Climate Risk Case Study

Khimti 1 Hydropower Scheme
Himal Power Limited – NEPAL

International Finance Corporation
World Bank Group

Acknowledgments

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Foreword

It is increasingly recognized that a changing climate is creating risks and opportunities for the performance of private sector investments. Yet, to date, the evidence base on the significance of these issues is poorly defined. Most climate change assessments have focused on large-scale impacts on natural and social systems, and on end of century timescales which appear to be of little relevance to business.

Recognizing this important knowledge gap, International Finance Corporation (IFC) undertook initial pilot studies starting in 2008 with the main aims of testing and developing methodologies for evaluating climate risks to the private sector and identifying appropriate adaptation responses.

The first three pilot studies are:

Khimti 1 hydro-power scheme, Nepal: A 60 MW run-of-river hydro-power facility, generating 350 GWh of electricity per year, located in Dolakha District, about 100 km east of Kathmandu. The facility utilizes a drop from 1,270 to 586 meters above sea level from the Khimti River, a tributary of the Tama Koshi River. Khimti 1 was built, and is owned and operated by Himal Power Ltd (HPL) and, as a Public Private Partnership project, will be transferred to the Nepalese Government in the future.

Ghana Oil Palm Development Company Ltd (GOPDC), Ghana: GOPDC is an integrated agro-industrial company with two oil palm plantations at Kwae and Okumaning, in Ghana's Eastern Region. GOPDC also operate a mill at Kwae, where oil palm fresh fruit bunches are processed into crude palm oil (CPO) and palm kernel oil (PKO). Also at Kwae, a refinery and fractionation plant processes up to 150 metric tons per day of CPO into olein and stearin products.

Packages Bulleh Shah Paper Mills, Pakistan: Packages Ltd is Pakistan's premier pulp and paper packaging company, and has been an IFC client since 1964. The company produces paper and paper board, writing and printing paper, tissue products and flexible packaging products. It uses wheat straw, recycled and waste paper, and imported pulp in its production lines. The newly-established Bulleh Shah Paper Mills (BSPM), near Kasur, has allowed the company to relocate existing pulp and paper production facilities from its headquarters in Lahore to larger premises, to enable it to increase its production capacity from 100,000 to 300,000 tpa.

This report presents the outcomes of the Khimti 1 hydro-power scheme pilot study.

Overview of the approach to the pilot studies

Potentially, the performance of a private sector investment—measured in financial, environmental and social terms—can be affected by changing climatic conditions, particularly when the investment relies on long-lived fixed assets or has complex supply chains. To evaluate potential climate impacts for the three pilot studies, we utilized a climate risk assessment and management framework originally developed in the U.K. Applying the framework involves understanding the linkages between various aspects of business performance and climatic conditions. In some cases, these relationships were developed from data recorded at the study site, and where no site-specific data were available, we drew on the scientific literature. The impacts of future climate change scenarios (based on global climate models) were then evaluated. To analyze financial impacts, we perturbed elements of the clients' financial models. Recommendations were made for adaptation actions that could be considered by the companies, reflecting on the level of confidence in the assessments of risk.

In practical terms, the pilot studies involved:

- Literature reviews and qualitative analysis of impacts,
- A site visit (except in the case of Packages),
- Meetings with in-country sector experts and climate change experts—from the public sector, research institutions, universities and NGOs,
- Meetings with the IFC client, to discuss climatic sensitivities and vulnerabilities, obtain data, reports etc,
- Quantitative modeling of impacts where possible.

There are challenges and uncertainties in undertaking these assessments, which have been revealed through the pilot studies, including:

- Gaps in understanding of the relationships between climate and various aspects of business performance.
- Uncertainties in baseline climate data and in scenarios of future climate change on timescales and spatial scales relevant to individual business. These uncertainties are particularly apparent in relation to changes in extreme climatic events, which may hold the most significant consequences.
- On the shorter timescales of relevance to business, natural climatic variability often dominates the 'signal' of climate change.

However, despite these constraints, the studies have been able to generate new information about climate risks to the private sector. They have also demonstrated some of the practical approaches that can be applied to understand these risks better, and to reduce uncertainty about the future.

Contents

Climate Change Adaptation Case Study: Khimti 1 Hydro-Power Scheme, Himal Power Limited, Nepal

Executive Summary

This report presents the outcomes of a study analyzing the potential risks from climate change for the Khimti 1 run of the river hydro-electric power scheme in Nepal. Khimti 1 is owned and operated by the Himal Power Ltd (HPL). The plant has a capacity of 60MW and an annual production of 350 gigawatt hours. Located in Dolakha District about 100 kilometers east of Kathmandu, it utilizes a drop from 1,270 to 586 meters above sea level from the Khimti river, a tributary of the Tama Koshi river.

Table 1 below presents a high level summary of the risk analyses undertaken for this project.

As described in the climate chapter of this report the area around Khimti Khola has a warm, sub-tropical climate with temperatures between 22–27°C in summer and 10–15°C in winter. The monsoon period lasts from June to September, bringing 250–450mm of rainfall per month. Across Nepal, annual temperature has not risen significantly between 1960 and 2003; in fact, temperatures have decreased slightly between March and August.

Projections of seasonal mean temperature for the area around Khimti Khola indicate an increase in winter of 0.8–3.4°C by the 2030s, rising to 2.0–5.0°C by the 2060s, across a range of 15 global climate models. Corresponding increases for summer months are 0.5–2.0°C by the 2030s, rising to 1.1–3.5°C by the 2060s.

Projections of rainfall change in mountainous regions are more challenging because of the difficulty in adequately representing local climatic effects of varied topography in general circulation models. This is further complicated by the fact that current climate models perform poorly in predicting monsoon behavior. Ensemble mean projections for the area around Khimti Khola indicate a 7% decrease in winter precipitation by the 2030s, with a 12% decrease by the 2060s. For summer, the ensemble mean indicates an increase of 2% by the 2030s, rising to 8% by the 2060s. Depending on the emissions scenario, however, the range of ensemble results is very broad, making projections of seasonal rainfall very uncertain.

There is good agreement among GCMs on future temperature trends in this region; however projections of future precipitation differ widely. This uncertainty means that the benefits of downscaling (which is often recommended as a way to identify specific local impacts) are less relevant. A focused modeling effort on improving understanding of monsoon processes would certainly be beneficial for interpreting divergent GCM results in this part of the world.

This region already deals with a significant amount of inter-annual variability in precipitation. The difficulty of predicting monsoon behavior and changes in precipitation during the dry season with any certainty underlines the need for contingency planning in case of extreme events.

The risk analyses have assessed (within the limitations of the available information) how variability in current climate conditions together with future climate change can affect HPL's operations and have impacts for the local communities. The report identifies where the most important sensitivities are. For some impact relationships between climatic factors and direct and indirect impacts on HPL's operations the lack of baseline information has prevented further analysis. An example of this is the increased risk of flooding on both the Khimti Khola and the Tama Koshi. This illustrates the need for further monitoring and research on baseline conditions in countries like Nepal to enable informed decision making in the face of further climatic change.

The analyses have identified a number of direct project risks, opportunities and vulnerabilities, for example a glacial lake outburst flood and the risk and damage to the main power house buildings. The report also considers some of the indirect project risks where impacts on the local communities may have additional consequences for HPL and its operations.

Adaptation (risk management) options have been proposed for HPL to consider. For the most part these measures are focused on building adaptive capacity rather than delivering adaption action.
In some cases the adaptation options are for others to consider, as for example in the case of potential changes to the PPA.

The report identifies a number of lessons for future hydro-power production in Nepal. These lessons will also have a relevance to the development of similar schemes in other developing countries.

Table 1. High Level Summary of the Risk Analyses Undertaken for this Project

Issue	Most important climate factors	Description of climate risks	Financial impact (US$)	Confidence in the assessment	Recommended adaptation options (owner)
Generation during dry season	Changes in precipitation	Changes in precipitation will have a direct effect on the hydrology of the Khimti Khola river. A hydrological model developed for the case study using inputs from four climate models shows significant changes in dry season flows in the Khimti Khola.	The impact on generating output is most significant during the dry weather season. However there is little consistency between the climate models, with two showing increases in flows and two showing decreases in flows.	Low confidence in projections of changes in precipitation due to inconsistency between GCM model outputs. High confidence in the link between precipitation, flow and generating output.	The information available at this stage is insufficient to enable HPL with any degree of certainty to make any decision on asset replacement or further capital investment. At this stage in the early years of the current PPA and with the major assets having a significant future asset life it is recommended that the adaption options taken by HPL are for the most part directed at building adaptive capacity rather than delivering adaption action. (HPL) Section 8 on Adaptation options contains further recommendations.
Generation during wet season	Changes in precipitation	Changes in precipitation will have a direct effect on the hydrology of the Khimti Khola river. A hydrological model developed for the case study using inputs from four climate models shows significant changes in wet season flows in the Khimti Khola.	Although the impact on flows is greater in the wet season, there is no impact on generating output and revenue. Khimti 1 already operates at capacity during the wet season.	Low confidence in projections of changes in precipitation due to inconsistency between GCM model outputs.	No adaptation options recommended. (Additional capacity could (in theory) be provided by increasing the main tunnel size and adding new turbines. The costs would be prohibitive and would not be utilized during the dry weather season).

Issue	Most important climate factors	Description of climate risks	Financial impact (US$)	Confidence in the assessment	Recommended adaptation options (owner)
Extreme flood event on the Tama Koshi	Changes in precipitation. Changes in temperature.	Changes in precipitation and temperature (including impacts on snow and glacial melt) will have a direct effect on the hydrology of the Tama Koshi river.	Insufficient information is available to undertake a flood risk assessment. HPL's insurance cover does provide for protection in the event of a major flood.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified. Low confidence in ability to calculate financial impacts, resulting from lack of baseline information.	Undertake a detailed flood risk assessment (HPL)
Extreme flood event on the Khimti Khola	Changes in precipitation. Changes in temperature.	Changes in precipitation and temperature (including impacts on snow melt) will have a direct effect on the hydrology of the Khimti Khola river. Sediment loads would increase. The intake structure and sediment channels would be at risk.	Insufficient information is available to undertake a flood risk assessment. HPL's insurance cover does provide for protection in the event of a major flood.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified. Low confidence in ability to calculate financial impacts, resulting from lack of baseline information.	Undertake a detailed flood risk assessment (HPL)

Issue	Most important climate factors	Description of climate risks	Financial impact (US$)	Confidence in the assessment	Recommended adaptation options (owner)
Landslide blocking the Khimti Khola	Changes in precipitation.	Changes in precipitation will have a direct effect on the landslide risks in the area. The risks are compounded by geology and the lack of vegetation and tree cover in many areas. A blockage of the river upstream of Khimti 1 would prevent electricity generation. A flood risk would also be created in the river.	Insufficient information is available to undertake a flood risk assessment. HPL's insurance cover does provide for protection in the event of damage due to landslide and a major flood. Generating outputs and revenues would be affected for the duration of the blockage.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified.	HPL actively monitors landslide risks in the vicinity of its intake structure. No further adaptation measures are recommended.
Landslide blocking road access to Kirne	Changes in precipitation.	Changes in precipitation will have a direct effect on the landslide risks in the area. The risks are compounded by geology and the lack of vegetation and tree cover in many areas. A blockage of the access road would create a temporary restriction.	There are frequent landslides in the area. HPL's site contingency plans provide for storage of essential supplies on site. The main assets can all be reached by helicopter. It is unlikely that generating outputs and revenue would be affected.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified.	No specific adaption options are recommended.

Issue	Most important climate factors	Description of climate risks	Financial impact (US$)	Confidence in the assessment	Recommended adaptation options (owner)
Local community livelihoods	Changes in rainfall and precipitation during both the dry and wet seasons).	The subsistence farming in the area creates existing vulnerabilities. Farmers report declining yields due to changes in the monsoon. Other aspects of community well-being are also vulnerable to climate, including transport, health, and water quality.	The direct financial impacts on HPL and Khimti 1 are minimal.	Low confidence in the climate models ability to show changes in the monsoon at a regional level.	Continued support for local communities. (HPL)
Glacial lake outburst flood	Combination of temperature and precipitation.	Glacial retreat has been observed in some parts of the Himalayas. The IPCC recently reaffirmed that 'widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century. The deterioration of the moraine dam on the Tsho Rolpa glacier and its potential implications downstream on the Tama Koshi catchment are well documented. Remedial works have been undertaken to the Tsho Rolpa glacial lake.	It is not known if a GLOF would affect Khimti 1. Insufficient information is available to undertake a flood risk assessment. HPL's insurance cover does provide for protection in the event of a GLOF.	High confidence in projections of higher temperatures. Low confidence in ability to calculate financial impacts, resulting from lack of baseline information.	Reinstate early warning remote monitoring systems (Nepal Government). Undertake a detailed flood risk assessment (HPL)

Issue	Most important climate factors	Description of climate risks	Financial impact (US$)	Confidence in the assessment	Recommended adaptation options (owner)
Power Purchase Agreement	Changes in precipitation	The dry weather flows in the Khimti Khola will change.	There are underlying issues with regard to the PPA that are unrelated to the impacts of climate change. A number of the adaptation recommended in Section 8 will need to be considered within the context of these underlying issues and their resolution.	High confidence in the link between precipitation, flow and generating output.	The analysis using some of the climate models points to changes in flows.
Increase in irrigation demand. Pressure to increase minimum flow at Khimti 1 intake	Changes in rainfall are most critical (during both the dry and wet seasons), though temperature extremes can also affect crops	Yields are declining for many of the crops grown using traditional forms of subsistence farming. Other aspects of community well-being are also vulnerable to climate, including transport, health, and water quality.	Climate impacts on agriculture will have social and economic impacts for the local community. It may also result in pressure on the NEA to review the PPA, and on HPL to increase the minimum flow. Generating output under all climate scenarios would decrease.	High confidence in the adverse impact on revenues if the minimum flow is increased.	HPL may wish to consider the following actions: 1. Provide support to local farmers for the construction of irrigation systems drawing water from tributaries of the Khimti Khola. 2. Actively support the development of alternative agricultural practices and crops. By encouraging the use of drought resistant crops the need for additional irrigation may be reduced when compared with the needs for current agricultural practices.

1. Introduction

This report presents the approach, methods, results, lessons learned and conclusions of the climate change risk assessment and management study undertaken for the hydropower project named ‘Khimti 1’ and owned in majority by the company Himal Power Limited (HPL).

The report provides a concise technical review of the climate risk case study. It should be read in association with the information and data located in Appendix 4.

2. Description of the Khimti 1 Project

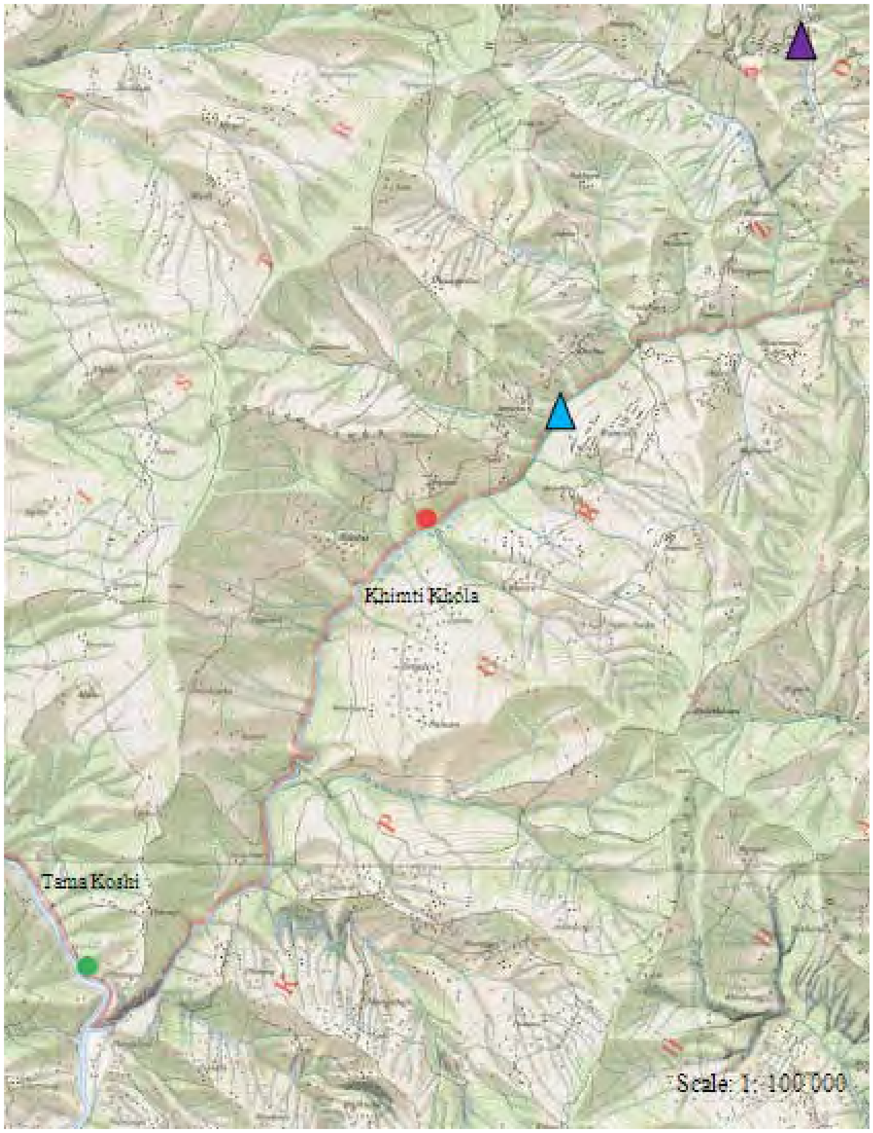
General Description

The Khimti 1 Project (‘the Project’) is a run-of-the-river hydroelectric power generation plant located in the Dolakha district, in the central region of Nepal (Figure 1). It is owned and operated by HPL and has been in operation since July 2000. Its construction was financed half by debt and half by equity.

Facts	
Location	Dolakha District 100 kms east of Kathmandu, Nepal
Installed capacity	60MW
Type	Run-of-river
Annual average output	350 GWh
Gross head	684 meters
Design flow	$2.15m^3$/sec per turbine, $10.75m^3$/sec total flow
Main assets	Five double jet pelton turbines, underground powerhouse, steel lined penstock
Commercial operation commenced	July 2000
Capital cost	US$140million
Power Purchase Agreement	20 year PPA with the Nepal Electricity Authority
Current Equity owners	SN Power 50.4%, Bergenshalvoens Kommunale Kraftselskap AS 23%, Butwal Power Company 14.9%, ALSTOM Power Norway AS 5.8%, GE Energy Norway AS 5.8%
Original project financing provided by:	IFC, ADB, Exsportfinans AS, NORAD, Nordic Development Fund

Figure 1. General Indication of the Khimti Khola Catchment in Nepal (red tag)

Access to the Project area is by a road 22 km long constructed by the Government of Nepal to link the power house site at Kirne to a junction where there was a pre-existing road to Jiri, 175 km from Kathmandu. There is no road access between the intake and the power house. There is a helicopter landing platform at the intake structure and at the power house site.



Legend

Jiri meteorological gauging station

Rasnalu flow gauging station

Khimti 1 intake point

Kirne – location of Khimti 1 power house and outfall to the Tama Koshi river

Figure 2. Khimti Khola River

Technical Description

The main technical features of the scheme are:

- A concrete diversion dam of about 2.5 meters high leads water through a two chambered de-sanding basin. The open basin is located on the right river bank and includes a flushing system.
- Water flows into a low-pressure headrace tunnel of 7,620 meters which ends in a surge chamber.
- A steel-lined and concrete pressure shaft (pipe) with an inclination of 45º leads water to the underground powerhouse.
- The powerhouse has an access tunnel 890 meters long and a volume of 6,700 m^3. It has five horizontal double jet Pelton turbines fitted on the extended shaft of the alternators (12,000 kilowatt, 750 RPM).
- The design flow for each turbine is 2.15 m^3/sec with a total flow of 10.75 m3/sec.
- Water flows through a tailrace tunnel, approximately 1,418 meters long, into the Tama Koshi River.
- The generated power is transferred at 10 kilovolt through bus-bars located in the access tunnel to outdoors transformers, forming HPL's Kirne substation, where the voltage is stepped up to 132 kilovolt for supply to the national grid.
- In total, the maximum vertical distance (gross head) between the water intake at elevation 1270 meters and the downstream tail water injected back in the Tama Koshi river at elevation 586 meters is of about 684 meters. The total length of the waterways within the Project, including the headrace and tailrace tunnels—is approximately 10 km.
- The Khimti 1 plant was designed with a total installed generating capacity of 60 megawatts and an average annual production of 350 million kilowatt-hours (or 350 megawatt-hours) of electrical energy.

The project agreement between the Government of Nepal and HPL was signed on the 15 January 1996. This sets out a number of obligations on both parties including, for example a responsibility on the Government of Nepal to undertake remedial works to the Tsho Rolpa lake to minimize the risk of a glacial lake outburst flood (GLOF).

Khimti 1 Power House and Compound at Kirne

Power Purchase Agreement (PPA)

HPL signed a 20-year Power Purchase Agreement (PPA) with the Nepal Electricity Authority (NEA) on the 15 January 1996. All the generated electricity is sold to the NEA. HPL does however retain the right to sell electricity to any third party.

The PPA provides for the ownership of the plant to be transferred to the NEA in stages in 2020 and 2050. In 2050 the Government will have full responsibility for both operational (revenue) expenditure and capital expenditure to maintain the Project, replace assets at the end of their operational life and carry out any improvements or adaptation actions.

In the years since the plant became operational HPL has been able to generate energy above the contract level during the dry season.

HPL's Social and Environmental Responsibilities

The Project has complied with the social and environmental performance standards of the Asian Development Bank and the IFC. One of HPL's shareholders, SN Power, is part owned by a Norwegian risk capital investor funded by the government which also has social and environmental objectives.

During the four-year construction phase the Project employed an average of 2,300 people per annum of which 62% originated in the two districts in which the project is located. The project now employs approximately 150 people who reside in the local area.
It is widely acknowledged that HPL's investment in community development has had a positive impact on the livelihoods of approximately the people living in the project area. The Project committed up to US$ 25,000 per annum to contribute to local development initiatives put forward by the Village Development Committees (VDC) with jurisdiction in the project area.

HPL has various community development programs including the following:

- The Project has supported the 'Jhankre Rural Electrification and Development Project' which is providing power to approximately 40,000 people;
- HPL provided support to farmers on irrigation for agriculture within the Project area by constructing, refurbishing and repairing irrigation canals that use flows from the tributaries of the Khimti River;
- The project has monitored fish stock levels and has provided advice and support to fishermen, including discouraging the inappropriate use of poison and supporting fish breeding schemes;
- Improvements made to sanitation and drinking water;
- HPL funded the construction and improvement of footbridges;
- HPL promotes enterprise development and supports the development of literacy skills and skills training of local community;
- HPL constructed a new school and has continued to support education in the area by improving buildings and providing salaries for additional teachers—and 'Non-Formal Education' classes (particularly women's credit groups);
- HPL has promoted public health awareness, constructed a new clinic and dispensary and supported the training of health personnel;
- HPL constructed two police posts.

During the period of the insurgency ending with the election in 2008, HPL continued to provide support and assistance to the local communities.

Future Developments

The NEA is constructing a new transmission line from Khimti 1 to Dalkhebar. This will give NEA and HPL the option of dispatching energy from Khimti 1 to the eastern parts of Nepal.

3. Risk Assessment and Management Methodology

Key Messages

- Maintaining full project documentation is important to enable subsequent climate risk assessments to be undertaken. This should ensure that the host country has access to the information, subject to any commercial confidentiality concerns. This would assist in building climate change adaptive capacity.
- A standard requirement on hydro-power projects to provide a copy of all hydrological assessments and data to relevant local in-country stakeholders is recommended.
- The availability of adequate baseline data creates challenges for risk assessment and the design, appraisal, construction and operation of infrastructure projects in Nepal.

Introduction

The project uses a risk assessment and management framework adapted from a 'best-practice' process recommended by the UK Climate Impacts Programme (UKCIP).

The framework sets out eight stages, of which the first six were used in the project (see Figure 3):

- Stage 1: Establish the project objectives.
- Stage 2: Establish the project decision-making criteria.
- Stage 3: Assess project climate change risks.
- Stage 4: Identify adaptation options to address the climate change risks identified.
- Stage 5: Appraise adaptation options against the project decision-making criteria.
- Stage 6: Formulate recommendations to HPL for making adaptation decisions.

Figure 3 illustrates the risk-uncertainty decision-making framework which forms the basis of the case study methodology. The key questions to ask at each stage of the process are shown in the speech boxes in the figure.

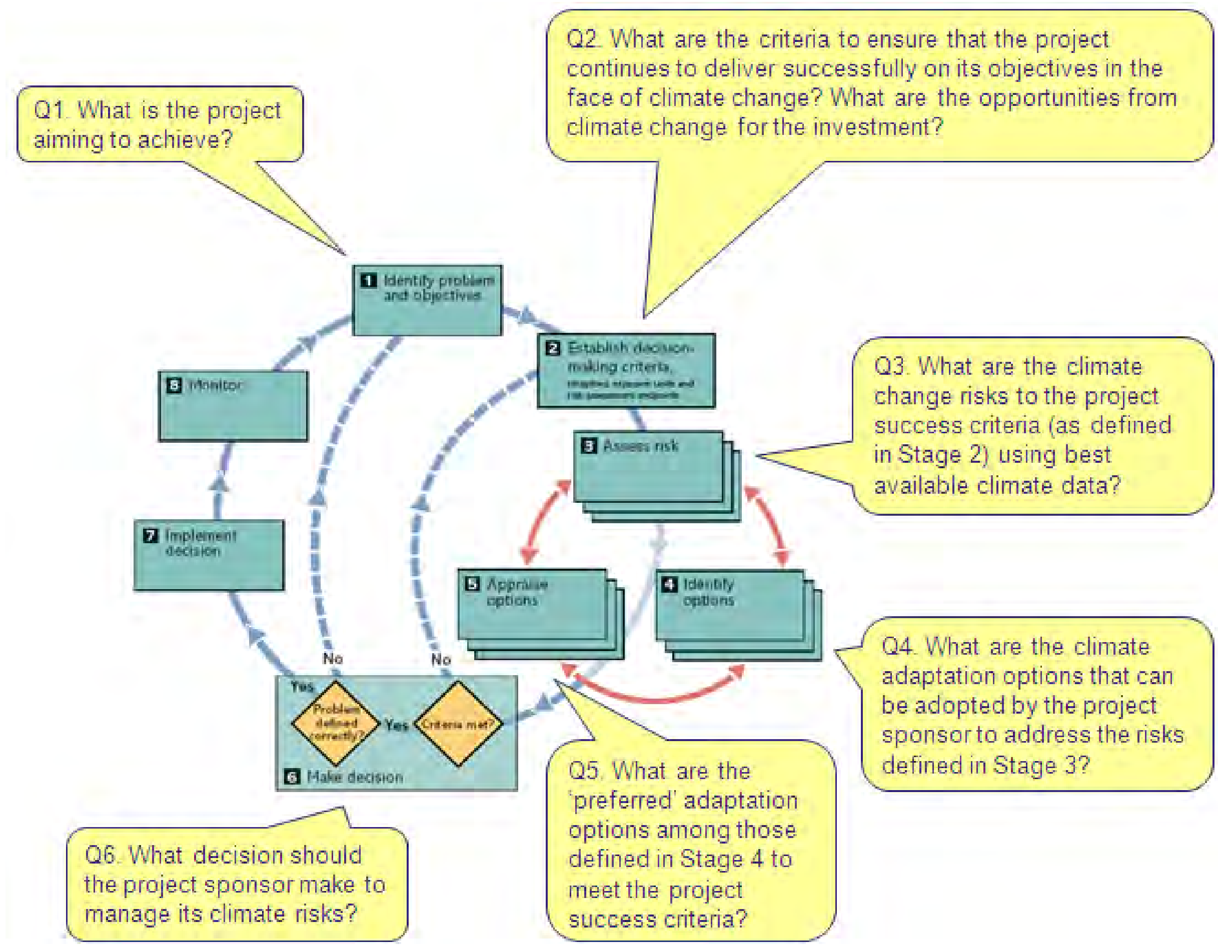


Figure 3. Risk Assessment and Management Methodology Used in the Study

Source: Adapted from Willows and Connell, 2003.

Stage 1: Establish the Project Objectives

Methodology

Based on available information and following discussions with IFC and HPL the parameters of the risk assessment and management study were established.

The Project objectives of HPL, IFC and the NEA were defined using the following:

- IFC's published information,
- Discussions with HPL and IFC staff, and
- Information provided in the contractual agreements between HPL and the Nepalese Government.

The impact of current climate conditions and the existing control measures in place to manage climate variability were identified. Key stakeholders were also identified and their climate-related vulnerabilities and the risks and potential implications for Khimti 1. For a list of other stakeholders with an interest in the project, please refer to Appendix 4, page 71 (top).

Results

Project objectives

Figure 4 below summarizes the key Project objectives for HPL. IFC and the NEA. Further information is available in Appendix 4, pages 70 (bottom) and 88 (top).

HPL	IFC	NEA
Generate electricity to supply it to the national grid on a commercial basis. Return on investment. Secure income, managed operational costs and profit. Excellent community relations, social and environmental management. Competitive advantage through enhanced reputation.	Return on investment. Delivery of sustainable social and environmental improvement objectives.	Develop Nepal's hydropower potential. Secure 60MW electricity into the grid system Develop rural electrification schemes. Environmental impacts minimized. Secure the construction of a new school and clinic Provide local .employment and procurement opportunities. Transfer technical and managerial skills and expertise. Develop Nepalese technical capability. Develop literacy skills and skills training of local community.

Figure 4. Objectives of HPL, IFC and the NEA Regarding Khimti Khola

Climate-Related Project Vulnerabilities

Design, appraisal and operational documents for the Khimti 1 project were reviewed in order to assess existing climate-related vulnerabilities and to identify control measures. The original EIA for the site together with engineering design and hydrological assessments were not found within the IFC records for the site. HPL also was unable to provide copies of these documents. Maintaining full project documentation is important to enable subsequent climate risk assessments to be undertaken. IFC should ensure that its documentation is complete and in furtherance of its own sustainability objectives should ensure that the host country has access to the information, subject to any commercial confidentiality concerns. This would assist in building climate change adaptive capacity.

The full hydrological assessment for the project was not available. Extracts from a report were included within subsequent reports (for example a report looking at the impact of the project on fisheries) and these were used. There is no evidence that at the Project appraisal stage any potential change in climate or in the hydrology of the river due to climate change was considered. The power house site was designed taking into account a ‘probable maximum flood’ (PMF). However neither IFC nor HPL had any information regarding the basis of the PMF, and its calculation. There was also no information regarding flood levels.

The Project appraisal documentation did refer to the risk of flooding from a GLOF from Tsho Rolpa, but again without providing any information on potential flood levels, risks, and damage. In the discussions with the NEA the risks from Tsho Rolpa were recognized and covered in the Project Agreement. HPL has provided a set of flood gates on the main entrance tunnel to the turbine house. Discussions with HPL’s insurers have also included recognition of the potential risk. It is understood that the flood risk cover provided by the insurer includes GLOF.

Remedial works have been undertaken to Tsho Rolpa to reduce the risk of a GLOF. A series of remote early warning and monitoring stations was installed in the late 1990’s although it is understood that these are no longer operational.

HPL has not undertaken and has no current plans to assess the potential impacts of climate change on the Khimti 1 site.

For further information on climate-related vulnerabilities and control measures, please refer to Appendix 4, page 70 (top).

The potential implications of not addressing existing climate variabilities for the Project were defined as:

- Changes in river flows and water temperature could influence a change in the minimum river flow requirement to protect downstream fisheries and allow abstraction for irrigation.
- Changes in precipitation will change the return periods and intensity of flood events.
- Flows in the Tama Koshi will be affected by increasing snow and glacial melt. Anecdotally, local communities reported that they have observed the snowline rising in altitude and more snow falling on the mountains, as well as more rainfall. (The Khimti Khola does not have any glaciers within its catchment and for the most part is below the snowline).
- Increasing storm intensity together with changes in precipitation and river flow will increase the significant risk of erosion and landslide with implications for access roads, operational structures, bridges and sediment loads. Anecdotal evidence from farmers reports that the Project area is experiencing more localized extreme storm events.
- Changes in air and water temperature, precipitation and water quality may create health risks to Khimti Khola workers, local partners and communities.

Climate-Related Issues Accounted for at the Project Level

HPL has installed a set of gates to the turbine hall entrance tunnel to protect against flooding of the generators and tunnel.

The Government of Nepal has taken remedial actions at the Tsho Rolpa glacier lake to reduce the risk of a GLOF and installed an early warning system. The early warning system is no longer in operation.

Project Timescales

HPL provided information on the design asset life for individual items of plant equipment, for example, 15 years for control gear, 40 years for generators and 75 years for the main tunnel. Subject to the standard of maintenance Khimti 1 and appropriate levels of investment and operational expertise Khimti 1 can be expected to be operating in the following century, although clearly individual assets would need to be replaced.

The timescale of HPL's financial exposure in Khimti Khola informed the scope of the study. In particular it was noted that:

- IFC's direct involvement in the project has now finished, although it retains an interest in the long term sustainable development benefits of the Project.
- HPL will transfer ownership of Khimti Khola in 2020 and 2050 to the Nepal Electricity Authority. This will have implications for the risk attitude that HPL may have and the timing, implementation and financing of potential adaptation measures before the transfer.

For more details please refer to Appendix 4, page 71.

Stage 2: Establish the Project Decision-Making Criteria

Methodology

Based on the information and discussions with IFC and HPL the most important decision-making criteria were identified. A value chain approach was used to explore these criteria and vulnerabilities of Khimti 1 (see Figure 5).

These decision-making criteria are important to identify the key climate change risks to the Project and appraise possible adaptation options. It is by understanding the linkages between climate hazards and these decision-making criteria that the likelihood of critical thresholds being exceeded due to climate change can be assessed.

This stage also involved establishing HPL's 'risk attitude' with regard to Khimti 1 given the uncertainties in the timing and magnitude of the impacts of climate change.

Results

Project Decision-Making Criteria

The following key decision-making criteria for the operation and management of Khimti 1 were identified:

- **Maintaining generating output above the contract output level**:
  This is for HPL to ensure excess energy payments during low-flow dry weather conditions.

- **Maintaining operating efficiency:**
  HPL has to meet a 'Minimum Performance Standard' set out in the PA requiring both a net electricity generating capacity of at least eighty percent (80%) of the Project's nameplate capacity and a net generating capacity per unit of no less than 9,000 kilowatts. This requires maintaining the integrity and operational performance of the major Project assets (including the tunnel and turbine runners) and to keep a well-managed and technically competent workforce.

- **Minimize risk of flooding from the Khimti Khola and Tama Koshi rivers**
  The intake and power house structures, together with the accommodation blocks at Kirne are potentially at risk from extreme flooding events (normally associated with the monsoon period). On the Tama Koshi the maximum flood discharge has been estimated as 3,900 m^3/sec (as stated in the PPA). No supporting evidence or calculations have been found for this figure.

- **Monitor river flows in both the Khimti Khola river:**
  HPL is under an obligation to maintain dry weather flows above 0.5 m^3/sec downstream of the Khimti 1 intake.

- **Minimize risk of GLOF:**
  In the catchment of the Tama Koshi the Tsho Rolpa lake provides the case study for GLOFs in the IPCC Fourth Assessment Report. It is understood, following discussions with HPL, that a flood risk assessment has not been undertaken for Khimti 1, despite the potential high consequences of such an event. The PPA between HPL and the Government contains an obligation on the Government of Nepal to undertake remedial works to the Tsho Rolpa lake and to install an early warning system for the GLOF.

- **Maintain a secure supply chain:**
  Khimti 1's isolated location makes it very vulnerable to supply disruption. It relies on the NEA grid system for transmitting the power it generates. The PPA commits the NEA to purchase the generating output even if the transmission system has failed. Reliable fuel supplies are required for plat operation and maintenance. Khimti 1 relies on the availability of local and regional procurement for food and other essential supplies (including raw materials). The PPA agreement contains an obligation on the Government of Nepal to ensure that Khimti 1 has priority access to supplies in the event of a shortage.

- **Enhance reputation and brand:**
  Brand value can be important in delivering competitive advantage when seeking licenses and regulatory approvals for new operations.

- **Minimize social and environmental impacts and maintain a positive relationship with the local community:**
  Due to the isolated location of the Project in a poor rural area and the period of insurgency until the end of 2007 social issues were considered as critical success. In an area where there is limited government presence, HPL has taken on a de-facto role in ensuring socio-economic and political community stability by providing power, heath and education services. It has also created local employment and procurement opportunities.

Linkages Between Decision-Making Criteria and Implications of Climate Change

The Project value chain diagram below presents Khimti Khola's key decision-making criteria and how they may be impacted by changes in climate and their compound effects.

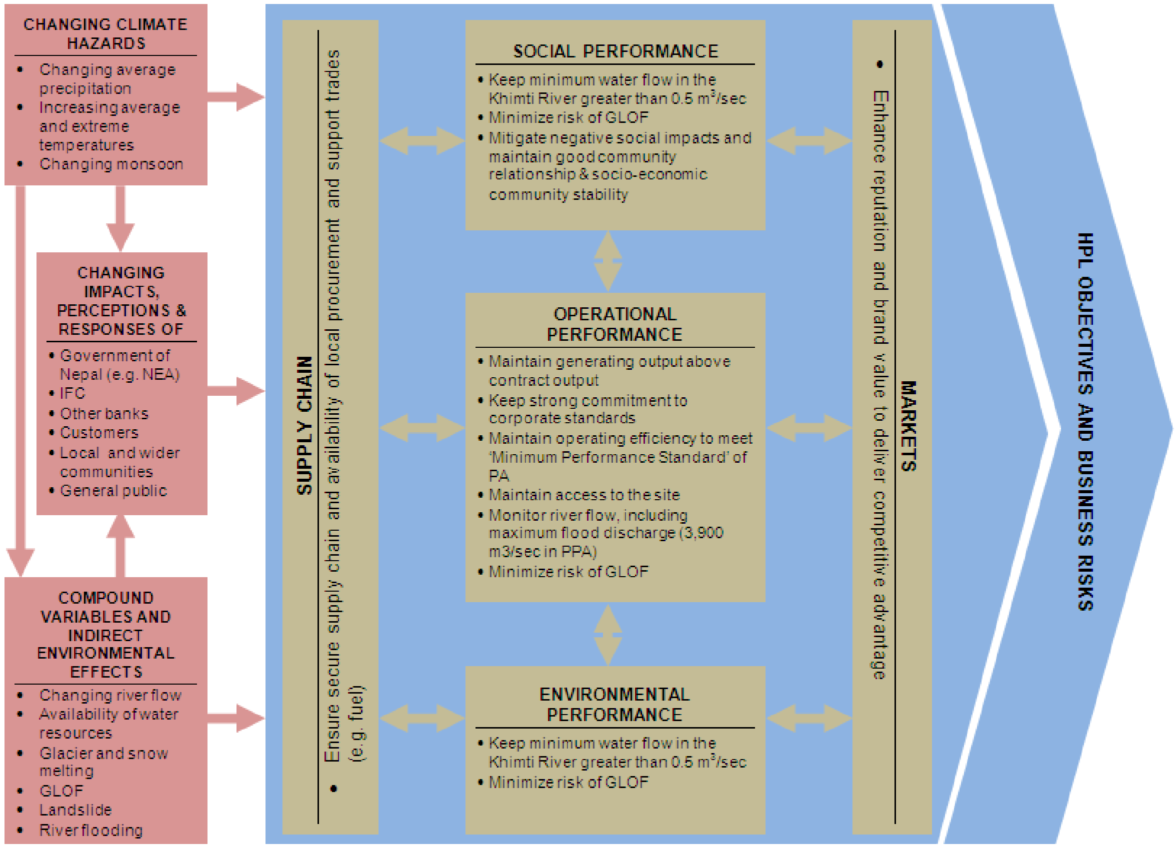


Figure 5. Value Chain Diagram Representing the Linkages Between Changes in Climate Factors, their Compound Effects and the Project Success Criteria

See Appendix 4 for further information.

Decision-Making Constraints:

In assessing risk and recommending adaptation options, consideration was given to the influence that the PPA has in future decision making and adaptation responses.

HPL's Risk Attitude

Khimti Khola is inherently a high risk project for the following reasons:

- It was the first private hydropower scheme in Nepal.
- The project is in a challenging environment.
- The construction of the project involved complex logistical and technical engineering issues (particularly with regard to the construction of the tunnel).
- The region has an unstable political context and no favorable investment climate.

Adaptation Constraints Stemming from the Project

Khimti 1 may have detrimental impacts on the adaptive capacity of the local population and surrounding ecosystems arising from changes in demands and increased competition for water from the Khimti Khola. Increasing temperatures and changes in precipitation during the dry weather season may increase the need for additional irrigation. Additional flows may also be needed to maintain viable downstream fisheries and ecosystems. This issue is explored as a potential indirect risk for Khimti Khola in scenario 6.

However these potential constraints should be set against the social and economic improvements that have taken place in the area as a direct result of the Khimti 1 project.

Stage 3: Assess Project Climate Change Risks

Existing Project Climate Vulnerabilities

The environmental, social and engineering issues were considered to understand Khimti 1's existing vulnerabilities and exposures. A literature review was undertaken supplemented with further discussions with HPL and key stakeholders to identify those issues that may be influenced by climate change.

The following key issues were identified:

- Low river flows below 0.5 m^3/sec prevent electricity generation.
- Flooding from localized storm events creates short duration flooding, higher sediment loads and detritus causing operational problems for the management of the intake and increasing the risk of erosion to structures.
- Localized storms can create landslides, blocking access roads. Although there have not been any landslides affecting the operation of the Khimti 1 assets during its operation, the risks associated with the geology of the area are recognized. In the vicinity of the intake, small landslides can occur due to the unstable geology. Preventive works have been undertaken to the intake structure in the event of a landslide on the hillside above the settlement chambers to stabilize the ground.
- In 2000 before generation commenced a landslide blocked the Khimti Khola upstream of the inlet. Construction machinery was still on site allowing the blockage to be removed. Any future blockage would have to be removed by manual labor. Generating output would be lost during the blockage.
- Lightning strikes occur regularly and cause damage to the transmission system. As soon as a strike occurs it trips the switches (protecting the power station) which can then be reset in a couple of hours. HPL could not recall any other incidents of transmission loss.

Development of Climate Change Risk Scenarios

Five scenarios were developed for direct and indirect business risks as a result of climate change for Khimti 1. It was decided with the IFC Project Manager that for some risk scenarios (GLOF, extreme river flooding, and major landslide) that only a qualitative appraisal would be undertaken. The absence of adequate baseline data on which to base an assessment prevented any quantitative analysis. One scenario received a more detailed analysis, change in stream flow on the Khimti Khola river.

Presentation of Climate Change Direct Risk Scenarios (see Appendix 4, pages 98 (bottom) through 103)

- **Scenario 1: Glacier Lake Outburst Flooding (GLOF)**
  GLOFs are a type of flooding event specific to lake glaciers where moraine dams overflow or burst as a result of increased glacier melting and erosion. GLOFs have occurred in Nepal many times in the past with significant consequences for communities and infrastructure. According to one study (Pokharel) there are a total of 159 glacial lakes in the Tama Koshi catchment, including the Tsho Rolpa lake which provides the case study for GLOFs in the IPCC Fourth Assessment Report.

  Scenario 1 refers to a 'low probability and high consequence' event of extreme flooding affecting the turbine house, the power station site, the main access road and/or the workforce accommodation.

- **Scenario 2: Extreme river flooding on the Tama Koshi**
  Although there have not been any serious flood events affecting the Khimti 1 plant since it was constructed, there is a risk of catastrophic monsoon flood. Indeed, there have been a number of severe floods in Nepal as documented by the International Centre for Integrated Mountain Development (ICIMOD in Shrestha et al., 2007), including several events on the Tama Koshi for which limited information is available.

  Scenario 2 is a 'low probability and high consequence event' that has the potential to affect the power station site, the main access road and/or the workforce accommodation.

- **Scenario 3: Extreme river flooding on the Khimti River and its tributaries**
  Since Khimti Khola was constructed, there have not been any serious flood events on the Khimti River affecting the intake structure. However, the risk of a catastrophic monsoon flood remains. For example, there have been a number of severe floods in Nepal as documented by ICIMOD.

  Scenario 3 is a 'low probability and high consequence' event that has the potential to affect the intake structures.

- **Scenario 4: Change in stream flow on the Khimti River**
  Scenario 4 explores the impact of climate-triggered changes in river flow on the Khimti Khola and the affect on power plant generating output. An empirical hydrological model specific to the site using a multivariate regression analysis was developed for this report.

  Scenario 4, is a 'high probability and high consequence' event, that has the potential to affect the generating output and revenues for Khimti 1.

- **Scenario 5: Major landslide blocking flow in the Khimti River**
  Scenario 5 explores the impact of a major landslide blocking river flow on the Khimti River.

  Scenario 5 is a 'low probability and medium consequence' event that has the potential to temporarily affect the generating output and revenues for Khimti 1.

Changes in the sediment loading in the Khimti Khola river were not explored as a direct business risk scenario, although it has the potential to affect turbine efficiency. In discussions with HPL it was agreed that the operational impacts are low at Khimti 1 due to the design of the sedimentation channels which have been operating very efficiently. In addition the maintenance regime and the ability to regularly change the runners have reduced the potential impact on turbine efficiency. HPL has stated that the erosion observed on the turbine runners has been less than expected.

Stage 4: Identify Adaptation Options

For both climate change scenarios 4 and 6, the revenue impacts of not taking any actions to adapt to the consequences of climate change were assessed. A number of adaptation options were identified to ensure that Khimti 1 continued to meet the overall project objectives and decision-making criteria. The following broad categories of adaptation options were considered:

- 'No-regret' measures that deliver benefits exceeding costs, whatever the extent of climate change.
- 'Low-regret' measures that are low cost and have potentially large benefits under climate change.
- 'Win-win' measures that contribute both to climate adaptation and to other business objectives and key performance indicators.
- Adaptive management which consist of keeping options open for future climate adaptation, for example by putting in place incremental adaptation options over a project's lifetime, rather than undertaking large-scale adaptation in one step.
- Avoiding adaptation constraining actions which will make it more difficult to cope with future climate risks.

Stage 5: Appraise Adaptation Options

Appraising different adaptation options against the decision-making criteria identified in Stage 2 involved making trade-offs between the engineering, environmental, social and financial implications of the adaptation measures considered. It also included choices of *how much* (if any) adaptation HPL might want to invest in and *when* to carry out such measures.

Stage 6: Recommendations

This stage corresponds to the summary and presentation of the study results as a 'package' with a final report making recommendations on how to best manage the climate change risks identified.

4. Climate Analyses (Baseline and Modeling)

Key Messages

- The area around Khimti Khola has a warm, sub-tropical climate with temperatures between 22–27°C in summer and 10–15°C in winter. The monsoon period lasts from June to September, bringing 250–450mm of rainfall per month.
- Across Nepal, annual temperature has not risen significantly between 1960 and 2003; in fact, temperatures have decreased slightly between March and August.
- Projections of seasonal mean temperature for the area around Khimti Khola indicate an increase in winter of 0.8–3.4°C by the 2030s, rising to 2.0–5.0°C by the 2060s, across a range of 15 global climate models. Corresponding increases for summer months are 0.5–2.0°C by the 2030s, rising to 1.1–3.5°C by the 2060s.
- Projections of rainfall change in mountainous regions are more challenging because of the difficulty in adequately representing local climatic effects of varied topography in general circulation models. This is further complicated by the fact that current climate models perform poorly in predicting monsoon behavior. Ensemble mean projections for the area around Khimti Khola indicate a 7% decrease in winter precipitation by the 2030s, with a 12% decrease by the 2060s. For summer, the ensemble mean indicates an increase of 2% by the 2030s, rising to 8% by the 2060s. Depending on the emissions scenario, however, the range of ensemble results is very broad, making projections of seasonal rainfall very uncertain.
- **(Department of Hydrology and Meteorology) (Nepal Government)** There is good agreement among GCMs on future temperature trends in this region; however projections of future precipitation differ widely. This uncertainty means that the benefits of downscaling (which is often recommended as a way to identify specific local impacts) are less relevant. A focused modelling effort on improving understanding of monsoon processes would certainly be beneficial for interpreting divergent GCM results in this part of the world.
- **(All stakeholders)** This region already deals with a significant amount of inter-annual variability in precipitation. The difficulty of predicting monsoon behavior and changes in precipitation during the dry season with any certainty underlines the need for contingency planning in case of extreme events.

Introduction

An overview of historical, present day (baseline) and future climate data is presented in this chapter for the area around Khimti Khola, including the best currently available projections of future climate. As far as possible, projections have been provided on timescales which correspond with the project financial model. The future climate projections presented here are used in subsequent chapters to assess climate change-related risks to the Khimti Khola project. A number of freely accessible data sets, methodologies and tools for climate change risk assessment were sourced for use in this section.

See Appendix 4, pages 72 through 81 (top).

Results

Observed Long-Term (30-year) Average Climate

Observed climate for the project location was analyzed using meteorological data provided by the Royal Netherlands Meteorological Institute (KNMI), which collates and validates meteorological data from around the world. These are provided for the two closest meteorological stations to the project site: Jiri and Janakpur (station numbers 1103 and 1111). Jiri and Janakpur are both approximately 20km (north and south) from Khimti Khola power station, at altitudes of about 2,000m and 78m, respectively. This difference in altitude explains the difference in baseline climate for each station. By comparison, the project altitude is approximately 700m. Observed monthly data from 1971 to 2000 for maximum and minimum air temperature (°C) and monthly average rainfall (mm) are shown below.

Average Monthly Maximum and Minimum Air Temperature

Figure 6 shows observed monthly air temperatures over the period 1971–2000, for two meteorological monitoring stations near Khimti Khola (the project site is roughly mid-way in altitude between Jiri and Janakpur). It is important to remember that these monthly averages of minimum and maximum air temperature may encompass both a high daily and a high inter-annual variability.

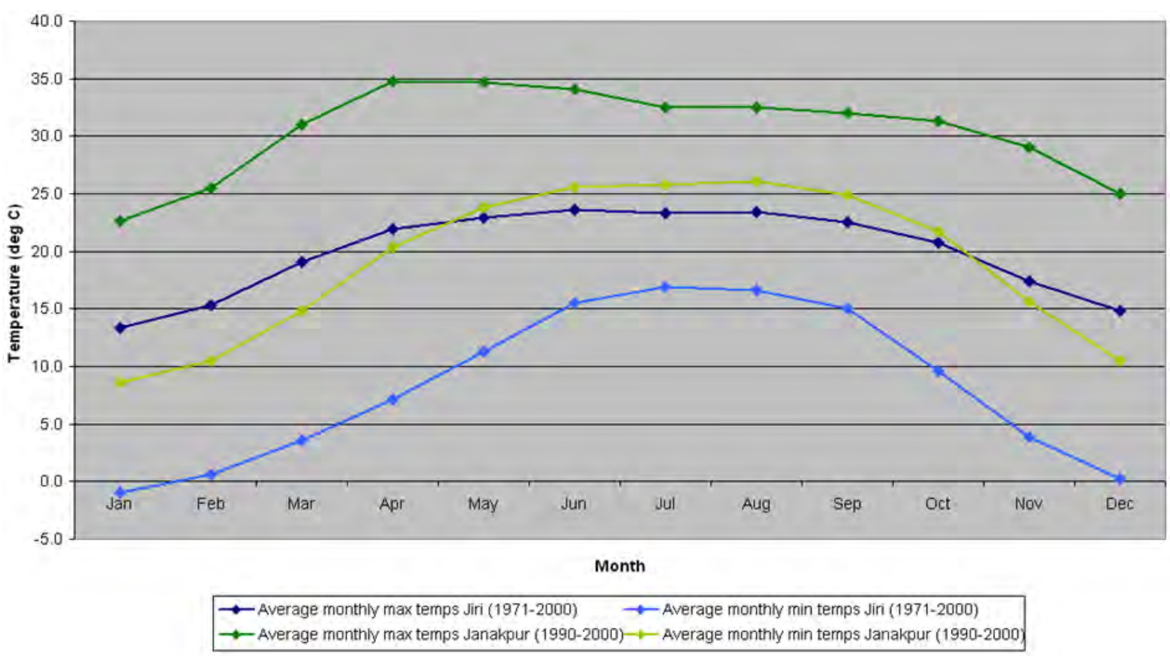


Figure 6. Average Monthly Maximum and Minimum Air Temperature (°C) for Jiri and Janakpur Meteorological Stations Between 1971 and 2000

Source: Data provided by the Royal Netherlands Meteorological Institute.

Average Monthly Rainfall

Local meteorological records show a very high daily variability in precipitation which is somewhat masked by monthly average estimates.

Based on published information,[i] the rainfall pattern in Nepal is characterized by three rainfall seasons:

- The dry pre-monsoon season (March–May),
- The wet monsoon season (June–September), and
- The dry post-monsoon season (October–February).

The values from Jiri for 1997–2006 (in) clearly show the monsoon season, from an average of 100–200mm in May to over 600mm in July. The monthly average rainfall during the dry season is below 100mm per year (from October until June).

Figure 7 shows that monthly rainfall at Jiri is highly variable from year to year (as shown by the error bars depicting the range of minimum and maximum monthly rainfall), particularly during the monsoon season.

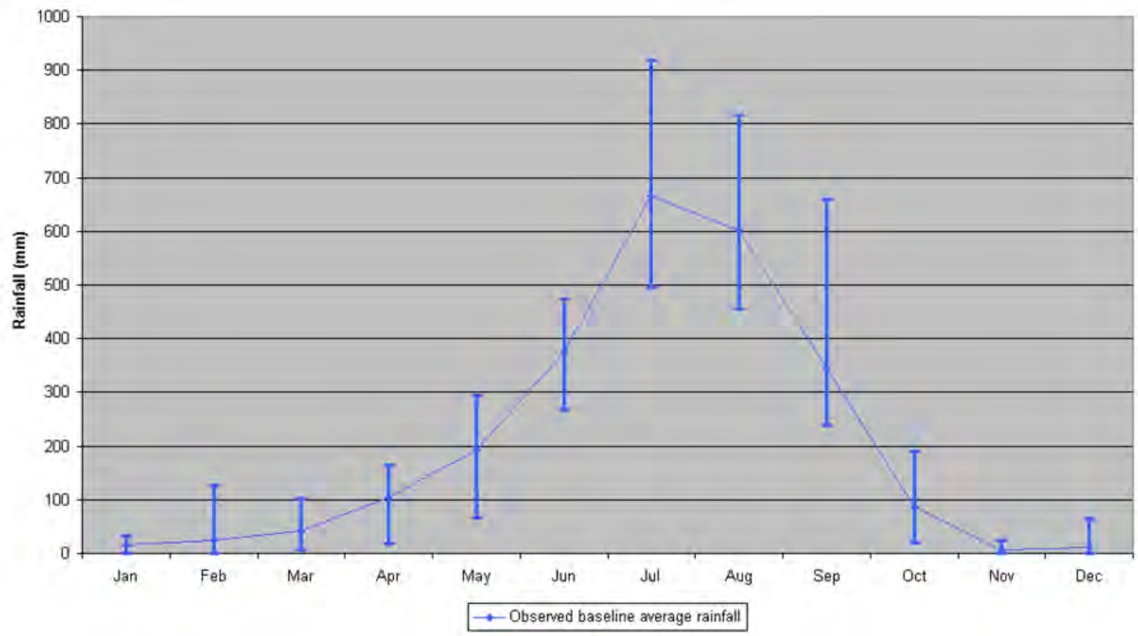


Figure 7. Average Monthly Precipitation (mm) for Jiri Meteorological Station Between 1997 and 2006 (error bars show the range of minimum and maximum monthly rainfall over this period)

Source: Based on daily data purchased through the Nepalese Meteorological Office.

Recent Trends in Temperature and Rainfall

Annual average temperature has not changed significantly in Nepal between 1960 and 2003. However, temperatures have decreased slightly during the months of March to August.[ii]

Average monthly rainfall in Jiri between 1985 and 2006 does not show any significant trends—even though the linear regression line for July–September (JJAS) seems to indicate a slight increase in monsoon precipitation (Figure 8). This trend is not statistically significant.

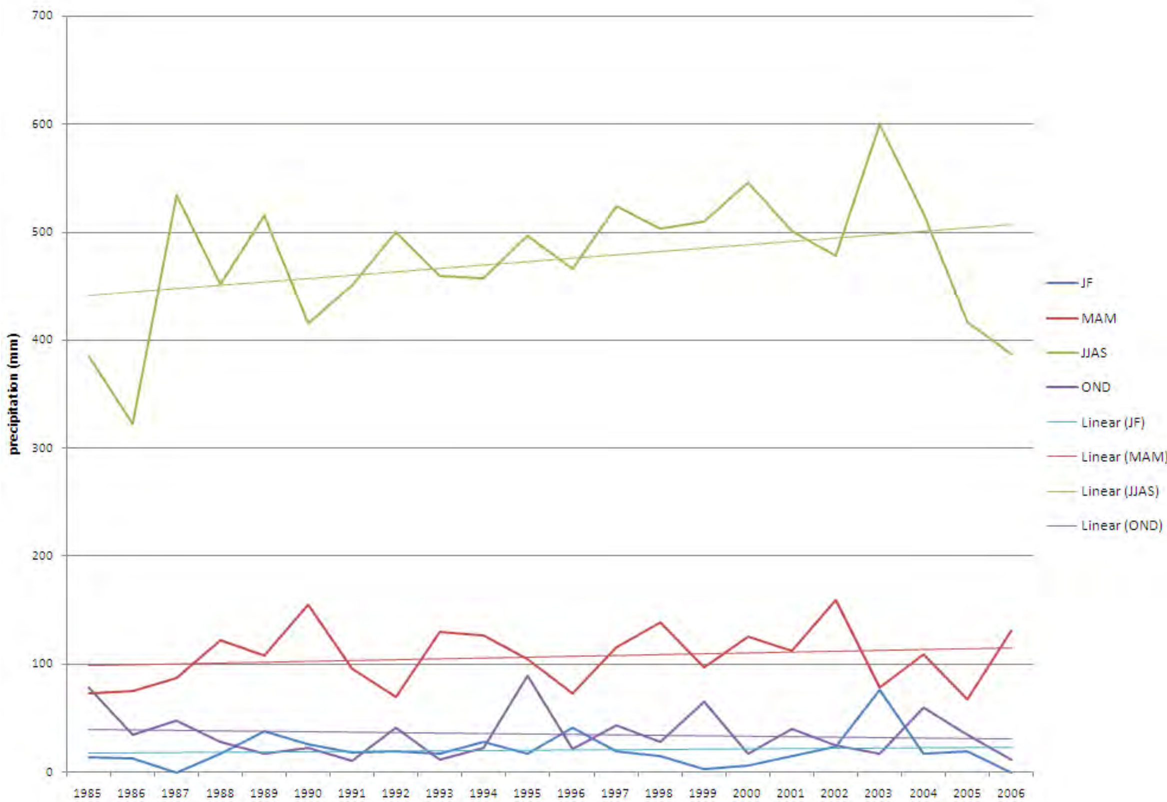


Figure 8. Time Series of Average Monthly Rainfall Between 1985 and 2006

Source: Based on daily data purchased through the Nepalese Meteorological Office.

Projected Changes in Average Monthly Air Temperature and Rainfall

Applying change factors extracted from four GCMs and two greenhouse emission scenarios to daily meteorological data (using values for Jiri as a proxy for the project site) enabled future monthly projections to be created for average temperature and average rainfall.

Here we present the projected estimates for two of the future time slices we considered: 2020s and 2050s. We also considered how climate change might impact monsoon rainfall more specifically.

Methodology

To develop the hydrological baseline and future projections of river flow, daily data (for the following variables: average rainfall in mm, minimum, average and maximum air temperatures in °C) for Jiri[1] meteorological station covering 1986–2007 were purchased from the Nepalese Meteorological Office. The series was 95% complete, with missing data primarily in the monsoon season.

In order to obtain future estimates of monthly average temperature, monthly average minimum and maximum temperature and monthly average rainfall, GCM outputs from the UNDP's Climate Change Country Profiles were used.

[1] The data time series for Janakpur meteorological station was incomplete.

Four robust GCMs were chosen to represent a good spread of results across the models. They are:

- GISS-ER (NASA, USA)
- CSIRO-Mk3.5 (Commonwealth Scientific and Industrial Research Organisation, Australia)
- CGCM 3.1 (Canadian Centre for Climate Modelling and Analysis, Canada)
- GFDL-CM2.0 (US Department of Commerce/Geophysical Fluid Dynamics Laboratory, US)

They all offer decadal climate change projections, except for GFDL-CM2.0 which has an annual projection data series.

To project changes in future climate conditions, two future greenhouse gas (GHG) emission scenarios from the Intergovernmental Panel on Climate Change (IPCC) were used: A1B and A2 (please see Appendix 1, which describes the rationale behind the different GHG emissions scenarios, for more detail).

Change factors were applied to the monthly observed data from Jiri to obtain future climate projections for five time slices: 2010s, 2020s, 2030s, 2040s and 2050s (in line with our modeled future projections of the project's financial indicators). Projections for minimum monthly air temperature (°C) and monthly average rainfall (mm) were used as inputs for the hydrological model developed for this study.

Future Projections for Monthly Average Temperature (Figure 9)

Projections of monthly mean temperature (in degree Celsius)[2] up to the 2020s show very similar increases across all months, with a slightly larger range of estimates for the months of October to December. When temperature increase is averaged annually, the four sets of projections give a range of change by the 2020s of between 0.8°C and 1.1°C (for the models with respectively the lowest and the highest averaged annual temperature increase).

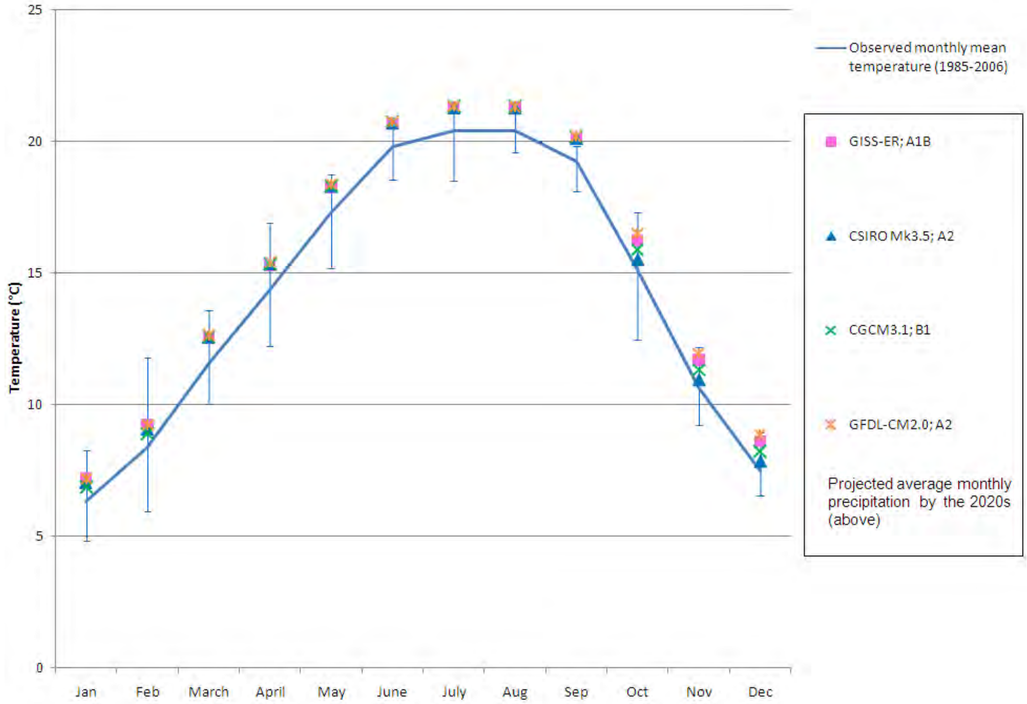
Temperature increase averaged across the four sets of projections is strongest during the spring season (March–May), with a range of monthly temperature increase between 0.9°C and 1.1°C. The months between October and December are characterized by the highest range of increase across the four models (from 0.4°C to 1.4°C).

Projections of monthly mean temperature up to the 2050s show a wider range of estimates across the different model results, compared with projections for the 2020s. When temperature increase is averaged annually, the four sets of projections give a range of change by the 2050s between 1.4°C and 2.9°C (for the models with respectively the lowest and the highest averaged annual temperature increase).

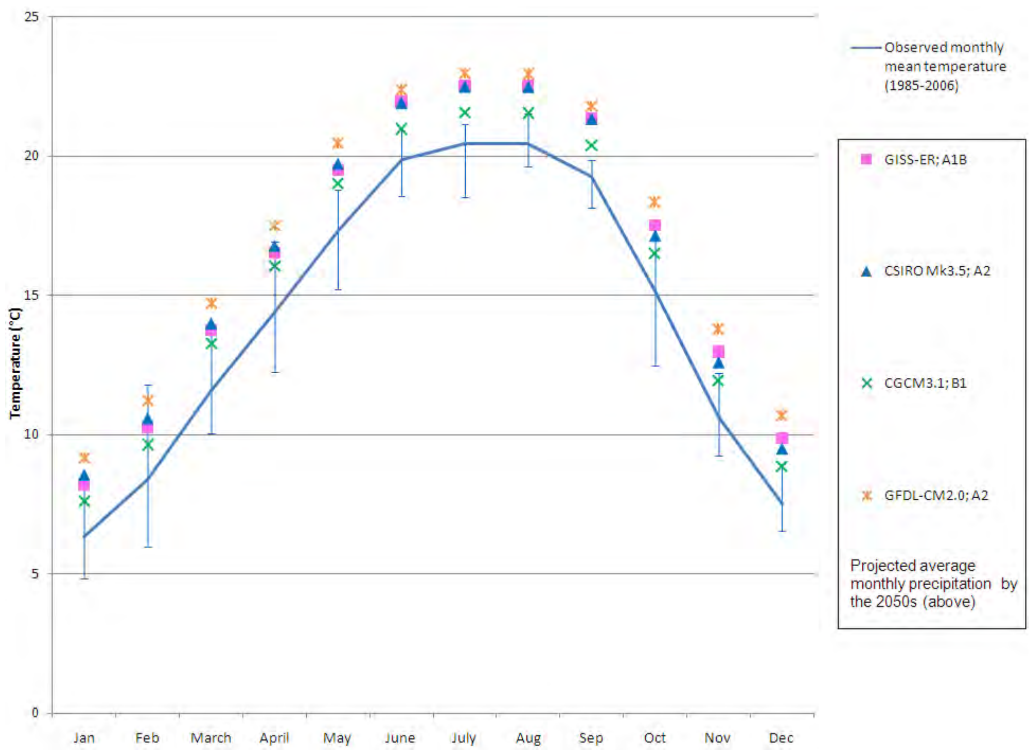
Temperature increase averaged across the four sets of projections is most significant in the months of March, April and May with a range of monthly temperature increase between 1.7°C and 3.1°C. The months between October and December are characterized by the highest range of increase (similarly to the projections for the 2020s) across the four models (from 1.3°C to 3.2°C).

Across the four models, projections are very similar, except for the months of October, November and December where the range of estimates is higher, which may call for added contingency in business planning.

[2] To present these climate projections the change factors were scaled back to take into account the difference in baseline (the projections used were calculated in relation to 1970–1999 whereas the baseline was 1985–2006). For the purpose of this analysis, a linear rate of change was assumed, although it was recognised that the rate of change may change over time.



(a) Projections for the 2020s



(a) Projections for the 2050s

Figure 9. Observed and Projected Monthly Mean Temperature (°C) Around Khimti Khola for (a) the 2020s and (b) the 2050s. Error Bars Show the Observed Range of Natural Variability for Each Month.

Source: Based on baseline data purchased from the Nepalese Meteorological Office and outputs from 4 GCMs available through the United Nations Development Program.

The UNDP's Climate Change Country profiles can be used to gather more detailed information of multi-model projections of climate change across Nepal. Figure 10 depicts projected changes in mean seasonal temperature by the 2030s and 2060s, relative to the mean climate of 1970–1999.

Note: Results for the 2030s are shown in the left column, and the 2060s are shown in the right column. All values are anomalies relative to mean climate of 1970–1999. In each grid, the central value reflects the ensemble median and the upper and lower corners give the ensemble maximum and minimum. Table 2 provides projections of average temperature rise for the climate model grid cell representing the area around Khimti Khola (spatial resolution is approximately $275 km^2$ at this latitude). The temperature rise given here reflects the A2, or 'medium', greenhouse gas emissions scenario.

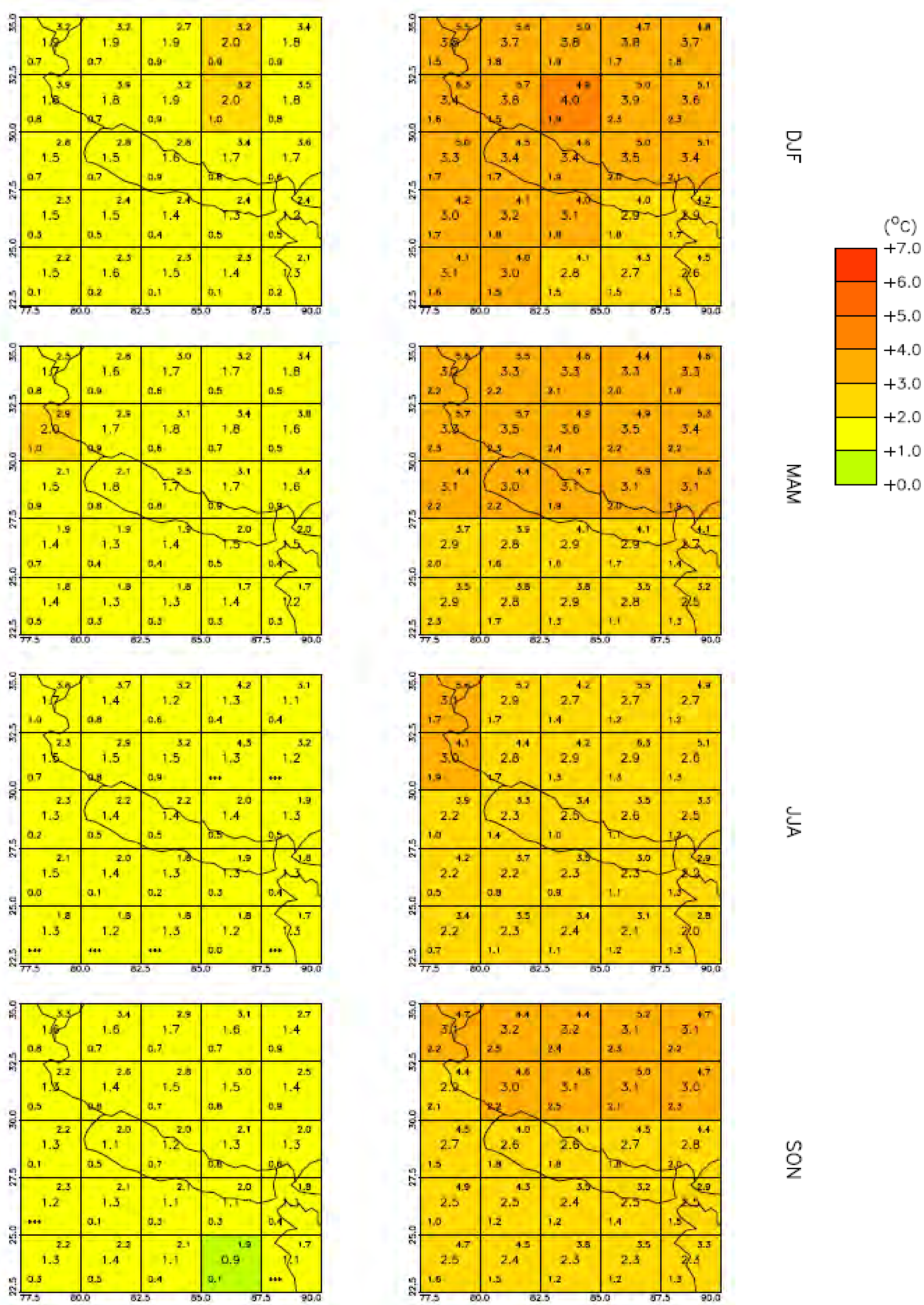


Figure 10. Spatial patterns of projected change in mean seasonal temperature (from top to bottom: winter, spring, summer and autumn) under the SRES A2 scenario, from an ensemble of 15 GCMs

Note: Results for the 2030s are shown in the left column, and the 2060s are shown in the right column. All values are anomalies relative to mean climate of 1970–1999. In each grid, the central value reflects the ensemble median and the upper and lower corners give the ensemble maximum and minimum.

June/July/August	December/January/February
2030s: 0.5, 1.4, 2.0°C 2060s: 1.9, 3.1, 4.7°C	2030s: 0.8, 1.7, 3.4°C 2060s: 2.0, 3.5, 5.0°C

Table 2. Increase in average temperature for the grid cell representing Khimti Khola by the 2030s and 2060s, projected by an ensemble of 15 climate models under the A2 emissions scenario

Note: The ensemble minimum, median and maximum values are given for two future time periods.
Source: McSweeney et al., 2008.

Future Projections for Monthly Average Rainfall (Figure 11)

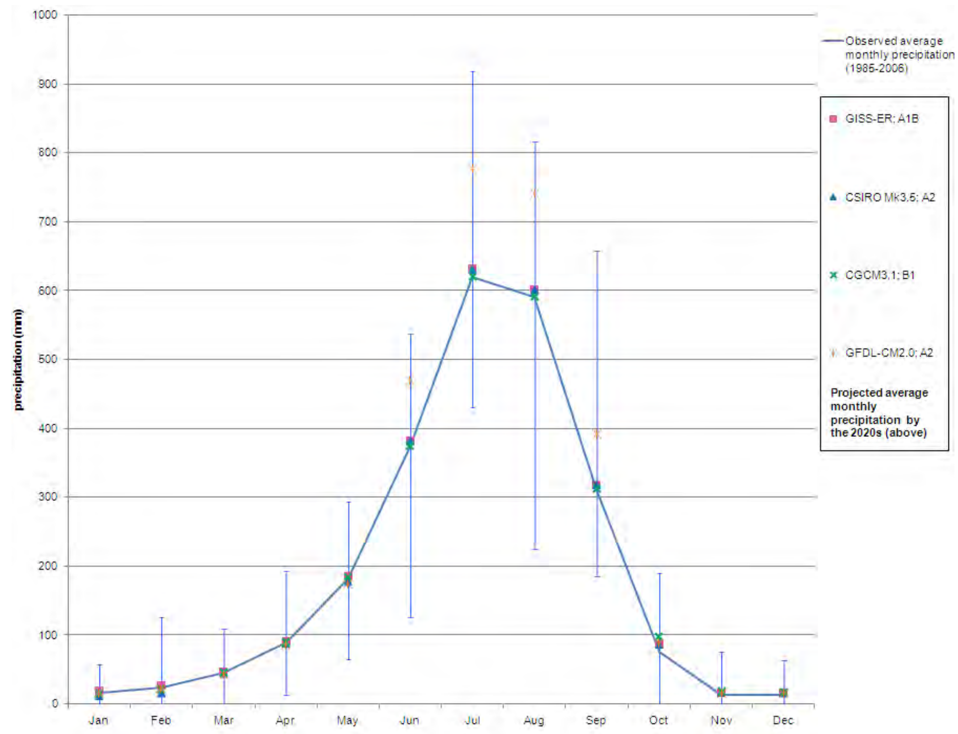
Projections[3] were developed for up to the 2050s. The future estimates presented in Figure 11 were obtained in relation to average monthly rainfall values observed between 1985 and 2006. However, it is important to note that climate change will also affect particularly wet or dry months so that maximum and minimum rainfall values may be different in the future.

Projections of average monthly rainfall for the 2020s show a narrow range of future estimates between the four models except for the months between June and September (of higher average precipitation). For those months, models predict a small increase with one model projecting significantly higher precipitation (about 25% higher compared to the baseline precipitation). It is important to note that during dry months (i.e. when rainfall is close to zero), large percentage changes in future precipitation actually result in very small changes in absolute rainfall values. Even though absolute changes are small, they could be of particular significance to Khimti Khola during low river flow months.

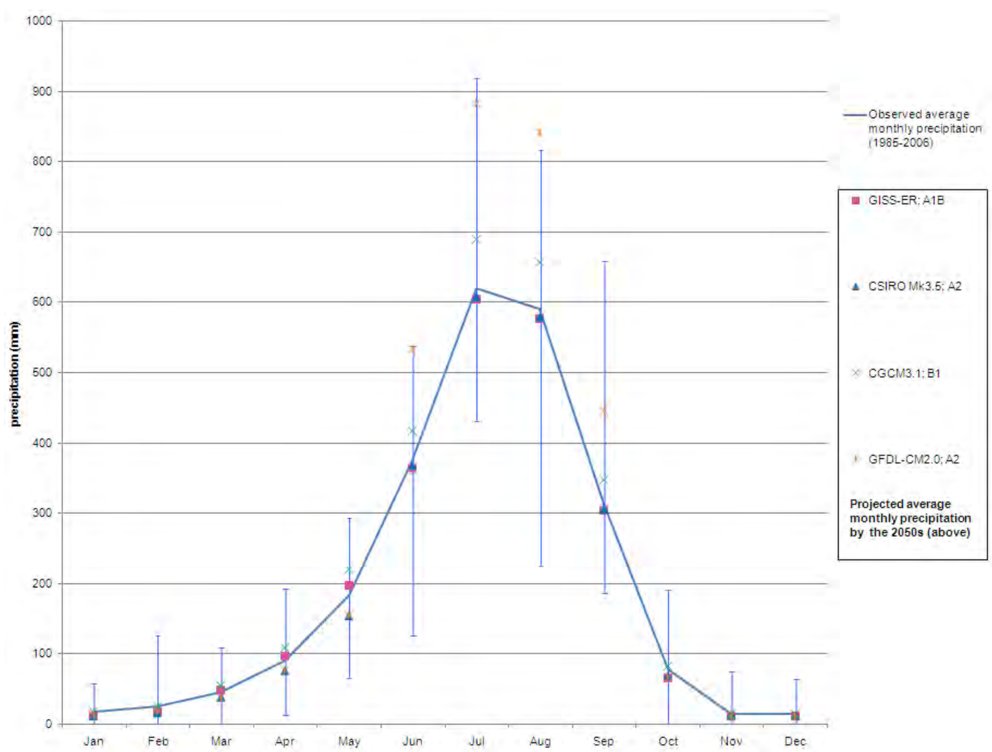
Projections for the 2050s show a much wider range of projections for some months: for those between June and September the range is approximately -2.5% to +42.5%. This translates into a large difference in absolute average rainfall value as they are characterized by higher average precipitation. The future estimates presented in 11 were obtained in relation to average monthly rainfall values observed between 1985 and 2006.

It is worth comparing the projected changes based on an average value of monthly rainfall (calculated for 1985–2006) against the observed rainfall variability represented by the error bars in Figure 11 (showing the minimum and maximum average rainfall for each month 1985–2006). It reflects the fact that the project already faces large variability of rainfall—especially during the monsoon—and that climate change will superimpose a long-term trend on it, thus possibly influencing high and low rainfall events.

[3] As for average annual temperature, the change factors were scaled back to take into account the difference in baseline (the projections used were calculated in relation to 1970-1999 whereas the baseline was 1985-2006). For the purpose of this analysis, a linear rate of change was assumed, although it is recognised that the rate of change may change over time.



(a) Projections for the 2020s



(b) Projections for the 2050s

Figure 11. Observed and projected average monthly precipitation (mm) around Khimti Khola for the 2020s (a) and the 2050s (b)

Source: Based on baseline data purchased from the Nepalese Meteorological Office and outputs from 4 GCMs available through the United Nations Development Program.

The UNDP's Climate Change Country profiles were utilized to gather information on projected future rainfall across Nepal. Figure 12 depicts the spatial projected change in monthly rainfall, relative to the mean climate of 1970–1999.

Note: In each grid, the central value reflects the ensemble median and the upper and lower corners give the ensemble maximum and minimum.
Source: McSweeney et al, 2008.

Table 3 provides projections on the change in rainfall for the climate model grid cell representing the area around Khimti Khola. The projections presented here reflect the A2, or 'medium', greenhouse gas emissions scenario.

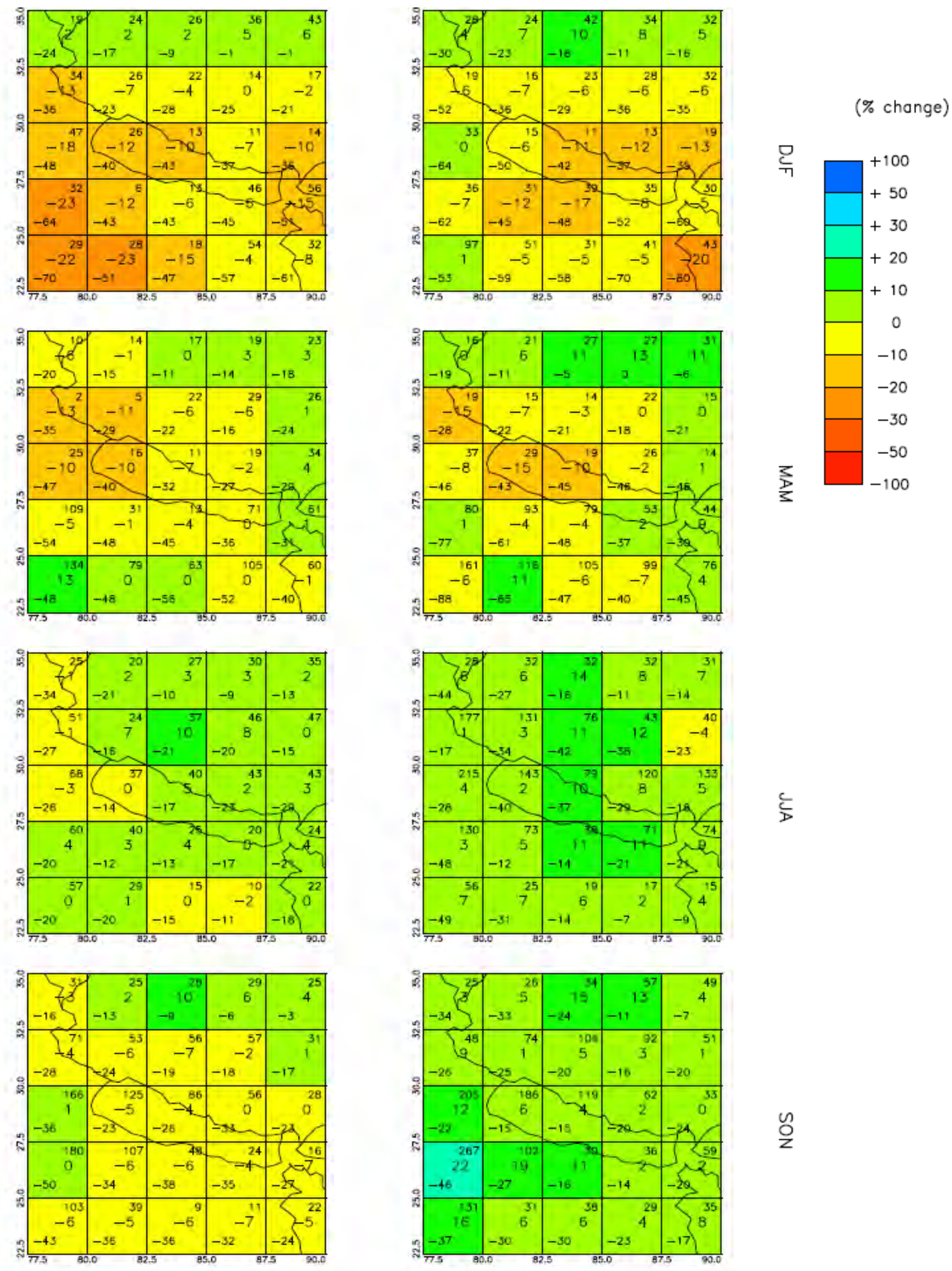


Figure 12. Spatial patterns of projected change in monthly rainfall for 10-year periods (from top to bottom: winter, spring, summer and autumn) under the SRES A2 scenario, from an ensemble of 15 GCMs. All values are percentage anomalies relative to mean climate of 1970–1999

Note: In each grid, the central value reflects the ensemble median and the upper and lower corners give the ensemble maximum and minimum.
Source: McSweeney et al, 2008.

June/July/August	December/January/February
2030s: -23, +2, +43% 2060s: -29, +8, +120%	2030s: -37, -7, +11% 2060s: -37, -12, +13%

Table 3. Projected change in rainfall for the grid cell representing Khimti Khola by the 2030s and 2060s, projected by an ensemble of 15 climate models under the A2 emissions scenario

Note: The ensemble minimum, median and maximum values are given for two future time periods.
Source: McSweeney et al., 2008.

The rainfall projections for Khimti Khola show a wide range of changes in rainfall. Projected changes range from -23 to +43% for June–August and -37 to +11% for December–February by the 2030s. The range of projections across the model ensemble is large; nevertheless it is useful to note that the ensemble mean indicates an increase in rainfall in the wet months of July–August and a decrease in the dry months of December–February.

Future Projections for Monsoon Rainfall

Local farmers near Khimti Khola have reported that monsoon precipitation has been arriving later in the year for the past few years. The scientific understanding of monsoon processes is incomplete and current climate models perform poorly in predicting future monsoon behavior. Most models agree that mean summer rainfall will increase slightly by 2050. Some models indicate that the number of rainy days will decrease while the intensity of heavy rainfall events increases.[iii] For more information on future monsoon precipitation trends, please see Appendix 4, page 80 (bottom).

In general, projections of changes in precipitation in this part of the world are challenging because GCMs have trouble representing both large-scale monsoonal features (e.g., El Niño Southern Oscillation), as well as the small-scale influences of varied topography on precipitation. The rainfall of Nepal is directly influenced by these two processes, and the fact that GCMs struggle with them makes precipitation projections highly uncertain. For a more general discussion of model agreement on changes in precipitation across Nepal and the surrounding area, please refer to Appendix 4, page 78 (top).

5. Analyses of Direct Project-Related Risks, Opportunities and Vulnerabilities

Key Messages

- Observed flow on the Khimti river has seasonal features. Between December and May, average river flow is low (around or below 10 m^3/sec), while during the monsoon season (June–September) it is relatively high (from a low average of 40 m^3/sec in June to around 120 m^3/sec in August). During the months immediately following the monsoon (October and November) average river flow remains relatively high compared to the rest of the dry season.
- River flow is highly variable from year to year (observations for the period 1985 to 2006 were analysed).
- Observed data shows a clear decrease in average river flow over 1985–2006 for most months. The largest observed decreases have occurred in July, August, September and October. Annual flow characteristics for the first part of the observed timeseries are substantially different from the last part. For this reason, the river flow analysis treats Part 1 and Part 2 separately.
- Flow projections based on Part 1 and Part 2 of the observed dataset differ significantly. The maximum changes are much greater for Part 1 projections than for Part 2 projections. This explains the difference in scale between the two sets of projections. For example, by the 2050s Part 1 highest average flow projection for July–August is over 160 m^3/sec, while Part 2 highest projection is of 80 m^3/sec for the same months.
- For the 2020s, projections based on Part 1 predict a consistent increase in river flow throughout the year. Part 2 projections include both increases and decreases in flow. Part 1 projections show the largest percentage changes during Nepalese dry months (between November and March), while Part 2 largest projections occur during the monsoon months.
- Projections for the 2050s between Part 1 and Part 2 remain different and are characterized by:
  - very significant increases for Part 1 across scenarios, especially during the monsoon, and
  - relatively lower and more heterogeneous changes (in %) across scenarios for Part 2.
- There is agreement between Part 1 and Part 2 2050s projections for dry months (November–February) that river flow is likely to increase, though this increase varies widely between 2% and 200%.
- Large percentage changes (even the significant changes projected for Part 1) during low flow months will translate into very low absolute changes (m^3/sec), but potentially significant operational and financial impacts.
- **(Department of Hydrology and Meteorology) (Nepal Government) (NEA) (HPL)** Good quality observed data is paramount to achieving robust future flow analysis. Changes in instrumentation or ambient conditions or extreme events are important factors to document. The heterogeneity in available hydrological data for Khimti Khola led to the construction of two different river flow models (Part 1 and 2) projecting different future estimates. It is difficult to attach different levels of confidence to these models. Further, the lack of observations of snow melt in the project catchment area prevented inclusion of the potential effects in the design of the model or in future flow projections. Improved monitoring of river flow would be beneficial for future flow projections.
- **(IFC) (Department of Hydrology and Meteorology) (Nepal Government) (NEA) (HPL)** The difference in projections across climate change models and scenarios reflects the relatively high uncertainty characteristic of climate change projections for rainfall in the region. A focused modelling effort on improving understanding of monsoon processes would certainly be beneficial for combating divergent GCM results in this part of the world.

Introduction

Five scenarios were developed as set out previously on page 21 of this report. In this section a detailed description of scenario 4 is provided. Scenarios 1, 2, 3 and 5 are described in Appendix 2.

Scenario 4: Change in the River Flow on the Khimti Khola River

Introduction

An overview of observed river flow and the results of future flow modeling are presented in this section.

An empirical model was designed and developed specific to the Khimti Khola river in order to evaluate the implications of changing climatic conditions on river flow and electricity generation for HPL.

Future flow projections for the 2010s up to the 2050s are available in Appendix 4, pages 81 (bottom) through 91 (top).

Climate observations and projections used in this river flow modeling are described in section 5.

Khimti Khola river downstream of the Khimti 1 intake

Observed River Flow (1985–2006)

The daily observed river flow measurements for 1985–2006 taken at Rasnalu on the Khimti river (hydrological station #650), 1 kilometer upstream of the intake of the hydropower tunnel provided the baseline data.
Data was provided by the Department of Hydrology and Meteorology (DHM) of Nepal and collected by a DHM employee who is contracted to take the measurements. The dataset was 94.6% complete, with missing data primarily in the dry months of 1986–1988, 1990–1992 and 2002–2003.

The data sample reveals a significant difference in flow characteristics between two time periods: 1985–1994 and 1995–2006. Figure 13 shows that between 1985 and 1994 high flow values are much higher and inter-annual variability is more significant than for 1995–2006. Anecdotal evidence suggests that the instrumental method to measure stream flow may have changed in 1994 with a relocation of the gauging station. In discussions with DHM it was also suggested that there may have been issues with the incorrect recording of flows by the operator.

Taking into account this difference in river flow characteristics between 1985–1994 and 1995–2006 and following the advice of hydrologists, the 22-year daily time series was split into two data sets: Part 1 (1985–1994) and Part 2 (1995–2006). This was a necessary condition to achieve a significant correlation between flow and climate factors for each of the two parts of the time series.

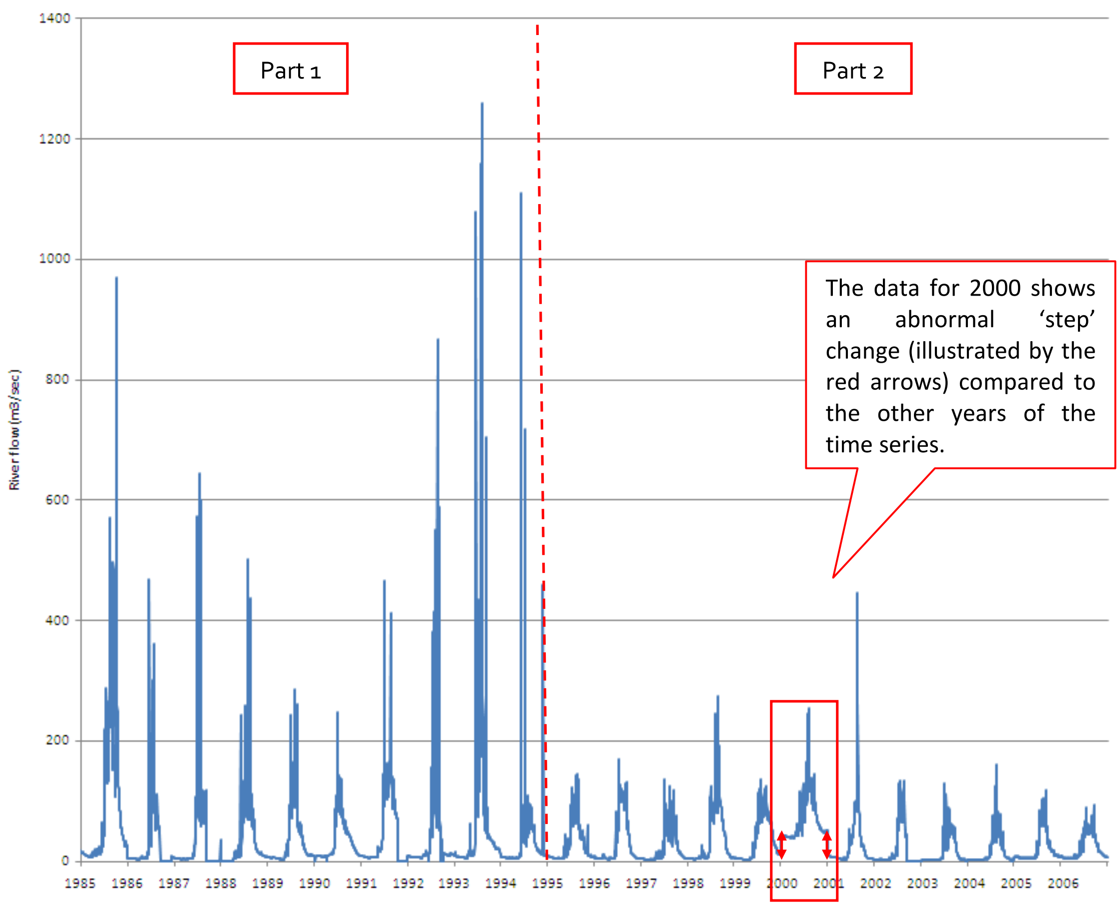


Figure 13. River flow data from 1985 to 2006 taken at Rasnalu and used as a baseline for modeling

Source: Based on data provided by DHM, Nepal.

It was also apparent that river flow values (dry season as well as monsoon season) for the year 2000 were consistently higher than for any other year. It is illustrated in Figure 13 by a ‘step’ change in recorded river flow values which start and finish abruptly at the beginning and end of the year 2000 compared to any other years of the time series. It is possible that this was due to a data processing error, a change in the way that data was collected, or an ‘abnormal’ event on the river which disrupted river flow for every day of the year 2000. Because the anomaly was not explained, and because it would significantly skew construction of the hydrological model, this year’s data was removed from the analysis.[4]

River flow seasonality on the Khimti is characterized as follows (see Figure 14):

- Between December and May, average river flow is low (around or below 10 m^3/sec).
- During the monsoon season (June–September) average river flow is high (from an average of 40 m^3/sec in June to around 120 m^3/sec in August).
- During the months immediately following the monsoon (October and November) average river flow remains relatively higher than the rest of the dry season (respectively around 40 and 20 m^3/sec) before falling back to the dry season level.

However, river flows at Rasnalu reveal some interesting patterns of inter-annual variability (represented by the black vertical bars in Figure 14. The range of monthly average river flow estimates across 1985–2006 goes from approximately 0 to 300 m^3 per second.

River flow is highly variable from year to year during the 5 months of and around the monsoon season (June–October), ranging from a minimum of 10 m^3/sec to a maximum of 300 m^3/sec. By contrast, river flow is relatively constant from year to year (between 0 and 20 m^3/sec) between December and May.

For an illustration of river flow variability from day to day using daily river flow data aggregated across the 22-year baseline, please see Appendix 4, pages 83 (top) through 85 (top).

[4] Please note that other years showed relatively high river flow throughout all months (for example 1985) which might be due to differences in data collection.

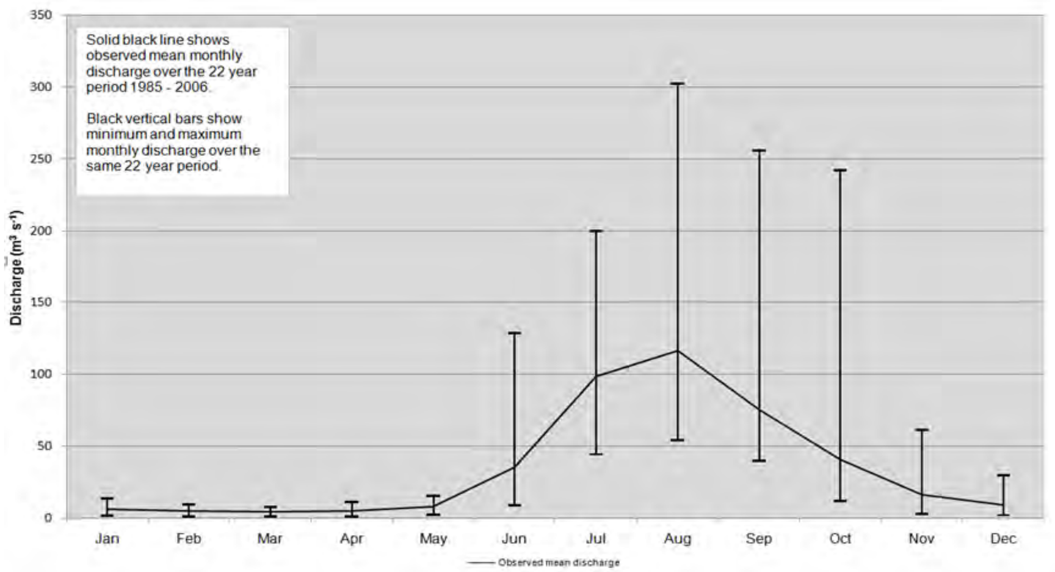


Figure 14. Monthly average river flow (m3/sec) at Rasnalu across 1985–2006

Source: Based on data provided by the DHM, Nepal.

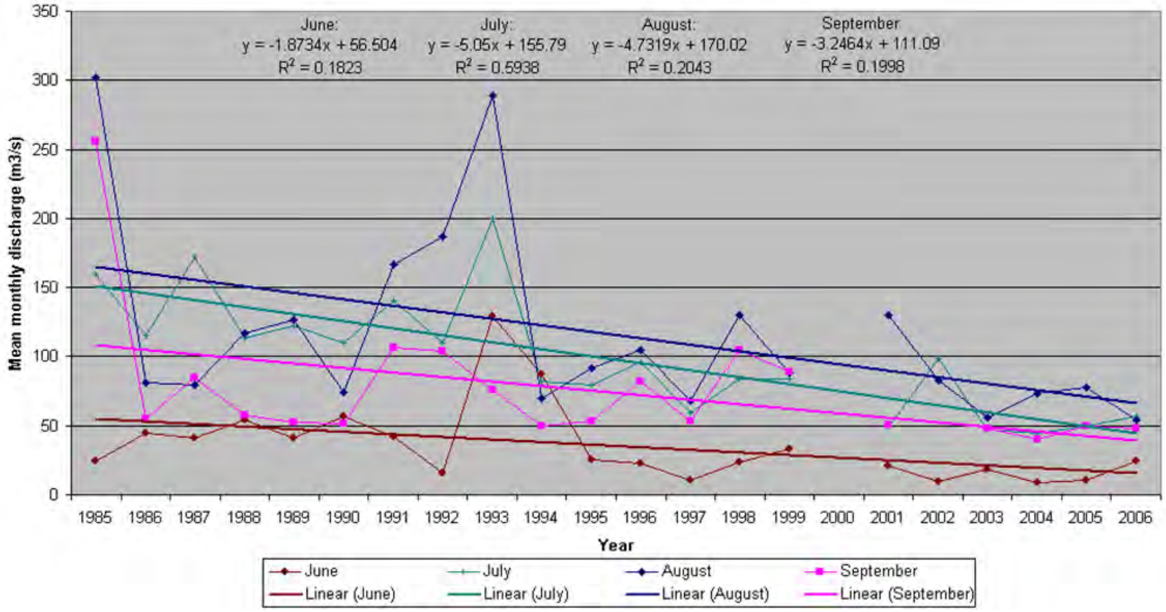
Recent Monthly River Flow Trends (1985–2006)

The average monthly flow across the 22-year record of shows a clear decrease in flow for most months.

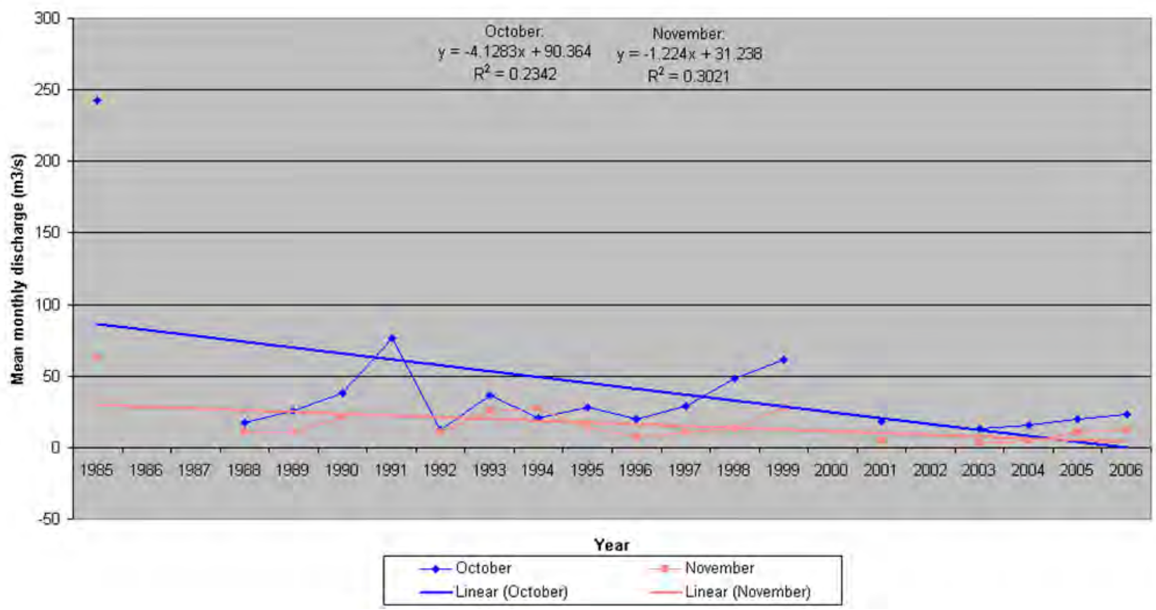
The largest observed decreases occurred during the months of the monsoon or post-monsoon (in particular July, August, September and October, as shown on Figure 15).

The trend lines (represented in Figure 15 by the lines without markers) illustrate the linear average monthly decrease in river flow across the 22 years. They provide a clearer picture of changes across the 22-year period than the monthly river flow values for each year of the time series (illustrated in Figure 15 by the lines with markers) which are characterized by inter-annual variability.

For example, average river flow in August appears very variable year to year (varying between 50 and 300 m^3/sec during 1985–2006). In 1990 it was 70 m^3/sec and in 1993, 280 m^3/sec. However, the linear trend indicates that the average river flow for August has decreased between 1985 and 2006.



(a) July, August and September



(b) October

Figure 15. Observed monthly trends in average river flow between 1985 and 2006 for (a) July, August and September, and (b) October

Source: Based on data provided by DHM, Nepal.

Projected Changes in River Flow (up to 2050s)

Generally, changes in river flow due to climate change in the Khimti Khola depend on changes in the volume, timing and intensity of precipitation and snowmelt. Changes in temperature, solar radiation, atmospheric humidity, and wind speed also affect potential evaporation from the land surface and water bodies. Transpiration from plants can also either slightly offset any increase in rainfall or further exaggerate the effect of decreased rainfall.[iv]

To model future river flow at Khimti Khola, a stepwise method was used to find the best-fitting multiple linear regression between observed monthly flow at Rasnalu and observed climatic factors at Jiri. The use of this empirical modeling approach was justified because of the lack of an existing calibrated and appropriate water resource model for the area. Furthermore, integrated water resource models do not allow for easy input of future climatic conditions. Multiple linear regression has been used in previous studies in the region and is appropriate for the level of assessment required in this study.[v]

Before identifying significant and robust predictors of river flow to develop our future flow model specific to the Khimti river at Rasnalu, a review of available published information was undertaken on the characteristics of river flow in the Himalayas. Additional expert advice was provided by the Centre for Ecology and Hydrology in Wallingford (U.K.).

Scientists commonly agree that precipitation is the most significant factor when considering stream-flow in steep catchments such as those founded in the Himalayas.[vi] Other factors include temperature, glacial and snow melt, hydrogeology, soil types, topography, land-use, catchment size and slope.[vii] The forest cover (from observation on site, and photographs) in the catchment is limited and will not have a significant impact on flows. There are no glaciers within the catchment of the Khimti river.

Temperature is important in controlling snow melt.[viii] Because of the lack of available data on snow melt in the Khimti Khola catchment area, future changes in the seasonality and volume of snow and their contribution to river flow could not be included in the river flow projections presented below. Anecdotally there is believed to be limited prolonged winter snow cover in the Khimti catchment. Based on the latest IPCC assessment,[ix] it can be expected (with high confidence) that climate change is likely to:

- induce a seasonal shift in river flow by increasing the ratio of winter to annual flows, on-setting earlier and faster snow melt in spring, and
- reduce the overall contribution of snow melt to river flow because of decreased snow water storage.

Further, as temperature continues to increase, the likelihood of precipitation falling as rain rather than snow increases in which case the run-off will be far quicker with less attenuation and increased sediment loads.

There is generally a time lag between precipitation and river flow, which depends on local conditions (very thin soils, little vegetation and very steep slopes for Khimti Khola). Upstream of the intake to Khimti 1 there is a significant reduction in the amount of land used for agriculture with far fewer terraces.

Taking the above into consideration the following variables for Khimti river flow were considered: precipitation, mean and extreme temperature and antecedent precipitation (over a range of time periods) for the previous year (12 variables in total). A hierarchical method was used to find the best-fitting empirical regression model. This involved entering average precipitation and temperature as constant factors in the regression equation, and using a stepwise approach of adding the antecedent precipitation amounts. The regression coefficients were assessed at each step through a T-test, based on the 95% confidence level and the antecedent precipitation predictor was either kept or taken out of the next run based on whether the probability was less than 0.05. The addition of new predictors caused the significance of the existing predictors to vary, and predictors that became insignificant were taken out.

Recognising the Khimti Khola catchment characteristics and based on the features of river flow at Rasnalu and climate at Jiri, the best correlation coefficient was achieved using two variables as predictors of river flow: the sum of rainfall over 20 antecedent days and the minimum temperature of the antecedent day.

Two different correlation equations were created for Part 1 and Part 2 of the time series. Each of these correlation equations is represented by a modeled baseline of river flow which aims to simulate the shape of observed river flow and is then used to incorporate future changes in climate conditions.

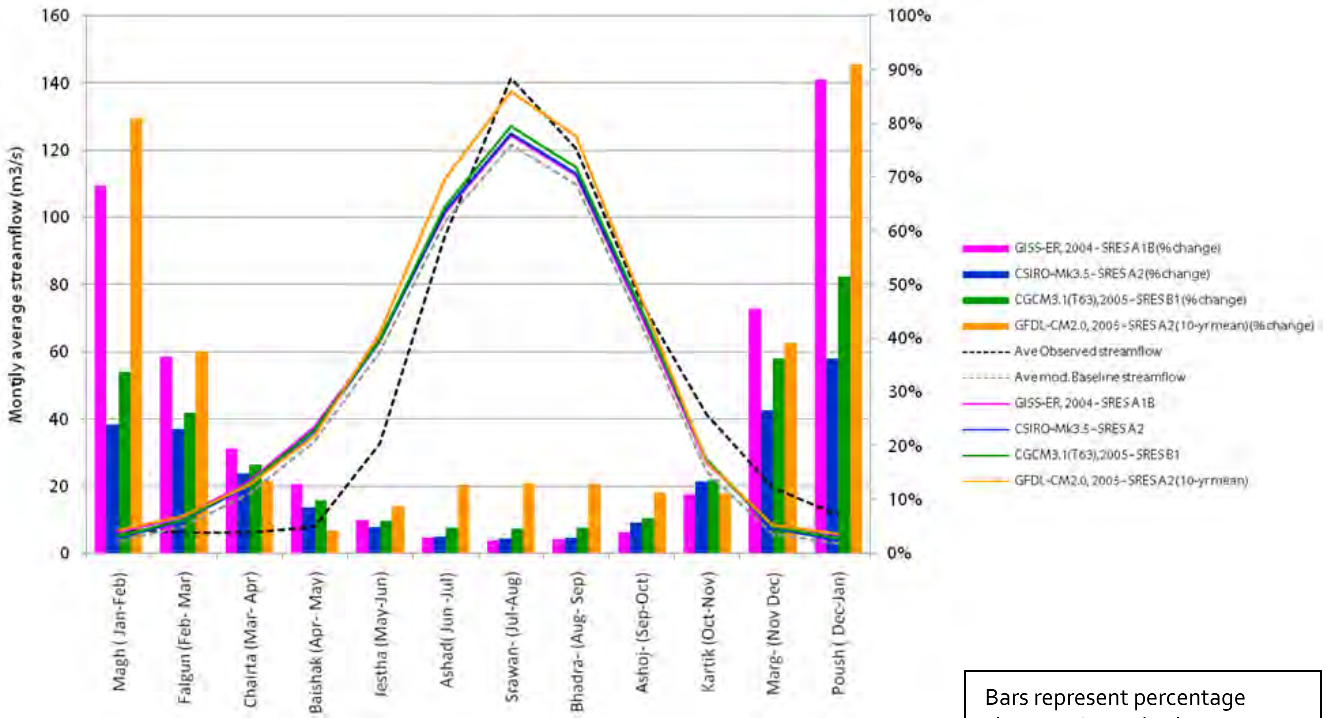
The empirical river flow models achieved for Part 1 and Part 2 both provide a good proxy for observed flow at Rasnalu. Both regression models capture annual flow patterns (see Figures 16a and 16b).

The differences between observed river flow and modeled river flow (represented respectively by the black dotted lines and the blue dotted lines) indicate that generally the river flow models tend to overestimate river flow between February and July and underestimate it between July and January.

The correlation factor achieved for Part 2 is a little better than the one achieved for Part 1. In Figure 16 it can be seen that Part 2 captures the inter-annual variability of river flow more effectively than the modeled baseline for Part 1. Additionally, there is some evidence that Part 2 data may be of better quality, as described above in this section.

Two sets of projections, for Part 1 (1985–1994) and Part 2 (1995–2006) of the data series, have been produced for five time slices: the 2010s, 2020s, 2030s, 2040s and 2050s. The complete set of results presented in a series of tables is available in Appendix 4, pages 104 through 123.

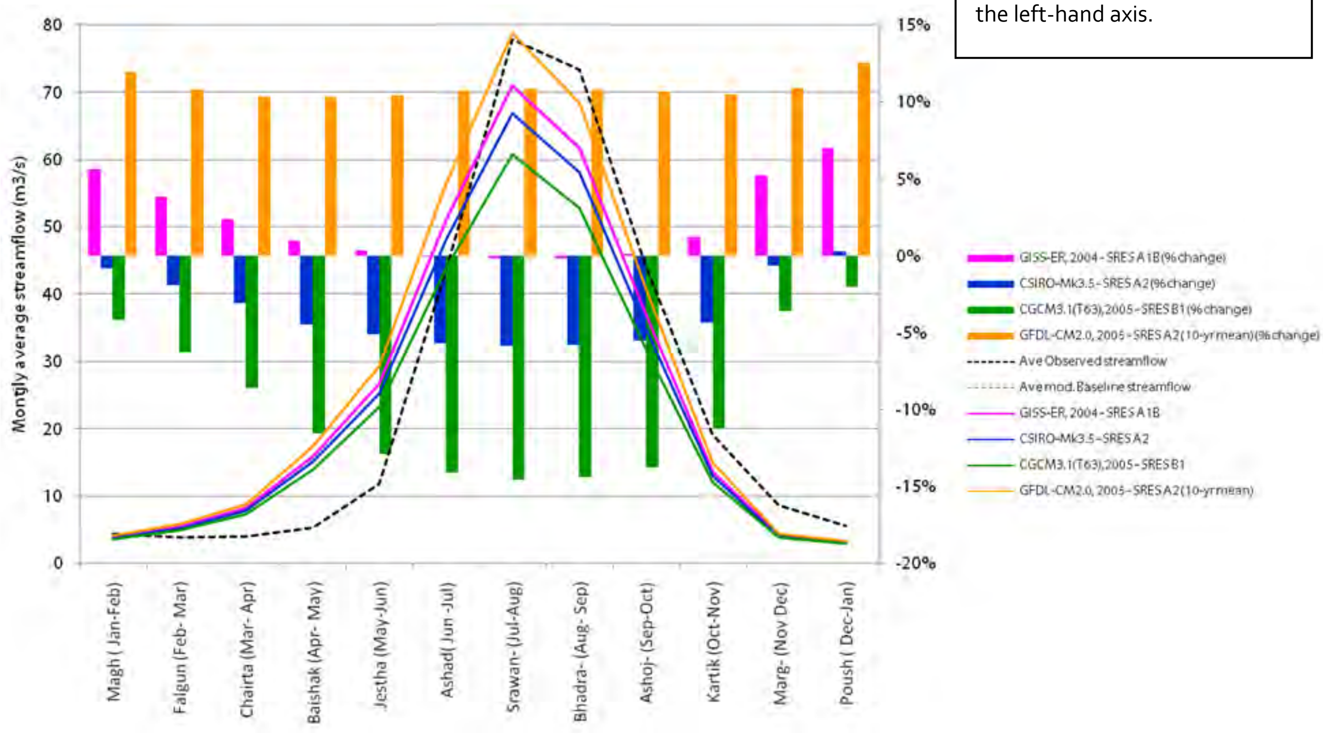
The most relevant projections for the 2020s and 2050s (as they correspond to the two time deadlines for Khimti Khola transfer of ownership to the NEA) are presented below.



Bars represent percentage changes (%) and values are read on the right-hand axis.

Lines represent future flow values (m^3/sec) and are read on the left-hand axis.

(a) Part 1 projections for the 2020s



(b) b) Part 2 projections for the 2020s

Figure 16. Monthly projections (using Nepalese months) of streamflow at Rasnalu (m^3/s) under 4 GCMs for the 2020s using our empirical river flow models: a) Part 1 (1985–1994); b) Part 2 (1995–2006, excluding 2000)

The two sets of projections for 2020s (see Figure 16) illustrate the following:

- **Projections for 2020s based on Part 1 and Part 2 of the dataset differ significantly.**

  While projections based on the Part 1 model show a consistent increase in river flow throughout the year (see Figure 16a), projections for Part 2 show a more varied picture (see Figure 16b). Projections for Part 1 show much larger percentage changes during the dry months (between November and March), while estimates based on Part 2 of the dataset evidence larger relative projections during the monsoon months.

  The maximum changes are also much larger for Part 1 projections (up to 90% in December–January for two out of the four projections), than for Part 2 projections (up to around 12% for December–January). The difference in scale between the two graphics of Figure 16 is explained by the difference in the correlation coefficients between Part 1 and Part 2 models.

- **Differences in projections across climate change models and scenarios underline the relatively high uncertainty of climate change projections for the region of Nepal (see section on climate):**

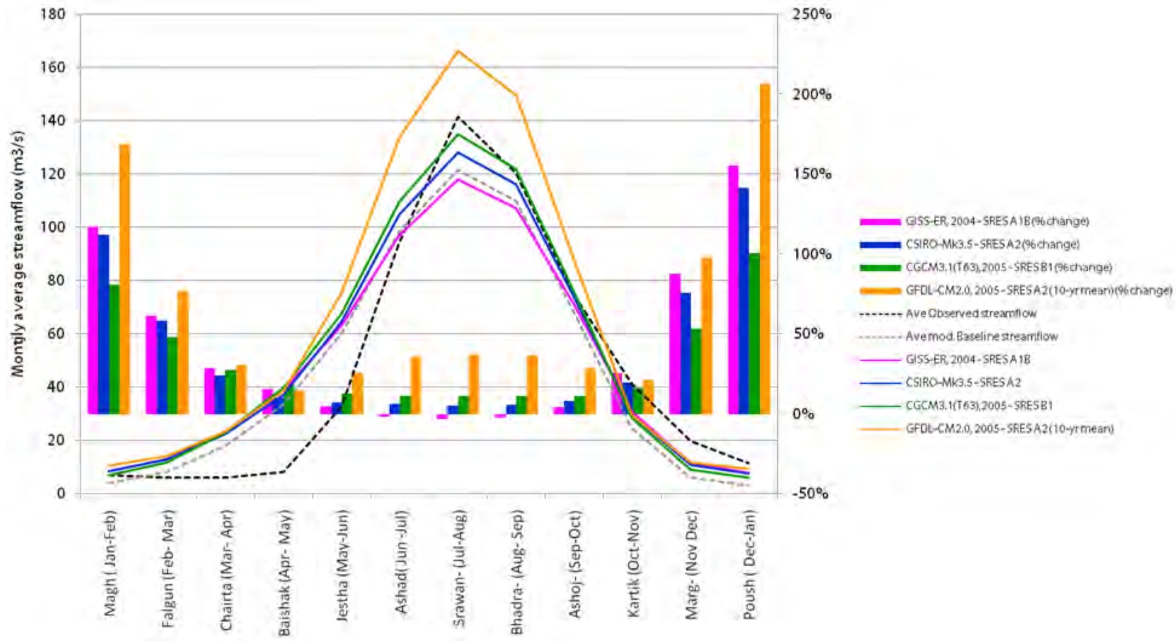
  For Part 1 of the data series, model projections show an increase in precipitation for all months with larger changes during low flow months (between November and March) of between approximately 25% and 90% and more modest changes for the rest of the year of between approximately 2% and 12%.

  For Part 2 model projections, the river flow change varies between scenarios. The estimates based on the change factors obtained from the US GCM (GFDL-CM2.0) project a consistent increase in river flow throughout the year of around 10%. Similarly, for most months, projections based on estimates from the US GCM (GISS-ER), show more modest increases in river flow. The two remaining models are consistent in projecting decreases in river flow—except in December–January for CSIRO-Mk3.5—with larger changes during or around the monsoon period.

- **Changes in percentage need to be compared to absolute changes (in cubic meters per second) in order to understand the significance of the projections in terms of risks to Khimti Khola power output:**

  Part 1 projections show the largest increases in river flow during the dry months of the year when monthly average river flow is below approximately 20 m^3/sec. This means that large percentage increases in river flow of between around 25% and 90% would only equal to modest absolute changes (or an increase of less than about 5 and 18 m^3/sec, respectively). The dry weather months are critical in terms of the revenue implications for Khimti 1 when even small changes can become important due to the excess energy payments.

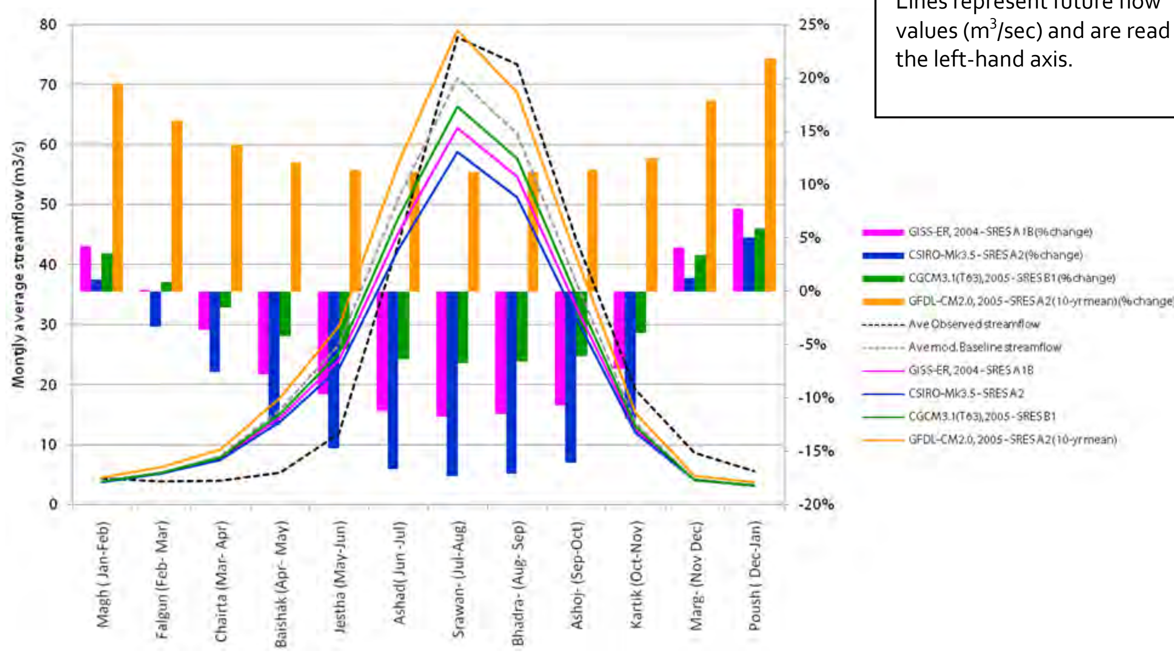
  By contrast, Part 2 projections have much larger (and negative) estimates for months around the monsoon period. Two models show percentage decreases in river flow (about 5–15%).



(a) Part 1 projections for the 2050s

Bars represent percentage changes (%) and values are read on the right-hand axis.

Lines represent future flow values (m^3/sec) and are read on the left-hand axis.



(b) Part 2 projections for the 2050s

Figure 17. Monthly projections (using Nepalese months) of streamflow at Rasnalu (m^3/s) under 4 GCMs for the 2050s using our empirical river flow models: a) Part 1 (1985–1994); b) Part 2 (1995–2006, except 2000)

Projections for the 2050s, when the complete transfer of ownership of Khimti Khola to the NEA is completed, show the following (see Figure 17):

- **Results for Part 1 and Part 2 remain different, except notably for dry months (November–February):**

  Projections based on Part 1 model show a consistent increase in river flow throughout the year (see 17a)—except for the GISS-ER model which predicts a very small decrease between June and September. By the middle of the century, the projected changes using Part 1 regression model are very significant: the largest changes projected during low-flow months (particularly between November and March) range from 50% to 200%, while the future increase for wetter months is less than 30%.

  Projections based on Part 2 regression model again show a more variable picture (see 17b). The projected changes (in %) are also not as significant as those obtained based on Part 1 of the dataset. Divergences in the sign of change from model to model for most months continue to underline the uncertainty associated with climate change projections (especially rainfall) for the region. However, three out of four models project a clear decrease of stream flow during wetter months, particularly of between 5% and 17% from April until October.

- **Climate change projections for dry months (between November and February) by the 2050s across Part 1 and Part 2 models and across all the different climate change scenarios show an increase in river flow (see Figure 17).**

  Interestingly, some trends across river flow and climate change models are better visible in projections for the 2050s than in those for the 2020s. In Part 2 model projections, all four models predict an increase in river flow for dry months, between 2% and 22% monthly between November and February. The change is consistent with projections based on Part 1 model for the same months, even though the percentage increase in flow remains much higher in Part 1 projections (between 50% and 200%).

  Good model agreement for the months between November and February by the 2050s indicates a certain level of confidence in the trend of river flow change during those months. However, uncertainty remains as regards the significance of the river flow increase—projections for these months ranging from 2% to 200% across models and scenarios.

The difference between future estimates based on Part 2 of the dataset respectively for 2020s and 2050s (see Figures 16b and 17b) between November and February may indicate that the other source of uncertainty lies in the timescale of the change: increase in river flow during dry months might indeed only be realized after the 2020s.

Some projections of river flow up to 2050s may show significant changes (especially Part 1 model projections). However, this is to be compared with the current high inter-annual variability in river flow described in the sections above. The area around Khimti Khola already copes with high variability and climate change will affect the severity and frequency of extreme events. Therefore preparing for extremes is even more important under climate change as existing vulnerability from current extremes may be exacerbated under climate change but cannot yet be quantified.

Conclusions

There is considerable variation in the flows projected from the hydrological model using the four climate change scenarios. The uncertainties are driven by the characteristics of the four climate models.

The risk analyses have assessed (within the limitations of the available information) how variability in current climate conditions together with future climate change can affect HPL's operations and have impacts for the local communities. The report identifies where the most important sensitivities are. For some impact relationships between climatic factors and direct and indirect impacts on HPL's operations the lack of baseline information has prevented further analysis. An example of this is the increased risk of flooding on both the Khimti Khola and the Tama Koshi. This illustrates the need for further monitoring and research on baseline conditions in countries like Nepal to enable informed decision making in the face of further climatic change.

Adaptation (risk management) options have been proposed. For the most part these measures are focused on building adaptive capacity rather than delivering adaption action.

In some cases the adaptation options are for others to consider.

6. Analyses of Indirect Project-Related Risks, Opportunities and Vulnerabilities

Key Messages

- **(All stakeholders)** Climate change will increase the social, economic and environmental stress on local communities. As a consequence there is clearly a risk that this would lead to potential issues for the management of the Khimti 1 scheme, as for example, with regard to increased demands for water.
- **(IFC) (HPL)** The social investments made by the project directly and indirectly into the local communities will have increased the resilience to climate impacts.
- **(All stakeholders)** Local communities already have in place a variety of coping mechanisms to deal with existing climate variability. However the additional stress brought by incremental changes (chronic) and extreme events (acute) might have a cumulative effect or reach a threshold beyond which existing coping mechanisms are no longer sufficient.

Social and Environmental Baseline

The social objectives identified include the following (Appendix 4, pages 98 (bottom) and 99 (top)):

- Demonstration effect as the first private hydroelectric power plant in Nepal having groundbreaking social mitigation and development programs.
- Transfer of technology and skills.
- Mitigate any negative social impacts and maintain good community relationship in order to ensure a stable local operating environment by providing electricity, employment, private sector development, education and infrastructure.

Khimti 1 has complied with the IFC, ADB and Government of Nepal's environmental and social standards, all of which were considered as in en excess of the industry 'best-practice' at the time.

Several underlying factors explain why the project area is inherently vulnerable to climate change:

- Nepal has high levels of poverty with about 31% of its population living below the national poverty line (World Bank, 2007).
- Education and health care are not available to many living in the remote rural areas.
- It is the poorest country in terms of Gross National Income in South Asia (see Appendix 4, page 95 (bottom).
- 80% of the population is dependent on agriculture mainly in subsistence farming.
- The recent history of insecurity in rural areas because of the Maoist insurgency has left a legacy of livelihood insecurity, exclusion, lack of development and lack of trust in government.
- The ability of regional and national government to deliver public services in rural areas is constrained. Many areas depend on community-based development programs.
- Migration in search of work, to Kathmandu and to other countries,
- De-population of rural areas with an ageing population as young people leave in search of work is a major issue.
- Within the project area there are no opportunities for employment other than that directly or indirectly related to Khimti 1.

However, it is important to note that the region is already subject to high levels of climate variability and extreme events. Local communities already have in place a variety of coping mechanisms. However the additional stress brought by incremental changes (chronic) and extreme events (acute) might have a cumulative effect or reach a threshold beyond which existing coping mechanisms are no longer sufficient.

Social and Environmental Impacts

Climate conditions generate risks and opportunities for the communities of the Khimti Khola area (see Appendix 4, pages 95 (bottom) through 98 (top)). Five stakeholder groups were identified:

- **Landowners who were relocated or compensated by HPL during the construction phase for Khimti 1 (represented by circle 1 in Figure 18).**

  The construction of Khimti 1 affected small areas of land on the transmission line right-of-way, headworks, power house and accommodation areas. Nine households and 18 farm outbuildings had to be relocated. Landowners were compensated ten times the market value of their land. More specifically, compensation for housing structures exceeded government compensation rates by 60 to 150 percent depending on the type of materials with which the houses were constructed. HPL also purchased land from several landowners in the headworks area. It agreed to hold the land titles in trust and sell the land back to their former owners at the original purchase price on completion of the Project. In addition, HPL gave these landowners priority employment on the Project by way of additional compensation for lost agricultural production during the life of the Project.

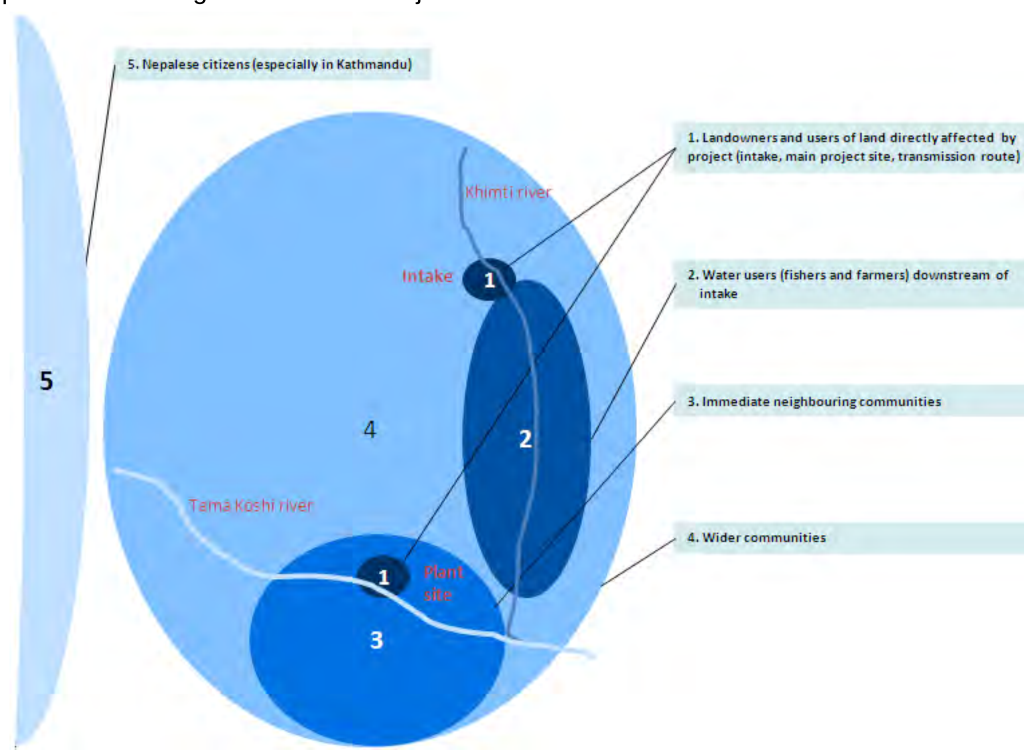


Figure 18. Location of Khimti Khola Project Stakeholders
Source: Synergy

- **The water users (farmers and fishermen) downstream of the intake (represented in Figure 18 by circle 2).**

  The section of the Khimti river affected by the plant is used for irrigation and fishing. Before Khimti Khola power plant, there was only one irrigation channel that used the Khimti river during dry periods. During the dry season a number of people fish in the river to supplement livelihoods.

  Lower flows downstream of the intake have resulted in pools being formed. The river has been overfished with illegal practices.

  HPL has supported these stakeholders through the following actions:

  - Assistance to the farmers of the Project area in constructing, refurbishing and repairing irrigation canals that use flows from the tributaries of the Khimti river.
  - Monitoring fish stock levels and advising fishermen on fishing methods.
  - Supporting local initiatives in fish farming and breeding.

- **The immediate neighboring communities in the Kirne area (represented in Figure 18 by circle 3).**

  HPL has invested in community development with a positive impact for many of the people living in the vicinity of Khimti 1. The various initiatives put forward are described in Appendix 4, page 97 and range from the provision of health facilities, health awareness and education, a new school, physical improvements to local infrastructure, support for rural electrification projects, local employment and procurement opportunities.

  A socio-economic review of the Project in 2001 identified a number of positive impacts attributed to the Project community development actions compared to 1995, including:

  - A 15% increase in female literacy among the sample population (namely 10% of all project area households).
  - A 10% increase in the number of children receiving immunization (EPI) vaccinations.
  - A 13% increase in contraception use.
  - An 8% decrease in infant mortality.

Kirne village

- **The wider communities in the region of Khimti Khola (represented in Figure 18 by circle 4).**

  The rural electrification schemes will have a wider benefit for local communities near to Khimti 1. The health care and education facilities designed originally to meet the needs of the immediate neighboring communities, are being used by surrounding communities.

- **The Nepalese citizens, especially in Kathmandu (represented in Figure 18 by the shape 5.**

  Khimti 1 has had a major impact on the supply of electricity to Kathmandu with benefits to residents, business and the NEA through revenues.

Social and Environmental Impacts due to Climate Change

- **Landowners**

  When not properly managed, involuntary resettlement may result in long-term hardship and impoverishment and reduce individual adaptive capacity.

  Despite the relatively good process for relocation and compensation and the good compensation rate, HPL did not have a formal Resettlement Action Plan and did not appear to have a formal monitoring or follow-up methodology to ensure that livelihoods were restored after the construction of Khimti 1.

  The number of people directly affected in this way is however small.

- **Risks regarding water users**

  Climate change may exacerbate the risks attached to low dry season flow on stakeholders using the river for irrigation and fishing.

  Increases in temperature and changes in precipitation, together with changes in the commencement and duration of the monsoon period will place existing agricultural practices under stress.

  Farmers are already reporting lower yields due to the later arrival of the monsoon and recognize that they need to introduce new crops. The limiting factor for many alternative crops is the availability of irrigation water during the dry season. Yet, projected climate changes are likely to result in increased variability of river run-off. This may lead to an increase in community 'perceived' impacts of Khimti 1 on water flows. Additionally, lower river flows, combined with higher temperatures, may result in decreased water quality leading to incidence of water-borne diseases.

- **Risks regarding neighboring communities**

  The improvement in health and education will have made a positive contribution to increasing the adaptive capacity of communities to climate change. The communities are still however vulnerable to extreme events (GLOF, floods and landslides) and to the incremental changes affecting agricultural production.

- **Risks regarding the wider communities in the region of Khimti Khola**

  Climate change may intensify migration as a coping strategy leading to further de-population and an aging demographic profile.

Climate change will increase the social, economic and environmental stresses on local communities. This may create issues for HPL and the operation and management of Khimti 1. One area in particular that may be seen as key adaption option for local communities is the need to increase irrigation water to cope with the impacts on agriculture.

Khimti 1 Intake structure and low flow weir

7. Adaptation Options

Key Messages

- The adaptation options are focused on those that can manage either the risks or opportunities arising from changes in river flow and the potential impact on generation revenues.
- The analysis of the climate models and, the hydrological assessment do not provide consistent results.
- The information available at this stage is insufficient to enable HPL with any degree of certainty to make any decision on asset replacement or further capital investment. At this stage in the early years of the current PPA and with the major assets having a significant future asset life it is recommended that the adaption options taken by HPL are for the most part directed at building adaptive capacity rather than delivering adaption action.
- Future PPAs in Nepal (and elsewhere) should include a provision for periodic reviews to take into account changes in flows. This would allow the contract energy/excess energy level to be varied as the climate change impacts became clearer.

Potential Adaption Measures

1. A watching-brief should be maintained on flows during the dry weather months. Regular (daily) flow monitoring should be undertaken at the KK intake.
2. The information obtained from an enhanced flow monitoring program and future assessments of climate change should be used to guide decisions on replacing assets and operating procedures.
3. Flow monitoring and hydrological assessments for future upstream hydro power projects should be used to undertake a new analysis of the potential climate change impacts for both Khimti 1.
4. The development of upstream hydro power projects may have an impact on the operation of Khimti 1. HPL should request that the developers of other projects undertake an assessment of the impact of climate change on flows and the impact on the production outputs from Khimti 1.
5. Although the projections on future flows in the Khimti Khola vary based on the climate models, there are opportunities for HPL to use the spare capacity in its existing turbines to maximize output during the dry weather months.
6. The dry weather period is used by HPL to carry out routine annual maintenance and any major operational improvements. If flows increase in the dry weather period as projected by some of the models then HPL will need to review its maintenance and operational improvement programs.
7. In order to avoid pressure from farmers requiring greater dry weather flows (and protect the currently advantageous dry weather excess energy revenues), HPL may wish to consider the following actions:
    a. Provide support to local farmers for the construction of irrigation systems drawing water from tributaries of the Khimti Khola.

b. Actively support the development of alternative agricultural practices and crops. By encouraging the use of drought resistant crops the need for additional irrigation may be reduced when compared with the needs for current agricultural practices.

8. Lessons Learned and Observations for the Hydropower Sector

The project has provided an opportunity to meet with senior officials (including First Secretaries and Director Generals) in all the key Government Departments, Nepali and international engineering consultants, investment banks, NGOs, hydropower operators and local communities. The discussions, information sources collected and analyses undertaken provide an opportunity to put forward some observations on the current and future prospects for hydropower and water resource management in Nepal.

The ending of the insurgency and the transition towards a democratic republic will open up enormous opportunities to develop hydropower projects (at micro, small and large scales) and water resource management projects. The demand for electricity in Nepal requires new generating capacity (40+ hours load shedding in Kathmandu every week, insufficient power for industry, increasing urbanization and little power in rural areas).

The demand in Nepal is far lower compared to its neighbor to the south, India. The potential energy demands in Nepal are still significant particularly in the development of run-of-river schemes up to 60+MW and smaller rural electrification plants. The alternative is a continuing reliance on imported fossil fuels. The impact of high oil prices on the economy of Nepal is all too obvious, together with the social and environmental impacts.

India has indentified Nepal as one of its major future sources of electricity and a number of Indian corporates are seeking licenses to secure water rights. India is also concerned that glacial retreat in the Himalayas will have serious impacts on the main rivers of northern India during the dry season. These rivers are dependant on glacial melt to maintain flows. The development of large dams to both generate power and regulate flows is therefore seen as a matter of national security. Glacial retreat has been observed in some parts of the Himalayas, with the greatest retreat at the edges of the Tibetan Plateau (Yao et al., 2007), although there is a lack of long-term observational records. The IPCC recently reaffirmed that 'widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century.' (IPCC Chair and Vice Chair, 2010).

Even if the political situation in Nepal remains unstable, the potential social, economic and environmental value to India is likely to drive the development of both hydro and water resource management projects in Nepal.

The Nepal Government has previously stated its intention to encourage international investment in hydropower. One of the key changes will be the removal of a mandatory requirement that all power generated by private companies is sold to Nepal under their system of PPAs. This will create a free market for generators to sell to India or to Nepal and remove a major disincentive to investment. In addition the monopoly power of the Nepal Electricity Authority will be removed, again creating the opportunity for new transmission systems connecting to India.

Nepal is emerging from a period of instability. It will be some time before the institutional, political and regulatory capacity is available to enable the generating potential to be realized. Nepal wishes to utilize its natural resources to create an economic revolution, but it is very conscious of the need to do this sustainably and ensure that all environmental and social impacts are included into projects. Further support is required in the following areas:

- Institutional capacity building at technical levels.
- The development of a national plan for electricity.

- Project financing.
- Energy regulatory, legal and pricing systems.
- Corporate governance.
- Baseline hydrological and meteorological data.
- Environmental and social monitoring.
- Climate impact and risk management.
- Water resource management.

There are major issues for potential projects if the risks (and opportunities) arising from climate change are not factored into their financing, feasibility, design, construction and operation. Changes in hydrology (precipitation, snow and glacial melt), sedimentation, glacial lake outburst flood risks (GLOF), flood events; together with changes in the wider environment (e.g. changes in ground cover and land use) and impacts on local communities (greater conflict over water rights during dry periods) can have major impacts on projects. The direct effects of changes in hydrology may of course completely undermine the basis for feasibility and design with significant effects on generating output and the rate of return.

There is good agreement among GCMs on future temperature trends in this region, however projections of future precipitation differ widely. This uncertainty means that the benefits of downscaling (which is often recommended as a way to identify specific local impacts) are less relevant. A focused modeling effort on improving understanding of monsoon processes would certainly be beneficial for interpreting divergent GCM results in this part of the world.

This region already deals with a significant amount of inter-annual variability in precipitation. The difficulty of predicting monsoon behavior and changes in precipitation during the dry season with any certainty underlines the need for contingency planning in case of extreme events.

For some impact relationships between climatic factors and direct and indirect impacts on HPL's operations the lack of baseline information has prevented further analysis. An example of this is the increased risk of flooding on both the Khimti Khola and the Tama Koshi. This illustrates the need for further monitoring and research on baseline conditions in countries like Nepal to enable informed decision making in the face of further climatic change.

Good quality observed data is paramount to achieving robust future flow analysis. Changes in instrumentation or ambient conditions or extreme events are important factors to document. The heterogeneity in available hydrological data for Khimti Khola led to the construction of two different river flow models (Part 1 and 2) projecting different future estimates. It is difficult to attach different levels of confidence to these models. Further, the lack of observations of snow melt in the project catchment area prevented inclusion of the potential effects in the design of the model or in future flow projections. Improved monitoring of river flow would be beneficial for future flow projections.

The difference in projections across climate change models and scenarios reflects the relatively high uncertainty characteristic of climate change projections for rainfall in the region. A focused modeling effort on improving understanding of monsoon processes would certainly be beneficial for combating divergent GCM results in this part of the world.

Appendix 1: Future Climate Change Scenarios

To provide a basis for estimating future climate change, the Intergovernmental Panel on Climate Change (IPCC) prepared the Special Report on Emissions Scenarios, detailing 40 greenhouse gas and sulphate aerosol emission scenarios that combine a variety of assumptions about demographic, economic and technological factors likely to influence future emissions. Each scenario represents a variation within one of four 'storylines': A1, A2, B1 and B2. Further details of the storylines are provided below. Projected carbon dioxide, methane, nitrous oxide and sulphate aerosol emissions based on these scenarios are shown in Figure 19 below for six 'marker scenarios'. All the scenarios are considered equally sound by the IPCC and no probabilities are attached.

Storylines for scenarios of greenhouse gas emissions:

A1: The A1 storyline describes a future world of very rapid economic growth, a global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 storyline develops into three scenario groups that describe alternative directions of technological change in the energy system. They are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources and technologies (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2: The A2 storyline 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.

B1: The B1 storyline describes a convergent world with the same global population as in the A1 storyline (one that peaks in mid-century and declines thereafter) but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives, i.e. it does not include implementation of the United Nations Framework Convention on Climate Change or the Kyoto Protocol.

B2: The B2 storyline describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is 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 B1 and A1. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

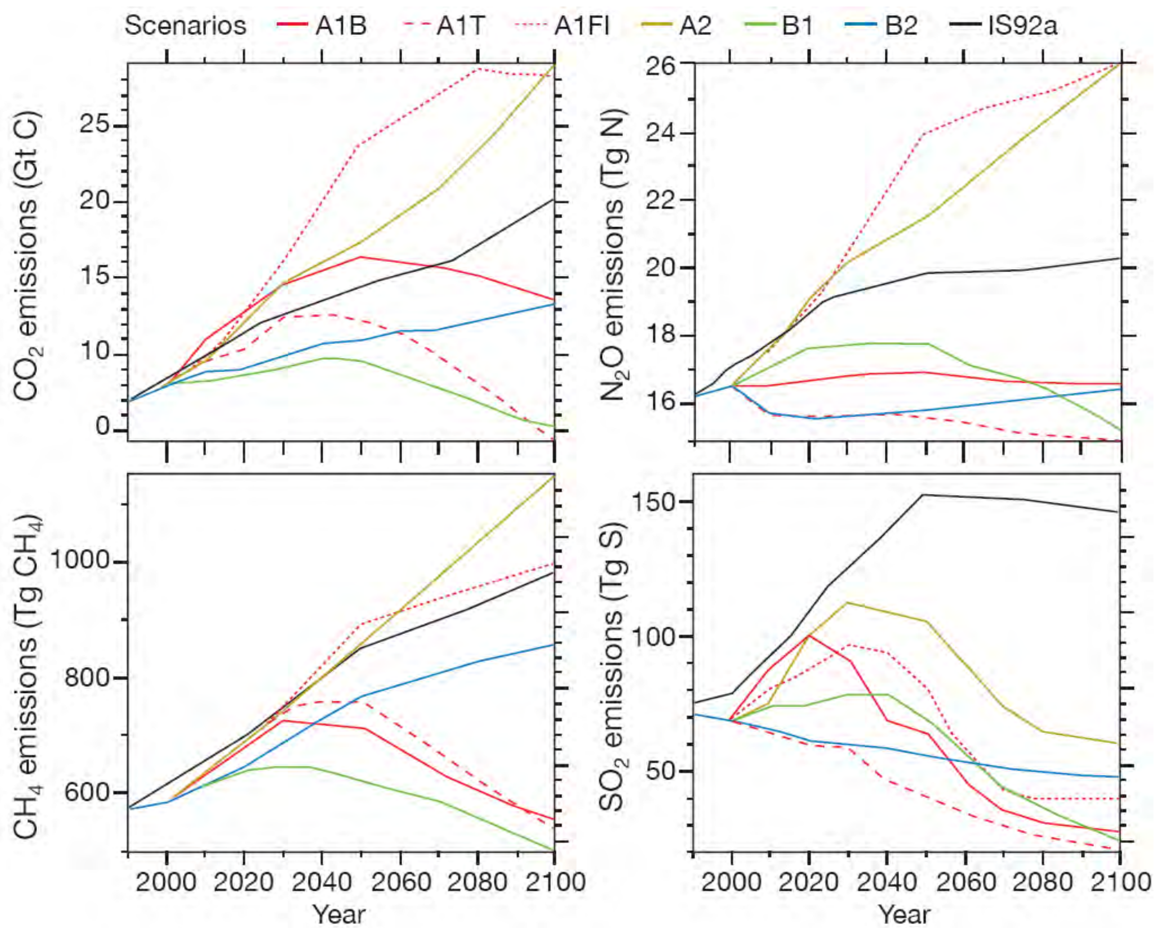


Figure 19. Anthropogenic emissions of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and sulphur dioxide (SO2) for six SRES scenarios (see Box 1) and the IS92a scenario from the IPCC Second Assessment Report in 1996 for comparison

Source: Nakićenović and Swart, 2000.

Appendix 2: Additional Scenarios

Scenario 1: Glacier Lake Outburst Flooding (GLOF)

Methodology

A literature review of available information on GLOFs in Nepal was undertaken and discussions held with experts of the region in order to understand the risk for Khimti 1.

Observations

In the Himalayas, glacial retreat has led to the formation of many glacial lakes, often dammed by moraines. These natural moraine dams are composed of unconsolidated sediments consisting of boulders, gravel, sand and silt. Because of their inherent instability, they are prone to catastrophic collapse, causing GLOFs. GLOFs may be triggered by displacement waves originating after a rockslide or a snow/ice avalanche, by an earthquake or seepage of the dam structure leading to failure.

GLOFs can have disastrous consequences for downstream riparian communities and infrastructure, as the released water rushes down the stream channel in the form of flood waves. Many GLOF events have been recorded in Nepal in the past (see Rana et al., 2000). The disastrous GLOF at Dig Tsho in August 1985 attracted considerable scientific and government attention.

Based on government-funded glacier research (by the Nepalese Water and Energy Commission Secretariat) and following a joint study by the Department of Hydrology and Meteorology (DHM) and a specialist consultancy (Reynolds Geoscience Limited, 1997), the Tsho Rolpa Glacier Lake in central Nepal was identified as one of the most dangerous glacier lakes in the Nepal Himalayas. Previously in 1992 a hazard assessment recommended lowering the lake level by several meters and monitor the lake level fluctuations at the discharge point.

Tsho Rolpa is the largest glacial lake in Nepal and contains about 100 million m^3 of water behind an unconsolidated moraine dam. Observations report that the 150 meters high dam has been deteriorating rapidly (Rana et al., 2000).

After several studies, including a risk assessment requested by the NEA and completed in 2000 (Reynolds et al., 1996), remedial works have been carried out at Tsho Rolpa comprising an open drainage channel cut through the moraine in order to lower the lake water level by 3.5 meters. This was a temporary remedial work as the lake has continued to grow with the continued retreat of the glacier. The dam is becoming unstable and further lowering of the lake level may be needed in order to achieve an acceptable level of safety. Preliminary assessments suggest that a further lowering of 17m of the lake is necessary for the permanent prevention of a GLOF event (Rana et al., 2000).

A dam break model was run to simulate the implications of a GLOF at Tsho Rolpa (DHM, 2000). The worst scenario estimates a peak water discharge of about 7,000 m^3/sec and a downstream impact up to 100 kilometers.

Figure 20 shows that such an event would affect Khimti 1, although there is no available information about the scale of the impacts and flooding at the site.

An early warning system, consisting of sensors located downstream of the end moraine and connected to 19 downstream stations equipped with audible alarms, was put in place in 1998 (Germanwatch, 2004) but is currently non operational.

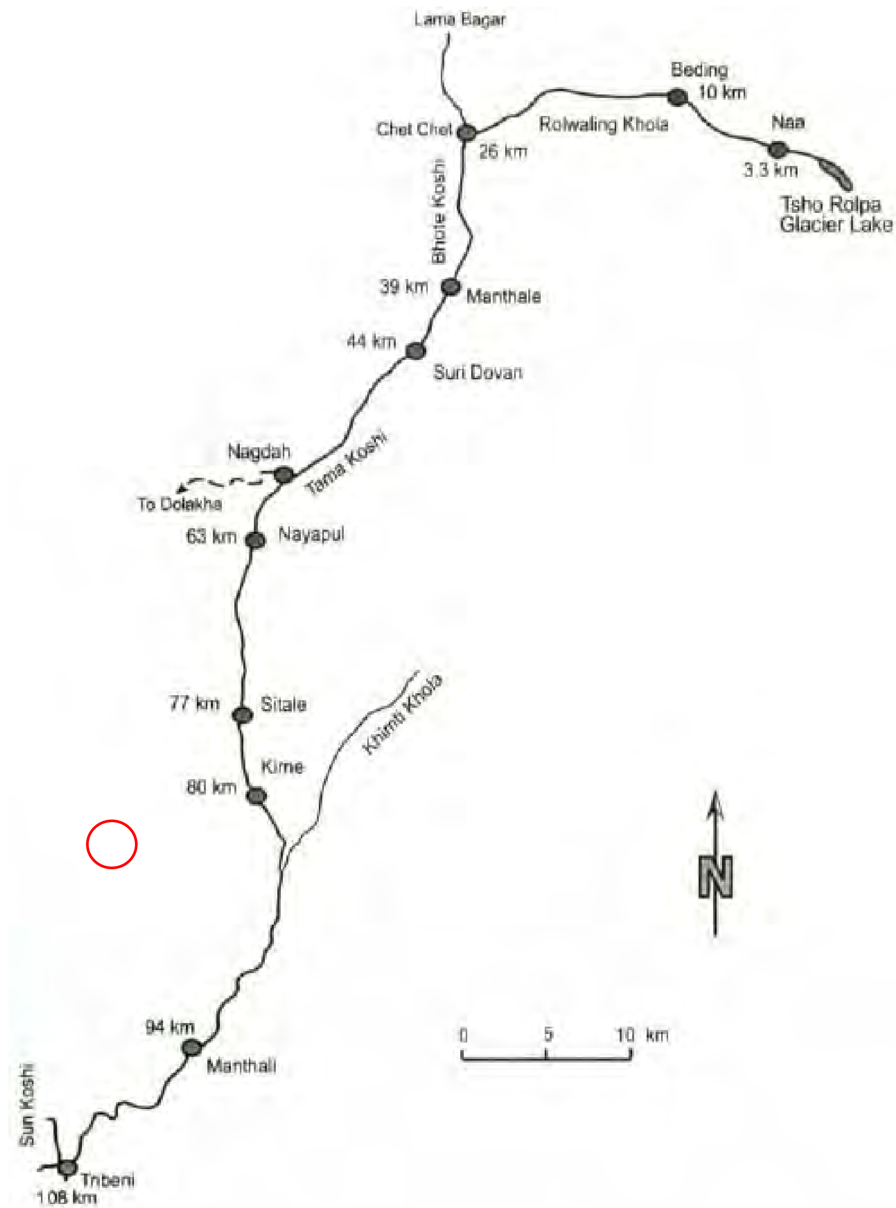


Figure 20. Geographic delimitation of the impact of the Tsho Rolpa Glacier Lake outburst (up to 100 kilometers downstream). The red circle represents the discharge point of Khimti Khola hydropower plant on the Tama Koshi (about 80 kilometers of the lake).

Source: Rana et al., 2000, p. 566.

An update of the 2000 risk assessment is planned. All relevant Nepal Government departments, research institutions and HPL have been asked if they know of the existence of a flood risk assessment. It would appear that such an assessment has not been undertaken.

Projections

Over time, assuming that glacial melt continues, the risk of a Tsho Rolpa GLOF would increase with potential implications for Khimti 1, including:

- Operation of the facility—flooding of the power station control building and other external facilities (e.g., transformers, plant maintenance buildings). The turbine house is protected by flood gates, although the design parameters for these gates are not known.
- Generating output—until remedial works could be undertaken.
- Access to the site—for example the access road may be at risk and undermining of the bridge piers could cause the bridge over the Tama Koshi to collapse.
- Workforce—who live in, or near, the floodplain areas.

It is not known if the existing Khimti 1 assets at Kirne could withstand a potential peak river flow of 7,000 m^3/sec in the event of a GLOF at Tsho Rolpa.

Scenario 2: Extreme river flooding on the Tama Koshi

Methodology

A review of the existing information on floods in the Tama Koshi was undertaken. There is no available baseline data or information on flood return periods and flood levels for the Tama Koshi (Geospatial Systems Limited, 2007). It was agreed with the IFC Project Manager not to model the impacts of climate change on flood return periods and flood levels on the Tama Koshi in view of the absence of this baseline information.

Observations

Based on recorded data, flash floods are comparatively frequent in Nepal.

No record of flood levels on the Tama Koshi is available, but anecdotally the maximum flood level is considered to be the lowest level at which the adjoining hillsides were terraced. However an inspection during the site visit and from the available maps suggests that there is a significant alluvial floodplain along the Tama Koshi. The power station control building, the sub-station, workshops and living accommodation together with the access road are all constructed on the alluvial floodplain. The inference to be drawn is that historically there have been significant flood events which may have the potential to affect Khimti 1.

Alluvial flood plain on the Tama Koshi immediately upstream of Kirne

Projections

If such a flood happened, the consequences would be significant disruption to:

- Operation of the facility—flooding of the power station control building and other external facilities (e.g. transformers, plant maintenance buildings).
- Generating output—until remedial works could be undertaken.
- Access to the site—for example the access road may be at risk and undermining of the bridge piers could cause the bridge over the Tama Koshi to collapse.
- Workforce—who live in, or near, the floodplain areas.

Scenario 3: Extreme river flooding on the Khimti Khola

Methodology

There is no baseline data or information on flood return periods for the Khimti Khola other than that produced for the original project appraisal.

Observations

An analysis of the baseline flow data on the Khimti Khola was undertaken. The observed river flow duration curve for Khimti Khola (Figure 21) clearly shows that river flow exceeded 200 m^3/sec 2% of the time in 1985–2006.

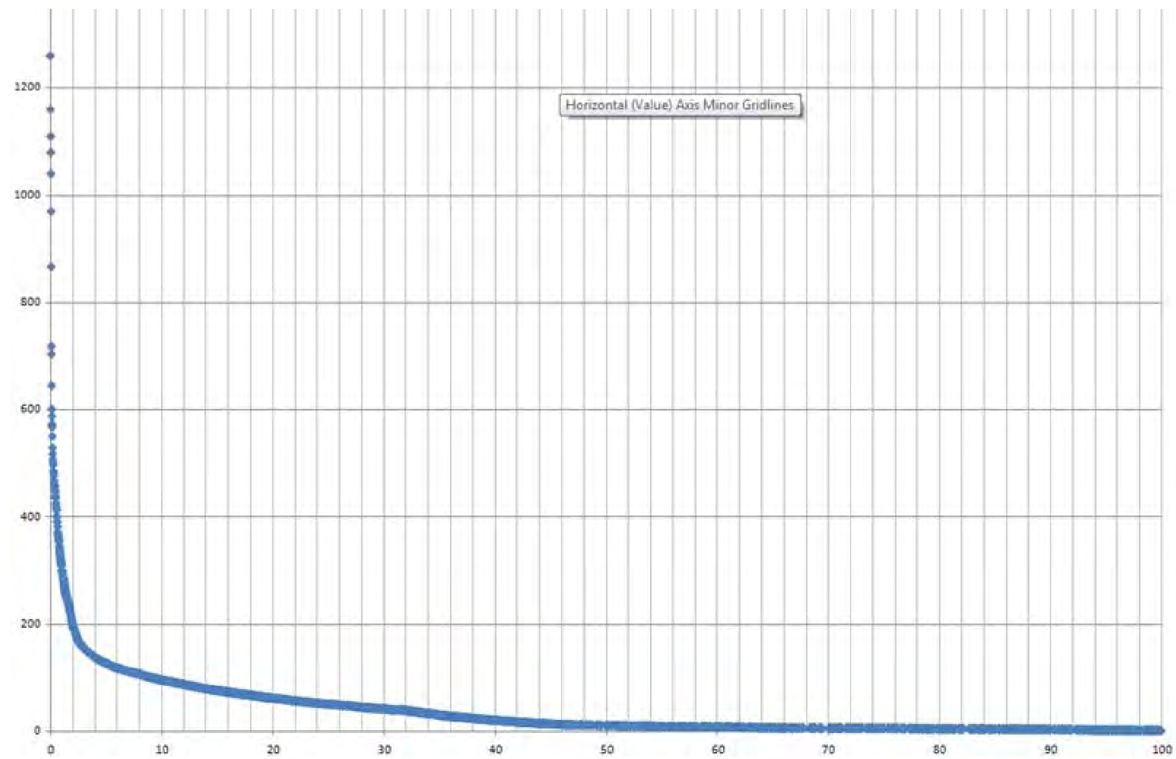


Figure 21. River flow duration curve for the Khimti Khola based on average daily observed data from the Rasnalu hydrological station between 1985 and 2006 (in m^3/sec)

Source: Based on the meteorological data of Rasnalu (station #650, DHM).

If a flood occurred on the Khimti River, it is assumed that the intake structure would be inundated arising from either an overtopping of the intake wall or undermining of the intake structure foundations leading to a collapse of the intake wall. Severe damage to the control gates and electrical equipment would occur. Sedimentation chambers would be filled with material. Generating output would be disrupted until such time as the sediment chambers are cleared and the intake structure is repaired.

Scenario 5: Major landslide blocking flow of the Khimti Khola

Methodology

A review of the available information on landslides in the area was undertaken. There is little baseline information on which an assessment of risk could be made. This part of Nepal is recognized as being a landslide risk area due to the geology and the effect of storms. It was agreed with IFC Project Manager that a quantitative assessment would not be possible given the availability of baseline information.

Observations

The geology of the area creates a significant landslide risk. Localized landslides are common, occurring most years, although a major event resulting in a blockage of the river would be less likely. In 2000, there was a landslide that blocked the Khimti Khola upstream of the hydropower plant inlet prior to commissioning. This created a temporary dam across the river restricting downstream flows. The blockage was removed quickly by construction machinery still on site. A further landslide occurred on the Paluti Khola (a tributary of the Khimti Khola) in 2002.

Remedial works to prevent landslide on unstable ground at Khimti 1 intake structure

Projections

Our climate change risk scenario assumes that a landslide occurs upstream of the intake following a localized storm and blocking the Khimti Khola during the dry weather season. It is estimated that a major blockage would take several weeks to remove. Additionally, during the period of the blockage downstream flows could fall below the minimum dry weather flow condition of 0.5 m^3/sec. Even if it is assumed that the blockage can be removed without any damage to the intake structure, generating output would be lost with significant revenue consequences.

Appendix 3: Influence of Black Carbon on Global Climate Projections

Climate change is caused, in part, by human activities which alter the amounts of greenhouse gases, aerosols (small particles), and cloudiness in Earth's atmosphere. Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence.

Aerosols are small particles present in the atmosphere in widely varying sizes, concentrations and chemical compositions. Aerosols contain both naturally occurring compounds and those emitted as a result of human activities. Fossil fuel and biomass burning have increased aerosols containing sulphur compounds, organic compounds and black carbon (soot).

The contributions to radiative forcing from some of the factors influenced by human activities are shown in Figure 22. The values reflect the total forcing relative to the start of the industrial era (about 1750). Aerosol particles influence radiative forcing directly through reflection and absorption of solar and infrared radiation in the atmosphere. Some aerosols cause a positive forcing while others cause a negative forcing. Since the start of the industrial era, land cover changes (largely due to net deforestation) have increased surface albedo. This results in a negative radiative forcing. Over the same period, the presence of black carbon particles has reduced surface albedo, modifying the reflective properties of snow and ice. This has increased snowmelt and resulted in positive radiative forcing, although this is associated with a low level of scientific understanding.

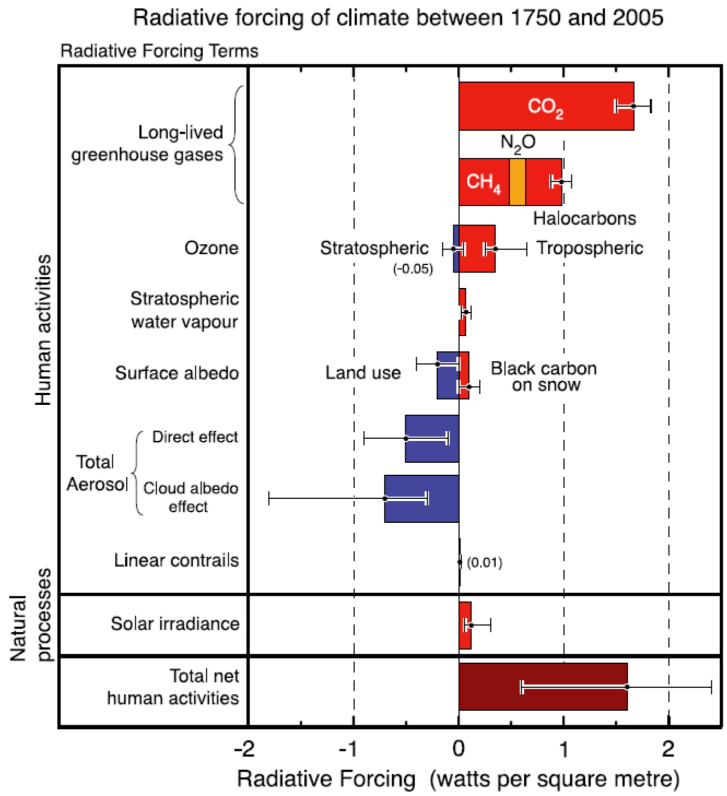


Figure 22. Summary of the principal components of radiative forcing of climate change. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750).

Note: Positive forcings lead to warming and negative forcings lead to cooling of climate. The thin black line attached to each colored bar represents the range of uncertainty for the respective value.
Source: IPCC, 2007.

Emissions of black carbon have decreased significantly in the UK, Germany, the former Soviet Union and the USA over the period 1950–2000, though significant increases have been reported in India and China over the same period.

The forcing agents included in each global climate model experiment in the IPCC's Fourth Assessment Report are shown in Table 4. Of the four models used to analyze projected changes in temperature, precipitation and runoff at Khimti Khola (GISS-ER, CSIRO-MK3.5, CGCM 3.1 and GFDL-CM2.0), two take account of the effect of black carbon on radiative forcing, while two do not.

Model	Forcing Agents																		
	Greenhouse Gases						Aerosols										Other	
	CO_2	CH_4	N_2O	Stratospheric Ozone	Tropospheric Ozone	CFCs	SO_4	Urban	Black carbon	Organic carbon	Nitrate	1st Indirect	2nd Indirect	Dust	Volcanic	Sea Salt	Land Use	Solar
BCC-CM1	Y	Y	Y	Y	C	4	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	C	C
BCCR-BCM2.0	1	1	1	C	C	1	2	C	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	C	C	C
CCSM3	4	4	4	4	4	4	4	n.a.	4	4	n.a.	n.a.	n.a.	Y	C	Y	n.a.	C
CGCM3.1(T47)	Y	Y	Y	C	C	Y	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	C	C	C	C
CGCM3.1(T63)	Y	Y	Y	C	C	Y	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	C	C	C	C
CNRM-CM3	1	1	1	Y	Y	1	2	C	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	C	n.a.	n.a.
CSIRO-MK3.0	Y	E	E	Y	Y	E	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ECHAM5/MPI-OM	1	1	1	Y	C	1	2	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
ECHO-G	1	1	1	C	Y	1	6	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	C	n.a.	n.a.	C
FGOALS-g1.0	4	4	4	C	C	4	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C
GFDL-CM2.0	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	n.a.	n.a.	C	C	C	C	C
GFDL-CM2.1	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	n.a.	n.a.	C	C	C	C	C
GISS-AOM	5	5	5	C	C	5	2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.
GISS-EH	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	Y	n.a.	Y	C	Y	C	Y	Y
GISS-ER	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	Y	n.a.	Y	C	Y	C	Y	Y
INM-CM3.0	4	4	4	C	C	n.a.	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	n.a.	C
IPSL-CM4	1	1	1	n.a.	n.a.	1	2	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
MIROC3.2(H)	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	Y	Y	Y	C	Y	C	C
MIROC3.2(M)	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	Y	Y	Y	C	Y	C	C
MRI-CGCM2.3.2	3	3	3	C	C	3	3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	n.a.	C
PCM	Y	Y	Y	Y	Y	Y	Y	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	C	n.a.	n.a.	C
UKMO-HadCM3	Y	Y	Y	Y	Y	Y	Y	n.a.	n.a.	n.a.	n.a.	Y	n.a.	n.a.	C	n.a.	n.a.	C
UKMO-HadGEM1	Y	Y	Y	Y	Y	Y	Y	n.a.	Y	Y	n.a.	Y	Y	n.a.	C	Y	Y	C

Table 4. Radiative forcing agents included in the multi-model global climate projections used in the IPCC's Fourth Assessment Report.

Note: Entries mean:
Y – forcing agent is included;
C – forcing agent varies with time during the 20th Century *Climate in Coupled Models (20C3M) simulations;*
E – forcing agent is represented using equivalent CO2; and
n.a – forcing agent is not specified in either the 20th century or scenario integrations.

Sources:
IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

Appendix 4: Baseline Data and Methodological Application

Identification of Project Objectives

- **Is the project explicitly aimed at managing present-day climate or adapting to future climate change?**
  - The project undertook an assessment of the hydrology (and the baseline climate) as a key factor in the design and operation of the generators.
- **If the main driver is not related to climate or climate change, is climate change likely to be a key factor?**
  - Measures were taken to protect the main tunnel from the risk of flooding due to a glacial lake outburst flood (GLOF). There is no evidence from the project documentation that any other potential climate change hazard and impact was considered.
  - Climate change during HPL has not undertake any subsequent investigation of the impacts of climate change and has no current plans
  - the asset design life of the project is likely to be a significant factor with implications for the operation of the plant. Social and environmental impacts will have implications for the project.
    - Flows in the Khimti Khola are significantly reduced during the dry weather period (December-May). Relatively small changes in flow due to changes in precipitation can have impacts on the operation of the plant and its income generation potential.
    - Maintaining a minimum low-flow is an important operational restriction to protect downstream fisheries and to allow abstraction for irrigation.
    - Changes in precipitation will change the intensity of floods and the return periods for flood events.
    - Flows in the Tama Koshi will be affected by increasing glacial melt.
    - Anecdotal evidence from farmers suggests that the monsoon period is arriving later resulting in reduced yields. Changes in river flows and temperature will have implications for both agriculture and fisheries.
    - Increasing storm intensity together with changes in precipitation and river flow will increase the significant risk of erosion and landslide with implications for access roads, operational structures, bridges and sediment loads.
    - Changes in air and water temperature, precipitation and water quality will create health risks.

- **What are the consequences of failing to address climate change adaptation for:**
  - The project sponsors (HPL):
    - Changes in operational costs.
    - Changes in generating output and revenue.
    - Reduction in asset life.
    - Implications for profit and rates of return.
    - Potential increased in capital investment.
    - Breakdown in local community relations.
    - Environmental degradation.
  - IFC:
    - Long-term sustainable and social development objectives compromised.
    - Implications for other hydro-power projects in Nepal and elsewhere – implications not correctly assessed, other projects compromised.
  - Government of Nepal:
    - Increasing financial exposure as ownership of Khimti Khola is transferred in 2020 and 2050.
    - Impact on electricity supplies (security and generating output).
    - Potential increase in load shedding.
    - Loss of revenue from reduced electricity sales to customers.
    - Impact on economic growth.
    - Impact on investor confidence with regard to other hydro-power schemes.
  - Local communities:
    - Impact on employment and procurement.

- **Who are the main stakeholders directly affected by the project?**
  - Project sponsors (HPL) and its shareholders and financers, including IFC.
  - Government of Nepal (including various Government departments and agencies).
  - Customers.
  - Suppliers.
  - Local communities.

- **Other stakeholders with an interest in the project:**
  - Development aid agencies.
  - UN and other similar international development and environmental organizations.
  - NGOs.
  - Other hydro-power constructors and operators.

- **What is the lifetime of the project?**
  - HPL has provided details of the asset life for each of the mains assets. These are contained in the attached spreadsheet (Insert link to spreadsheet). Note that decisions by HPL on asset replacement are likely to be determined in part by the PPA licence which provides for ownership of the plant to be transferred to the Nepal Electricity Authority in stages in 2020 and 2050. The requirement to transfer ownership will have implications for the implementation and financing of potential adaptation measures. (Note this is an issue that will be considered in the financial modeling scenarios).

- **What are the timescales for IFC's exposure on the project?**
  - IFC's direct financial involvement in the project has now finished. However it has a retained interest in the projects in which it invests and lends to, delivering long term sustainable development benefits beyond the period of its own financial interests.

- **What are the timescales for HPL's exposure on the project?**
  - Under the current PPA and PA agreements HPL will transfer x% of the ownership of Khimti Khola in 2020 to the Government of Nepal. In 2050 it will transfer full ownership to the Government.
  - There are provisions in the PA for HPL to require the Government to purchase Khimti Khola in the event of certain 'Buyout Special Force Majeure Events' meaning any of the specified acts or omissions of, or circumstances or occurrences caused by, the Government affecting HPL or any contractor or supplier of HPL which prevents HPL from performing its material obligations under the PPA.
  - HPL can exercise its powers at any time to dispose of its assets as a commercial decision acting in the interest of its shareholders.

- **What are the timescales for the Government of Nepal's exposure on the project?**
  - Continuous throughout the operation of the Khimti Khola plant, in accordance with its legal obligations to HPL under the PA and the PPA.
  - The Government's exposure will increase in 2020 and 2050 on transfer of the ownership of Khimti Khola. The Government in 2050 will have full responsibility for both operational (revenue) expenditure and capital expenditure to maintain the asset, to replace assets at the end of their operational life, and to carry out any improvements or adaptation actions.

Observed Climate Normals Jiri and Janakpur Meteorological Stations

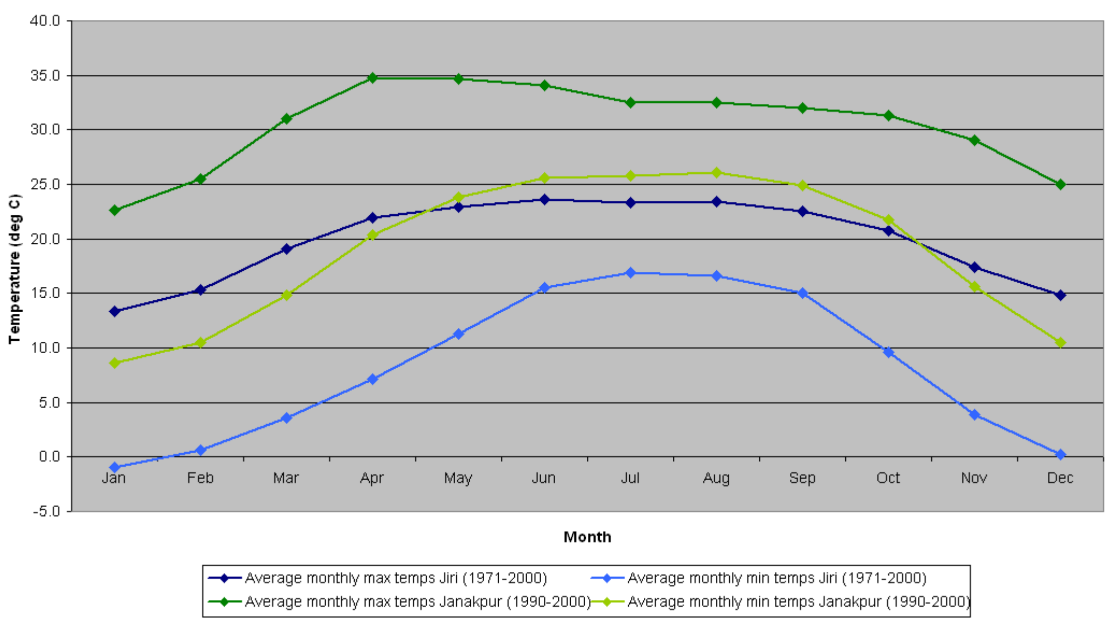
Jiri and Janakpur are each approximately 20km from Khimti Khola power station

Janakpur is at low elevation while Jiri is high in the mountains. This difference in altitude is reflected in the temperature and precipitation charts on the following two slides. The power facility is roughly one-third of the way up in elevation between the two met stations.

Normal (Average) Maximum, Minimum Temperature (°C) and Rainfall (mm) through 2000 year														
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Monsoon	Period
Index 1103		JIRI													
Max temp (°C)	13.4	15.3	19.1	21.9	22.9	23.6	23.3	23.4	22.5	20.8	17.4	14.8	19.9		1971-2000
Min Temp (°C)	-1.0	0.6	3.6	7.1	11.3	15.5	16.9	16.6	15.0	9.6	3.9	0.2	8.3		
Rainfall (mm)	16.9	19.9	43.4	84.9	179.6	374.9	590.9	560.3	289.3	73.3	17.3	15.3	2232.1	1791.9	
Index 1111		JANAKPUR AIRPORT													
Max temp (°C)	22.6	25.5	31.0	34.8	34.7	34.1	32.5	32.5	32.0	31.3	29.0	25.0	30.4		1990-2000
Min Temp (°C)	8.6	10.5	14.8	20.4	23.8	25.6	25.8	26.1	24.9	21.7	15.6	10.5	19.0		
Rainfall (mm)	11.8	12.5	12.6	41.0	96.7	207.3	422.9	313.0	194.1	69.4	3.7	10.4	1395.6	1137.4	1971-2000

Source: Nepal DMH

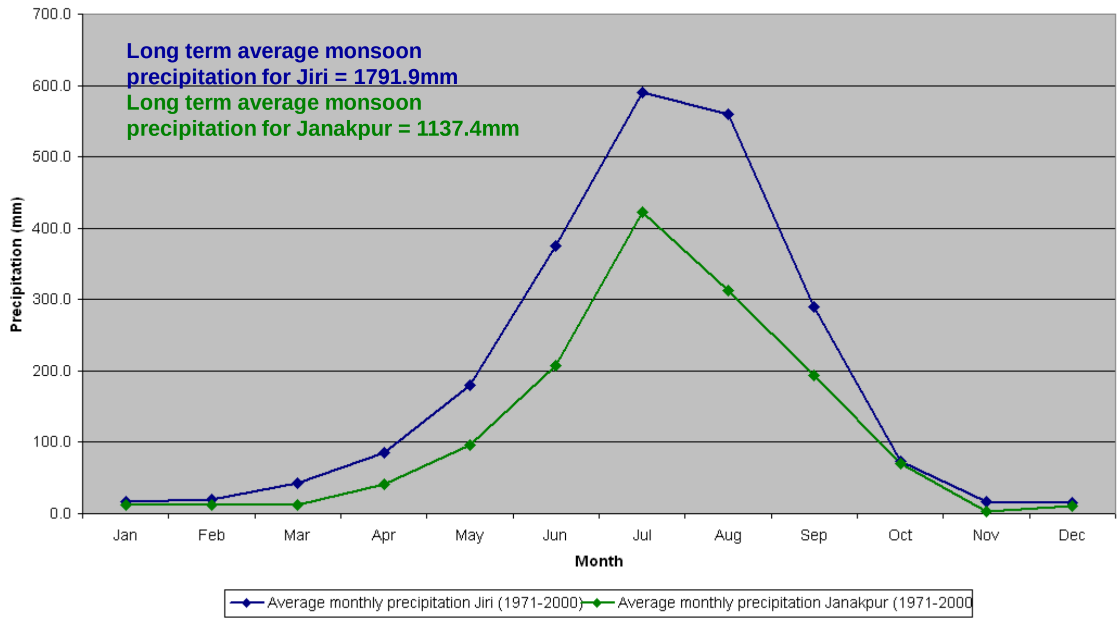
Observed Climate Normals – Maximum and Minimum Temperatures Jiri and Janakpur Stations



Average monthly maximum and minimum temperatures for Jiri and Janakpur stations

Source: Nepal DMH

Observed Climate Normals – Average Precipitation Jiri and Janakpur Stations



Average monthly precipitation for Jiri and Janakpur stations

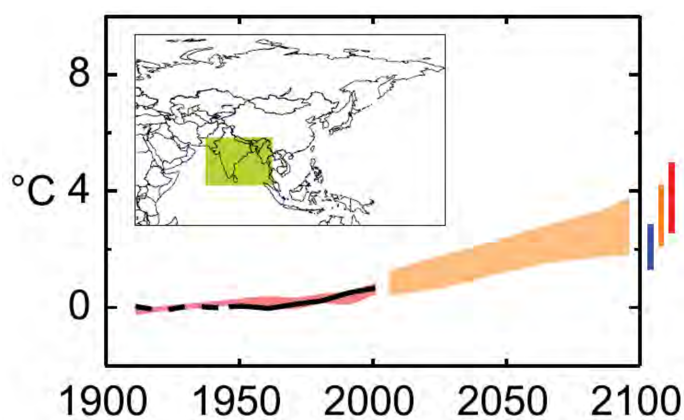
Source: Nepal DMH

Future Changes in Average Temperature

The IPCC AR4 projects temperature increases of 0.5-1.5°C by the 2020s and 1-2.5°C by the 2050s for Nepal (A1B scenario).

These figures show temperature anomalies (with respect to 1901-50):

- for 1906-2005 (black line),
- as simulated by AR4 models (red envelope), and
- as projected from 2001-2100 by AR4 models for the A1B scenario (orange envelope).



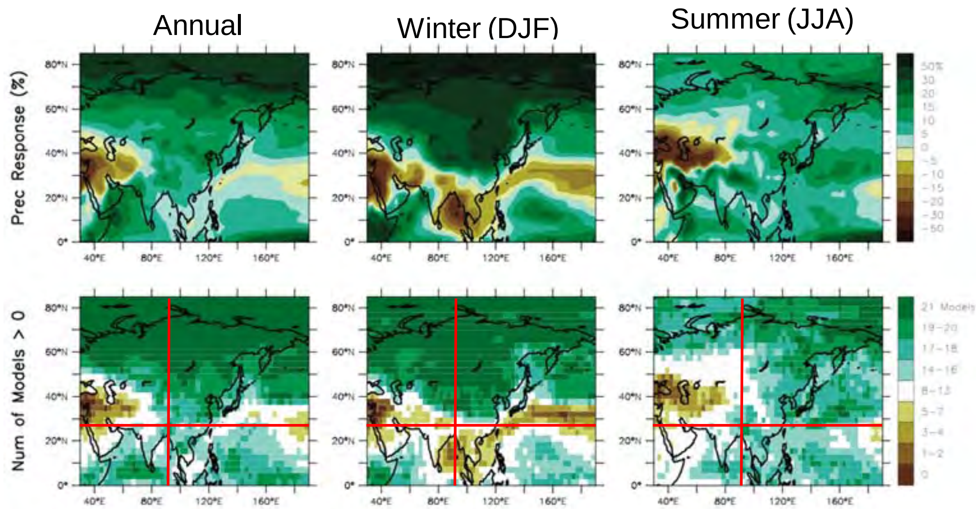
Bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 for the B1 scenario (blue), the A1B scenario (orange) and the A2 scenario (red).

Note that the orange envelope includes the models' estimate of natural climate variability, which may mitigate or amplify the projected climate response. For this reason the envelope range may differ from the range of values indicated by the bars.

[IPCC AR4, 2007]

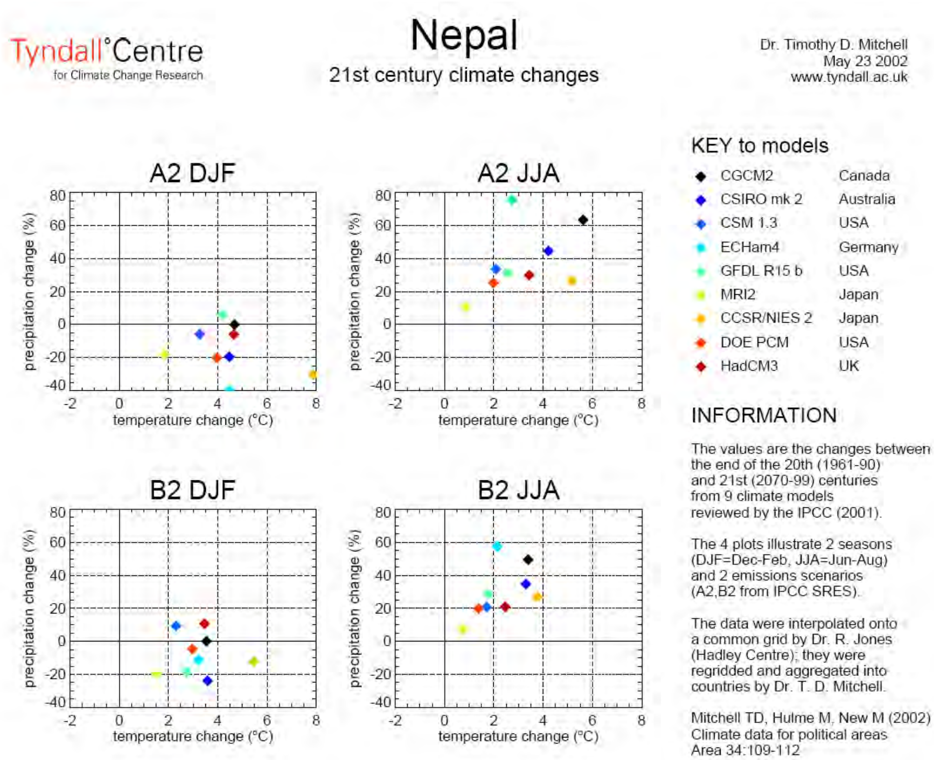
Further Information on Agreement Between Climate Models (GCMs) in Relation to Changes in Precipitation

- Khimti Khola is at 27º29'15''N, 86º6'33''E, as shown by the red crosses below
- The white area over Nepal in the bottom row, middle, indicates that the models are not in good agreement over changes in winter (dry season) precipitation.
- The green area over Nepal in the bottom row, right, indicates good model agreement over increases in summer precipitation. Some 80% of Nepal's rainfall occurs during the monsoon (June to September)



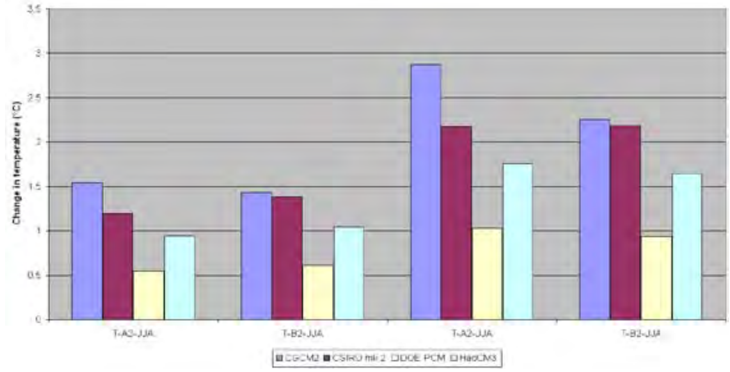
IPCC AR4 WGII, 2007

Future climate: Temperature and Precipitation, 2071–2100 Many Scenarios

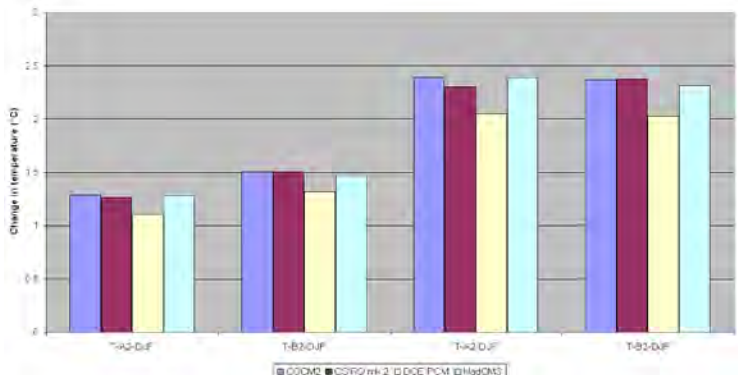


Source: Mitchell T.D., Carter T.R., Jones P.D., Hulme M., New M. (2003) A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Journal of Climate.

Future Climate: 2025 and 2050 – Seasonal Temperature Change for Nepal as Projected by Four Global Models



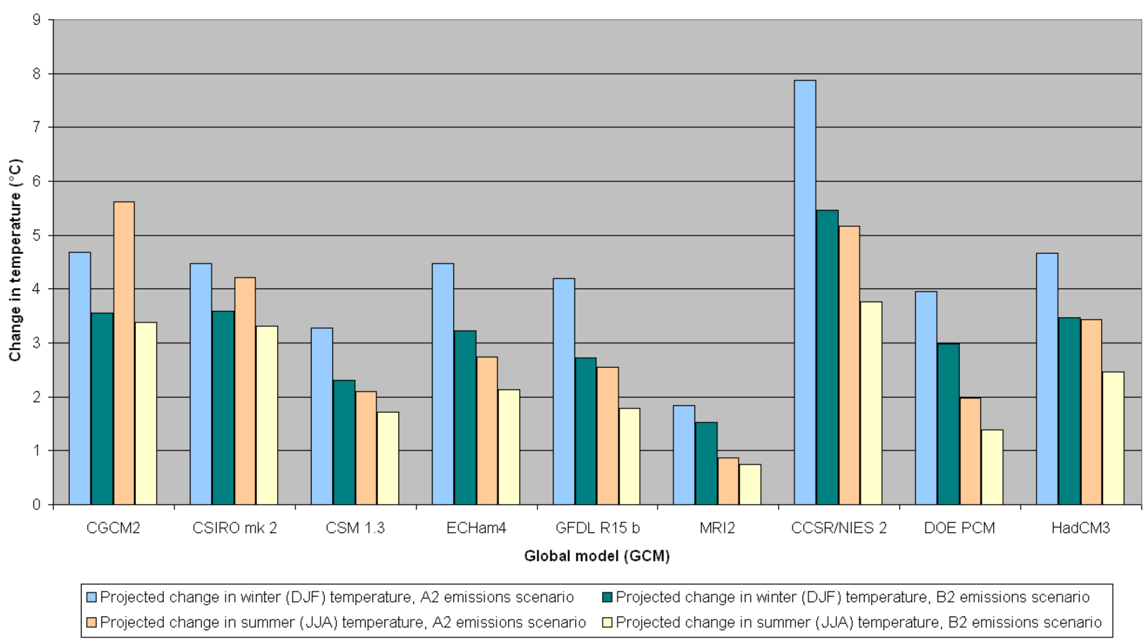
Change in summer (JJA) temperature, as projected by four models under two emissions scenarios for the years 2025 and 2050



Change in winter (DJF) temperature, as projected by four models under two emissions scenarios for the years 2025 and 2050

Source: Mitchell,T.D., Hulme,M., and New,M., 2002: Climate data for political areas. Area 34:109-112.

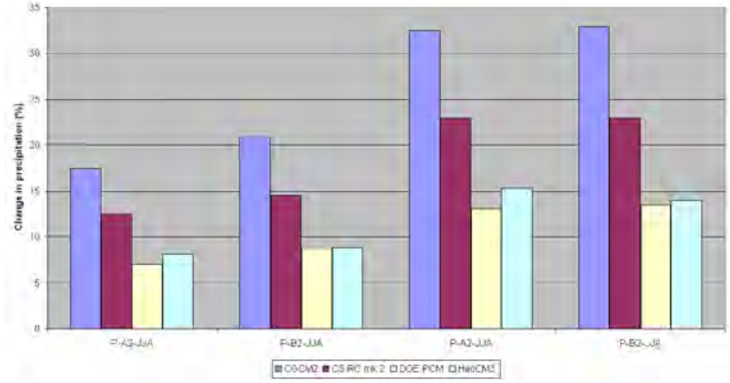
Future Climate: End of Century – Seasonal Temperature Change for Nepal as Projected by Nine Global Models



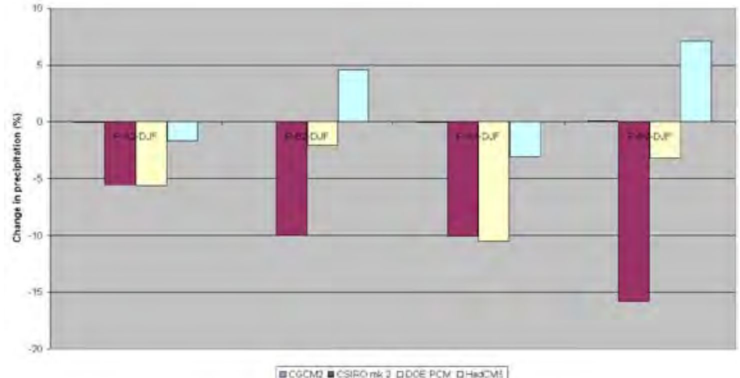
Projected change (1961-90 to 2070-99) in seasonal temperature under two emissions scenarios

Source: Mitchell,T.D., Hulme,M., and New,M., 2002: Climate data for political areas. Area 34:109-112.

Future climate: 2025 and 2050 – Seasonal Precipitation Change for Nepal as Projected by Four Global Models



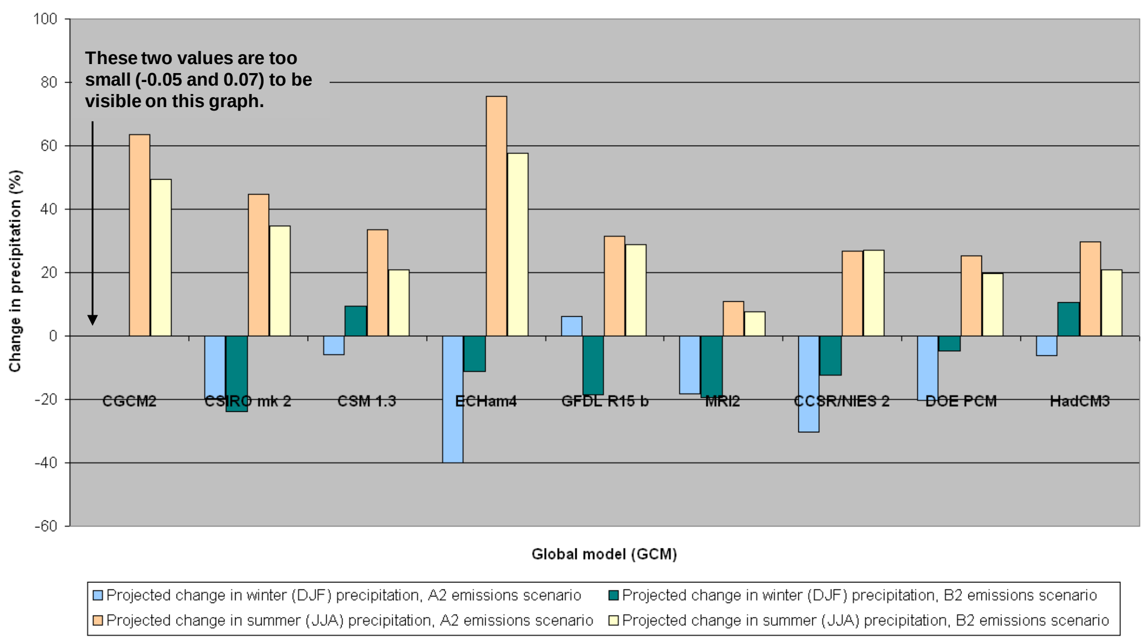
Change in summer (JJA) precipitation as projected by four models under two emissions scenarios for the years 2025 and 2050



Change in winter (DJF) precipitation as projected by four models under two emissions scenarios for the years 2025 and 2050

Source: Mitchell,T.D., Hulme,M., and New,M., 2002: Climate data for political areas. Area 34:109-112.

Future Climate: End of Century – Seasonal Precipitation Change for Nepal As Projected by Nine Global Models



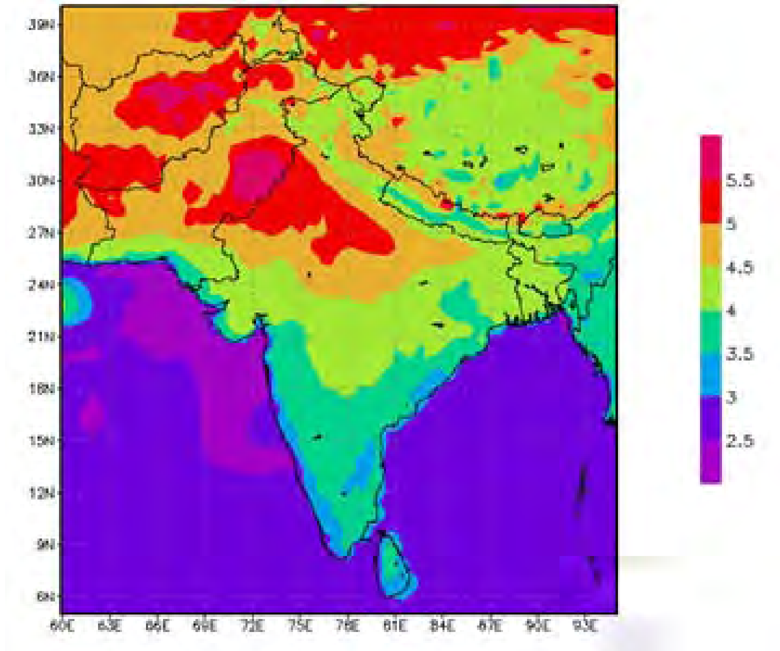
Projected change (1961-90 to 2070-99) in seasonal precipitation under two emissions scenarios

Source: Mitchell,T.D., Hulme,M., and New,M., 2002: Climate data for political areas. Area 34:109-112.

Future Climate: Temperature, 2071-2100, A2 Scenario

Right: South Asia PRECIS domain, showing change (in °C) in annual average temperatures

Future projections of extremes in daily temperatures show increases in highest maximum temperatures of about 4°C, and increases in lowest minimum temperatures of about 6°C (i.e., night time minimums seem to be increasing at much higher rates than the day time maximum).

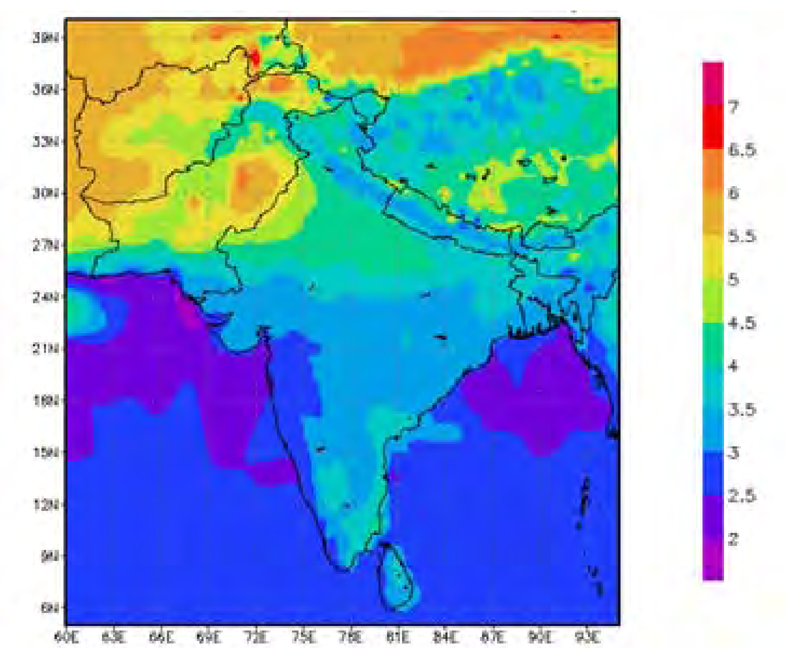


Difference of mean temperature

Source: excerpt Siraj Ul Islam, Nadia Rehman presentation "Assessment of future change in Temperature and Precipitation over Pakistan, simulated by PRECIS RCM for A2 scenario. http://precis.metoffice.com/docs/final-results-monthly_siraj.ppt#573,26,Slide 26

Future Climate: Temperature, 2071-2100, A2 Scenario

South Asia PRECIS domain, showing change (in °C) in summer average temperatures.

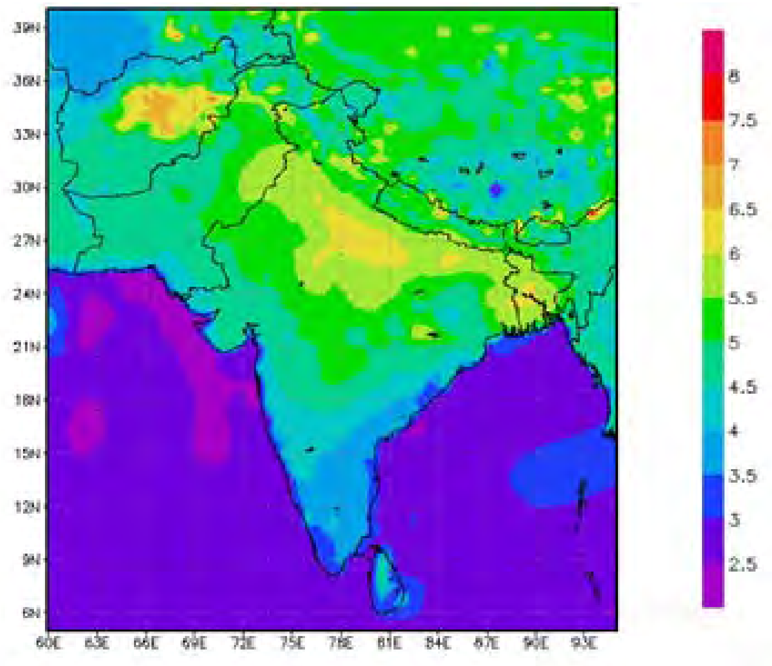


Difference of summer average temperature

Source: excerpt Siraj Ul Islam, Nadia Rehman presentation "Assessment of future change in Temperature and Precipitation over Pakistan, simulated by PRECIS RCM for A2 scenario. http://precis.metoffice.com/docs/final-results-monthly_siraj.ppt#573,26,Slide 26

Future Climate: Temperature, 2071-2100, A2 Scenario

South Asia PRECIS domain, showing change (in °C) in winter average temperatures

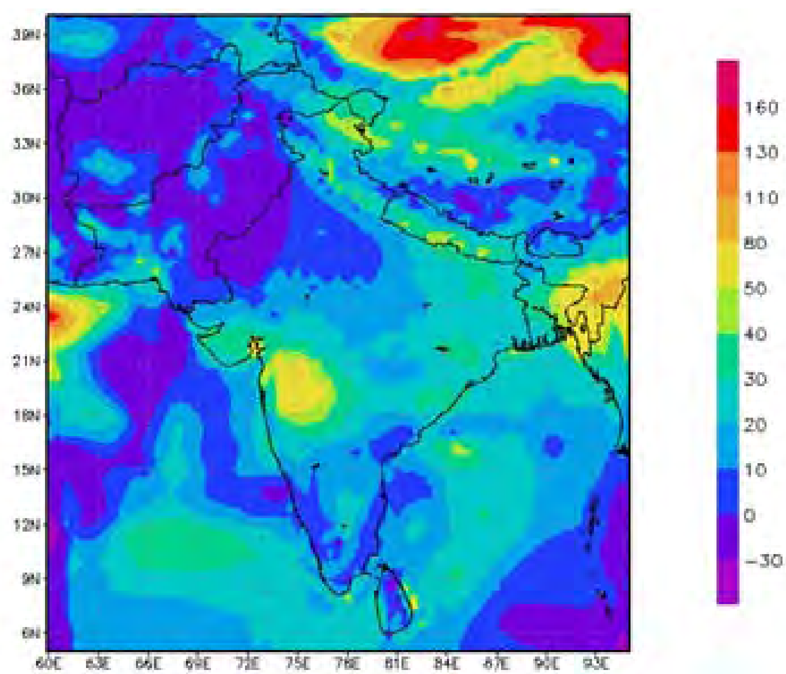


Difference of winter average temperature

Source: excerpt Siraj Ul Islam, Nadia Rehman presentation "Assessment of future change in Temperature and Precipitation over Pakistan, simulated by PRECIS RCM for A2 scenario. http://precis.metoffice.com/docs/final-results-monthly_siraj.ppt#573,26,Slide 26

Future Climate: Precipitation, 2071-2100, A2 Scenario

South Asia PRECIS domain, showing percent change in annual average precipitation

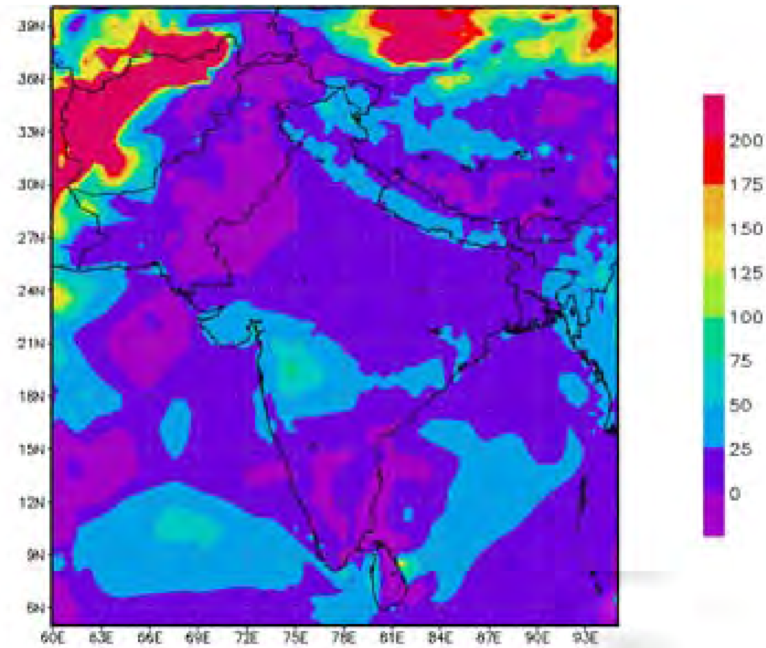


Percentage change of average precipitation

Source: excerpt Siraj Ul Islam, Nadia Rehman presentation "Assessment of future change in Temperature and Precipitation over Pakistan, simulated by PRECIS RCM for A2 scenario. http://precis.metoffice.com/docs/final-results-monthly_siraj.ppt#573,26,Slide 26

Future Climate: Temperature, 2071-2100, A2 Scenario

South Asia PRECIS domain, showing percent change in summer average precipitation

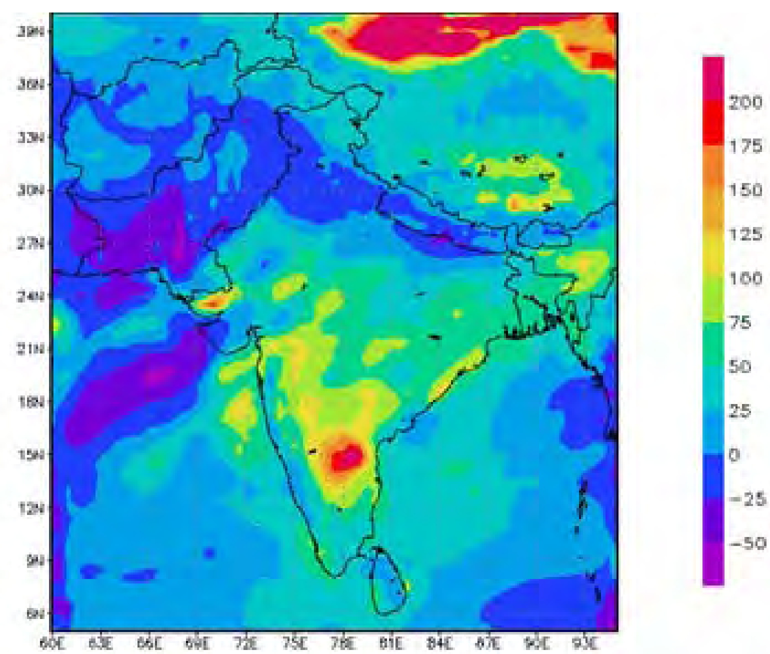


Percentage change of summer average precipitation

Source: excerpt Siraj Ul Islam, Nadia Rehman presentation "Assessment of future change in Temperature and Precipitation over Pakistan, simulated by PRECIS RCM for A2 scenario. http://precis.metoffice.com/docs/final-results-monthly_siraj.ppt#573,26,Slide 26

Future Climate: Temperature, 2071-2100, A2 Scenario

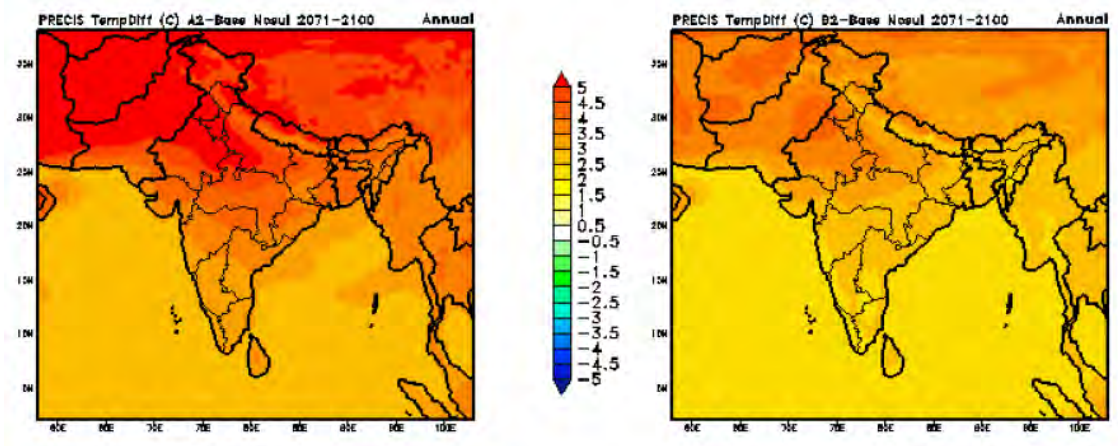
South Asia PRECIS domain, showing percent change in winter average precipitation



Percentage change of winter average precipitation

Source: excerpt Siraj Ul Islam, Nadia Rehman presentation "Assessment of future change in Temperature and Precipitation over Pakistan, simulated by PRECIS RCM for A2 scenario. http://precis.metoffice.com/docs/final-results-monthly_siraj.ppt#573,26,Slide 26

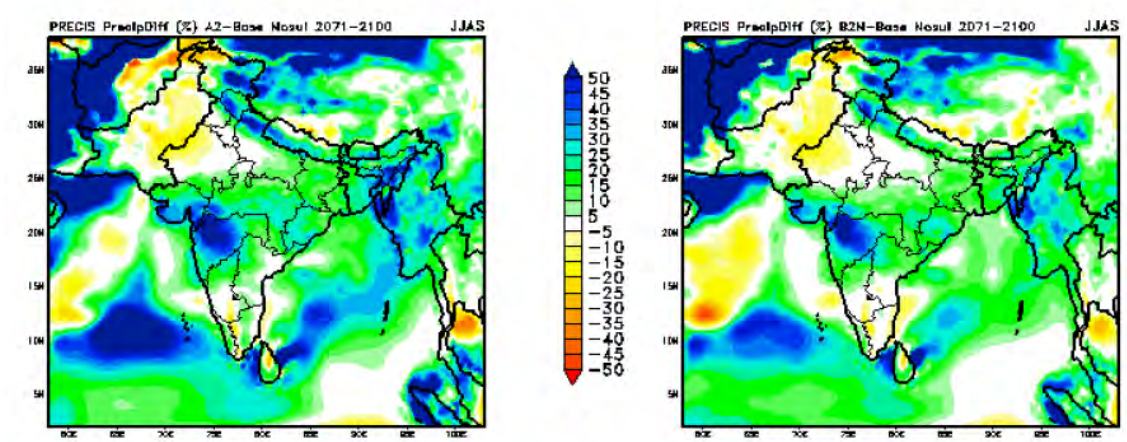
Future Climate – Annual Temperature, 2071-2100, A2 and B2 Scenarios All-India Analysis



Source: Kumar et al. (2006) High-resolution climate change scenarios for India for the 21st century. Current Science, Vol90, no3.

- Projected changes in surface air temperature, using the PRECIS RCM
- Warming is more pronounced over the northern parts of India

Future Climate – Monsoon Precipitation, 2071-2100, A2 and B2 Scenarios All-India Analysis



Source: Kumar et al. (2006) High-resolution climate change scenarios for India for the 21st century. Current Science, Vol90, no3.

- Projected changes in summer monsoon precipitation, using the PRECIS RCM.
- Spatial patterns indicate maximum increase over the west coast and northeast India for both A2 and B2 scenarios.
- PRECIS estimates a 20% rise in all-India summer monsoon rainfall in future scenarios as compared to the present.

Monsoon Rainfall

Observed

- Across the all-India region the monsoon rains are described as ‘remarkably stable’, and economic and social structures have been built around this stability. Over the last century standard deviation of seasonal mean monsoon rainfall has been roughly +/-10%.
- This makes the region very vulnerable to monsoon variability.
  - July 2002: monsoon rains failed completely. This resulted in a seasonal rainfall deficit of 19%, causing “profound” loss of agricultural production.
  - August 2005: very heavy monsoon rains lead to Maharashtra flooding disaster.
- Interannual variability tends to be larger (less stable) in some regions, particularly in NW India (~+/-30%).

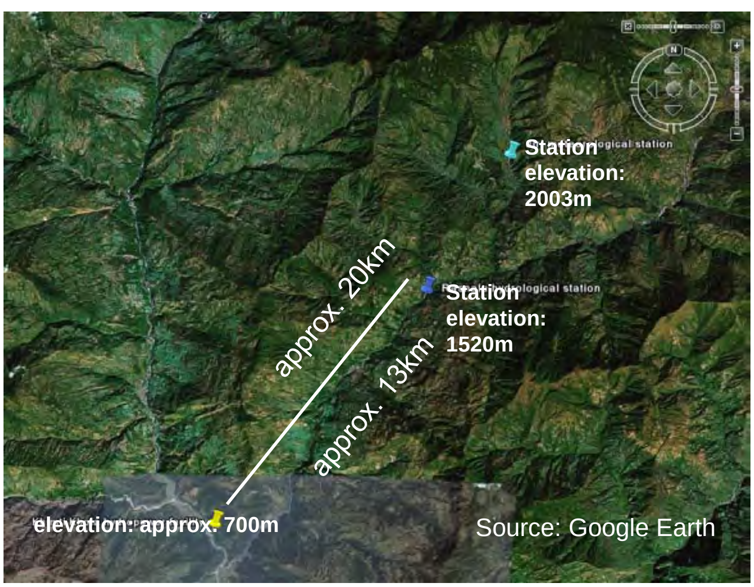
Projected future

- Understanding of monsoon processes is incomplete, and current climate models perform poorly in predicting monsoon behaviour.
- Most models agree that mean summer rainfall for all-India will increase by ~10% by the end of the century.
- Some models indicate that the number of rainy days will decrease while the intensity of heavy rainfall events increases.
- As temperatures rise, and as meltwater contribution to dry season flow decreases (as projected), changes in the intensity, duration and frequency of monsoon cycles will increase vulnerability.

Source: Challinor et al. (2006) Indian monsoon: contribution to the Stern Review.

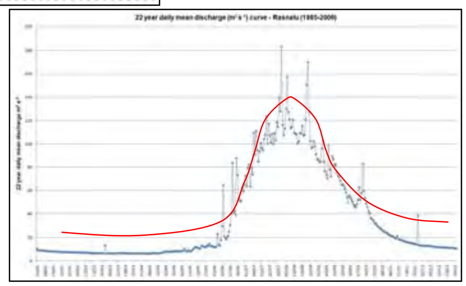
Location

- The analysis on the following 20 slides is based on observed precipitation data recorded at Jiri meteorological station, and observed river runoff data recorded at Rasnalu hydrological station.

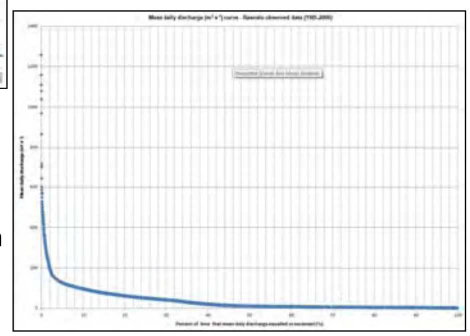


Our Methodology – Projecting Future Runoff At Rasnalu

Step 1. Analyze 22 years of daily runoff data at Rasnalu and remove outliers.



Step 2. Understand the relationship between runoff and contributing variables (e.g. precipitation), and apply appropriate 'change factors' – for future time periods under a range of emissions scenarios – derived from global circulation model (GCM) results.

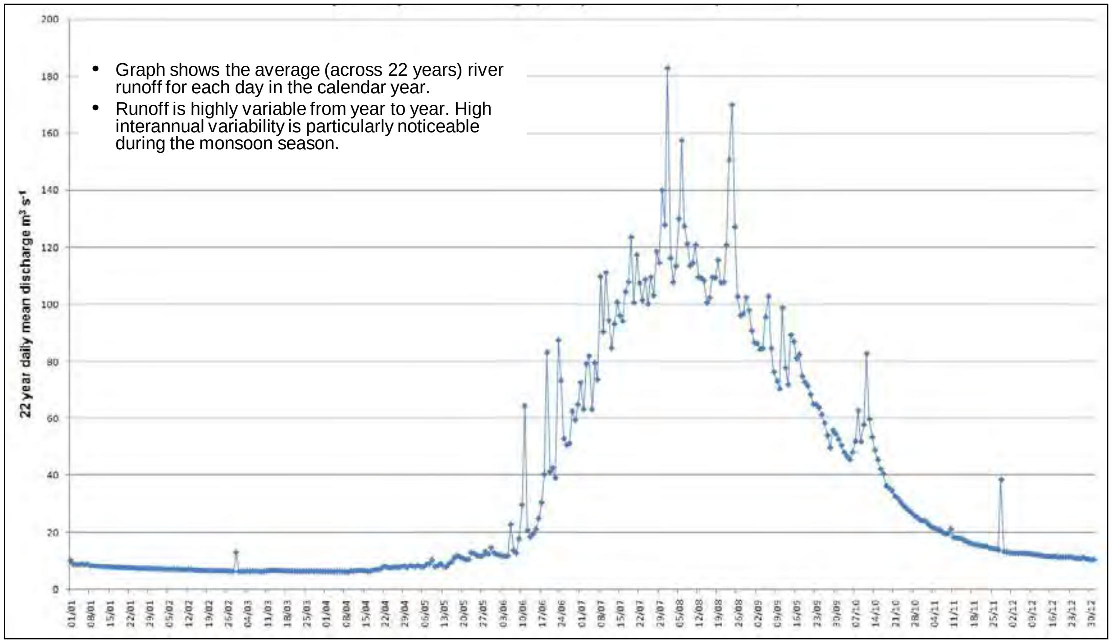


Step 3. Create projected future flow duration curves, showing the probability of exceeding a given discharge amount in m^3/s.

Step 1. Observed Runoff at Rasnalu

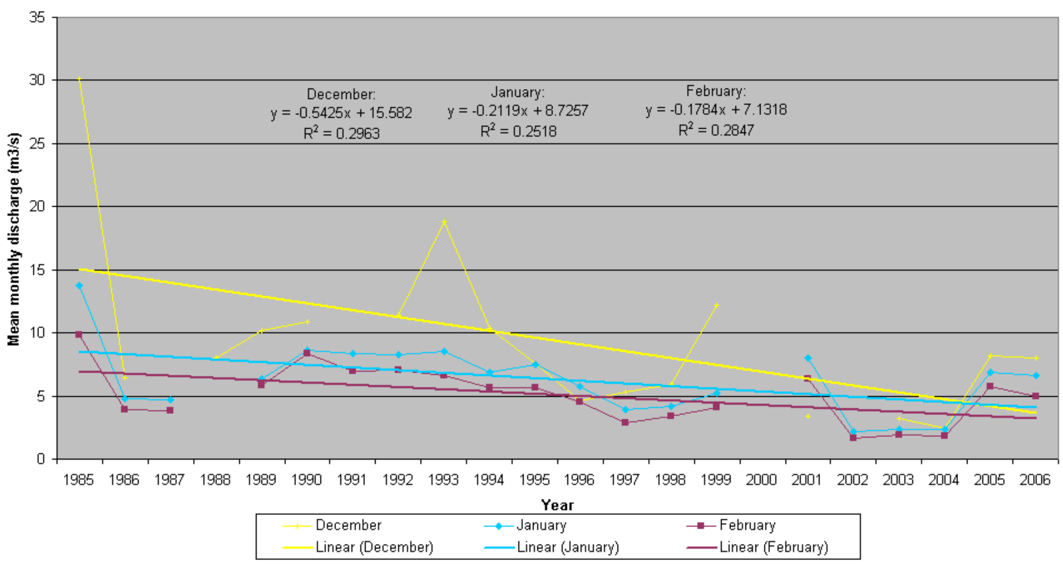
- We have analysed 22 years (1985 through 2006) of daily observed river runoff records at Rasnalu
- When aggregated at monthly level, the data show a clear decrease in average river runoff over this time period for most months.
- The largest decreases have occurred during monsoon (and post-monsoon) months:
  - July: slope -5.05
  - August: slope -4.73
  - September: slope -3.25
  - October: slope -4.13
- The following four slides provide more detail on monthly runoff over this 22-year time period.

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.



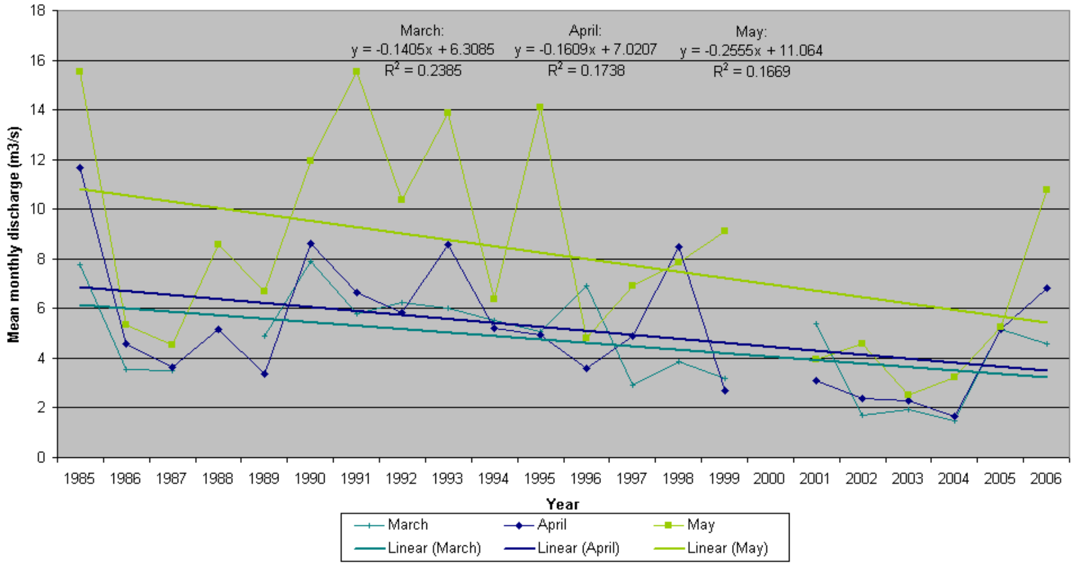
Twenty-two year daily mean discharge (m^3s^{-1}) curve – Rasnalu (1985-2006)

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.



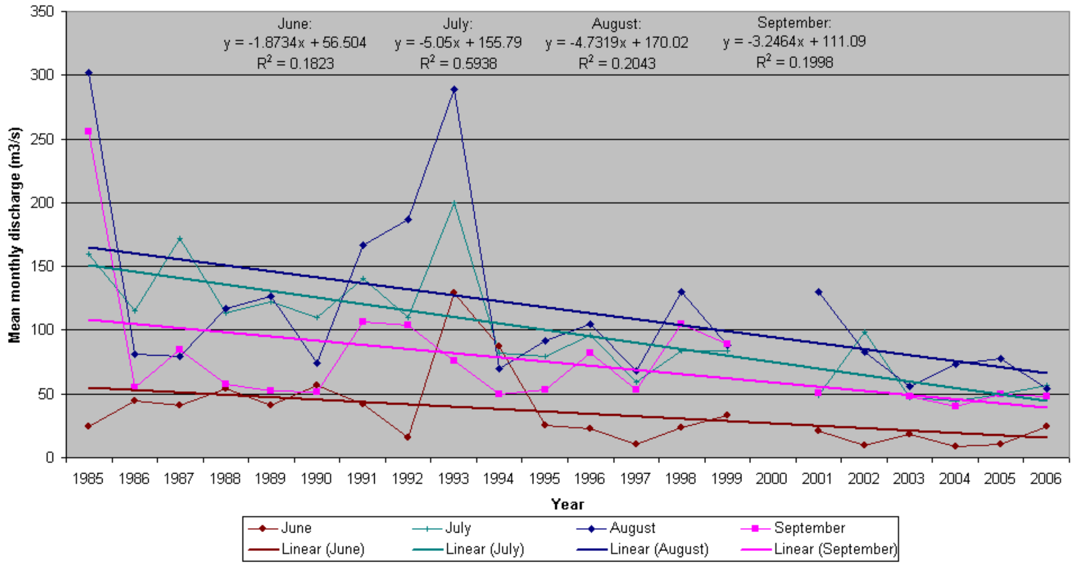
Rasnalu discharge – trend in monthly means – DJF

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.



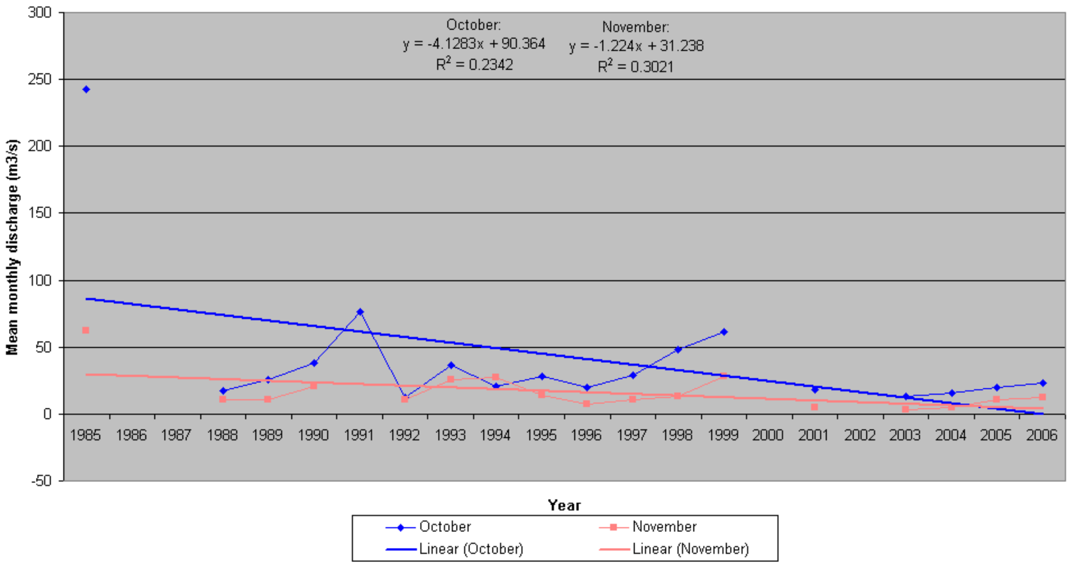
Rasnalu discharge – trend in monthly means – MAM

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.



Rasnalu discharge – trend in monthly means – JJAS

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.

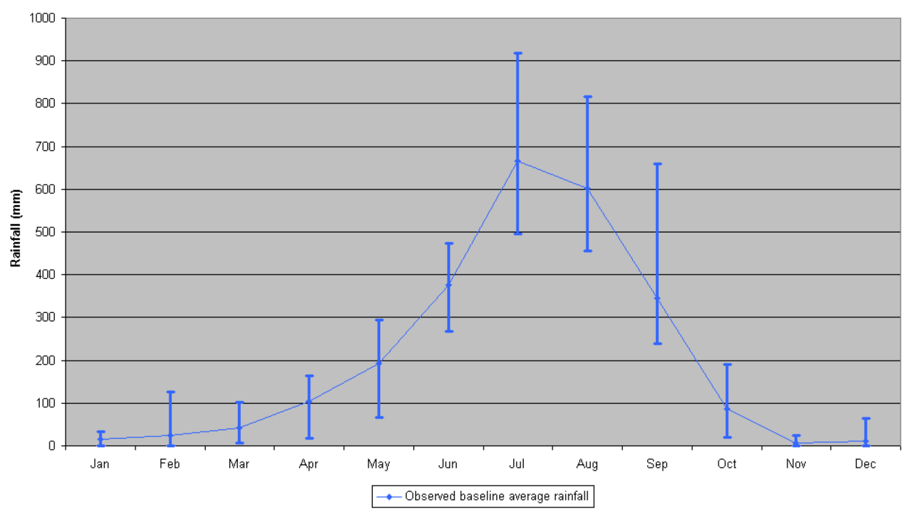


Rasnalu discharge – trend in monthly means – ON

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal

Variability of Observed Rainfall at Jiri

- Monthly rainfall at Jiri is highly variable from year to year.
- This graph shows the average (mean) monthly rainfall over the 10-year period, with error bars displaying the maximum and minimum monthly rainfall during the same period.

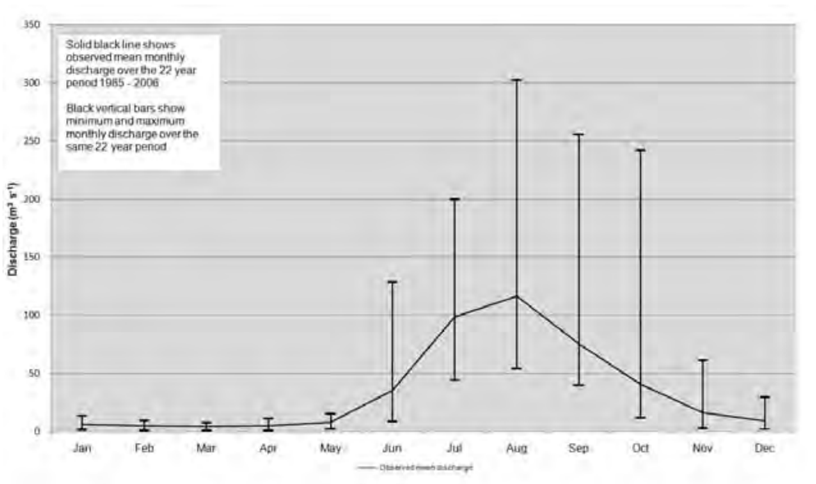


Variability of observed baseline rainfall – Error base the minimum and maximum monthly rainfall over this 10-year period

Source: Monthly observed rainfall values taken at Jiri (station #1103) from 1997-2006. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.

Variability of Observed Runoff at Rasnalu

- Monthly runoff at Rasnalu is also highly variable from year to year.
- This graph shows the average (mean) monthly runoff over the 22- year period, with error bars displaying the maximum and minimum monthly run off during the same period.

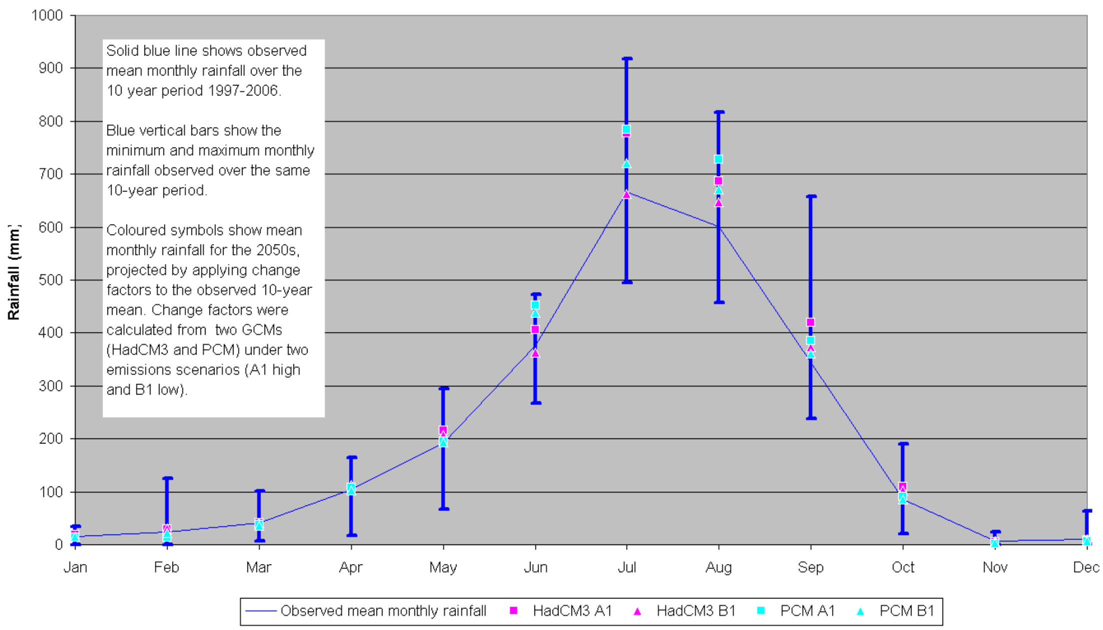


Observed (1985-2006) mean monthly discharge at Rasnalu

Source: Monthly observed discharge values taken at Rasnalu (station #650) from 1985-2006. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.

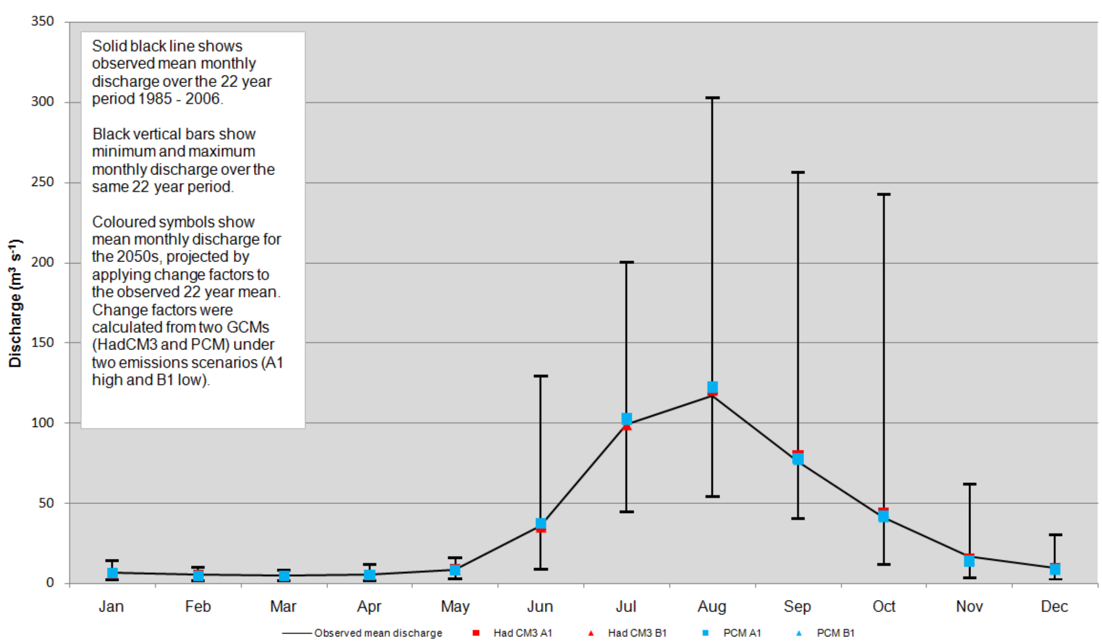
Step 2. Predicting Future Runoff

- The following 3 slides show projected monthly percentage changes in rainfall and runoff, compared to interannual variability.
- Key message: projected climate changes in rainfall and runoff (using a simple monthly rainfall-runoff model) are very small when compared to current variability.
- Though projected changes are small by comparison, they will affect the extremes of the distribution – making intense rainfall and runoff more frequent and more severe.
- This emphasises the importance of planning for extremes.



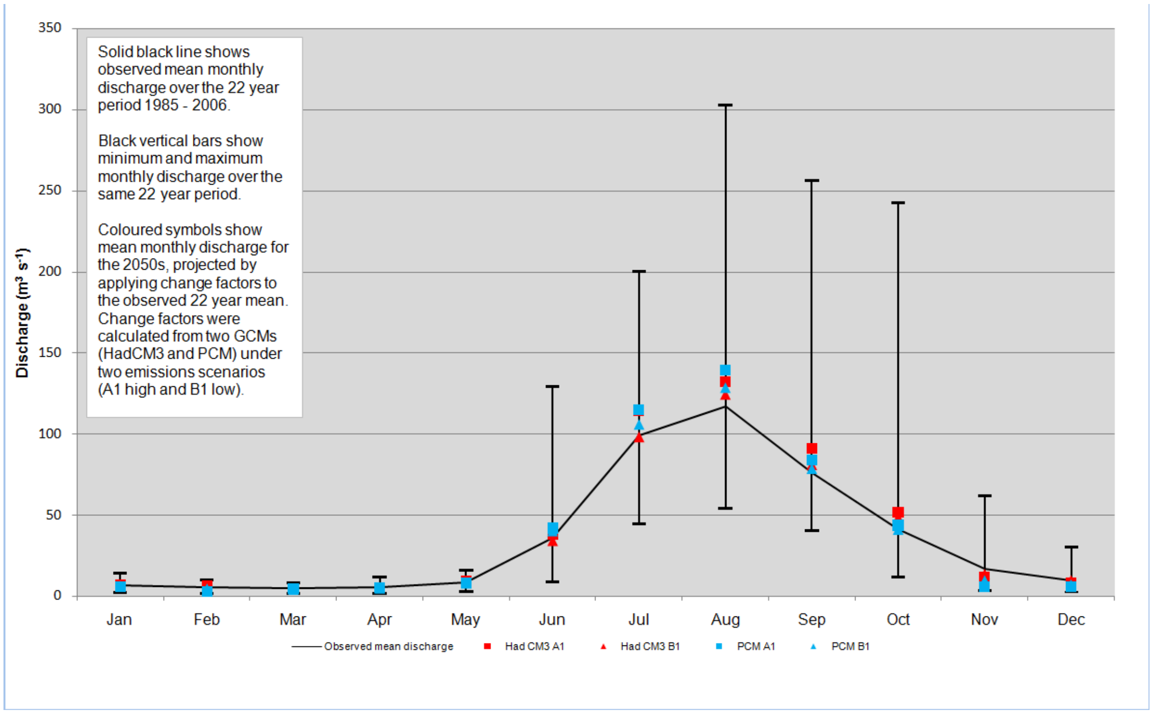
Observed (1997-2006) and future projected (2050s) mean monthly rainfall at Jiri

Source: Monthly observed rainfall values taken at Jiri (station #1103) from 1997-2006. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.



Observed (1985-2006) and future projected (2020s) mean monthly discharge at Rasnalu

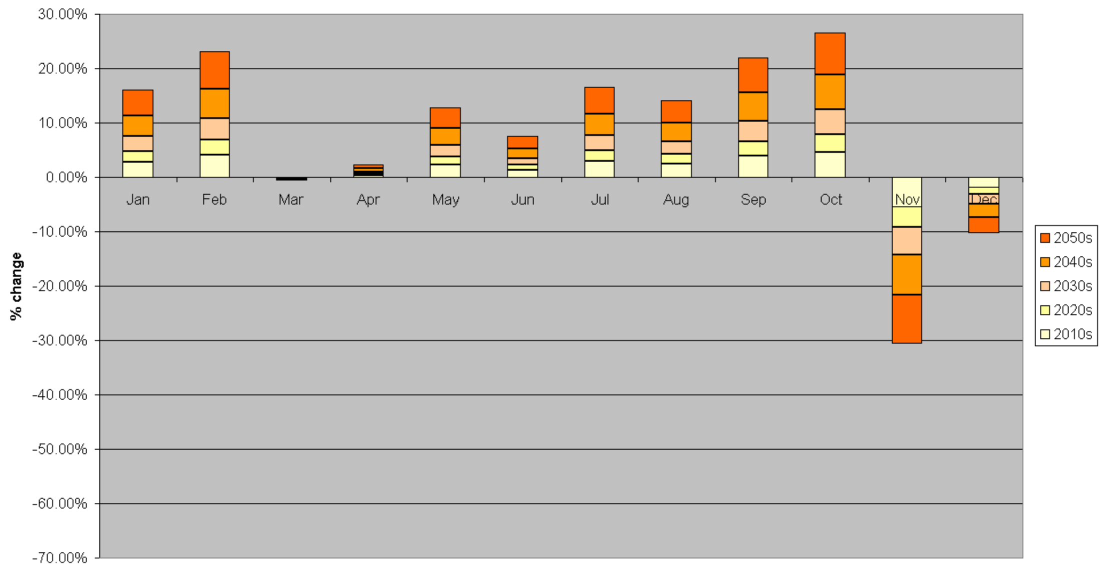
Source: Monthly observed discharge values taken at Rasnalu (station #650) from 1985 -2006. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.



Observed (1985-2006) and future projected (2050s) mean monthly discharge at Rasnalu

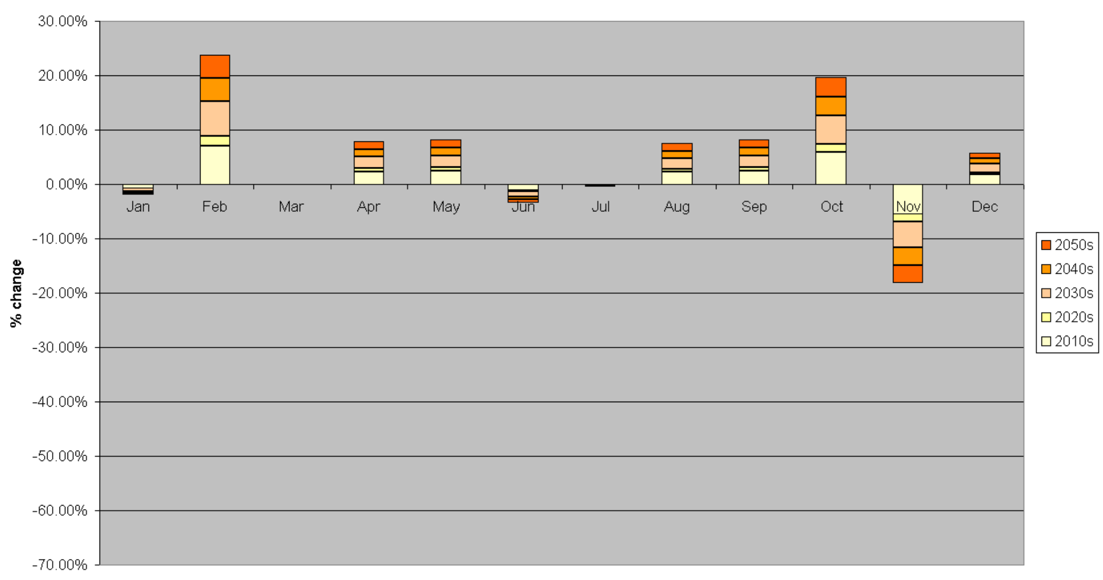
Source: Monthly observed discharge values taken at Rasnalu (station #650) from 1985 -2006. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.

- The following 4 slides show monthly change factors, by decade, as projected by two GCMs under two GHG emissions scenarios.
- Key message: there is little agreement between the GCMs on the extent of projected change; in some months the models do not even agree on the direction of the change.



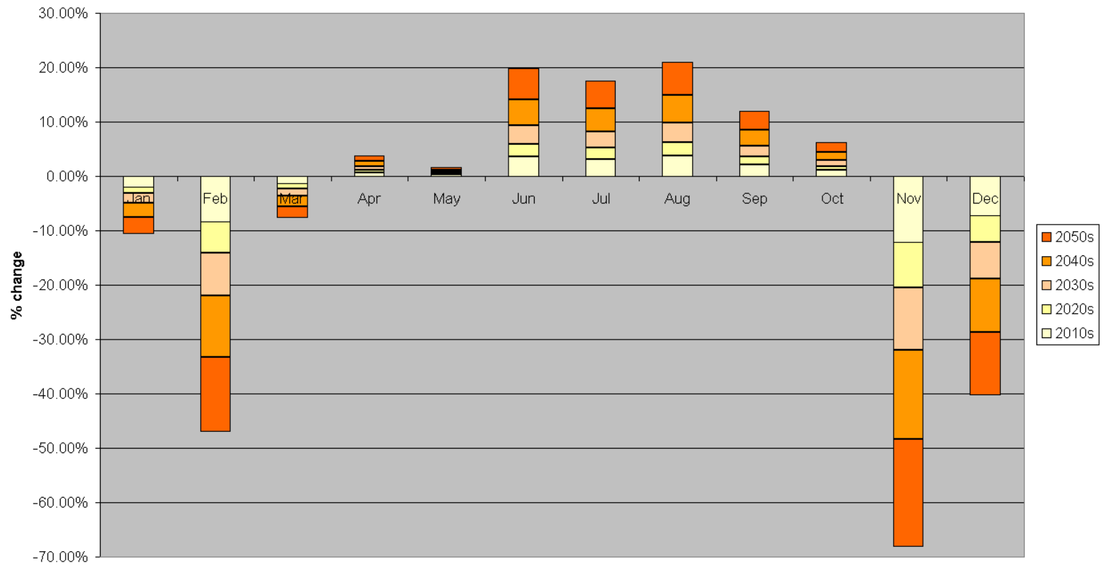
Monthly change factors calculated form the HadCM3 global circulation model under the A1 (high) emissions scenario

These charts show the cumulative monthly percentage climate change factors, from the 2010s to the 2050s, as projected by two GCMs (HadCM3 and PCM) under the A1 (high) and the B1 (low) emissions scenarios.



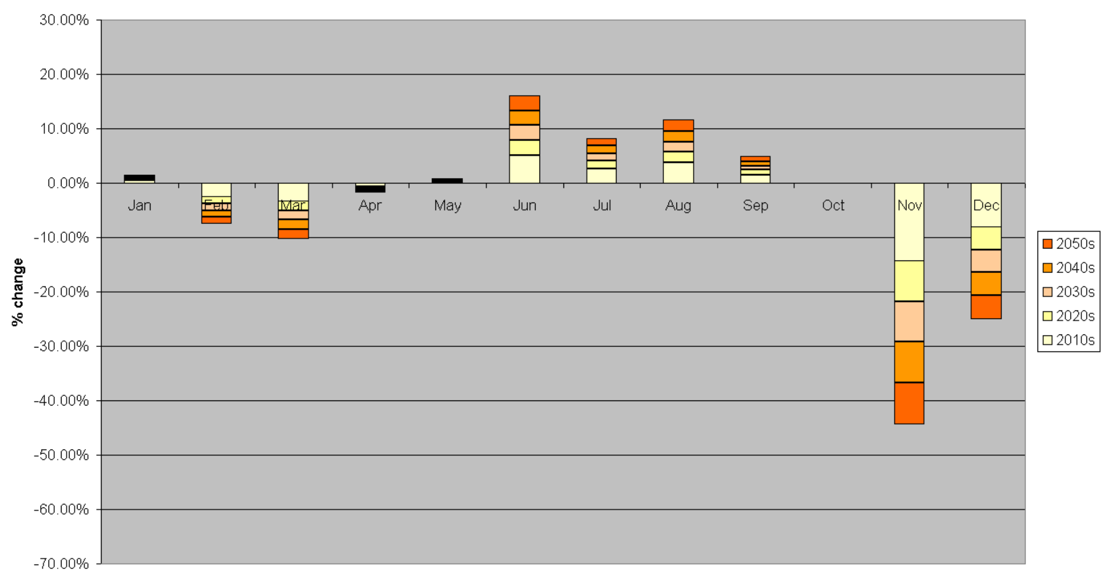
Monthly change factors calculated form the HadCM3 global circulation model under the B1 (low) emissions scenario

These charts show the cumulative monthly percentage climate change factors, from the 2010s to the 2050s, as projected by two GCMs (HadCM3 and PCM) under the A1 (high) and the B1 (low) emissions scenarios.



Monthly change factors calculated form the PCM global circulation model under the A1 (high) emissions scenario

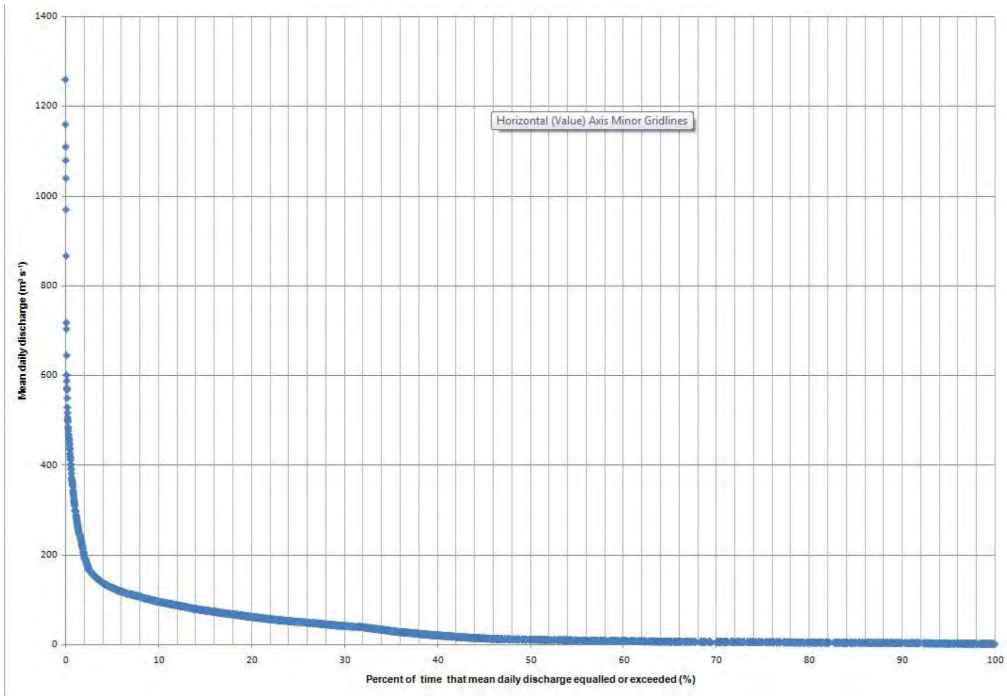
These charts show the cumulative monthly percentage climate change factors, from the 2010s to the 2050s, as projected by two GCMs (HadCM3 and PCM) under the A1 (high) and the B1 (low) emissions scenarios.



Monthly change factors calculated form the PCM global circulation model under the B1 (low) emissions scenario

These charts show the cumulative monthly percentage climate change factors, from the 2010s to the 2050s, as projected by two GCMs (HadCM3 and PCM) under the A1 (high) and the B1 (low) emissions scenarios.

Step 3. Future Flow Duration Curve



Mean daily discharge ($m^3\ s^{-1}$) curve – Rasnalu observed data (1985-2006)

Source: daily observed river runoff values taken at Rasnalu Village (station #650), on the Khimti Khola river. Data provided by the Department of Hydrology and Meteorology (DHM) Nepal.

Stage 1 – Identify Project Objectives

1. Where does the need to develop the project come from? What are the main drivers behind the project? What beneficial objectives are intended?
2. Is the project explicitly aimed at managing present-day climate or adapting to future climate change?
3. If the main driver is not related to climate or climate change, is climate change likely to be a key factor?

- **The main purpose of the project is to generate electricity and supply it to the national grid on a commercial basis for Nepal's national energy needs**
  - Due to the location of the project in an isolated poor rural area, and the insecurity in the region, positive community relations and local development became critical factors in achieving successful business outcomes.
- **The project also has a variety of secondary objectives which relate to its development impact:**
  1. **Demonstration effect**
     - To develop Nepal's hydropower potential – the first private hydroelectric power plant in Nepal, which has amongst the world's highest hydropower potential
     - Consideration of social issues in the project was seen as ground-breaking, within private sector projects in Nepal, within IFC and within the hydropower sector
  2. **Transfer of technology and skills**
  3. To execute and operate the project in an **environmentally friendly** way
  4. To **mitigate negative impacts** on the inhabitants in the project area
- Negative impacts were avoided and minimised wherever possible. Mitigation programmes were put in place to manage unavoidable impacts, particularly resulting from employee health and safety, land acquisition and impacts on water resources

1. Where does the need to develop the project come from? What are the main drivers behind the project? What beneficial objectives are intended?
2. Is the project explicitly aimed at managing present-day climate or adapting to future climate change?
3. If the main driver is not related to climate or climate change, is climate change likely to be a key factor?

5. To **provide positive impacts** for the inhabitants in the project area, primarily to ensure a stable local operating environment
   - Various benefits including provision of electricity, employment, private sector development, and infrastructure
   - **The project started with strong social objectives and social success criteria, however these have largely not been documented or formalized**
   - The institutional arrangements for the project created drivers for considering these secondary objectives:
   - Consideration of socio-economic issues was part of financing and legal requirements
   - Ownership of NPL also drove consideration of socio-economic issues (e.g. SN Power part owned by Norwegian aid agency)
   - IFC and MIGA involvement increased scrutiny of technical, environmental and social aspects

Stage 2 – Establish Decision-Making Criteria

- **What are the operational and engineering success criteria for the project?**
  - Maintaining generating output above the contract energy output level to ensure that excess energy payments are secured during low-flow dry weather conditions. The PPA sets contract energy levels for each month.
    - Contract energy – wet season: During the wet months (mid May – mid November) there is a fixed price for contract energy for pre-determined monthly generating levels. The NEA has to buy all the energy up to that contract level at an agreed price.
    - Excess energy – wet season: This refers to energy generated above the pre-determined contract energy output levels. In the wet season, NEA has the *option* to buy this additional output.
    - Contract energy – dry season: In the dry season (mid November – Mid May) there is a contract energy set by the PPA reflecting the lower generating capacity due to the lower flows in the Khimti Khola. The NEA has to buy this at an agreed price.
    - Excess energy – dry season: In the dry season, NEA ***has*** to buy any additional output over the contract energy level. In the years since the plant became operational the HPL has been able to generate energy above the contract level, earning increased revenues from the NEA.
    - The contract/excess energy level for the dry season was agreed following an assessment of the likely low flows in the river during the feasibility stage for the project. Dry weather flows since the commissioning of the plant have been in excess of the design flows, implying that either the dry weather flow was incorrectly assessed, or that there have been changes in the hydrology of the river resulting in increased flows.
  - Maintaining the operating efficiency of the Khimti Khola plant to enable generating output to be maximised.
  - A well managed and technically competent workforce to maintain and operate the plant.
  - A secure supply chain and availability of local procurement of support trades. Access to fuel supplies (this is a significant issue in Nepal given the fuel shortages, the PA agreement contains an obligation on the Government of Nepal to ensure that Khimti Khola has priority access to supplies in the event of a shortage).
  - Strong commitment to corporate standards set by HPL and SN Power
  - Enhancing reputation and brand to deliver competitive advantage when seeking licences and regulatory approvals for hydro-power schemes in Nepal and elsewhere.

- **What are the operational and engineering success criteria for the project?**

  - A safe, healthy and secure environment for the workforce. Provision and maintenance of good quality living accommodation for the resident workforce and their families. Security has become an extremely important issue in recent years. The Nepal Army has permanent garrisons established at the power house and at the intake, following the terrorist attack on the intake. HPL has commissioned its own security risk assessment and management plan from leading international advisors.
  - Dry weather flows in the Khimti Khola greater than 500 litres/second. HPL have agreed not to abstract water once the flow drops below this figure. This is not a legal requirement, but is something that has been agreed between HPL, Government Departments and the local communities. (This is a loophole recognised by the Dept of Electricity Development – new legislation will ensure that environmental mitigation measures are included with conditions on future Government licences).
  - HPL report that they continuously monitor flows at the weir and when flows fall below 500 litres per second, they cease abstraction. However, they do not make any flow *recordings*, so the only way it is possible to know when flows have fallen below 500 litres per second is to examine the generating output data. [This information has been requested. We will analyse this data once received. This will also help to establish a baseline dry weather flows over the last 8 years].
  - A secure legal right to abstract water from the Khimti Khola. The Project Licence gives HPL the right of uninterrupted flow of the water of the Khimti River to the Project. The Government of Nepal is prevented from issuing any other permits for use of water in the catchment area that will impair the flow in any way.
  - The PA contains a "Minimum Performance Standard" requiring a net electricity generating capacity of at least eighty percent (80%) of the Project's rated nameplate capacity; provided, that no Unit shall have a net electricity generating capacity of less than 9,000 kilowatts.
  - Maintaining adequate access to the site. There is currently only one road serving Khimti Khola which has been blocked on previous occasions by landslide.
  - Managing sediment load. HPL consider that this is under control at KK because of the design of the sedimentation channels, which are operating very effectively – the erosion seen on the turbine runners has been less than expected. HPL recognised that anything that changes the sedimentation regime would need to be monitored and understood.
  - Maintaining the integrity of major assets and the effective operational performance of assets. For example with regard to the tunnel for which regular inspections are undertaken. The tunnel was constructed through difficult geological conditions. There is some ingress of water associated with poor geological conditions. During construction a number of geotechnical problems were encountered. (Note some farmers claim that the tunnel has affected the hydrogeology in the area causing some hillside springs to dry up. HPL does not consider that there is any evidence to support this view). All assets have to be maintained to a level appropriate to enable the plant to maximise generating output and revenue.
  - Maintenance of the current transmission system is not an operational and engineering success criterion for the project. The PPA contracts the NEA to purchase the generating output even if the transmission system has failed.
  - There is a new privately operated transmission system under construction that will allow power to be sold to India through a connection to the Indian grid system. Once this is constructed and a connection is provided to Khimti Khola, then this will provide HPL with an option to sell to a different customer. Maintaining this new transmission line will be a success criterion in the future.

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- **What are the operational and engineering success criteria for the project?**

  – Minimising the risk from dangerous flood conditions on both the Tama Koshi and the Khimti Khola during monsoon periods. Although there have not been any serious flood event affecting the plant, there is a risk of a catastrophic monsoon flood. If such a flood happened, the consequence would be disruption to operation, due to flooding of the power station control building and other external facilities, e.g. transformers, plant maintenance buildings. There would also be major impacts on the workforce, who live in, or near, the floodplain areas. Access to the site would also be affected. There is no data or information on flood return periods and flood levels for either the Tama Koshi or the Khimti Khola. The PPA refers to the probable maximum flood discharge on the Khimti Khola as 3,900 m^3/sec (We are undertaking further analysis with the available hydrological data to identify the return period)

  – Anecdotally the maximum flood level is considered to be the lowest level at which the adjoining hillsides were terraced. However an inspection during the site visit and from the available maps suggests that there is a significant alluvial floodplain along the Tama Koshi. The inference to be drawn is that historically there have been significant flood events which may affect part of the Khimti Khola plant and the adjoining accommodation.

  – A major storm on the Paluti Khola in 2002, (a small stream which enters the Khimti Khola directly opposite the intake structure created significance concerns about risks to the KK intake structure. The key concerns were erosion and undercutting of the concrete structures at the intake and secondly, damage to the sedimentation channels and equipment due to material in the river. The storm moved large boulders over some distance. It also caused H&S concerns. This was viewed as a freak event, although again anecdotally it was reported that the area is experiencing more localised extreme storm events.

  – Minimising the risk of a GLOF. GLOFs are low probability, high consequence events. In the catchment of the Tama Koshi there are several glacial lakes (this information is being checked with ICIMOD). The Tso Rolpa lake provides the case study for GLOFs in the IPCC Fourth Assessment Report. Remedial works have been carried out to the moraine dam at Tso Rolpa and the lake levels have been lowered. A risk assessment of the Tso Rolpa moraine dam was undertaken at the request of the NEA by Reynolds Geoscience (UK) in 2000, and an update is planned. [A request has been made to the NEA for this report]. All relevant Nepal Government departments, research institutions and HPL have been asked if they know of the existence of a flood risk assessment. It would appear that such an assessment has not been undertaken.

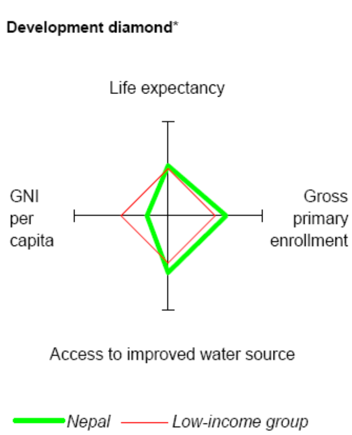
  – The PA between HPL and the Government contains an obligation on the Government of Nepal to undertake remedial works to the Tso Rolpa lake and to install an early warning system for the GLOF. Both these actions were completed, although the early warning system is no longer operational.

Stage 2 – Establish Decision-Making Criteria: Social

1. What are the success criteria for the project?

- **Mitigation of negative social impacts.** Criteria:
  - Irrigation water - access to sufficient water from Khimti river to irrigate fields
  - Fishing - sufficiency of fish stocks in Khimti river to maintain livelihoods
  - Resettlement - Restoration of livelihoods of people physically and economically displaced
  - Groundwater – Local people stated that some mountain springs dried up since the tunnel was built
- **Stable community relationships** – the project kept operating through the insurgency through diplomacy and by providing net benefits to communities which avoided any disruption, except for one incident. Criteria:
  - Project's understanding of stakeholders
  - Number of complaints and grievances, including legal cases, from local stakeholders
  - Project's fulfilment of commitments made to stakeholders
  - Community related incidents, e.g. blockades, strikes, direct action
  - Lost time, damage to people and property, and staff time spent due to managing community disputes
- **Socio-economic and political stability in communities** – the limited presence of government support in the area required the project to become the de facto government in order to provide basic services and development in the area, in addition to providing opportunities for local employment and procurement. Criteria:
  - Access to health and education services
  - Literacy levels and education
  - Employee and community health levels
  - Demographic profile changes (emigration and irrigation) – vulnerable groups
  - Access to power
  - Levels of local employment – numbers, %,
  - Levels of local procurement - total $ value of local spend
  - Other employment, economic activities, and agricultural productivity
  - Access to markets
  - Security
- **It has not been possible to identify or define critical thresholds for these success criteria.**

Stage 3 – Assess Risks Tier 1 / 2 Social Context – Non CC Factors



- **Several factors mean that the project area is inherently vulnerable to climate change impacts.**
- **However, as the region is already prone to climatic variability and extreme events, local communities already have a variety of coping mechanisms in place.**
- The region which is already subject to **high levels of climatic variability** such as significant floods which cause erosion, loss of roads and bridges, and reshaping of river valleys.
- Nepal has **high levels of poverty** - 31% of the population live below the national poverty line (World Bank 2007), Nepal remains the poorest country in terms of GNI in South Asia and ranks as the twelfth poorest country in the world – but with considerable progress in reducing poverty over the last decade
- 80% of the Nepalese population has a **dependence on agriculture**, often at subsistence levels and often reliant on irrigation from rivers
- The recent history of **insecurity in rural areas** due to the Maoist insurgency has left a legacy of livelihood insecurity, exclusion, lack of development and a lack of trust in government
- There is a **lack of government capacity** to deliver public services (e.g. health, education, agricultural extension, etc) in rural areas
- There is a **successful history of community-based development programs**.
- The **political transition** in April 2006 and peace agreement, and Constituent Assembly elections in April 2008 has laid the foundation for improved governance reforms and development.
- **Migration** is a common livelihood strategy, within and outside Nepal
- There are **no other large-scale business opportunities** in the project area other than hydropower, despite tourism being an important sector in other areas of Nepal.

Stage 3 – Assess Risks Tier 1 / 2
Key Social Risks – Low Flow on Khimti River

- The reduction in river flow during the dry season on the section of the Khimti river downstream of the inlet is one of the few direct negative social impacts of the project.
- Currently the low flow on the Khimti river is maintained at more than 500 lps throughout the dry season.
- This section of the river is used by two groups of stakeholders:
  - **Irrigation for agriculture -** Prior to KHP-I, there was only one irrigation canal that used the Khimti river to service a small farmland in Khimti Bensi, about 8 km downstream of the hydropower intake site, mainly for dry season irrigation.
  - **Fishing.** A number of people fish in the river during the dry season. Fishing is used to supplement agricultural livelihoods and is not the primary livelihood for anyone using this section of river. The low flow has resulted in pools being formed which resulted in over-fishing, partly through use of natural poisons.
- The project has supported these stakeholders in several ways:
  - **Support to irrigation for agriculture -** As part of the project, HPL has assisted farmers within the project area in constructing, and refurbishing and repairing irrigation canals that use flows from the tributaries of the Khimti River.
  - **Support to fishing.** The project has monitored fish stock levels and has provided advice and support to fishers, including discouraging the inappropriate use of poisons. The project is also investigating the potential for fish farming as an alternative.
- CC predictions indicate that dry season flows may generally decrease but be more variable and this low flow may not be maintained consistently.
- The lack of government support and limited alternative livelihood options available increase the level of risk associated with this impact.
- **The relatively small numbers of people affected and the existing mitigation measures in place reduce the risk of this issue.**
- **CC may exacerbate the existing negative impacts [success criteria] on the two stakeholder groups after by low flows if the existing mitigation measures are not adequate to adapt to future changes.**
- The sustainability of the existing mitigation measures will be critical in the management of this risk area. Additional support may be required to ensure that the irrigation canals can be maintained without ongoing HPL support and that management of fishing during the dry season is sustainable.

Stage 3 – Assess Risks Tier 1 / 2
Key Social Risks - Resettlement & Land Use

- **Unless properly managed, involuntary resettlement may result in long-term hardship and impoverishment for affected persons and communities. Land acquisition and resettlement therefore has the most significant potential to increase vulnerability and reduce adaptability, particularly to climate change.**
- The project directly affected relatively small areas of land for the transmission line, headworks and project site, as well as compensation payments made to the landowners relating to the land slide at Koile.
  - 9 households had to be relocated from the transmission line right-of- way. Another 18 farm outbuildings (cattle sheds, pig sties, etc.) also required relocation.
- The project appears to have used good process for compensation and relocation, which ensured an effective and fair negotiation process. The project compensated landowners approximately ten times the market value of the land used for the tower foundations on the transmission line.
  - Compensation rates for housing structures exceed standard government compensation rates by 60 to 150 percent according to the type of materials with which the house is constructed.
  - HPL purchased land from a number of landowners in the headworks area. HPL agreed to hold the land titles in trust and sell the land back to the former owners at the original purchase price on completion of the project. In addition, HPL gave these landowners priority in employment on the project by way of additional compensation for lost agricultural production during the life of the project.
- However the project was not required to produce and implement a formal Resettlement Action Plan and there does not appear to have been any formal monitoring and follow-up to ensure that livelihoods were restored.
- **The avoidance, minimisation and effective mitigation of resettlement impacts is likely to have reduced the risk of this issue.**
- **However, CC may exacerbate the existing negative impacts [success criteria] on groups affected by land acquisition and resettlement.**
- Detailed follow-up and monitoring of affected households is required to determine the level of risk climate change poses to these stakeholders.

Stage 3 – Assess Risks Tier 1 / 2
Key Social Risks - Community Development

- **HPL's investment in community development has had a positive impact on the livelihoods of the approximately 37,000 people living in the project area.**
- The project has supported community development in a wide variety of ways, including:
  - **Social investments** – HPL has promoted various programmes including public health awareness; enterprise development; Non-Formal Education (NFE) emphasizing female literacy; Community Forestry; and Women's Skill Development (including the formation of women's credit groups); improved sanitation and drinking water schemes; footbridge construction and improvement; construction of a new health post and training for health post personnel; construction of two police posts; physical improvements to school buildings and salary support for additional teachers; increased numbers of kitchen gardens; improved small livestock rearing; and improved local governance among a number of communities in the project area. The project committed up to US$ 25,000 per year to contribute to local development initiatives put forward by the Village Development Committees (VDC) with jurisdiction in the project area.
  - **Rural electrification** – the project has supported the development of the Jhankre Rural Electrification and Development Project which is providing access to electricity to neighbouring communities.
  - **Revenues** - 10% of HPL royalties paid to the government (approximately $600,000 are returned to the administration of the two districts in which the project are lies – Dolakha and Ramechap – which supplements development funds from central government
  - **Local employment** - During its four-year construction phase, the project employed an average of 2,300 persons per year of which 62% originated in the two districts in which the project is located. The project now employs approximately 150 people who reside in the local area.
  - **Local procurement** - HPL was committed to building local technical and management capacity in the engineering and construction fields during construction. After construction, HPL has launched a new enterprise - Khimti Service Pvt. Ltd. (KSPL). HPL is subcontracting a range of services from KSPL including engineering, construction, equipment maintenance, security and catering.
- **HPL's efforts are seen to be a model for promoting positive local developmental impacts from infrastructure investment.**

- However, HPL's contributions to community development have not been clearly defined in terms of objectives, intended results and measurable targets of achievement.
- The 2001 socio-economic review identified a number of significant positive impacts which were attributed to the project including: a 15 % increase in female literacy among the sample population (10% of all project area households) since 1995; a 10% increase in the number of children receiving EPI vaccinations; a 13% increase in contraception use; and an 8% decline in infant mortality. KECU provided literacy training to 275 people (90% women), training to 12 NFE facilitators, and support for the creation and operation of 12 NFE centers throughout the project area and also resulted in the formation of 17 Forest User Groups (six of which have been registered with the Forest Department), and at least 24 Women's Savings Groups.
- However:
  - Community development initiatives were not targeted at those most negatively affected by the project, only mitigation projects (e.g. support to fishing and irrigation canals)
  - It is unclear how strategic these were in terms of contributing to long-term business, government and community goals
  - There is an acknowledged need to shift from construction of infrastructure (e.g. new schools, canals, etc) to supporting long-term institutional sustainability and the ability of communities to own and manage projects themselves
  - Management of social issues is not formalized and not directly linked to socio-economic review.
- Current literature indicates that indicators of general community development (e.g. health, education, employment, etc) provide a good indication of the vulnerability and adaptive capacity of communities in relation to climate change.
- **HPL's existing support to community development has therefore made a significant contribution to increasing the adaptive capacity of communities to climate change.**
- **The relationship between climate change and community vulnerability and adaptive capacity present the most significant social risks to the project as there is the potential that this may undermine the project-community relationships and wider stable socio-economic and political context.**

Stage 3 – Assess Risks Tier 1 / 2
Key Social Risks - Other

- Other potential climate change induced risks include:
  - **Migration**
    - CC predictions indicate higher levels of migration as an adaptive strategy where other livelihood options fail.
    - Migration is already a common strategy in Nepal, therefore CC may intensify this.
    - People are more likely to migrate to the project area, rather than away from it. People migrated away from the troubled rural areas during the Maoist insurgency and are beginning to return. The project area is relatively well developed due to the presence of the project and therefore presents a relatively attractive place to migrate to, particularly from neighbouring areas.
    - There is therefore a risk that climate change will intensify the influx of people to the project area, resulting in a reduction in development (due to increased demand for limited land, water resources and public services) and an increase in social tensions and insecurity.
  - **Health issues**
    - Lower river flows during the dry season as a result of CC, potentially combined with higher temperatures, may result in decreased water quality leading to increased incidence of water-borne diseases.
    - This may reduce wider economic development as well as directly impact on the productivity of local employees.
  - **Increased pressure on water resources**
    - CC may lead to increased pressure on water resources, particularly during dry season droughts.
    - This pressure may lead to an increase in perceived impacts of the project on water, such as an increase in complaints relating to effects on groundwater and on the Khimti river.
    - There is therefore a risk that climate change will increase disputes between the project and community, resulting in a deterioration in project-community relationships.

Scenarios: Introduction

- **Scenario 1 GLOF**
  - Extreme flooding event affecting the turbine house, power station site, main access road and the workforce accommodation.
- **Scenario 2 Extreme river flooding on the Tama Koshi**
  - Affecting the power station site, main access road and the workforce accommodation.
- **Scenario 3 Extreme river flooding on the Khimti Khola**
  - Affecting the intake structures.
- **Scenario 4 Change in stream flow**
  - Impact on generating output.
- **Scenario 5 Major landslide blocking flow in Khimti Khola**
  - Impact on generating output.

Scenario 1: GLOF

- Scenario
  - GLOFs are low probability, high consequence events. In the catchment of the Tama Koshi there are several glacial lakes. The Tso Rolpa lake provides the case study for GLOFs in the IPCC Fourth Assessment Report. Remedial works have been carried out to the moraine dam at Tso Rolpa and the lake levels have been lowered. A risk assessment of the Tso Rolpa moraine dam was undertaken at the request of the NEA by Reynolds Geoscience (UK) in 2000, and an update is planned. All relevant Nepal Government departments, research institutions and HPL have been asked if they know of the existence of a flood risk assessment. It would appear that such an assessment has not been undertaken.
  - This scenario assumes that a severe GLOF will occur in the catchment of the Tama Koshi from Tso Rolpa or from another glacial lake. As the glaciers in the catchment continue to melt and retreat the risk of a GLOF will increase. The risk will be increased without significant investment in the monitoring of the glacial lakes and remedial works to lower lake levels
  - GLOFs have previously occurred in Nepal. Over time and with increased glacial melt the consequences to downstream communities and infrastructure will increase.
  - If such a flood happened, the consequence would be disruption to the operation of the KK facility, due to flooding of the power station control building and other external facilities, e.g. transformers, plant maintenance buildings. Generating output would be disrupted until remedial works could be undertaken. There would also be major impacts on the workforce, who live in, or near, the floodplain areas. Access to the site would also be affected. This scenario also assumes that the existing gates protecting the turbine tunnel would fail causing flooding of the turbine house.

Scenario 2: Extreme River Flooding on the Tama Koshi

- Scenario
  - Although there have not been any serious flood events affecting the Khimti Khola plant since it was constructed, there is a risk of a catastrophic monsoon flood. A severe monsoon flood would be a low probability, high consequence event. There have been a number of severe floods in Nepal as documented by ICIMOD including x events on the Tama Koshi (for which limited information is available).
  - The analysis of the GCMs and the PRECIS RCM indicate increasing precipitation during the monsoon period.
  - There is no baseline data or information on flood return periods and flood levels for the Tama Koshi.
  - Anecdotally the maximum flood level is considered to be the lowest level at which the adjoining hillsides were terraced. However an inspection during the site visit and from the available maps suggests that there is a significant alluvial floodplain along the Tama Koshi. The power station control building, the sub-station, workshops and living accommodation together with the access road are all constructed on the alluvial floodplain. The inference to be drawn is that historically there have been significant flood events which may affect the Khimti Khola site.
  - If such a flood happened, the consequence would be disruption to operation, due to flooding of the power station control building and other external facilities, e.g. transformers, plant maintenance buildings. Generating output would be disrupted. There would also be major impacts on the workforce, who live in, or near, the floodplain areas. Access to the site would also be affected. This scenario assumes that the existing gates protecting the turbine tunnel would protect the turbine house.
  - The inundation of the power station site is assumed to cause disruption to activities and some damage to buildings. It is assumed that the access road would be washed away and the bridge over the Tama Koshi collapses following undermining of the bridge piers.

Scenario 3: Extreme River Flooding on the Khimti Khola

- Scenario
  - Although there have not been any serious flood events on the Khimti Khola affecting the intake structure since it was constructed, there is a risk of a catastrophic monsoon flood. A severe monsoon flood would be a low probability, high consequence event. There have been a number of severe floods in Nepal as documented by ICIMOD.
  - The analysis of the GCMs and the PRECIS RCM indicate increasing precipitation during the monsoon period.
  - There is no baseline data or information on flood return periods and flood levels for the Khimti Koshi other than that produced for the original project appraisal.
  - An analysis of the baseline flow data on the Khimti Khola together with the analysis of the future flows based on the climate change model outputs has enabled amended flood return periods and flow duration curves to be developed.
  - If such a flood occurred it is assumed that the intake structure would be inundated arising from either an overtopping of the intake wall or undermining of the intake structure foundations leading to a collapse of the intake wall. Severe damage to the control gates and electrical equipment would occur. Sedimentation chambers would be filled with material. Generating output would be disrupted until such time as the sediment chambers are cleared and the intake structure is repaired.

Scenario 4: Change in Stream Flow

- Scenario
  - An analysis of the baseline daily time series of stream flow at Rasnalu (upstream of the Khimti Khola intake) together with baseline precipitation and temperature has been undertaken and a regression analysis developed.
  - Using the data from 4 different climate model/emission scenarios modelled stream flow in the Khimti Khola for 5 future time slices has been created.
  - The table below shows the percentage and actual change in the 2050s for each scenario relative to the average baseline flow during the period 1994-2006.

G	H	I	J	K	L	M	N	O	P
		Part 2 - 2050s							
	Ave mod. Baseline streamflow	Modelled A1B		Modelled A2		Modelled B1		Modelled 10-yr A2	
Jan	3.114250117	3.325437655	6.78%	3.231487535	3.76%	3.279054924	5.29%	3.802595515	22.10%
Feb	4.394018366	4.501407913	2.44%	4.359963003	-0.78%	4.498832667	2.39%	5.170843237	17.68%
Mar	6.305872765	6.217656526	-1.40%	5.986708385	-5.06%	6.297635842	-0.13%	7.249435897	14.96%
Apr	9.802759499	9.318945107	-4.94%	8.906983337	-9.14%	9.565884885	-2.42%	11.08353836	13.07%
May	21.81283241	19.84448505	-9.02%	18.75324635	-14.03%	20.71796544	-5.02%	24.3590567	11.67%
Jun	31.45617047	28.31016807	-10.00%	26.6800704	-15.18%	29.68067259	-5.64%	35.00625133	11.29%
Jul	70.80653835	62.53382159	-11.68%	58.55789606	-17.30%	66.06803338	-6.69%	78.7267325	11.19%
Aug	71.43220779	63.07031653	-11.71%	59.05358748	-17.33%	66.64216402	-6.71%	79.42841605	11.19%
Sep	52.12127772	46.26452152	-11.24%	43.39406574	-16.74%	48.77908777	-6.41%	57.98205903	11.24%
Oct	22.0798261	20.04554355	-9.21%	18.92413493	-14.29%	20.9468516	-5.13%	24.68225486	11.79%
Nov	5.12769968	5.197626215	1.36%	5.039039375	-1.73%	5.210862069	1.62%	5.936458767	15.77%
Dec	2.982793669	3.246869328	8.85%	3.177119196	6.51%	3.178165397	6.55%	3.62605618	21.57%

Scenario 4: Change in Stream Flow

- Timescale
  - This scenario examines the impact of changes in stream flow for each of five time slices from the 2010s to the 2050s.
- Proposed financial modelling
  - From 2010 through to 2050 the financial model will be perturbed to take into account the effect of changes in stream flow on generating output for each of four emissions scenarios.

Scenario 4: Change in Stream Flow
Basis for Design

- The Supplementary Environmental Assessment June 1994 prepared by Norconsult and BPC Hydroconsult contains extracts from the KK Prefeasibility Report December1992 by BPC and Statkraft. This is the only hydrological design information in the IFC records. HPL has not been able to provide any additional information. The key points from this document are:
  - The design return period for KK1 was selected using:
    - observed measurements from Rasnalu, and
    - flow measurements during February 1994 at various points along the Khimti Khola.
  - A 10 year return period low flow was selected representing a relatively dry year.
  - The 10 year return period corresponds to approx 3.7m^3/s. The February 1994 accumulated flows were adjusted by the ratio of the one in ten year low flow to the February 1994 measurement (4.0m^3/s). This provided a 10 year design curve.
  - The 10 year design curve was used to define the monthly contract energy/excess energy levels in the PPA.
  - The design curve gives a figure of 3.6m^3/s at KK1 intake.
  - A minimum pass through flow of 0.5m^3/s was proposed, providing for a design 10 year low flow figure of 3.1m^3/s.
- The PPA defines the minimum daily discharge (mean annual low) as 3.5m^3/s.

Scenario 4: Change in Stream Flow Modelling Methodology

- The HPL financial model uses two sets of figures for assumed production based on changes in hydrology:
  - 30 year 'hydrological values' (similar to PPA).
  - '2004-05' budget values (these look to be based on actual production from previous 4 years and reflect higher dry weather flows than those used in the design and the PPA).
- The production in the wet season is determined by the number of turbine sets.
- Changes in flows during the wet season from the hydrological assessment indicate that there will be no changes in production.
- Production can only be increased in the wet season by installing additional turbine sets, or by replacing with higher rated sets. The limiting factor is the tunnel capacity.
- The relationship between dry weather flow and production has been defined as:
  - average monthly production/average monthly streamflow.
  - The mean values for the dry weather months have been calculated for both dataset part 1 (to 1994) and dataset part 2 (from 1994) for the following scenarios:
    - Observed streamflow and 30 year 'hydrological values' production
    - Observed streamflow and 2004/05 budget production
    - Modelled streamflow and 30 year 'hydrological values' production
    - Modelled streamflow and 2004/05 budget production
  - All scenarios take into account the guaranteed $0.5m^3/s$ pass through flow.
  - The relationship that is considered to be most accurate is observed streamflow and 2004/05 budget production for dataset 2.

Scenario 4: Change in Stream Flow Modelling Methodology

- Hydrological assessment for:
  - two data sets
  - four climate models
- % increases in baseflows applied to the observed flow.
- Streamflow/production relationship used to calculate changes in production.
- Changes in production inserted into HPL's power sales model to calculate sales revenue under different climate change scenarios.

Scenario 5: Major Landslide Blocking Khimti Khola

- Scenario:
  - Localized storms and major flood events can create landslides blocking rivers.
  - The geology of the area creates a significant landslide risk. Localized landslides are common in the area, occurring most years, although a major a event resulting in a blockage of the river would be less likely.
  - In 2000 there was a landslide that blocked the Khimti Khola river upstream of the inlet. This created a temporary dam across the river restricting downstream flows. Construction machinery was still on site thereby allowing the blockage to be removed quickly. Any future blockage would have to removed by manual labour or by equipment brought in by helicopter. There is no road access to the intake structure.
  - This scenario is based upon an event during the dry weather season following a localized storm event creating landslides and localized flooding, for example such as occurred on the Paluti Khola (a tributary of the Khimti Khola) in 2002 .
  - The scenario assumes an landslide occurs upstream of the intake (in an area known to be prone to landslides, blocking the Khimti Khola. The blockage requires machinery to be brought in to remove the blockage. It is estimated that a major blockage would take several weeks to remove. It is assumed that the blockage is removed without any damage to the intake structure.
  - During the period of the blockage downstream flows are restricted and fall below the minimum dry weather flow restriction of 500 litres per second. Generating output is lost with consequential revenue implications.

Modelled Stream Flow October 2008

- Our 22-year (1985-2006) daily timeseries of streamflow at Rasnalu is split into two parts, because flow characteristics are markedly different pre- and post- 1994.
- The next 10 slides show modelled streamflow for 5 future timeslices for both parts of our timeseries, using 4 different model/emissions scenarios.

Modelled streamflow part 1

2010s: page 105 Top
2020s: page 105 Bottom
2030s: page 106 Top
2040s: page 106 Bottom
2050s: page 107 Top

Streamflow part 1 model equation:
Rasnalu streamflow = 0.309726 + 0.247084(x1) + 1.910853(x2)
Where:
x1=sum of rainfall over 20 antecedent days
x2=yesterday's Tmin

Modelled streamflow part 2

2010s: page 107 Bottom
2020s: page 108 Top
2030s: page 108 Bottom
2040s: page 109 Top
2050s: page 109 Bottom

Streamflow part 2 model equation:
Rasnalu streamflow = 1.849099 + 0.165096(x1) + 0.157717(x2)
Where:
x1=sum of rainfall over 20 antecedent days
x2=yesterday's Tmin

Table of the projected changes streamflow part 1

2010s: page 110
2020s: page 111
2030s: page 112
2040s: page 113
2050s: page 114

Table of the projected changes streamflow part 2

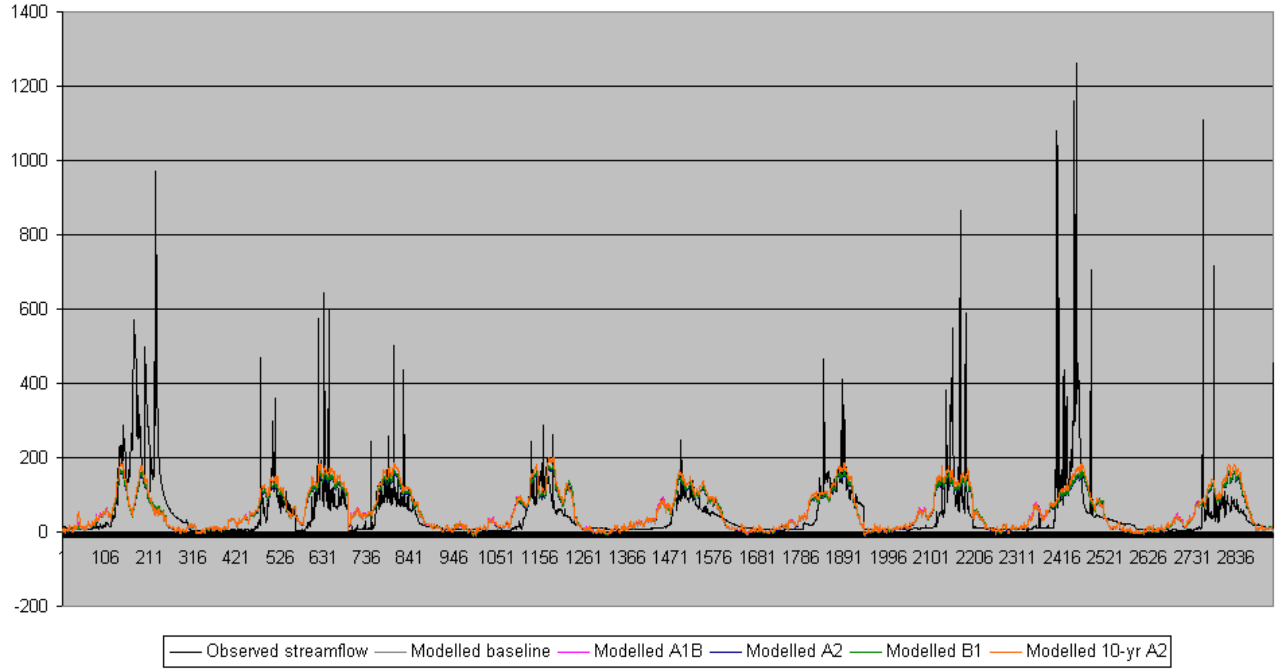
2010s: page 115
2020s: page 116
2030s: page 117
2040s: page 118
2050s: page 119

Chart of the projected changes streamflow part 1

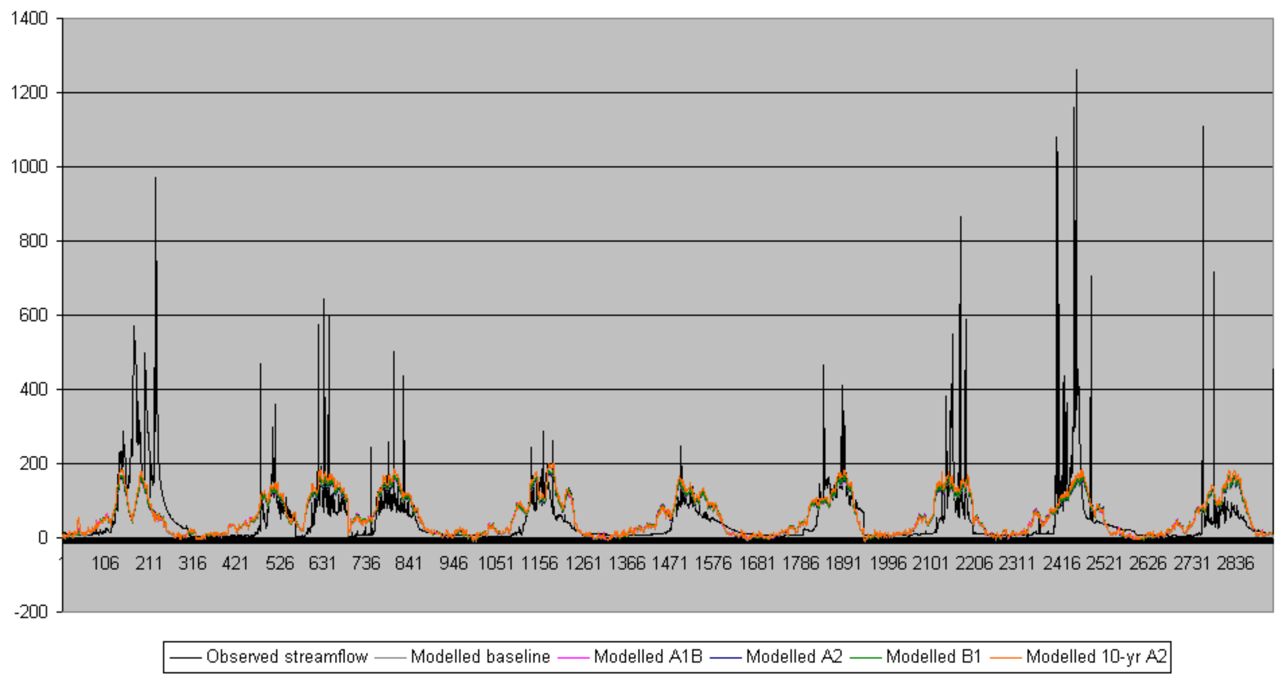
2010s: page 120 Top
2020s: page 120 Bottom
2030s: page 121 Top
2040s: page 121 Bottom
2050s: page 122 Top

Chart of the projected changes streamflow part 2

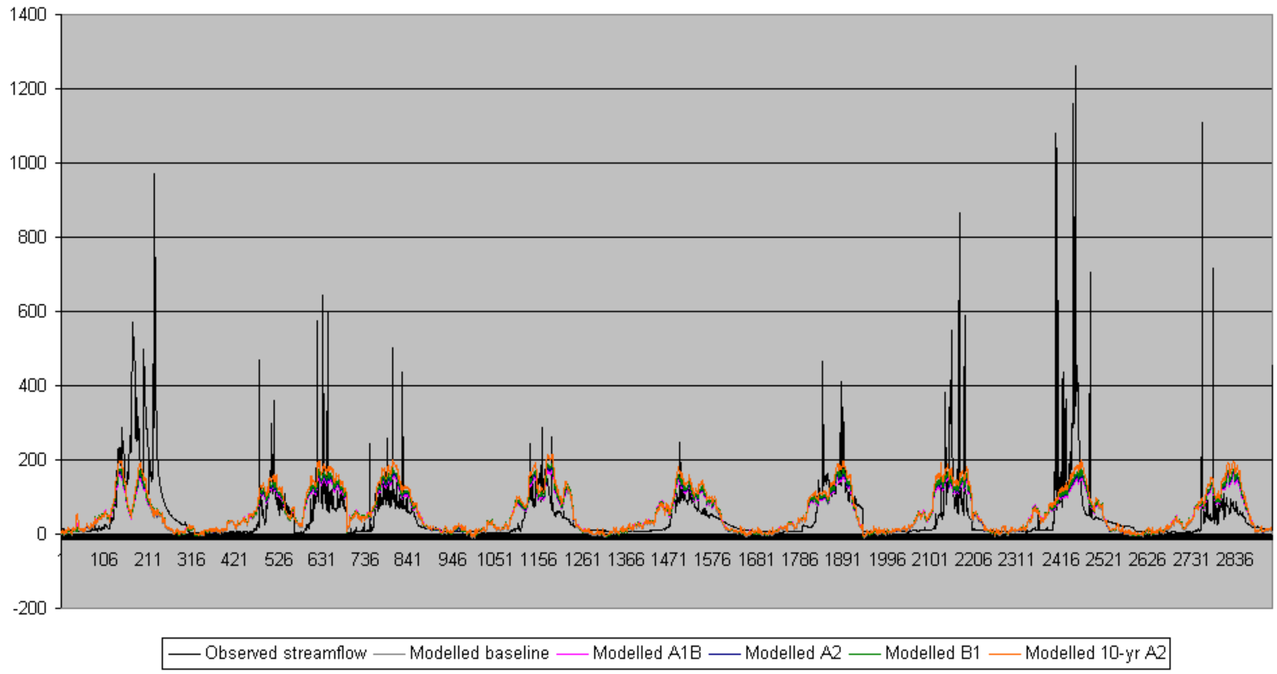
2010s: page 122 Bottom
2020s: page 123 Top
2030s: page 123 Bottom
2040s: page 124 Top
2050s: page 124 Bottom



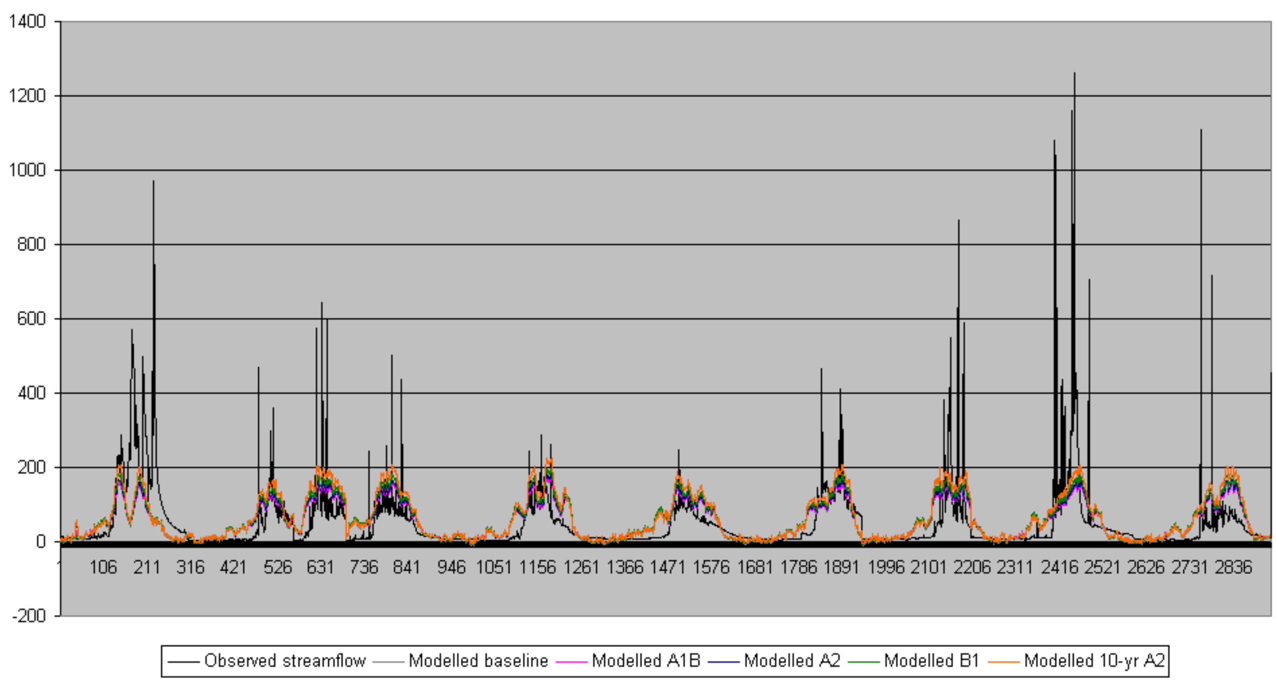
Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2010s under 4 scenarios – Dataset part 1 (to 1994)



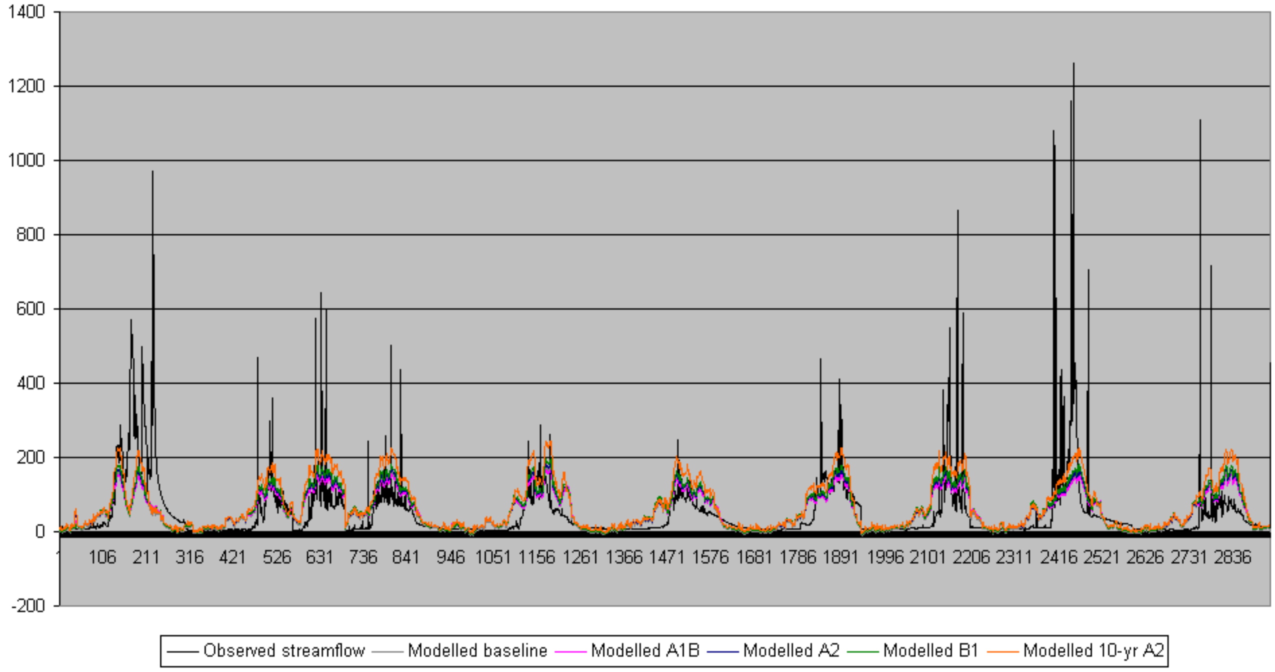
Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2020s under 4 scenarios – Dataset part 1 (to 1994)



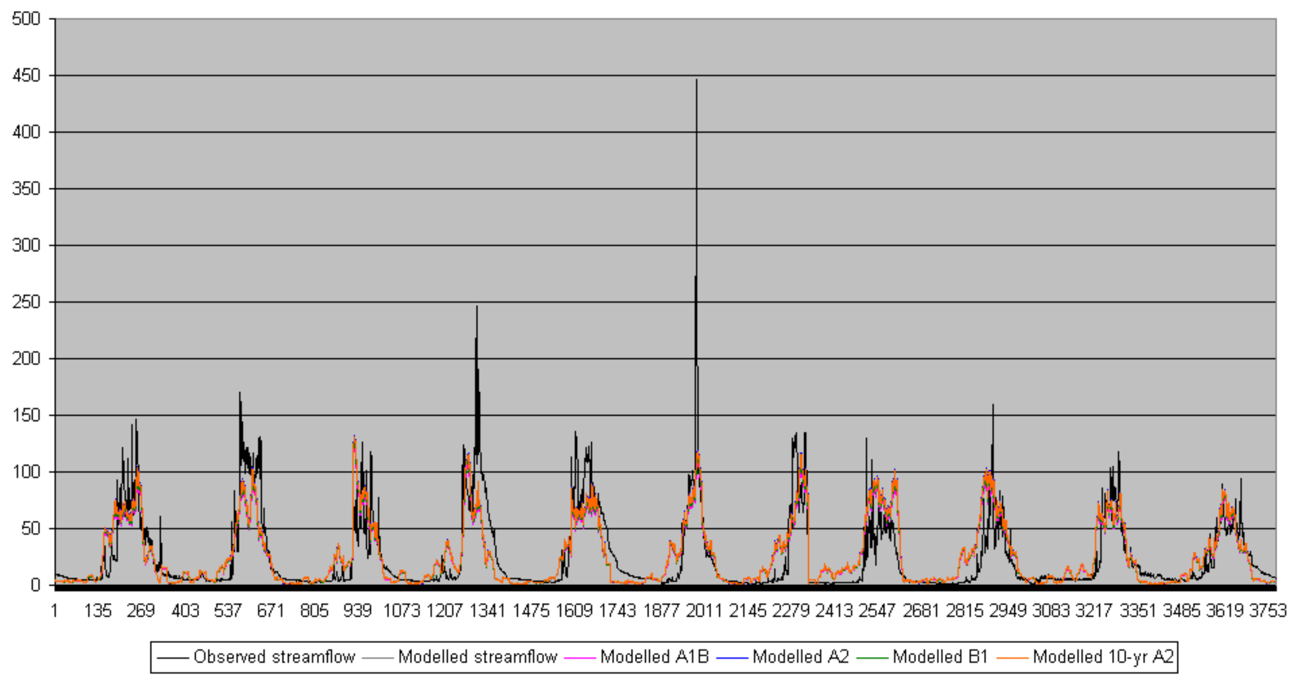
Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2030s under 4 scenarios – Dataset part 1 (to 1994)



Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2040s under 4 scenarios – Dataset part 1 (to 1994)

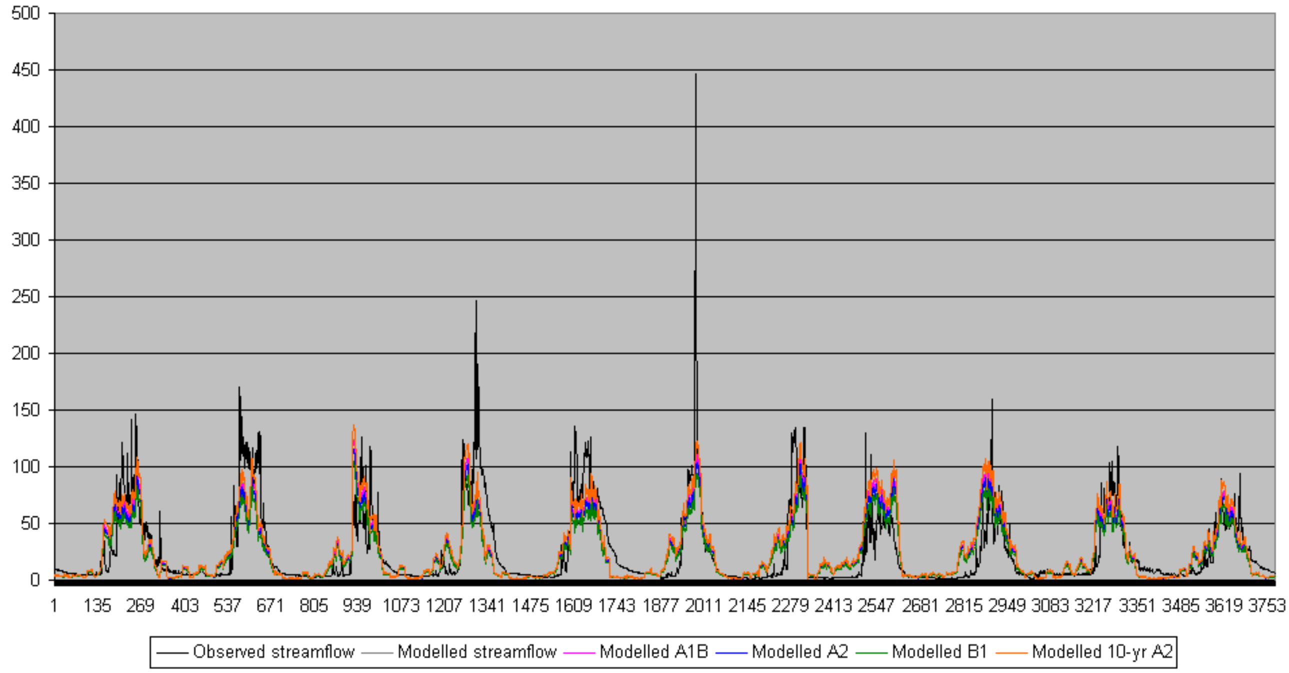


Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2050s under 4 scenarios – Dataset part 1 (to 1994)

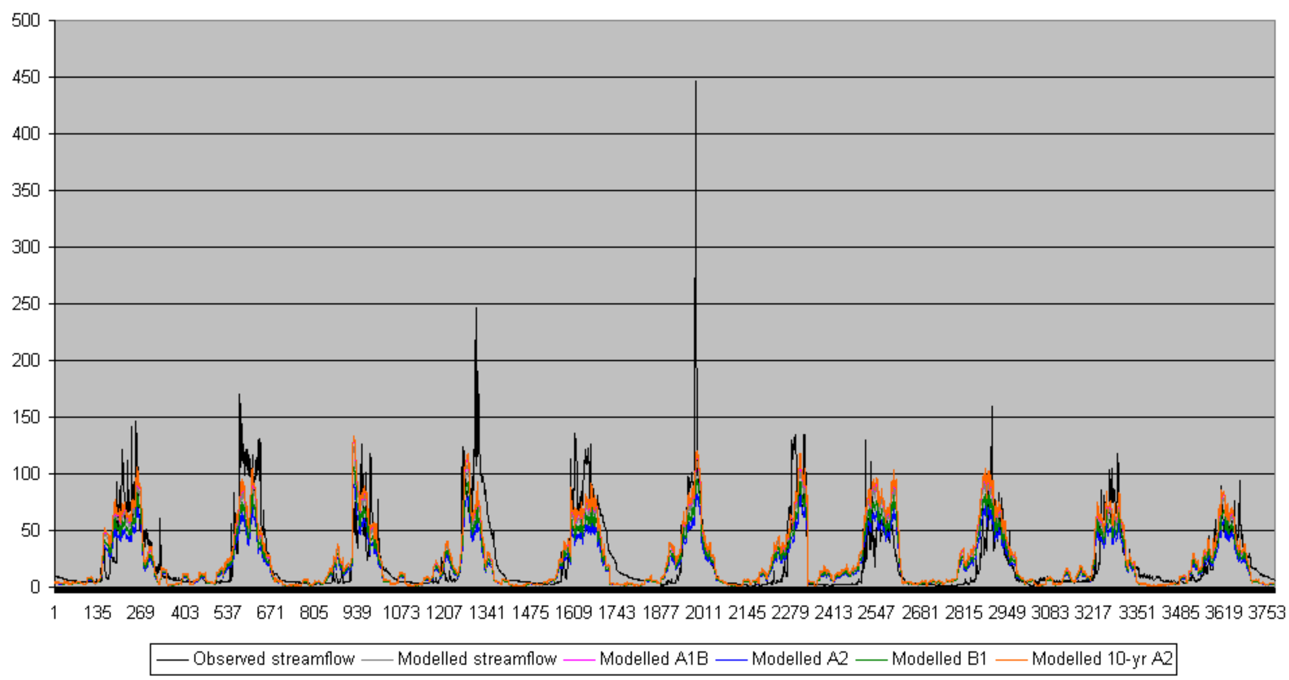


Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2010s under 4 scenarios – Dataset part 2 (from 1994), excluding year 2000

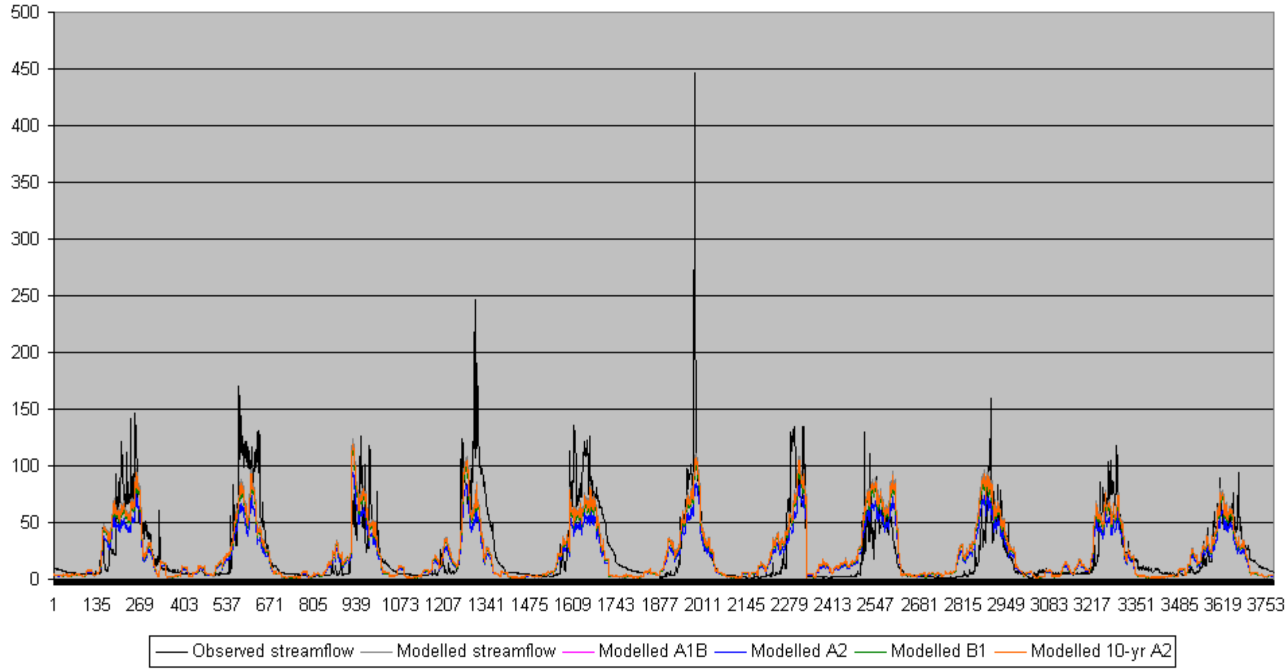
Note: All 5 modelled results are on this graph, even though they are not really visible. In the 2010s the climate models show such small changes that modelled future flow is essentially the same as modelled current flow.



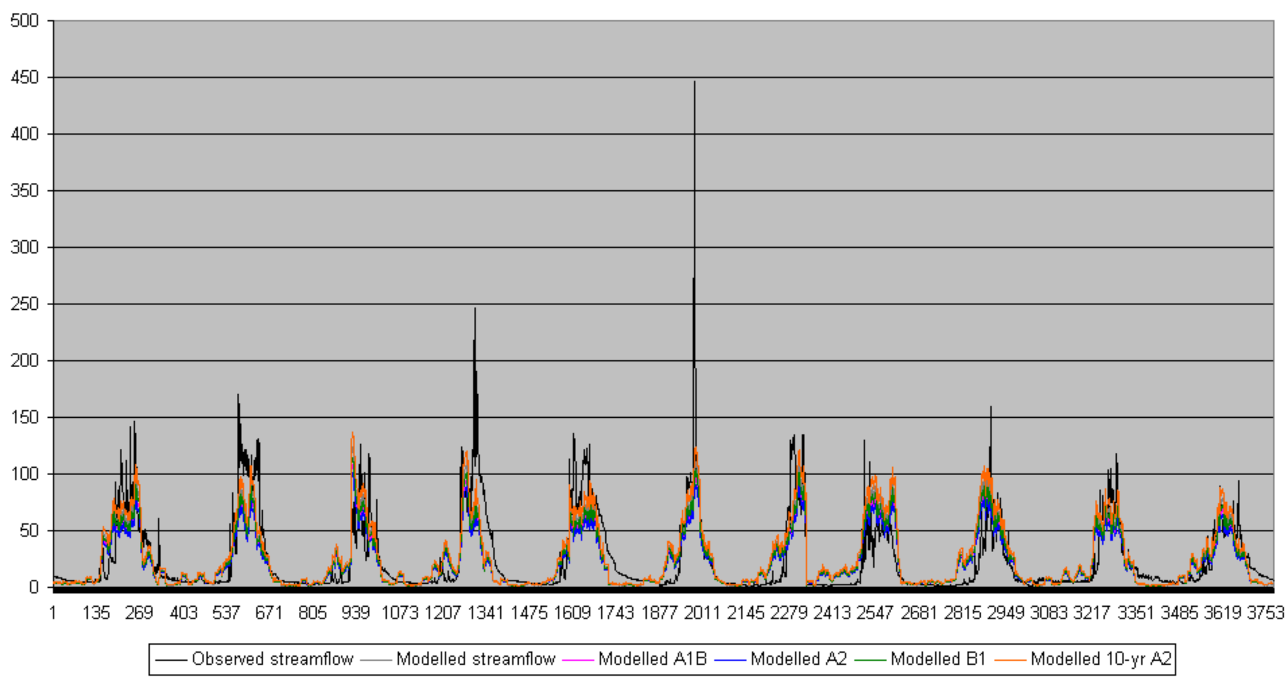
Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2020s under 4 scenarios – Dataset part 2 (from 1994), excluding year 2000



Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2030s under 4 scenarios – Dataset part 2 (from 1994), excluding year 2000



Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2040s under 4 scenarios – Dataset part 2 (from 1994), excluding year 2000



Observed streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2050s under 4 scenarios – Dataset part 2 (from 1994), excluding year 2000

Dataset part 1 (to 1994)

Part 1 - 2010s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	7.64	3.75	5.60	49.37%	5.05	34.69%	5.42	44.78%	6.32	68.64%
Feb	6.75	4.08	5.96	46.10%	5.22	27.76%	5.70	39.76%	6.51	59.54%
Mar	5.90	12.10	14.60	20.73%	14.14	16.92%	13.82	14.25%	15.21	25.77%
Apr	6.49	24.04	27.32	13.65%	25.95	7.96%	26.14	8.77%	26.56	10.48%
May	9.88	43.26	47.69	10.23%	45.66	5.55%	45.45	5.07%	45.64	5.51%
Jun	55.79	77.06	78.70	2.12%	77.83	0.99%	79.69	3.41%	86.65	12.45%
Jul	133.15	120.47	121.89	1.17%	120.32	-0.13%	123.80	2.76%	136.76	13.52%
Aug	149.95	122.82	124.22	1.14%	122.62	-0.16%	126.18	2.74%	139.47	13.55%
Sep	91.01	96.94	98.47	1.58%	97.26	0.34%	99.90	3.06%	109.72	13.19%
Oct	58.81	39.59	42.58	7.56%	42.61	7.62%	45.60	15.17%	41.87	5.76%
Nov	24.22	9.67	11.91	23.21%	10.96	13.36%	11.96	23.77%	11.71	21.10%
Dec	15.40	2.43	4.54	87.31%	3.43	41.26%	4.10	68.99%	4.43	82.44%

Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 1 - 2010s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	7.20	3.91	5.78	47.67%	5.13	31.08%	5.56	42.16%	6.42	63.89%
Falgun (Feb- Mar)	6.33	8.09	10.28	27.13%	9.68	19.65%	9.76	20.68%	10.86	34.29%
Chairta (Mar- Apr)	6.20	18.07	20.96	16.02%	20.05	10.96%	19.98	10.60%	20.88	15.60%
Baishak (Apr- May)	8.19	33.65	37.50	11.45%	35.81	6.41%	35.80	6.39%	36.10	7.28%
Jestha (May-Jun)	32.84	60.16	63.19	5.04%	61.74	2.63%	62.57	4.01%	66.15	9.95%
Ashad(Jun -Jul)	94.47	98.77	100.29	1.54%	99.07	0.31%	101.75	3.02%	111.71	13.10%
Srawan- (Jul-Aug)	141.55	121.65	123.05	1.16%	121.47	-0.15%	124.99	2.75%	138.11	13.54%
Bhadra- (Aug- Sep)	120.48	109.88	111.34	1.33%	109.94	0.06%	113.04	2.88%	124.59	13.39%
Ashoj- (Sep-Oct)	74.91	68.26	70.52	3.31%	69.94	2.45%	72.75	6.57%	75.80	11.03%
Kartik (Oct-Nov)	41.52	24.63	27.25	10.63%	26.78	8.75%	28.78	16.86%	26.79	8.77%
Marg- (Nov Dec)	19.81	6.05	8.23	36.07%	7.19	18.96%	8.03	32.84%	8.07	33.41%
Poush (Dec-Jan)	11.52	3.09	5.07	64.28%	4.24	37.27%	4.76	54.29%	5.37	74.06%

Dataset part 1 (to 1994)

Part 1 - 2020s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	7.64	3.75	6.42	71.40%	4.62	23.28%	4.90	30.72%	7.05	88.07%
Feb	6.75	4.08	6.77	65.81%	5.09	24.79%	5.58	36.67%	7.13	74.78%
Mar	5.90	12.10	15.33	26.71%	14.85	22.78%	14.84	22.65%	15.12	25.03%
Apr	6.49	24.04	27.90	16.08%	26.67	10.96%	27.27	13.47%	25.94	7.94%
May	9.88	43.26	48.07	11.12%	46.40	7.25%	46.75	8.07%	44.31	2.42%
Jun	55.79	77.06	79.88	3.65%	79.94	3.73%	81.00	5.11%	86.67	12.47%
Jul	133.15	120.47	123.49	2.50%	123.85	2.81%	126.10	4.67%	136.22	13.07%
Aug	149.95	122.82	125.84	2.46%	126.22	2.77%	128.53	4.65%	138.89	13.09%
Sep	91.01	96.94	99.85	3.00%	100.05	3.22%	101.68	4.89%	109.47	12.93%
Oct	58.81	39.59	42.20	6.59%	44.35	12.02%	43.97	11.05%	42.70	7.85%
Nov	24.22	9.67	12.42	28.44%	11.53	19.24%	12.03	24.48%	12.10	25.19%
Dec	15.40	2.43	5.20	114.29%	3.80	56.59%	4.45	83.62%	4.75	95.71%

Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 1 - 2020s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	7.20	3.91	6.59	68.49%	4.86	24.07%	5.24	33.82%	7.09	81.14%
Falgun (Feb- Mar)	6.33	8.09	11.05	36.57%	9.97	23.29%	10.21	26.19%	11.13	37.58%
Chairta (Mar- Apr)	6.20	18.07	21.61	19.64%	20.76	14.92%	21.05	16.54%	20.53	13.66%
Baishak (Apr- May)	8.19	33.65	37.99	12.89%	36.54	8.58%	37.01	10.00%	35.13	4.39%
Jestha (May-Jun)	32.84	60.16	63.97	6.34%	63.17	5.00%	63.88	6.17%	65.49	8.85%
Ashad(Jun -Jul)	94.47	98.77	101.68	2.95%	101.90	3.17%	103.55	4.84%	111.44	12.83%
Srawan- (Jul-Aug)	141.55	121.65	124.66	2.48%	125.04	2.79%	127.31	4.66%	137.55	13.08%
Bhadra- (Aug- Sep)	120.48	109.88	112.84	2.70%	113.14	2.97%	115.10	4.76%	124.18	13.02%
Ashoj- (Sep-Oct)	74.91	68.26	71.02	4.04%	72.20	5.77%	72.82	6.68%	76.08	11.46%
Kartik (Oct-Nov)	41.52	24.63	27.31	10.88%	27.94	13.43%	28.00	13.68%	27.40	11.26%
Marg- (Nov Dec)	19.81	6.05	8.81	45.66%	7.66	26.73%	8.24	36.34%	8.42	39.34%
Poush (Dec-Jan)	11.52	3.09	5.81	88.26%	4.21	36.37%	4.68	51.51%	5.90	91.07%

Dataset part 1 (to 1994)

						Part 1 - 2030s				
	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	7.64	3.75	7.50	100.07%	5.43	44.92%	5.36	43.16%	7.80	108.14%
Feb	6.75	4.08	7.68	88.20%	6.37	56.02%	6.03	47.76%	7.95	94.67%
Mar	5.90	12.10	15.84	30.93%	15.46	27.81%	15.33	26.78%	15.53	28.37%
Apr	6.49	24.04	28.02	16.58%	26.94	12.08%	27.59	14.80%	26.29	9.37%
May	9.88	43.26	47.61	10.04%	46.17	6.71%	46.80	8.18%	44.60	3.10%
Jun	55.79	77.06	78.21	1.48%	81.34	5.55%	83.60	8.49%	92.21	19.66%
Jul	133.15	120.47	119.98	-0.41%	125.95	4.55%	130.72	8.50%	145.96	21.16%
Aug	149.95	122.82	122.24	-0.47%	128.36	4.51%	133.26	8.50%	148.87	21.21%
Sep	91.01	96.94	97.30	0.38%	101.79	5.00%	105.24	8.57%	117.01	20.71%
Oct	58.81	39.59	45.95	16.05%	43.47	9.80%	45.43	14.75%	44.36	12.05%
Nov	24.22	9.67	13.72	41.92%	12.15	25.66%	12.62	30.56%	13.24	36.93%
Dec	15.40	2.43	6.09	151.08%	4.67	92.51%	4.89	101.78%	5.79	138.84%

			Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 1 - 2030s							
	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	7.20	3.91	7.59	93.88%	5.90	50.71%	5.70	45.56%	7.87	101.12%
Falgun (Feb- Mar)	6.33	8.09	11.76	45.38%	10.91	34.93%	10.68	32.07%	11.74	45.10%
Chairta (Mar- Apr)	6.20	18.07	21.93	21.38%	21.20	17.35%	21.46	18.81%	20.91	15.73%
Baishak (Apr- May)	8.19	33.65	37.81	12.38%	36.55	8.63%	37.20	10.55%	35.45	5.34%
Jestha (May-Jun)	32.84	60.16	62.91	4.56%	63.75	5.97%	65.20	8.38%	68.41	13.71%
Ashad(Jun -Jul)	94.47	98.77	99.10	0.33%	103.65	4.94%	107.16	8.49%	119.09	20.57%
Srawan- (Jul-Aug)	141.55	121.65	121.11	-0.44%	127.16	4.53%	131.99	8.50%	147.41	21.18%
Bhadra- (Aug- Sep)	120.48	109.88	109.77	-0.10%	115.07	4.73%	119.25	8.53%	132.94	20.99%
Ashoj- (Sep-Oct)	74.91	68.26	71.62	4.92%	72.63	6.40%	75.34	10.36%	80.69	18.20%
Kartik (Oct-Nov)	41.52	24.63	29.83	21.13%	27.81	12.92%	29.03	17.86%	28.80	16.93%
Marg- (Nov Dec)	19.81	6.05	9.90	63.82%	8.41	39.07%	8.76	44.85%	9.52	57.37%
Poush (Dec-Jan)	11.52	3.09	6.79	120.12%	5.05	63.62%	5.13	66.20%	6.80	120.21%

Dataset part 1 (to 1994)

Part 1 - 2040s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	7.64	3.75	7.44	98.63%	6.59	76.02%	6.20	65.42%	8.31	121.75%
Feb	6.75	4.08	7.92	94.09%	7.48	83.22%	6.72	64.73%	8.73	113.98%
Mar	5.90	12.10	16.81	38.98%	16.15	33.50%	16.17	33.66%	16.64	37.56%
Apr	6.49	24.04	29.19	21.45%	27.29	13.53%	28.97	20.53%	27.09	12.72%
May	9.88	43.26	49.08	13.44%	46.01	6.35%	48.99	13.25%	45.01	4.05%
Jun	55.79	77.06	78.13	1.39%	81.46	5.70%	85.75	11.28%	95.86	24.39%
Jul	133.15	120.47	119.15	-1.10%	125.49	4.16%	134.62	11.74%	152.12	26.27%
Aug	149.95	122.82	121.37	-1.18%	127.86	4.11%	137.26	11.76%	155.16	26.33%
Sep	91.01	96.94	96.87	-0.07%	101.62	4.84%	108.23	11.65%	121.85	25.70%
Oct	58.81	39.59	44.51	12.43%	42.57	7.53%	43.99	11.11%	42.94	8.47%
Nov	24.22	9.67	14.14	46.26%	12.94	33.87%	12.67	31.10%	13.86	43.36%
Dec	15.40	2.43	6.82	181.22%	5.75	136.99%	5.20	114.26%	6.76	178.60%

Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 1 - 2040s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	7.20	3.91	7.68	96.26%	7.04	79.77%	6.46	65.06%	8.52	117.70%
Falgun (Feb- Mar)	6.33	8.09	12.37	52.89%	11.81	46.05%	11.45	41.50%	12.69	56.84%
Chairta (Mar- Apr)	6.20	18.07	23.00	27.32%	21.72	20.22%	22.57	24.92%	21.87	21.04%
Baishak (Apr- May)	8.19	33.65	39.13	16.30%	36.65	8.92%	38.98	15.85%	36.05	7.14%
Jestha (May-Jun)	32.84	60.16	63.60	5.72%	63.73	5.94%	67.37	11.99%	70.43	17.07%
Ashad(Jun -Jul)	94.47	98.77	98.64	-0.13%	103.47	4.76%	110.19	11.56%	123.99	25.53%
Srawan- (Jul-Aug)	141.55	121.65	120.26	-1.14%	126.67	4.13%	135.94	11.75%	153.64	26.30%
Bhadra- (Aug- Sep)	120.48	109.88	109.12	-0.69%	114.74	4.43%	122.74	11.71%	138.51	26.06%
Ashoj- (Sep-Oct)	74.91	68.26	70.69	3.56%	72.10	5.62%	76.11	11.49%	82.40	20.71%
Kartik (Oct-Nov)	41.52	24.63	29.33	19.07%	27.76	12.70%	28.33	15.04%	28.40	15.32%
Marg- (Nov Dec)	19.81	6.05	10.48	73.33%	9.34	54.56%	8.94	47.78%	10.31	70.49%
Poush (Dec-Jan)	11.52	3.09	7.13	131.09%	6.17	99.98%	5.70	84.62%	7.53	144.09%

Dataset part 1 (to 1994)

Part 1 - 2050s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	7.64	3.75	8.20	118.76%	7.92	111.47%	6.84	82.46%	10.47	179.60%
Feb	6.75	4.08	8.82	116.04%	8.68	112.58%	7.34	79.76%	10.57	158.82%
Mar	5.90	12.10	17.27	42.80%	16.98	40.41%	16.60	37.26%	18.08	49.47%
Apr	6.49	24.04	29.29	21.84%	27.92	16.15%	29.59	23.12%	29.16	21.30%
May	9.88	43.26	48.62	12.38%	46.34	7.10%	49.90	15.35%	48.02	11.01%
Jun	55.79	77.06	77.36	0.38%	82.69	7.30%	85.46	10.90%	103.05	33.72%
Jul	133.15	120.47	116.95	-2.93%	127.00	5.42%	133.73	11.00%	164.80	36.80%
Aug	149.95	122.82	119.08	-3.04%	129.40	5.36%	136.34	11.01%	168.14	36.91%
Sep	91.01	96.94	95.41	-1.58%	102.99	6.25%	107.65	11.05%	131.66	35.82%
Oct	58.81	39.59	46.85	18.34%	44.62	12.70%	44.20	11.64%	44.24	11.75%
Nov	24.22	9.67	15.12	56.39%	14.30	47.94%	13.00	34.48%	15.49	60.26%
Dec	15.40	2.43	7.57	212.17%	6.99	188.28%	5.54	128.55%	8.45	248.25%

Averaging steam flow across Julian months to return streamflow across Nepalese months - Part 1 - 2050s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	7.20	3.91	8.51	117.34%	8.30	112.05%	7.09	81.05%	10.52	168.76%
Falgun (Feb- Mar)	6.33	8.09	13.05	61.28%	12.83	58.62%	11.97	47.98%	14.32	77.06%
Chaira (Mar- Apr)	6.20	18.07	23.28	28.85%	22.45	24.27%	23.10	27.85%	23.62	30.73%
Baishak (Apr- May)	8.19	33.65	38.95	15.76%	37.13	10.33%	39.75	18.12%	38.59	14.68%
Jestha (May-Jun)	32.84	60.16	62.99	4.70%	64.51	7.23%	67.68	12.50%	75.54	25.55%
Ashad(Jun -Jul)	94.47	98.77	97.15	-1.64%	104.85	6.15%	109.60	10.96%	133.93	35.60%
Srawan- (Jul-Aug)	141.55	121.65	118.01	-2.99%	128.20	5.39%	135.04	11.01%	166.47	36.85%
Bhadra- (Aug- Sep)	120.48	109.88	107.25	-2.40%	116.19	5.75%	122.00	11.03%	149.90	36.43%
Ashoj- (Sep-Oct)	74.91	68.26	71.13	4.20%	73.81	8.12%	75.93	11.22%	87.95	28.84%
Kartik (Oct-Nov)	41.52	24.63	30.98	25.80%	29.46	19.62%	28.60	16.12%	29.87	21.27%
Marg- (Nov Dec)	19.81	6.05	11.35	87.64%	10.65	76.09%	9.27	53.35%	11.97	97.97%
Poush (Dec-Jan)	11.52	3.09	7.88	155.47%	7.46	141.66%	6.19	100.58%	9.46	206.58%

Dataset part 2 (from 1994), excluding year 2000

Part 2 - 2010s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	4.99	3.11	3.25	4.34%	3.31	6.34%	3.28	5.40%	3.40	9.27%
Feb	3.91	4.39	4.52	2.81%	4.65	5.86%	4.58	4.27%	4.73	7.73%
Mar	3.96	6.31	6.41	1.61%	6.68	5.88%	6.53	3.57%	6.74	6.91%
Apr	4.24	9.80	9.86	0.58%	10.40	6.12%	10.10	3.06%	10.43	6.42%
May	6.64	21.81	21.70	-0.50%	23.27	6.69%	22.39	2.67%	23.17	6.23%
Jun	17.07	31.46	31.22	-0.77%	33.60	6.81%	32.26	2.56%	33.39	6.15%
Jul	70.31	70.81	69.99	-1.15%	75.91	7.21%	72.58	2.51%	75.26	6.29%
Aug	85.52	71.43	70.61	-1.16%	76.59	7.22%	73.23	2.51%	75.93	6.29%
Sep	61.37	52.12	51.58	-1.04%	55.83	7.12%	53.44	2.53%	55.39	6.27%
Oct	27.49	22.08	21.96	-0.53%	23.58	6.78%	22.67	2.69%	23.47	6.30%
Nov	10.98	5.13	5.25	2.33%	5.41	5.45%	5.32	3.80%	5.49	6.98%
Dec	6.35	2.98	3.12	4.73%	3.15	5.60%	3.14	5.30%	3.25	8.81%

Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 2 - 2010s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	4.45	3.75	3.88	3.45%	3.98	6.06%	3.93	4.74%	4.07	8.37%
Falgun (Feb- Mar)	3.94	5.35	5.46	2.10%	5.66	5.87%	5.56	3.86%	5.74	7.25%
Chairta (Mar- Apr)	4.10	8.05	8.13	0.99%	8.54	6.03%	8.32	3.26%	8.59	6.61%
Baishak (Apr- May)	5.44	15.81	15.78	-0.16%	16.84	6.51%	16.25	2.79%	16.80	6.29%
Jestha (May-Jun)	11.85	26.63	26.46	-0.66%	28.43	6.76%	27.33	2.60%	28.28	6.18%
Ashad(Jun -Jul)	43.69	51.13	50.60	-1.03%	54.76	7.09%	52.42	2.52%	54.32	6.25%
Srawan- (Jul-Aug)	77.91	71.12	70.30	-1.15%	76.25	7.22%	72.91	2.51%	75.59	6.29%
Bhadra- (Aug- Sep)	73.44	61.78	61.09	-1.11%	66.21	7.18%	63.33	2.52%	65.66	6.28%
Ashoj- (Sep-Oct)	44.43	37.10	36.77	-0.89%	39.70	7.02%	38.06	2.58%	39.43	6.27%
Kartik (Oct-Nov)	19.23	13.60	13.61	0.01%	14.49	6.53%	14.00	2.90%	14.48	6.43%
Marg- (Nov Dec)	8.66	4.06	4.19	3.21%	4.28	5.50%	4.23	4.35%	4.37	7.66%
Poush (Dec-Jan)	5.67	3.05	3.19	4.53%	3.23	5.98%	3.21	5.35%	3.32	9.05%

Dataset part 2 (from 1994), excluding year 2000

			Part 2 - 2020s							
	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	4.99	3.11	3.33	6.89%	3.11	-0.13%	3.02	-2.97%	3.52	13.05%
Feb	3.91	4.39	4.60	4.79%	4.34	-1.24%	4.18	-4.95%	4.89	11.27%
Mar	3.96	6.31	6.51	3.22%	6.16	-2.37%	5.85	-7.18%	6.97	10.52%
Apr	4.24	9.80	9.99	1.91%	9.46	-3.49%	8.87	-9.47%	10.81	10.23%
May	6.64	21.81	21.94	0.59%	20.75	-4.88%	19.10	-12.44%	24.09	10.44%
Jun	17.07	31.46	31.54	0.26%	29.82	-5.21%	27.33	-13.12%	34.74	10.45%
Jul	70.31	70.81	70.69	-0.17%	66.67	-5.84%	60.52	-14.53%	78.50	10.86%
Aug	85.52	71.43	71.31	-0.17%	67.25	-5.85%	61.03	-14.56%	79.20	10.87%
Sep	61.37	52.12	52.10	-0.05%	49.16	-5.68%	44.73	-14.17%	57.74	10.77%
Oct	27.49	22.08	22.21	0.57%	20.98	-4.97%	19.29	-12.64%	24.41	10.57%
Nov	10.98	5.13	5.34	4.08%	5.05	-1.42%	4.87	-5.12%	5.66	10.29%
Dec	6.35	2.98	3.20	7.27%	3.00	0.73%	2.95	-0.97%	3.34	12.10%

			Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 2 - 2020s							
	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	4.45	3.75	3.97	5.66%	3.72	-0.78%	3.60	-4.13%	4.20	12.01%
Falgun (Feb- Mar)	3.94	5.35	5.56	3.86%	5.25	-1.91%	5.01	-6.26%	5.93	10.83%
Chairta (Mar- Apr)	4.10	8.05	8.25	2.42%	7.81	-3.05%	7.36	-8.57%	8.89	10.34%
Baishak (Apr- May)	5.44	15.81	15.97	1.00%	15.10	-4.45%	13.99	-11.52%	17.45	10.38%
Jestha (May-Jun)	11.85	26.63	26.74	0.39%	25.28	-5.08%	23.21	-12.84%	29.42	10.45%
Ashad(Jun -Jul)	43.69	51.13	51.11	-0.04%	48.24	-5.65%	43.92	-14.10%	56.62	10.74%
Srawan- (Jul-Aug)	77.91	71.12	71.00	-0.17%	66.96	-5.84%	60.77	-14.55%	78.85	10.87%
Bhadra- (Aug- Sep)	73.44	61.78	61.70	-0.12%	58.21	-5.78%	52.88	-14.40%	68.47	10.83%
Ashoj- (Sep-Oct)	44.43	37.10	37.15	0.14%	35.07	-5.47%	32.01	-13.72%	41.08	10.71%
Kartik (Oct-Nov)	19.23	13.60	13.77	1.23%	13.02	-4.30%	12.08	-11.23%	15.03	10.52%
Marg- (Nov Dec)	8.66	4.06	4.27	5.25%	4.03	-0.63%	3.91	-3.59%	4.50	10.95%
Poush (Dec-Jan)	5.67	3.05	3.26	7.07%	3.06	0.29%	2.99	-1.99%	3.43	12.58%

Dataset part 2 (from 1994), excluding year 2000

Part 2 - 2030s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	4.99	3.11	3.50	12.52%	2.93	-6.06%	3.07	-1.50%	3.55	13.99%
Feb	3.91	4.39	4.84	10.09%	3.99	-9.25%	4.23	-3.80%	4.90	11.45%
Mar	3.96	6.31	6.85	8.63%	5.49	-12.96%	5.91	-6.23%	6.94	9.99%
Apr	4.24	9.80	10.55	7.63%	8.16	-16.81%	8.95	-8.67%	10.69	9.05%
May	6.64	21.81	23.33	6.94%	17.05	-21.84%	19.25	-11.76%	23.66	8.48%
Jun	17.07	31.46	33.58	6.74%	24.22	-23.00%	27.53	-12.48%	34.07	8.31%
Jul	70.31	70.81	75.57	6.73%	52.81	-25.42%	60.95	-13.91%	76.75	8.39%
Aug	85.52	71.43	76.24	6.74%	53.25	-25.46%	61.48	-13.94%	77.43	8.40%
Sep	61.37	52.12	55.64	6.75%	39.20	-24.80%	45.06	-13.54%	56.50	8.39%
Oct	27.49	22.08	23.63	7.01%	17.18	-22.20%	19.44	-11.97%	23.97	8.57%
Nov	10.98	5.13	5.59	9.03%	4.64	-9.46%	4.92	-4.10%	5.66	10.28%
Dec	6.35	2.98	3.35	12.16%	2.91	-2.60%	3.00	0.48%	3.38	13.46%

Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 2 - 2030s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	4.45	3.75	4.17	11.10%	3.46	-7.93%	3.65	-2.85%	4.22	12.50%
Falgun (Feb- Mar)	3.94	5.35	5.84	9.23%	4.74	-11.44%	5.07	-5.23%	5.92	10.59%
Chairta (Mar- Apr)	4.10	8.05	8.70	8.03%	6.82	-15.30%	7.43	-7.72%	8.81	9.42%
Baishak (Apr- May)	5.44	15.81	16.94	7.16%	12.60	-20.28%	14.10	-10.80%	17.18	8.66%
Jestha (May-Jun)	11.85	26.63	28.45	6.83%	20.63	-22.53%	23.39	-12.19%	28.87	8.38%
Ashad(Jun -Jul)	43.69	51.13	54.58	6.74%	38.52	-24.67%	44.24	-13.47%	55.41	8.37%
Srawan- (Jul-Aug)	77.91	71.12	75.91	6.73%	53.03	-25.44%	61.22	-13.92%	77.09	8.40%
Bhadra- (Aug- Sep)	73.44	61.78	65.94	6.74%	46.22	-25.18%	53.27	-13.77%	66.96	8.40%
Ashoj- (Sep-Oct)	44.43	37.10	39.63	6.83%	28.19	-24.03%	32.25	-13.07%	40.23	8.45%
Kartik (Oct-Nov)	19.23	13.60	14.61	7.39%	10.91	-19.80%	12.18	-10.48%	14.81	8.90%
Marg- (Nov Dec)	8.66	4.06	4.47	10.18%	3.77	-6.94%	3.96	-2.41%	4.52	11.45%
Poush (Dec-Jan)	5.67	3.05	3.42	12.34%	2.92	-4.37%	3.03	-0.53%	3.47	13.73%

Dataset part 2 (from 1994), excluding year 2000

Part 2 - 2040s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	4.99	3.11	3.34	7.25%	3.05	-2.01%	3.21	3.16%	3.44	10.49%
Feb	3.91	4.39	4.57	3.94%	4.13	-5.93%	4.42	0.67%	4.69	6.68%
Mar	3.96	6.31	6.38	1.17%	5.67	-10.05%	6.21	-1.59%	6.54	3.67%
Apr	4.24	9.80	9.68	-1.29%	8.41	-14.17%	9.44	-3.71%	9.91	1.07%
May	6.64	21.81	20.93	-4.03%	17.59	-19.35%	20.46	-6.19%	21.44	-1.69%
Jun	17.07	31.46	29.98	-4.69%	24.99	-20.56%	29.32	-6.78%	30.71	-2.37%
Jul	70.31	70.81	66.73	-5.76%	54.56	-22.95%	65.26	-7.83%	68.43	-3.36%
Aug	85.52	71.43	67.31	-5.77%	55.01	-22.99%	65.83	-7.84%	69.02	-3.37%
Sep	61.37	52.12	49.27	-5.47%	40.48	-22.33%	48.18	-7.55%	50.51	-3.09%
Oct	27.49	22.08	21.17	-4.13%	17.73	-19.69%	20.69	-6.32%	21.69	-1.76%
Nov	10.98	5.13	5.28	3.01%	4.80	-6.48%	5.13	0.09%	5.41	5.49%
Dec	6.35	2.98	3.24	8.47%	3.02	1.28%	3.12	4.48%	3.33	11.52%

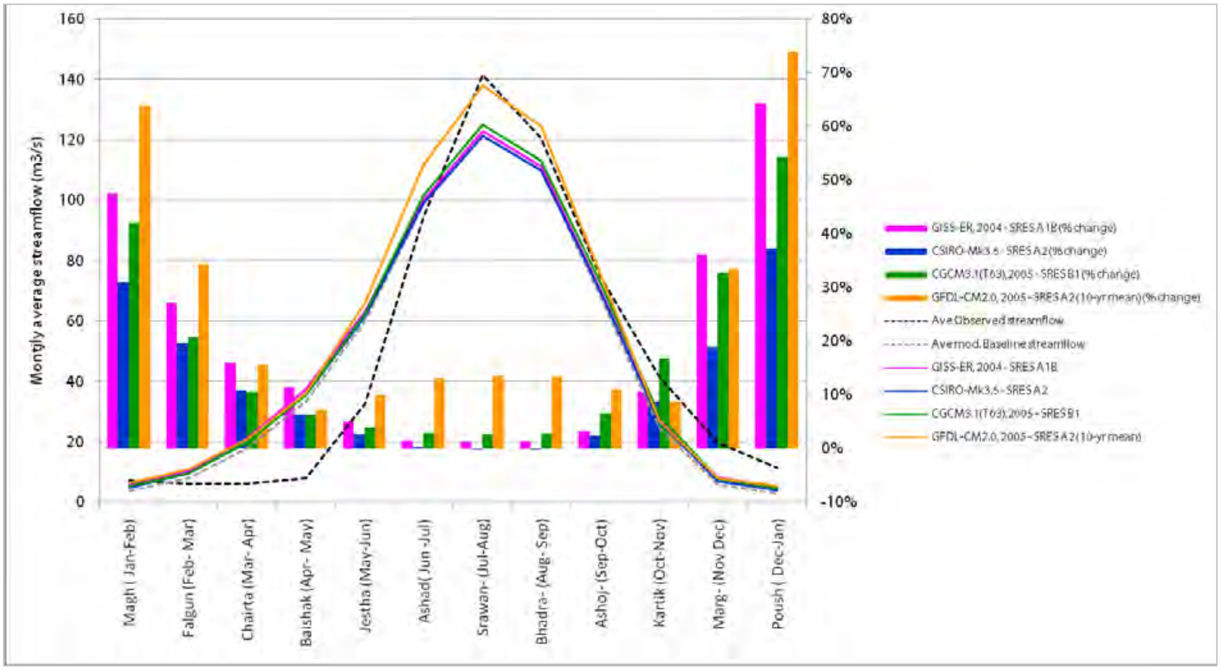
Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 2 - 2040s

	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	4.45	3.75	3.95	5.31%	3.59	-4.31%	3.82	1.71%	4.06	8.26%
Falgun (Feb- Mar)	3.94	5.35	5.47	2.31%	4.90	-8.36%	5.31	-0.66%	5.61	4.90%
Chairta (Mar- Apr)	4.10	8.05	8.03	-0.33%	7.04	-12.56%	7.82	-2.88%	8.22	2.09%
Baishak (Apr- May)	5.44	15.81	15.30	-3.18%	13.00	-17.74%	14.95	-5.42%	15.68	-0.83%
Jestha (May-Jun)	11.85	26.63	25.46	-4.42%	21.29	-20.07%	24.89	-6.54%	26.08	-2.09%
Ashad(Jun -Jul)	43.69	51.13	48.36	-5.43%	39.77	-22.21%	47.29	-7.51%	49.57	-3.05%
Srawan- (Jul-Aug)	77.91	71.12	67.02	-5.76%	54.79	-22.97%	65.55	-7.84%	68.73	-3.37%
Bhadra- (Aug- Sep)	73.44	61.78	58.29	-5.64%	47.75	-22.71%	57.01	-7.72%	59.77	-3.25%
Ashoj- (Sep-Oct)	44.43	37.10	35.22	-5.07%	29.11	-21.54%	34.43	-7.18%	36.10	-2.69%
Kartik (Oct-Nov)	19.23	13.60	13.22	-2.79%	11.26	-17.20%	12.91	-5.11%	13.55	-0.40%
Marg- (Nov Dec)	8.66	4.06	4.26	5.02%	3.91	-3.62%	4.12	1.71%	4.37	7.71%
Poush (Dec-Jan)	5.67	3.05	3.29	7.85%	3.04	-0.40%	3.16	3.81%	3.38	10.99%

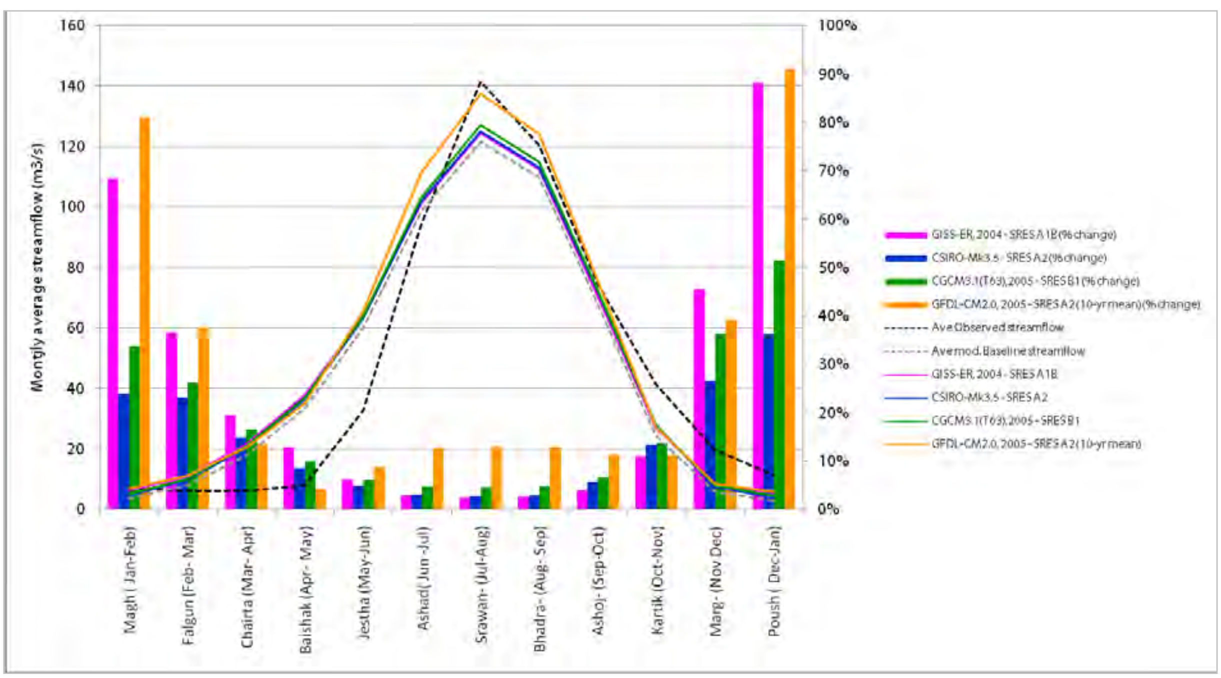
Dataset part 2 (from 1994), excluding year 2000

			Part 2 - 2050s							
	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Jan	4.99	3.11	3.33	6.78%	3.23	3.76%	3.28	5.29%	3.80	22.10%
Feb	3.91	4.39	4.50	2.44%	4.36	-0.78%	4.50	2.39%	5.17	17.68%
Mar	3.96	6.31	6.22	-1.40%	5.99	-5.06%	6.30	-0.13%	7.25	14.96%
Apr	4.24	9.80	9.32	-4.94%	8.91	-9.14%	9.57	-2.42%	11.08	13.07%
May	6.64	21.81	19.84	-9.02%	18.75	-14.03%	20.72	-5.02%	24.36	11.67%
Jun	17.07	31.46	28.31	-10.00%	26.68	-15.18%	29.68	-5.64%	35.01	11.29%
Jul	70.31	70.81	62.53	-11.68%	58.56	-17.30%	66.07	-6.69%	78.73	11.19%
Aug	85.52	71.43	63.07	-11.71%	59.05	-17.33%	66.64	-6.71%	79.43	11.19%
Sep	61.37	52.12	46.26	-11.24%	43.39	-16.74%	48.78	-6.41%	57.98	11.24%
Oct	27.49	22.08	20.05	-9.21%	18.92	-14.29%	20.95	-5.13%	24.68	11.79%
Nov	10.98	5.13	5.20	1.36%	5.04	-1.73%	5.21	1.62%	5.94	15.77%
Dec	6.35	2.98	3.25	8.85%	3.18	6.51%	3.18	6.55%	3.63	21.57%

			Averaging streamflow across Julian months to return streamflow across Nepalese months - Part 2 - 2050s							
	Ave Observed streamflow	Ave mod. Baseline streamflow	GISS-ER, 2004 - SRES A1B	GISS-ER, 2004 - SRES A1B (% change)	CSIRO-Mk3.5 - SRES A2	CSIRO-Mk3.5 - SRES A2 (% change)	CGCM3.1(T63),2005 - SRES B1	CGCM3.1(T63),2005 - SRES B1 (% change)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean)	GFDL-CM2.0, 2005 - SRES A2 (10-yr mean) (% change)
Magh (Jan-Feb)	4.45	3.75	3.91	4.24%	3.80	1.11%	3.89	3.59%	4.49	19.51%
Falgun (Feb- Mar)	3.94	5.35	5.36	0.18%	5.17	-3.30%	5.40	0.90%	6.21	16.08%
Chairta (Mar- Apr)	4.10	8.05	7.77	-3.55%	7.45	-7.54%	7.93	-1.52%	9.17	13.81%
Baishak (Apr- May)	5.44	15.81	14.58	-7.76%	13.83	-12.51%	15.14	-4.21%	17.72	12.10%
Jestha (May-Jun)	11.85	26.63	24.08	-9.60%	22.72	-14.71%	25.20	-5.39%	29.68	11.44%
Ashad(Jun -Jul)	43.69	51.13	45.42	-11.17%	42.62	-16.65%	47.87	-6.37%	56.87	11.22%
Srawan- (Jul-Aug)	77.91	71.12	62.80	-11.69%	58.81	-17.31%	66.36	-6.70%	79.08	11.19%
Bhadra- (Aug- Sep)	73.44	61.78	54.67	-11.51%	51.22	-17.08%	57.71	-6.58%	68.71	11.22%
Ashoj- (Sep-Oct)	44.43	37.10	33.16	-10.63%	31.16	-16.01%	34.86	-6.03%	41.33	11.41%
Kartik (Oct-Nov)	19.23	13.60	12.62	-7.22%	11.98	-11.92%	13.08	-3.86%	15.31	12.54%
Marg- (Nov Dec)	8.66	4.06	4.22	4.12%	4.11	1.30%	4.19	3.43%	4.78	17.90%
Poush (Dec-Jan)	5.67	3.05	3.29	7.79%	3.20	5.11%	3.23	5.91%	3.71	21.84%



Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2010s under four GCM scenarios – Dataset part 1 (to 1994)



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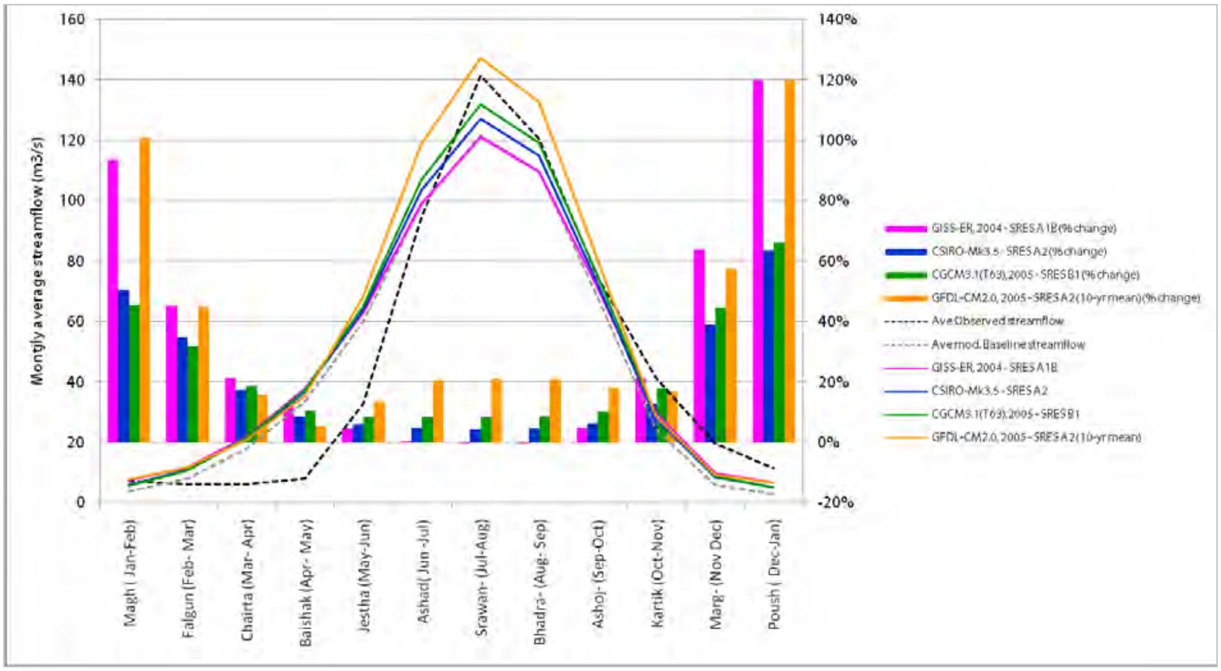
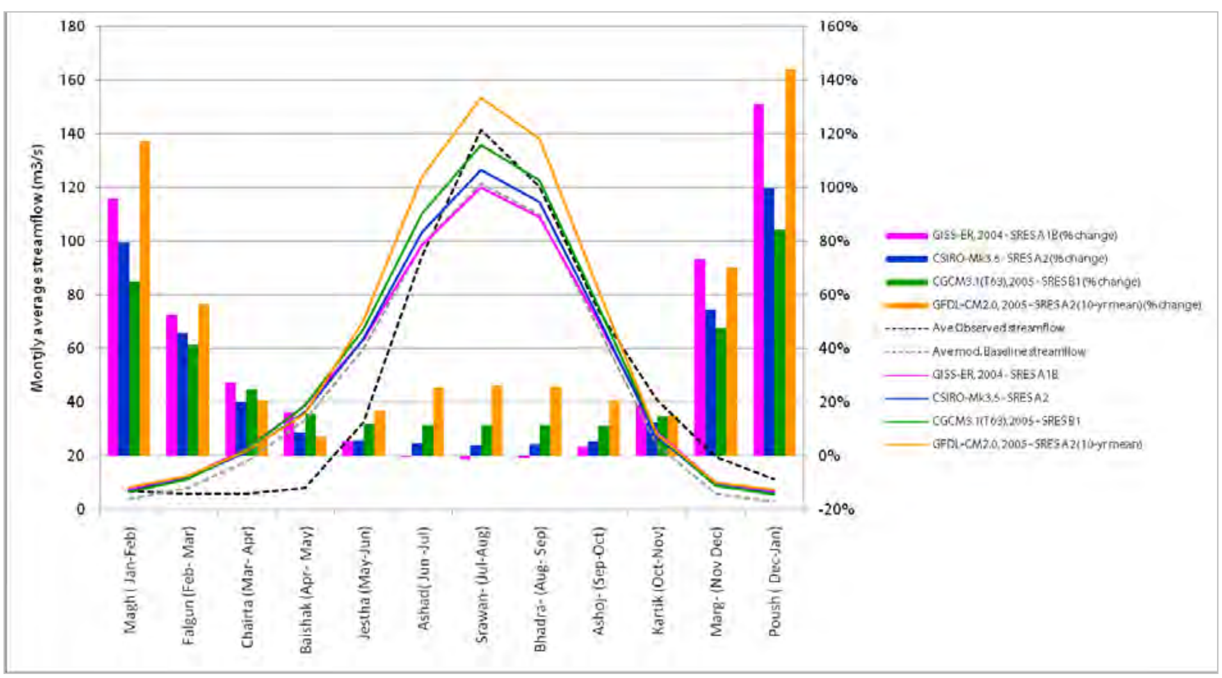


Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2030s under four GCM scenarios – Dataset part 1 (to 1994)



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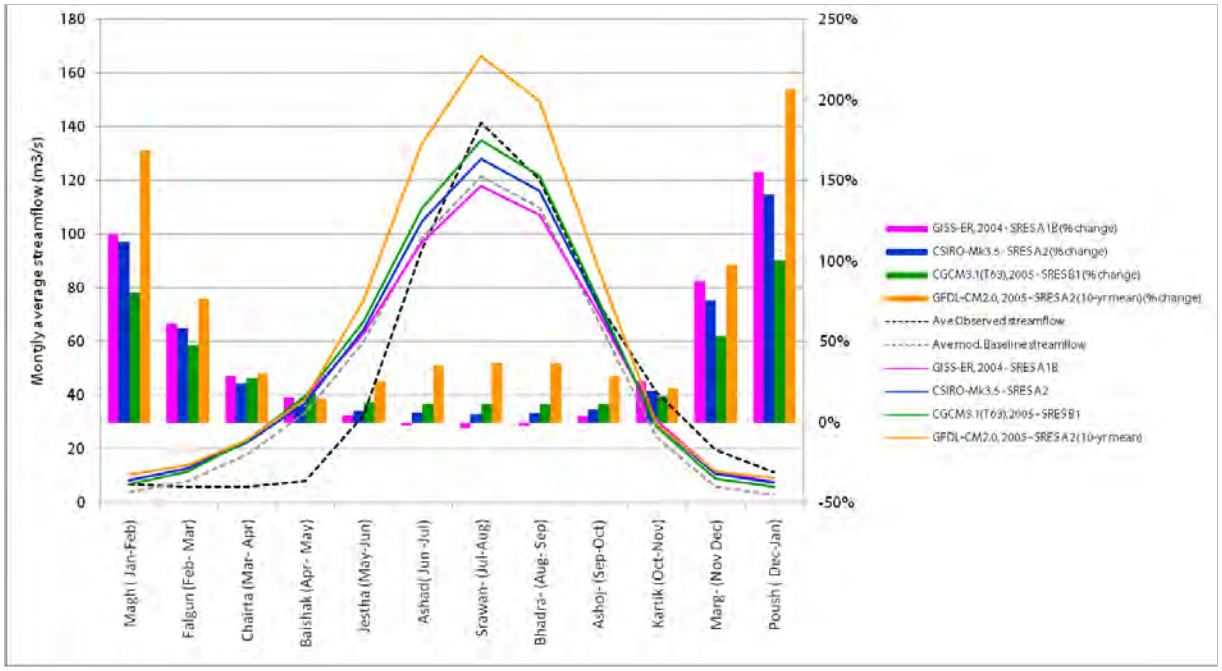

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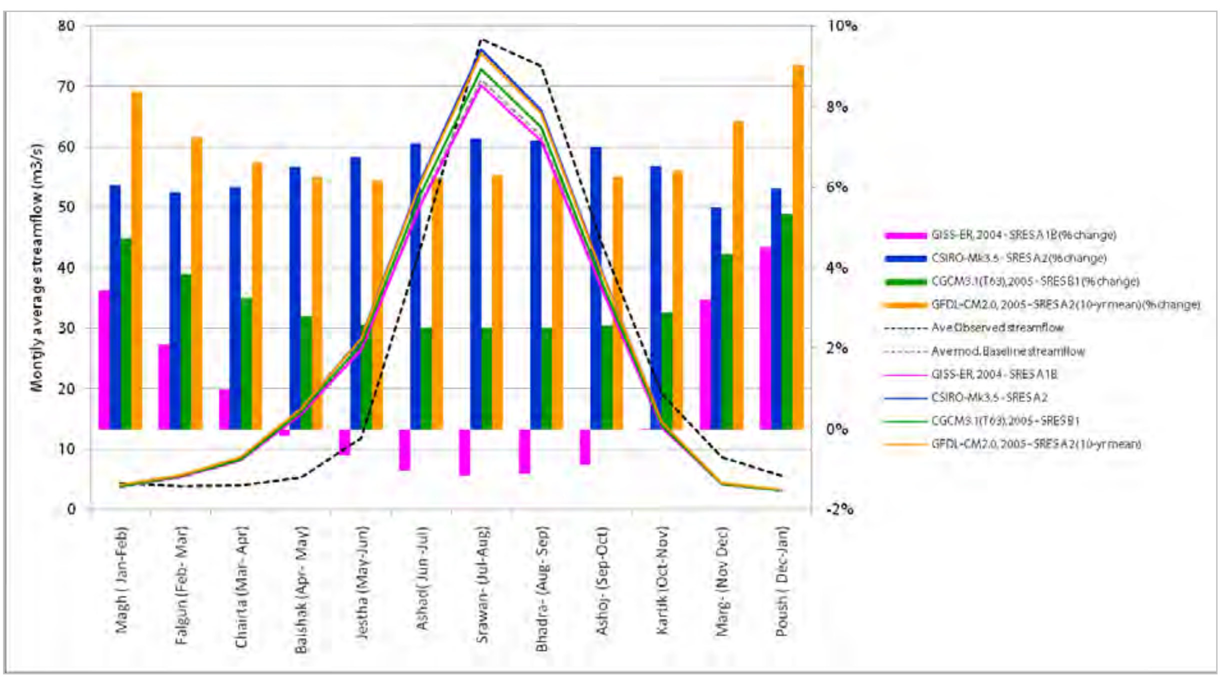
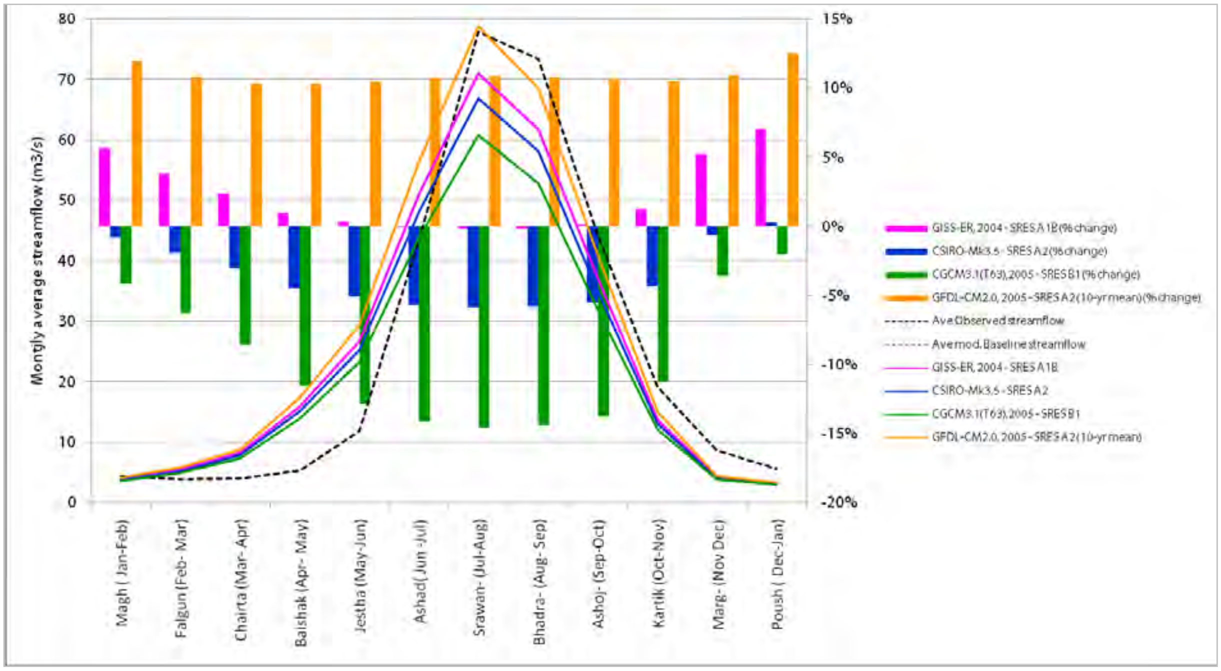
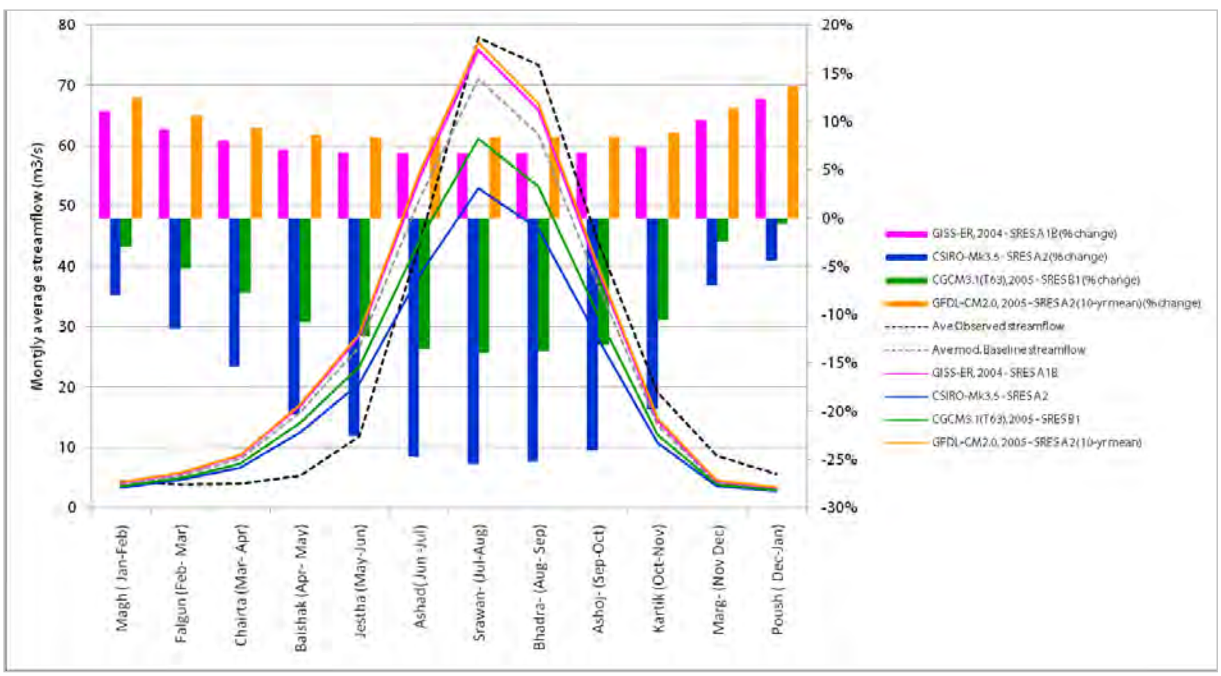


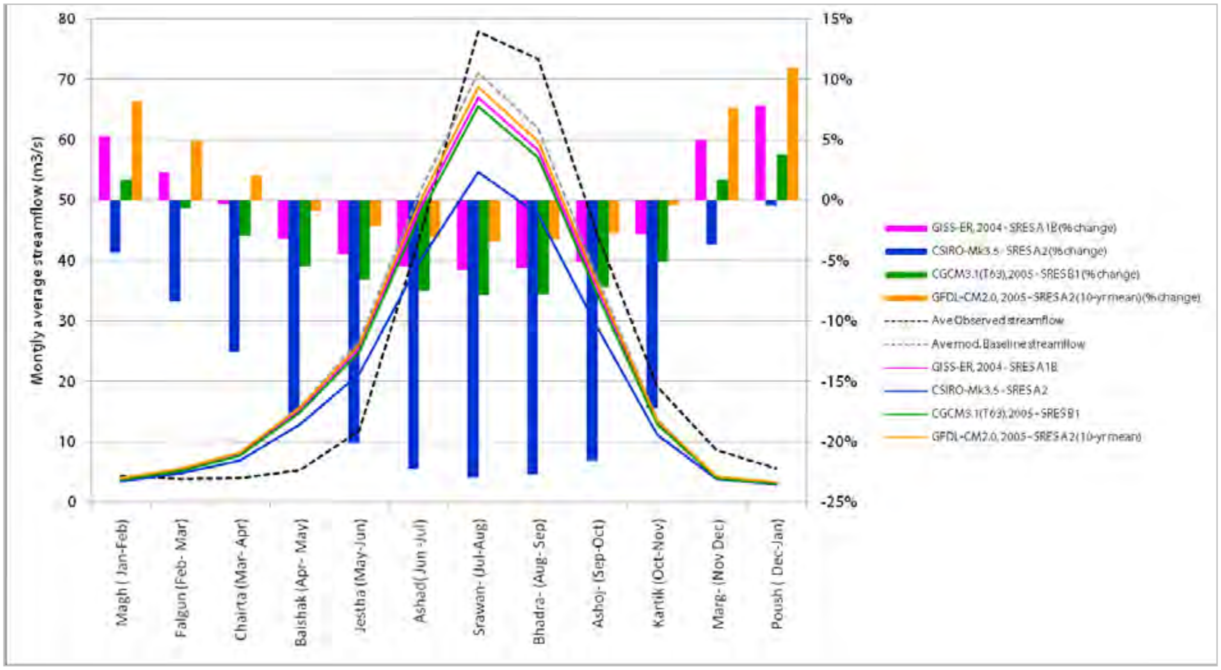
Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2010s under four GCM scenarios – Dataset part 2 (from 1994), excluding year 2000



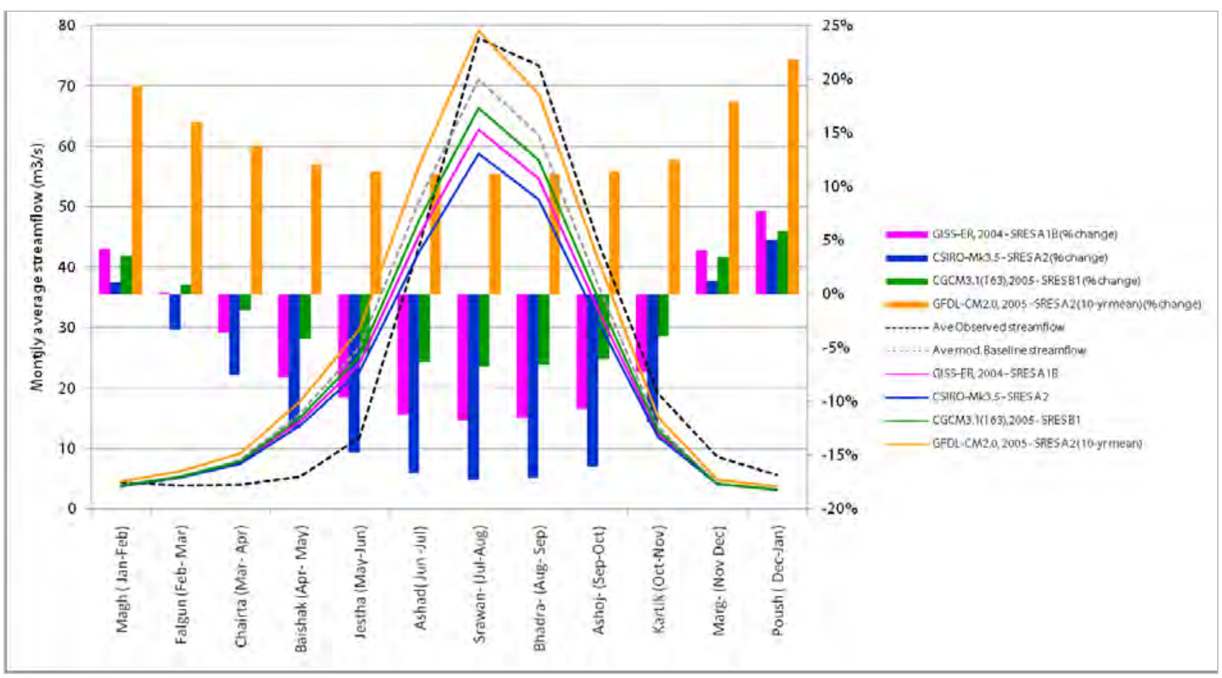
Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2020s under four GCM scenarios – Dataset part 2 (from 1994), excluding year 2000



Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2030s under four GCM scenarios – Dataset part 2 (from 1994), excluding year 2000



Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2040s under four GCM scenarios – Dataset part 2 (from 1994), excluding year 2000



Monthly (Nepalese months) average observed and modelled baseline streamflow at Rasnalu (m3/s) vs. modelled streamflow for the 2050s under four GCM scenarios – Dataset part 2 (from 1994), excluding year 2000

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