that encourage water use efficiency e.g. exchanging existing appliances to more water efficient ones
- Address family planning in light of available water resources
- Capacity building in water utilities and authorities to reconcile water demand and supply improvement

Water allocation: additional challenges

- **Risk for flooding and impact on water quality**
- **Risk for dam breaks due to inappropriate spillway design**

Existing dams were dimensioned on historical hydrological records. They will not necessarily be able to deal with future climate conditions. Climate change needs to be included as one of the factors to be taken into account when assessing the safety of current dams and in the design of new structures.

With the array of climate models that currently exist, there is not always agreement on what will happen in the future and the range of possible impacts makes planning for an uncertain future difficult, especially when alternative risks are possible (e.g. investing in measures against flooding or to reduce impacts of water shortages). Although this fact should not stop planners from taking action, they need to be receptive and adaptive to new information in water and climate research that will hopefully help limit uncertainties. Increasing awareness at individual level can enable them to influence decision makers to take account of the effects of climate change in all planning strategies. Improved skills and competence at all levels in society (from schools to high level decision makers) are needed to improved understanding of the need to include change in climate variability in long-term planning and in visions for the future.

Recommendations:

- Infrastructure modifications as well as updated design flood calculations, based on climate change scenarios, are required
- Climate change must be factored into dam safety reviews of existing dams and dam safety guidelines for new structures
- Ongoing training is needed for water allocation planners to incorporate new climate change information as it is released
- Promote educational programs to increase awareness of climate change for all citizens

Main challenges for Mhlwazini inhabitants related to infrastructure and household water

Identified by stakeholder participants in Mhlwazini as Likely to occur more often in the future with impacts that are Catastrophic.

- **Excessive rainfall causing problems to health and houses**
- **Insufficient household water**

For the small-scale farmers, both too much and too little water create extreme challenges. Too much rain causes their houses to weaken and eventually collapse. Digging furrows around the houses to lead water away from the walls eases the situation but more houses made of more sturdy materials are required. Insufficient household water makes all daily tasks difficult, cooking, washing, laundry, etc. Water needs to be stored when it is available to allow families to have water access even in drier periods. Water in streams can be kept cleaner by promoting correct farming practices (e.g. prevent overgrazing, accurate fertilizer application) and protecting streams from high runoff. Water should be purified before using to prevent disease. Even here, water must be used efficiently to make best use of what is available. Water can be used for more than one purpose, e.g. water from washing can be used to irrigate home gardens.

Recommendations:

- Government subsidies are needed for more sustainable houses
- Water tanks can store water when it is available. However, to ensure good water quality during storage, information is needed to prevent worms and insects from breeding
- Dams need to be dug to ensure better water availability for humans and livestock
- Training is needed so water can be used for more than one purpose
- Information needs to be given to prevent people and livestock from getting diseases from water shortage or excess
- Need to ensure that pipes do not break and that pumps are working
- Training and encouragement of correct farming practices to prevent erosion and excess fertilizer use
- Protect springs from high runoff by the building of stone structures

2.3.3. Wildlife, livestock and ecology

The Mhlwazini community is situated at the edge of the Cathedral Peak Game Reserve. The fact that tourism can generate incomes adds to the general interest to protect the environment. Many commercial, as well as small-scale farmers in the Bergville/Winterton area have cattle. All are concerned about the risk for fires. The Ecological Reserve determined for the Thukela River Catchment by the Department of Water Affairs[2] with regard to conservation of the aquatic riparian habitats of the river reads" *"Soils in the Drakensberg Mountain Range are relatively shallow. Pressure from human activities outside of the protected areas, particularly in the subsistence agriculture areas, is resulting in soil erosion with the consequent loss of habitat and siltation of dams in the upper Mweni Valley is the most affected."* It also states that *"Severe overgrazing and soil erosion problems are being experienced in the Driefontein Block and Matiwaneskop areas to the north west and north of Ladysmith. Similar problems are being experienced on the land reform projects around Weenen and Estcourt."* Although this does not

[2] Department of Water Affairs and Forestry, South Africa. 2004. Internal Strategic Perspective: Thukela Water Management Area : Prepared by Tlou & Matji (Pty) Ltd, WRP (Pty) Ltd, and DMM cc on behalf of the Directorate: National Water Resource Planning (East). DWAF Report No. P WMA 07/000/00/0304.

include the region in focus in this project, problems that might cause high sediment loads are prevalent there as well.

Table 3. *Identified risks for wildlife, livestock and ecology with high severity as well as probability for that it will happen more often in the coming years (2006-2050) compared to in 1961-2005. Impact on biodiversity is shown in* ***italics****. Underlined text is used for risks that also have a direct impact on people. Some identified problems for livestock identified by small-scale farmers (SSF) only.*

	Severity (Importance)	
Will this happen more often in the future? (based on climate change scenarios)	***Significant***	***Catastrophic***
Yes, it seems certain	Incidences of parasites and diseases for fishes and *breakdown in the food web.* More outbreaks of insects due to warmer water and lower flow in Aug-Sept *Loss of biodiversity and better conditions for alien species due to riparian vegetation being stressed by low flows or change in channel erosion*	Loss of grazing lands, and livestock etc due to winter fires (warmer, drier soils) *Change in biodiversity due to changed timing and frequency of flow peaks*
Yes, it seems likely	Increased number of mosquitoes and bilharzia due to low flows causing lower velocity and more reeds	Long periods of heavy rainfall causing animal disease (SSF) Insufficient water for livestock/wildlife in winter/dry periods (SSF) *Loss of biodiversity as small perennial rivers become non-perennial in dry years (increased number of days with low river flow)* *Spread of alien species due to inter-basin water transfers during dry years, which can make natural species extinct.* Wind erosion after long and hot periods

The change in timing and magnitude of low flows can have serious impacts on biodiversity and the invasion of riparian species. Serious effects might also arise from changes to water infrastructure. Such changes may enable improved water supply for household consumption and agricultural use to rural communities, but put greater stress on existing water reserves. The effects of such changes and solutions must be studied in a holistic manner to find the best solutions.

Wildlife, livestock and ecology: Main challenges

Identified by stakeholder participants as Likely or Certain to occur more often in the future with impacts that are Significant or Catastrophic.

- **More frequent fires, causing loss of grazing lands, buildings, infrastructure, livestock, etc.**
- **Changed timing and frequency of flow peaks can cause change in biodiversity**

The risk for fire is huge, with effects that are widespread and cause massive damage to people and property. Coping with the risk for fires is a question of responsibility. Landowners must be responsible for making firebreaks and burning in the times dictated by the law. Small-scale farmers need better access to resources to help them prevent the spread of fires (e.g. making fire breaks) and to fight fires (e.g. fire-extinguishing equipment). Commercial farmers hold close communication with one another during the dry months to follow the spread and development of any fires and they help one another to control and extinguish it. This network should include small-scale farmers who are currently on their own during fire outbreaks.

The riparian zones must be maintained to promote biodiversity and improve water purification.

Recommendations:

- Financial resources are needed to help small-scale farmers purchase equipment to prevent and control fires
- Educational programmes should encourage farmers to burn firebreaks responsibly
- Better organised farmer networks should include small-scale farmers to help reduce the spread and damage caused by fires

Wildlife, livestock and biodiversity: Additional challenges

- **Long periods of heavy rainfall may cause livestock and wildlife disease**
- **Dried up rivers case animal stress**
- **Loss of biodiversity due to small perennial rivers becoming non-perennial in dry years, changes to riparian vegetation and channel erosion**
- **Spread of alien species due to inter-basin water transfer during dry years, changes to riparian vegetation and channel erosion**
- **Wind erosion after long dry periods**
- **Incidences of parasites and diseases for fishes and breakdown in the food web and more outbreaks of insects**
- **More mosquitoes and bilharzia due to lower streamflow**

To prevent the risk of animal disease during wet periods, water should be drained off around the livestock kraals. Wildlife can migrate to avoid and escape problem areas but wildlife corridors are needed through agricultural land. Similarly, fish ladders in reservoirs aid the movement of fish.

If grazing lands run dry, livestock run the risk of starvation. Cutting grass in autumn and making bales is one safeguard. Insufficient water in winter can be supplemented by water storage in dams.

Loss of biodiversity and spread of alien species can occur due to lower and more frequent river flows. Lower flows cause changes to riparian vegetation, channel erosion and perennial rivers becoming non-perennial in extremely dry years. Farmers need to achieve best management practices that aim towards good conservation and adhere to the guidelines for biodiversity. Good examples exist where biodiversity and human needs not are contradictory and these need to be promoted. One sensitive issue is the need to regulate cattle numbers in areas where there is need for improved land management. This issue can only be dealt with if put in a larger perspective, where the fulfilment of short as well as long-term needs of small-scale farmers are put into focus, with healthy ecosystems as part of the sustainable solution.

Recommendations:

- Financial resources are needed to help farmers purchase equipment and materials (to drain excess water, make bales in wet periods, construct dams)
- Programs to encourage farmers to establish wildlife corridors and practice good conservation measures need to be started
- Fish ladders should be added to all reservoirs
- Biodiversity targets need to be set and plans made to reach them.
- Pro-active policy planning needs to include biodiversity targets
- Centres for ecosystem services need to be provided with necessary resources to disseminate knowledge to politicians and individuals

3. *Key messages from participating stakeholders to decision makers:*

Policy makers must enable communities to effectively deal with an uncertain future climate by allowing, supporting and enabling them to deal with their present challenges including current climate variability. It is comparatively easy to regulate big players but hard to regulate individuals. Therefore, there is a need to provide incentives that encourage individuals to use technology and management practices that are good for the environment, e.g. low flow showers, no-till farming, low energy appliances. Making laws is not enough as long as there are too few resources to enforce the laws. If poor farmers do not have the means to prioritize actions that promote sustainable environmental conditions, they will continue to make short-term decisions. Incentives must lead the way instead of only control measures. Encourage communication and open discussions with people that can influence the environment and the water situation with commercial farmers and union associations.

Assurance needs to be given to commercial farmers that they have an important part to play in maintaining good ecosystems and providing sustainable food security for the region. If grain is being grown with subsidies in other parts of the world, levies must be put on imported grain from subsidised countries to allow South African farmers to compete. Many commercial farmers are today sinking deeper and deeper into debt. After one good year they can continue for the short-term but with uneven conditions on South African farmers and the rest of the world, it will be difficult for South African farmers to compete. Without South African farmers, it will be difficult to ensure the food security of the nation. Instead of supporting many unproductive small farmers, it is more effective to support commercial farmers that want to farm. Target the small-scale farmers that want to become commercial farmers and guide them in the right direction, providing incentives for them to sustainably farm the land. Set up mentor programs between commercial and small-scale farmers to bridge the enormous knowledge gaps that exist.

Water allocators need to allow permits for reservoirs and irrigation structures in areas that are abundant in water and allow farmers in these regions to produce food for the nation. Water must be allocated in an equitable manner. Work needs to be undertaken from both ends, both increasing water supply and decreasing water demand.

Environmental organisations need to carry out important research and studies on the effects of climate change. Feedback needs to be given to citizens about how different ecosystems might be affected and how they can play a part in conserving them. Currently everyone is guessing about global warming. It is important that impact studies are not carried out in isolation from one another. Improving water supply for rural communities will put greater stress on water reserves that might negatively affect biodiversity. Holistic management must be based on effectual communication and good dialogue.

4. Conclusion

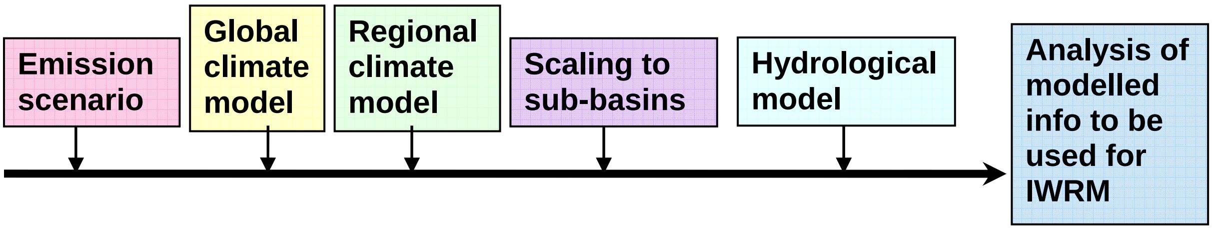
Learning about and adapting to possible effects of climate change is a never-ending process as new information continuously becomes available. Adaptive management is needed to keep updated on and be responsive to new information as it arises. One of the challenges for stakeholders is to keep abreast of the latest developments. An important task for researchers is to provide information to stakeholders and they should take this role seriously. Establishing relevant forums for information exchange should be an integral part of the adaptation process. All citizens and policy makers should do their part to support and find new solutions and adaptive measures to mitigate the effects of climate variability and change. Though much uncertainty still surrounds the specific effects of climate change, water resources can even today be used more efficiently and distributed more equitably. Good land and water management practices can pave the way for a better tomorrow.

Appendix I: Contact information and more comprehensive information of the results from the modelling, including information of available model-generated information.

1. Information available and contact details

The climate change results used here came from dynamical downscaling using a regional climate model (RCM). An RCM basically transforms the global climate model (GCM) results from larger areas to smaller ones. To get further information on the impacts to water resources, the RCM results were fed into an agro-hydrological model (ACRU), which produces estimates of streamflow, evaporation and related variables for water catchments.

Modelling future water resources as conditioned by climate change involves a chain of analyses:



- Two global climate models were used:
  - **ECHAM4**, developed and run at DKRZ, the Deutsches Klimarechenzentrum
  - The Community Climate System Model **CCSM3**, developed under the auspices of the National Center of Atmospheric Research in Boulder (USA)

- Model runs considered two emission scenarios with their consequences for greenhouse gas concentrations and aerosols. These included the **A2** (used only for the ECHAM4 model experiment) and **B2** emission (used both for the ECHAM4 and the CCSM3 model experiment) scenarios from the Intergovernmental Panel on Climate Change.

  - **A2:** Describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
  - **B2**: Describes a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

- **Downscaling techniques** were used to translate the three (ECHAM4-A2, ECHAM4-B2, CCSM3-B2) large-area results from the global models (GCM:s) to more local results. The methods used are typically defined as statistical or dynamical. The climate change results used here came from dynamical downscaling using a regional climate model (RCM). An RCM basically transforms the GCM results from larger areas to smaller ones. The RCM used was the Rossby Centre Regional Atmosphere Model, RCA, developed at SMHI, Sweden.

- To get further information on the impacts to water resources, the RCM results were fed into an **agro-hydrological model**, which produces estimates of streamflow, evaporation and related variables for water catchments. The hydrological model used was the ACRU model, developed at University of Kwa Zulu Natal, South Africa.

- Climate change time series of the following are available for the whole Thukela river basin for the period 1060-2050.
- The time series can be made available for non-commercial purposes. If you are interested in obtaining data, contact Lotta Andersson (lotta.andersson@smhi). Data are not available for down-loading from internet, sharing of data need to be based on individual agreements.

2. Table of available climate change related data

List of types of information available from the Thukela River Basin (1960-2050). ➢ All information is available as daily time series ➢ All units are in mm, except for streamflow (m^3/s) and temperatures (^oC).
Actual evapotranspiration (the quantity of water moisture that is actually is lost to the atmosphere from a land surface, as well as from the vegetation). Can be divided in evapotranspiration from the A and B soil horizons. Also possible to get only the part of the evapotranspiration that consist of water losses from the vegetation to the atmosphere (transpiration)
Potential evaporation (the ability of the atmosphere to remove water from the land surface through the processes of evapotranspiration, assuming unlimited water supply)
Streamflow from subcatchments, including upstream contributions, simulated peak discharge, stormflow leaving catchment outlet on a given day and baseflow (the portion of the streamflow that is generated by groundwater).
Rainfall
Maximum and minimum air temperatures
Sediment yields from sub-catchments
Soil water content Can be divided in A and B soil horizons.

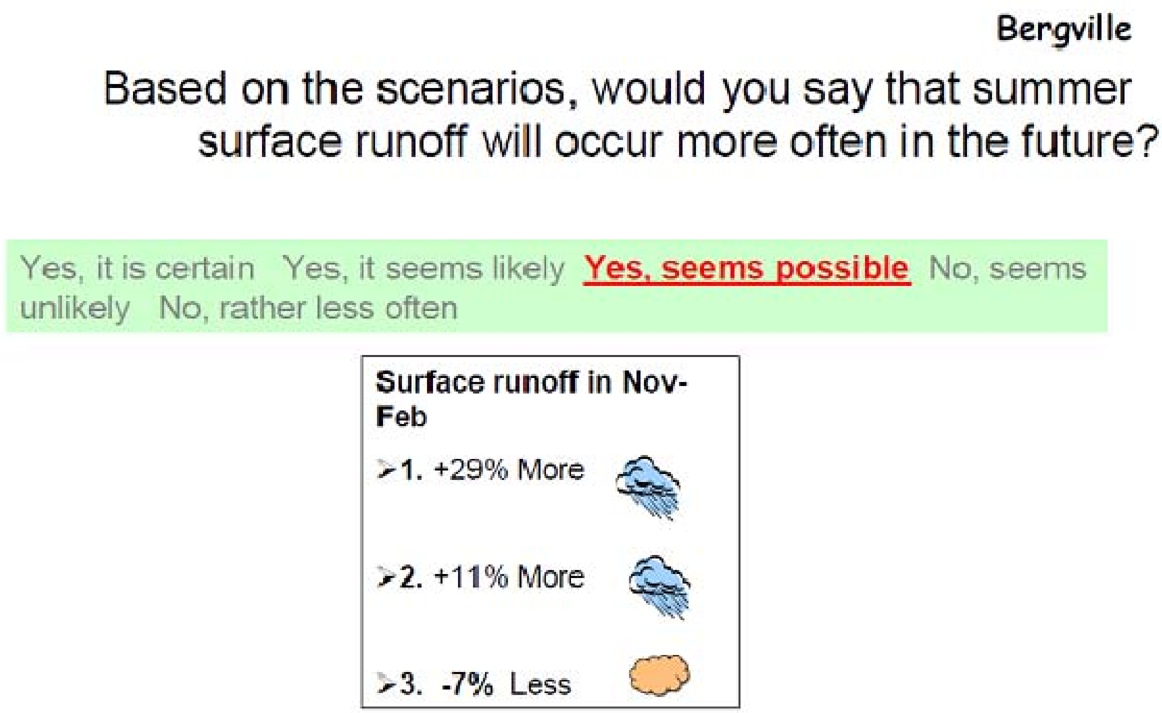
3. *Climate change information compiled after requests from stakeholder workshops and used during the workshops for assessments of probability for change*

This section presents information compiled and used during workshops for determination of vulnerability where the workshop participants, based on the available climate change scenario information, estimated the probability for various things to change in the coming decades, due to climate change.

Figures in 3.1 and 3.2 demonstrate the three climate scenario experiments presented, i.e. based on RCA downscaled climatological information using:

1. The CCSM3 global model combined with the B2 emission scenario
2. The ECHAM4 global model combined with the B2 emission scenario
3. The ECHAM4 global model combined with the A2 emission scenario

3.1. Commercial farmers (Bergville, Winterton)



Bergville

Based on the scenarios, would you say that there will be more winter fires in the future?

Yes, it is certain **Yes, it seems likely** Yes, seems possible No, seems unlikely No, rather less

30 hottest days in winter

- 1. +6% Hotter
- 2. +9% Hotter
- 3. +6% Hotter

Wetness in upper soil layer during 30 driest days in winter

- 1. +1% Same
- 2. 0% Same
- 3. +2% Same

Based on the scenarios, would you say that winter yields will be lower in the future?

1. Yes, it is certain 2. **Yes, it seems likely** 3. Yes, seems possible 4. No, seems unlikely 5. No, rather higher

Number of frost days in winter

- **1.** -37% Less
- **2.** -15% Less
- **3.** -24% Less

d. Summer stremflow average year

- 1. +7% More
- 2. -5% Same
- 3. -5% Same

e. Winter streamflow dry year

1. -2% Same
2. -27% Less
3. -41% Less

Days with high air temperature in winter (+32° C or higher)

- **1.** + 9 days More
- **2.** + 20 days More
- **3.** + 15 days More

. Based on the scenarios, would you say that yields will be lower during the summer growing season?

.Yes, it is certain . Yes, it seems likely . Yes, seems possible . No, seems unlikely . **No, rather higher**

a. Number of days when soil is dry (SMD > 30 mm) Nov-Feb

1. -4% Same

2. -8% Wetter

3. +2% Same

b. Rain in Nov-Dec

- 1. +7% More
- 2. -2% Same
- 3. +2% Same

c. Rain in Nov-Feb

- 1. +6% More
- 2. +1% Same
- 3. +7% More

Small-scale farmers and other inhabitants of the community Mhlwazini

Household water Mhlwazini

When you look at the three predictions, made by different experts, do they show that lack of household water will occur more often during the coming years?

Yes, it is certain **Yes, it seems likely** Yes, seems possible, No, seems unlikely No, rather less often

Days with very low river flow	Winter river flow (June-Aug.) Average year	Winter river flow (June-Aug. Dry year
-30% Less days	+20% More water	Same
+30% More days	-10% Less water	-30% Less water
+60% More days	-10% Less water	-10% Less water

Household water Mhlwazini

When you look at the three predictions, made by different experts, do they show that problems with health and houses due to too much water will occur more often during the coming years?

Yes, it is certain Yes, it seems likely **Yes, seems possible** No, seems unlikely No, rather less often

River flow in wet years	Surface runoff	Heavy rainfall
+20% Higher	+10% More	+20% Heavier
Same	-20% Less	Same
+10% Higher	+20% More	+30% Heavier

Agriculture Mhlwazini

When you look at the three predictions, made by different experts, do they show that problems with low yields due to too much rainfall and surface runoff during the summer growing season will occur more often during the coming years?

Yes, it is certain **Yes, it seems likely** Yes, seems possible
No, seems unlikely No, rather less often

Surface runoff

- +10% More
- -20% Less
- +20% More

Heavy rainfalls

- +20% Heavier
- Same
- +30%Heavier

Agriculture Mhlwazini

When you look at the three predictions, made by different experts, do they show that problems with low yields due to drought during the summer planting and growing season will occur more often during the coming years?

Yes, it is certain Yes, it seems likely **Yes, seems possible**
No, seems unlikely No, rather less often

Rain in Nov-Feb

- +10% More
- Same
- +10% More

Temperature in Nov-March

- +1°C Warmer
- +1°C Warmer
- +1°C Warmer

Number of days (Nov-March) when soil is dry

- -10% Fewer
- -10% Fewer
- +20% More

Cattle, wildlife, ecology Mhlwazini

When you look at the three predictions, made by different experts, do they show that problems with soil erosion/loss, sick animals (livestock and wildlife) due to heavy rains/flooding will occur more often during the coming years?

Yes, it is certain **Yes, it seems likely** Yes, seems possible
No, seems unlikely No, rather less often

Heavy rainfalls

- **+20%** Heavier
- Same
- **+30%** Heavier

River flow in summer in wet years

- **+20%** Higher
- Same
- **+10%** Higher

Cattle, wildlife, ecology Mhlwazini

When you look at the three predictions, made by different experts, do they show that problems with fires in winter will occur more often during the coming years?

Yes, it is certain Yes, it seems likely Yes, seems possible
No, seems unlikely No, rather less often

30 hottest days in winter

- **+2°C** Hotter
- **+3°C** Hotter
- **+ 2°C** Hotter

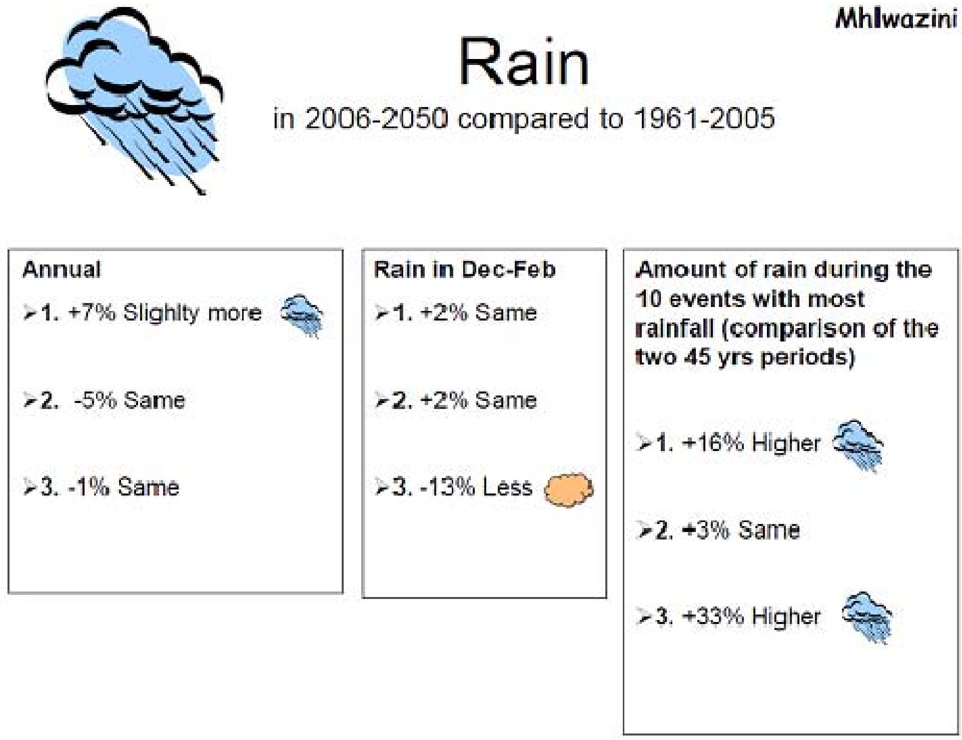
Number of hot days in winter

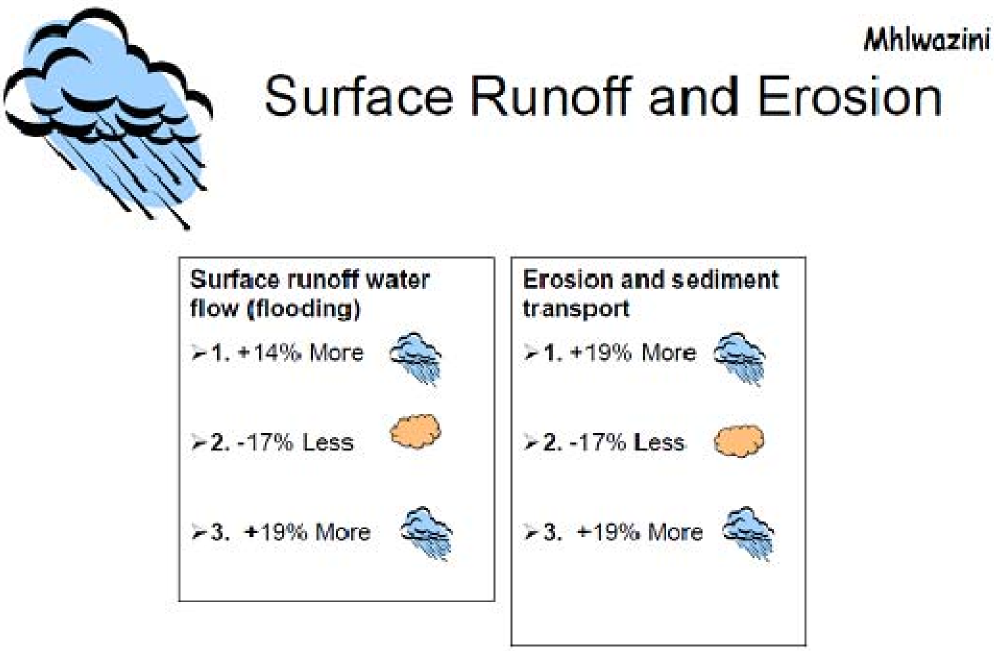
- +20% More
- +50% More
- +40% More

Wetness in the soil in winter

- Same
- Same
- Same

3.2. Climate change information requested by the authority stakeholder group and used by them in assessment of probability for climate change related risks





Mhlwazini

Temperature and soil moisture in winter
(July-Sept)

Number of frost days in winter

- **1.** -48% Less
- **2.** -9% Slightly less
- **3.** -26% Less

Days with high air temperature in winter (+32° C or higher)

- **1.** +22% More
- **2.** +49% More
- **3.** +23% More

Wetness in upper soil layer in winter

- **1.** +3% Same
- **2.** -6% Slightly drier
- **3.** -6% Slightly drier

Mhlwazini

Temperatures and soil moisture in summer
Nov-March

Daily max temperature

- **1.** +1.0°C Warmer
- **2.** +1.1°C Warmer
- **3.** +1.0°C Warmer

Number of days when soil is dry (smd > 30 mm)

1. -7% Slightly wetter

2. -8% Slightgly wetter

3. +16% Drier

Mhlwazini

River water flow in winter

(June-August)

Average year

- **1.** +18% More water
- **2.** -12% Less water
- **3.** -7% Slightly less water

Dry year

- **1.** -2% Same
- **2.** -27% Less water
- **3.** -7% Slightly less water

Mhlwazini

Days per year with very low flow in river

Average year

- **1.** +28% Less dry days
- **2.** +31% More dry days
- **3.** +55% More dry days

Mhlwazini

Change of river flow in summer

(Jan-March)

Average year

- **1.** +7% Slightly more water
- **2.** -5% Same
- **3.** -5% Same

Wet year

- **1.** +24% More water
- **2.** -5% Same
- **3.** +10% More water

4. Summary of climate change results for the Upper Thukela

Using temperature and rainfall inputs from the CCSM3 and ECHAM4 global models, the Acru model was set up and used for the entire Thukela River Catchment. As a primary interest for this study is with communities located in upstream areas, results were summarised over the upper catchment including both the Mhlwazini and Bergville communities. An overview of key climate findings is listed here. The change values represent differences between averages for the period 2006-2050 compared to the period 1961-2005. The breakdown of these periods was chosen to represent what we are accustomed to versus what we can expect in the near to intermediate future. It is important to keep in mind that the results presented below are long-term averages, which means that values for an individual day or month can be much higher.

Table A4.1 *Projected future change for the Thukela River Basin from three climate model simulations. Mean annual change is shown using the period 2006-2050 compared to 1961-2005. Results from both the Upper Thukela River Basin and the total Thukela River Basin are shown. Changes in runoff were generated with the ACRU agro-hydrological model.*

	Change for Upper Thukela River Basin			**Change for Total Thukela River Basin**		
Projection number	1	2	3	1	2	3
Projection name	CCSM3-b2	ECHAM4-b2	ECHAM4-a2	CCSM3-b2	ECHAM4-b2	ECHAM4-a2
Maximum Daily Temperature	1.0 ºC	1.6 ºC	1.8 ºC	0.6 ºC	1.2 ºC	1.5 ºC
Minimum Daily Temperature	1.0 ºC	1.2 ºC	1.0 ºC	0.9 ºC	1.2 ºC	1.1 ºC
Daily Rainfall	8.5 %	1.1 %	-8.0 %	10.2 %	2.5 %	-5.9 %
Daily Runoff	14.7 %	10.2 %	-23.3 %	16.0 %	9.8 %	-11.8 %

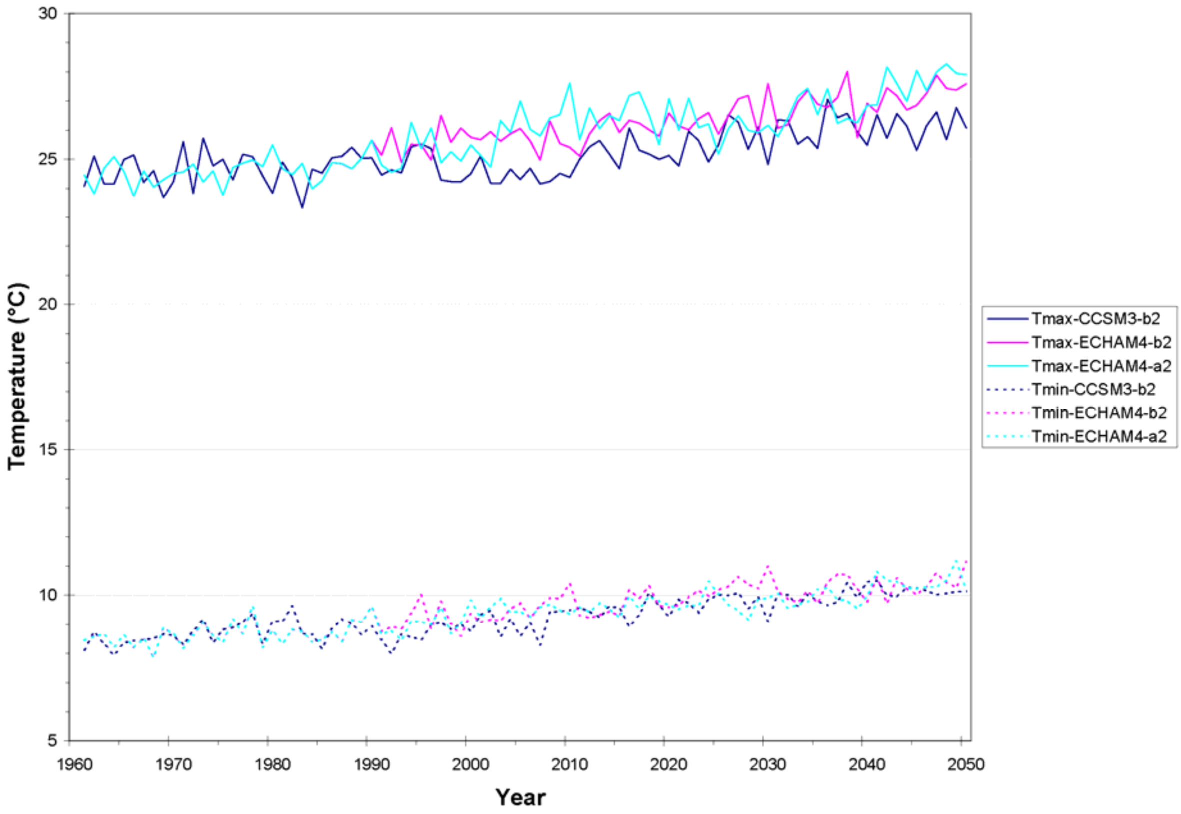
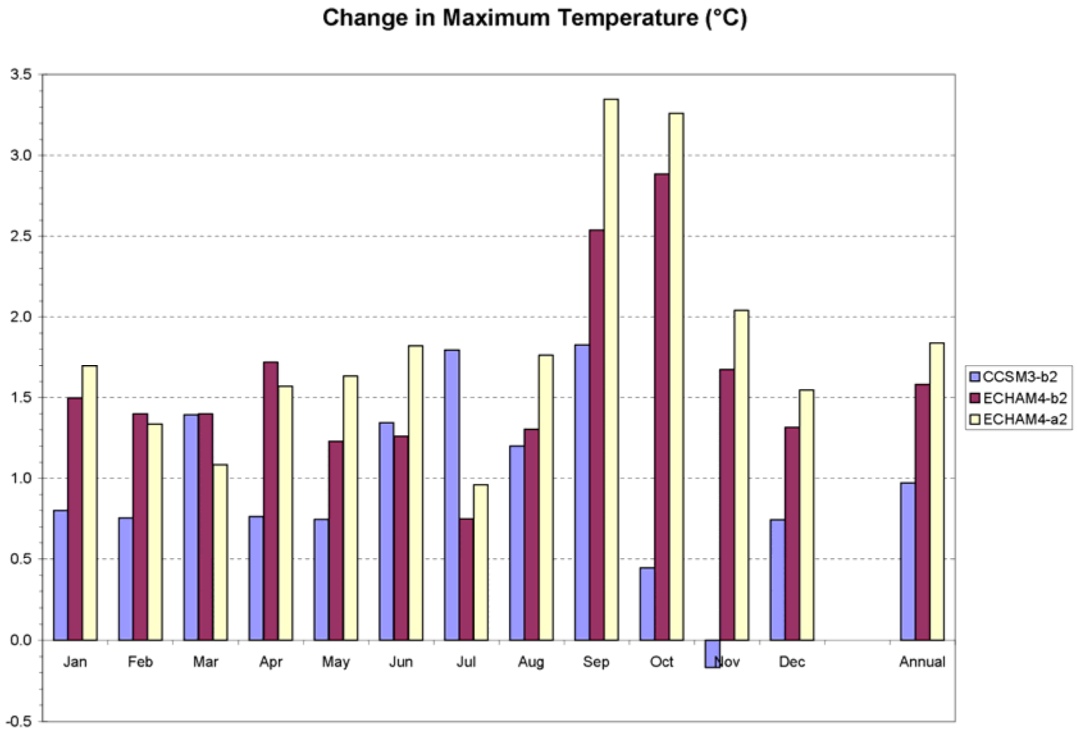


Figure A4.1 *Projected maximum and minimum temperatures for the Upper Thukela River catchment from three climate model simulations. Shown are mean annual values for the period 1961-2050. (Note that there is no difference between the two ECHAM4 simulations until after 1990.)*



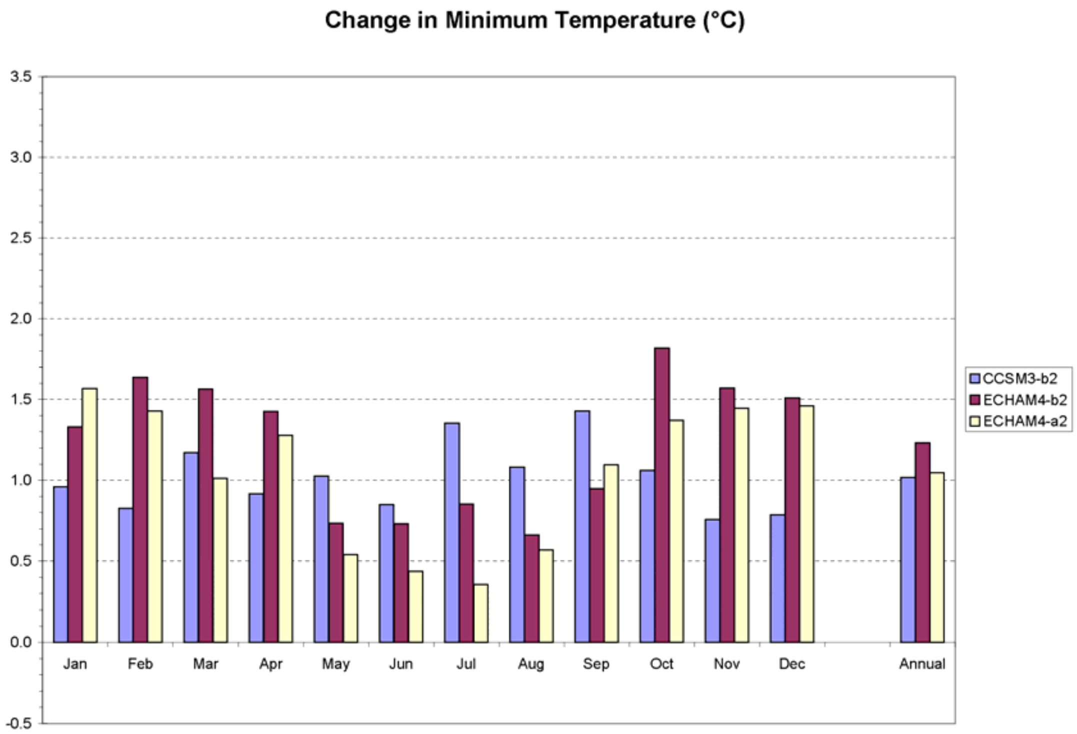


Figure A4.2 Projected *future change in both maximum and minimum temperature for the Upper Thukela River catchment from three climate model simulations. Mean monthly and annual changes are shown using the period 2006-2050 compared to 1961-2005.*

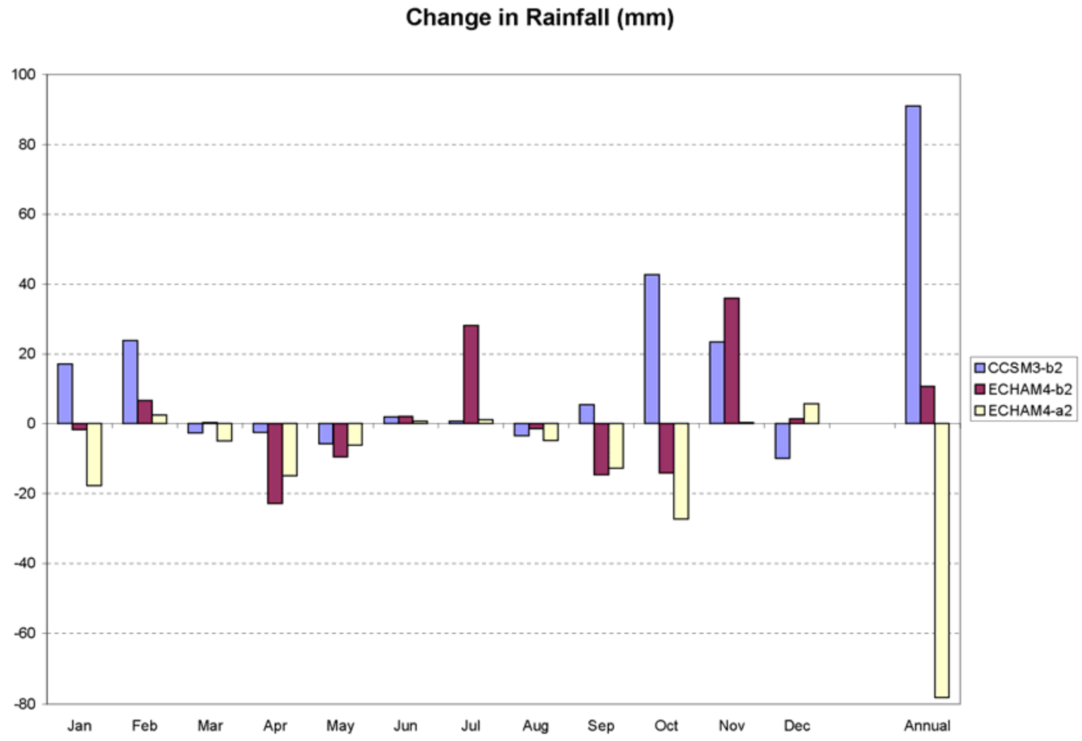


Figure A4.3 *Projected future change in rainfall for the Upper Thukela River catchment from three climate model simulations. Mean monthly and annual changes are shown using the period 2006-2050 compared to 1961-2005.*

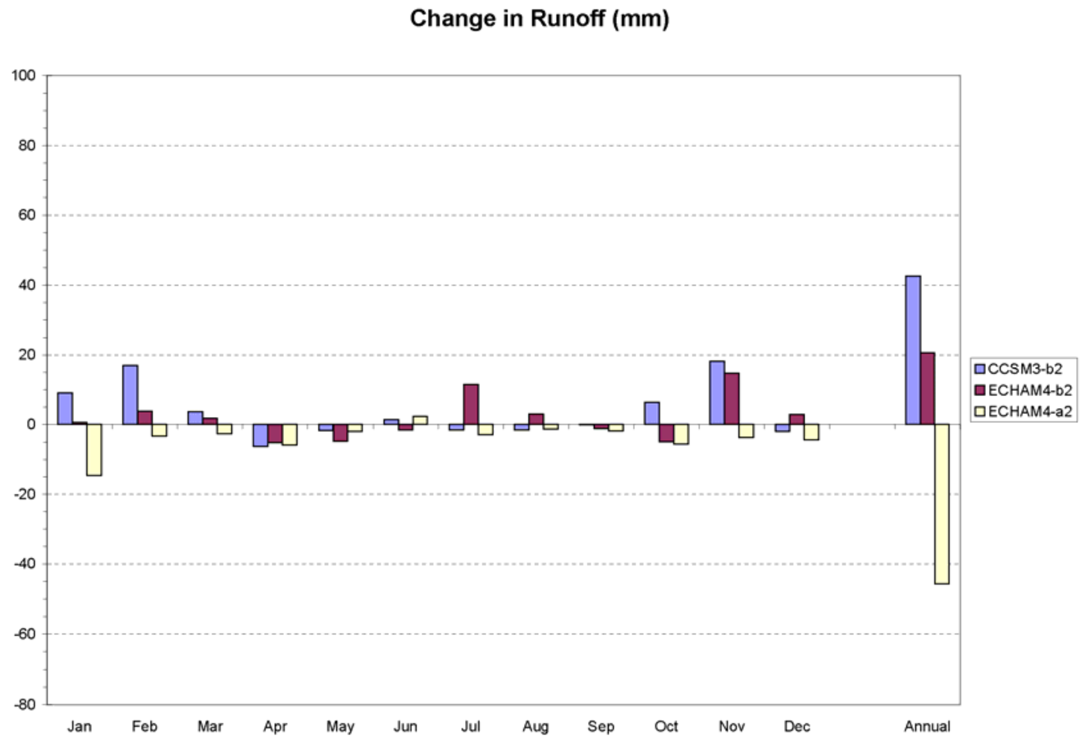


Figure A4.4 *Projected future change in runoff for the Upper Thukela River catchment from the ACRU agro-hydrological model using three climate model simulations. Mean monthly and annual changes are shown using the period 2006-2050 compared to 1961-2005.*

Appendix II: Complete tables from all three groups ranking all risks and the likelihood of their occurring more often in the future.

Stakeholder ranking of the severity of the identified problems according to if an increased occurrence of them would have an impact on society/and or environment that is:

Insignificant (1), Minor (2), Moderate (3), Significant (4) or Catastrophic (5)

Stakeholder ranking, based on the compiled climate change information (see examples in Section 3.2), estimated the ***likelihood*** of the different events occurring more often in the period 2006-2050 as compared to 1961 – 2005 as:

Remote (1), Unlikely (2), Possible (3), Likely (4), or Certain (5)

Combinations of severity and likelihood of events to occur more often determines for what type of events adaptation strategies need to be prioritized. A combination of high impact and high likelihood means that the need for adaptation measures must be given the highest priority. In the following matrixes, priorities are represented as shown in the table below:

Will this happen more often in the future?	**If this would happen more often, the severity of the impacts for them would be:**			
	Minor	**Moderate**	**Significant**	**Catastrophic**
Yes, seems certain	High priority	Highest priority	Highest priority	Highest priority
Yes, seems likely	Moderate priority	High priority	Highest priority	Highest priority
Yes, seems possible	Moderate priority	Moderate priority	High priority	Highest priority
No, seems unlikely	Low priority	Moderate priority	Moderate priority	High priority
No, rather less often	Low priority	Low priority	Moderate priority	Moderate priority

Small scale farmers and other inhabitants in the Mhlwazini community

Will this happen more often in the future?	**If this would happen more often, the small-scale farmers in the Mhlwazini community judge that the severity of the impacts for them would be:**			
	Minor	Moderate	Significant	Catastrophic
Yes, seems certain				**Winter fires after long hot and dry periods**
Yes, seems likely		**Too much rainfall and surface runoff in summer growing season causes low crop yield**		**Not enough household water and water for livestock/wildlife in winter/dry periods** **Wind erosion after long and hot periods** **Too much water causes houses to fall down and makes it wet and cold inside houses causing diseases.** **Heavy rainfall causing soil erosion** **Long periods of heavy rainfall causing animal disease**
Yes, seems possible			**Drought during the summer planting and growing season** **Too much water makes water dirty and spreads diseases**	
No, seems unlikely				
No, rather less often				

Commercial farmers in the Bergville/Winterton area

Will this happen more often in the future?	**If this would happen more often, commercial farmers in the Bergville/Winterton area judge that the severity of the impacts for them would be:**			
	Minor	Moderate	Significant	Catastrophic
Yes, seems certain			**Less frost days in winter causes more pests** **More frequent higher air temperatures (above 32^{o} C) in winter reduce winter yields**	
Yes, seems likely				**High occurrence of fires in winter**
Yes, seems possible		**More surface runoff in summer**	**Dry soil conditions in winter** **Low storage in dams in the beginning of winter**	
No, seems unlikely	**Extensive soil erosion (surface runoff) in winter**		**Dry soil conditions in summer** **Low rainfall during the summer**	
No, rather less often				

Authority group – statements about farming

Will this happen more often in the future?	**If this would happen more often, the authority group judge that the severity of impacts for the impact for <u>small scale farmers in Mhlwazini (SSF)</u> and *commercial farmers in the Bergville area (CF)* would be:**			
	Minor	Moderate	Significant	Catastrophic
Yes, seems certain			**Loss of yields due to pests and diseases (less frost days)**	
Yes, seems likely			<u>**Loss of yields due to reduced land cover, increased erosion (more surface runoff during summer) (SSF)**</u>	
Yes, seems possible	***Loss of yield due to reduced land cover, increased erosion (more surface runoff, more high intensity rainfall during summer) (CF)***		***Loss of yields due to less storage in dams (CF) (increased frequency of years with < 650 mm rainfall (CF)*** <u>**Loss of yields due to high intensity rainfall (SSF)**</u>	<u>**Loss of yields due to insufficient annual rainfall (increased frequency of years with < 650 mm rainfall (SSF)**</u>
No, seems unlikely	***Less summer yields due to low rainfall and dry soils (CF)*** ***Less winter yields due to soil erosion (more surface runoff) (CF)***	<u>**Less winter yields due to dry soils in winter ((SSF)**</u>	<u>**Less summer yields due to low rainfall and dry soils (SSF)**</u> ***Less winter wheat yields due to drier soils (CF)***	
No, rather less often				

Authority group – statement about water resources

Will this happen more often in the future?	**If this would happen more often, the authority group judge that the severity of impacts for water resources in Bergville/Mhlwazini area would be:**			
	Minor	Moderate	Significant	Catastrophic
Yes, seems certain				
Yes, seems likely			**Difficulties to supply water in winter due to increased number of single years with insufficient streamflow generation.** **Problems with off-takes, purification and water quality as well as with sedimentation due to stratification in dams (caused by temperature increase)**	**Dams run dry due to low rainfall during a number (about 5 years) of years.**
Yes, seems possible		**High river flows, caused by higher flow in summer which cause damage locally (including also water quality problems)**		**Major flooding events - risks for dambreaks due to inappropriate dam dimensions**
No, seems unlikely				
No, rather less often				

Authority group – statement about people, cattle and wildlife

Will this happen more often in the future?	**If this would happen more often, the authority group judge that the severity of impacts for *biodiversity* and the direct impact be for <u>people, cattle and wildlife</u> due to changed environmental conditions, in Bergville/Mhlwazini area would be:**			
	Minor	Moderate	Significant	Catastrophic
Yes, seems certain		***Erosion, loss of habitat for aquatic invertebrates,*** **<u>runoff of fertilizers causes Eutrophication</u> (higher river flow in Jan-March)**	**Incidences of <u>parasites and diseases for fishes</u> and *breakdown in the food web* and <u>more outbreaks of insects</u> (warmer water and lower flow in Aug-Sept).** ***Loss of biodiversity and better conditions for alien species*** **(riparian vegetation stressed by low flows, change in channel erosion.**	***Change in biodiversity*** **due to change in timing and frequency of flow peaks.** **<u>Loss of grazing lands, houses, infrastructure, livestock etc due to winter fires (warmer, drier soils)</u>**
Yes, seems likely		***Loss of cold water species and breakup of migration pathways*** **due to thermal stress and low flow.**	**<u>Mosquitoes and bilharzia</u> due to low flow (lower velocity, more reeds)**	***Loss of biodiversity*** **due to that small perennial rivers becoming non-perennial in dry years (increased number of days with low river flow)** ***Spread of alien species*** **due to water transfer to the basin during dry years which extinct natural species**
Yes, seems possible				
No, seems unlikely				
No, rather less often				

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