Climate Resilient Development Pathways: CRDP Pilot Report

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Quality Assurance Checklist

In preparing this document CRIDF can confirm that it has followed CRIDF's internal general procedures, including appropriate CRIDF generic scope of work and that it has undergone appropriate quality assurance (QA) and quality control (QC) procedures as detailed in CRIDF's QA manual. Furthermore, CRIDF can confirm the applicable specific internal process and procedures have been followed including:

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Disclaimer

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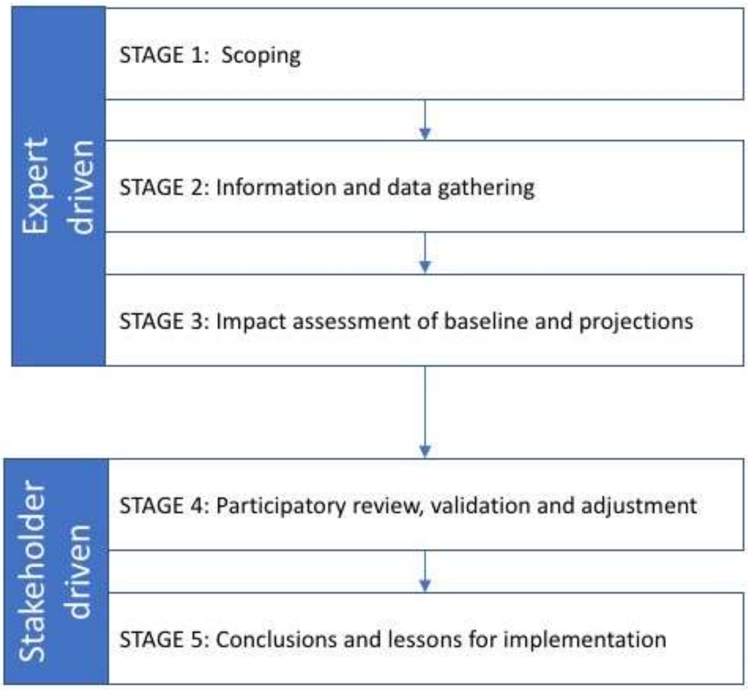
List of Acronyms

Acronym	Long-Form
BVAC	Botswana Vulnerability Assessment Committee
CGE	Computable General Equilibrium
CIVAT	Climate Impact and Vulnerability Assessment Tool
CORB	Cubango-Okavango River Basin
CRDP	Climate Resilient Development Pathways
CRIDF	Climate Resilient Infrastructure Development Facility
DFID	(UK) Department for International Development
EV	Equivalent Variation
FAO	Food and Agriculture Organization
FDC	Flow duration curve
GDP	Gross Domestic Product
GTAP	Global Trade Analysis Project
ITCZ	Inter-tropical convergence zone
IWRM	Integrated water resources management
MAR	Mean annual runoff
MSIOA	Multi-Sector Investment Opportunity Analysis
OKACOM	The Permanent Okavango River Basin Water Commission
RBO	River Basin organization
RCP	Representative concentration pathways
SADC	Southern African Development Community

SAREP	Southern African Regional Environmental Program
SES	Socio-ecological systems
TDA	Transboundary Diagnostic Analysis
TRB	Transboundary river basin

Executive Summary

This report presents the findings of the pilot test of the Climate Resilient Development Pathways (CRDP) project for the Okavango Delta. The broader purpose of CRDP was to help understand and address the implications of climate change on large-scale development programmes in transboundary river basins in Southern Africa by understanding the vulnerability of the basins and their populations and by exploring opportunities for proactively addressing those vulnerabilities by an improved understanding of what the most climate resilient development pathway option may be.



'Vulnerability' in the project was conceptualized as a combined outcome of sensitivity and socio-economic and ecological impacts on the one hand and ability to cope and adapt on the other. Furthermore, the project recognised that impacts of climate change cannot be understood in isolation and must be considered in the context of broader global and local change.

The generic CRDP approach developed for the project followed a 5-stage process as shown in the diagram, combining expert-driven and stakeholder-driven elements. The expert-driven component of the process involves establishing the spatial, temporal, technical and socio-economic context. This is followed by information and data gathering on socio-ecological baselines, relevant integrated models, and combinations of infrastructure development and climate scenarios. In the third stage the balance of impacts and vulnerabilities associated with the combined scenarios are calculated, assessed and packaged by experts. These results are presented to, discussed and refined by stakeholders in stage 4. Results are synthesized in stage 5.

As a pilot, the CRDP approach was applied to the Okavango river transboundary basin, which is home to internationally unique ecosystems but also faces challenges due to persistent poverty. It also has a history of vulnerabilities that may already be symptoms of climate change, such as the 2011-2015 drought in Namibia and Botswana or the serious flooding experience in Northern Namibia and Angola.

The starting point for the assessment were three development scenarios for the basin, each with different types of hydrological infrastructure: scenario LS1 with no new dams, 2,719 ha irrigation, and 134 mm/yr total abstraction; LS3 with the Mucundi dam added, 66,720 ha irrigation, and 698 mm3/yr total abstraction; and LS6, with the Malobas, Cuvango, Mucundi and Cuito dams added, 131,685 ha irrigation, and 1,559 mm3/yr total abstraction. The three development scenarios were analyzed through three possible climate futures each: no climate change (present day climate conditions), a higher probability future climate with moderate levels of climate change, and a lower probability climate with more severe climate change. The effects of extreme climate change were also analysed but only as a qualitative narrative. Projections were developed separately for the Highlands and the Delta section of the watershed due to significant differences in the climatic, ecological and socio-economic conditions between the two areas.

Four climate scenarios were prepared for the basin; the most likely scenarios were developed using a technique called self organising maps (SOMs) which helped identify clusters of General Circulation Models (GCMs) which had similar projections in terms of rainfall and temperature. The four climate scenarios were:

- The Current climate
- Higher (high) likelihood - In contrast with current climate and hydrological conditions, under the *higher likelihood scenario* by 2055 average temperature in the Highlands may rise by 1.5 ºC and rainfall (less evaporation) remains the same or may slightly increase, leading a the same or slightly increased streamflow that can offset some of the abstraction-related to potential developments. The Delta would experience a 2.0 ºC temperature increase in the same period but a 20% reduction in rainfall less evaporation, leading a small drop in streamflow at the Mohembo site (top of the delta section).
- Lower (high) likelihood - Under the *lower likelihood scenario* by 2055 average temperatures in the Highlands would increase by 1.25 ºC and rainfall less evaporation would drop by 25% but also come with greater oscillation between an increase in warm spells that comes with drought and increased flood risk due to growing rainfall intensity. These levels of rainfall reduction in the Highlands would result in a projected 58-66% decrease of streamflow at the entrance to the Delta.
- Extreme scenario - Looking beyond the lower likelihood scenario, at the extreme end, 5.0 ºC increases in temperature and a 50% increase or 55% reduction in rainfall less evaporation are conceivable.

Score	Impact	Color scheme
3	strong positive	
2	positive	
1	weak positive	
0	neutral	
-1	weak negative	
-2	negative	
-3	strong negative	

Average of indicator scores is calculated using equal weight.

MSIOA SCENARIO	CLIMATE SCENARIO	THEME	TIME PERIOD	
			Baseline	2016-2035
HIGHLANDS				
LS1	No climate change	Combined	0.00	-0.08
LS1	High probability	Combined	0.00	-0.08
LS1	Low probability	Combined	0.00	-1.08
LS3	No climate change	Combined	0.00	-0.22
LS3	High probability	Combined	0.00	-0.33
LS3	Low probability	Combined	0.00	-1.28
LS6	No climate change	Combined	0.00	-0.50
LS6	High probability	Combined	0.00	-0.58
LS6	Low probability	Combined	0.00	-1.14
DELTA				
LS1	No climate change	Combined	0.00	0.00
LS1	High probability	Combined	0.00	0.00
LS1	Low probability	Combined	0.00	-1.28
LS3	No climate change	Combined	0.00	-0.42
LS3	High probability	Combined	0.00	-0.42
LS3	Low probability	Combined	0.00	-1.25
LS6	No climate change	Combined	0.00	-0.81
LS6	High probability	Combined	0.00	-0.53
LS6	Low probability	Combined	0.00	-1.33

Based on the climate and hydrological projections the ecological, economic and social impacts for the two parts of the basin were assessed by experts using a scoring tool. Thematic projections were aggregated to produce a combined picture of impact under all combinations of infrastructure development and climate scenarios. The combined results provide conclusive evidence that climate change can fundamentally alter the feasibility and desirability of development scenarios, to the point where under the lower probability climate projections some irrigation projects or dams with storage could become inoperable and become stranded assets with significant economic, social and ecological liabilities. At the same time, at less intensive levels of climate change, moderate (i.e. smaller-scale) infrastructure could dampen negative effects, for instance through water storage during intensive storm events and release during drought.

The combined results of the impact assessment showed that in general the Delta is more sensitive to climate change. By the time the impacts of a reduction in rainfall in the Highlands reach the Delta they are amplified. As the results in the table also illustrate, impacts are also a function of the development scenario selected. At the aggregate level, almost all scenario assemblies have a negative score that appears to be worsening along the LS1 → LS3 → LS6 trajectory. However, the picture is more complex when one looks at disaggregated thematic scores. Ecological impacts are projected to be by far the most negative, while social impacts in the Delta and economic impacts in the Highlands are in the positive range for both the LS3 and LS6 scenarios under both high and low probability climate projections. These results indicate not only uncertainties and thresholds in the assessment, but also raise questions about the tradeoffs and synergies between the socio-economic and ecological domain, especially assumptions about the resilience of socio-economic development under flow reductions in the 50-60% range.

Based on the results of the project, key recommendations include:

- **Options for reducing the impacts of future climate change in the basin should be developed, as climate change is predicted to have a bigger impact on the basin than even the most intense MSIOA[1] development option:** A study should be commissioned to look at options to reduce the impact of climate change on the Okavango basin. This study would need to look at institutional, green, blue and built infrastructure solutions. It will also need to take into account the development scenarios prepared under the MSIOA project, as well as other relevant development proposals and plans within the basin. Finally, it would need to assess the level of their preparedness / adaptive capacity for institutions and stakeholder groups in the basin, which would enable capacity building to be targeted more efficiently.
- **Climate change impacts must be taken into account in infrastructure development planning:** Relevant authorities of the three countries should require any major future hydrological infrastructure

[1] In order to 'operationalise' the delivery phase of OKACOM's Basin Vision, OKACOM initiated a basin-wide Multi-Sector Investment Opportunities Analysis (MSIOA). This analysis aims to identify individual and aggregated development opportunities in all three Member States, derived from sector plans and aligned with overall development objectives of each State. It assesses the water demands of these developments, evaluates the economic benefits and assesses the social and ecological impacts.

development proposals to systematically consider the impacts of climate change as a matter of routine from the beginning of the project preparation process (i.e. prefeasibility).

- **Strengthen and make use of cooperative frameworks for climate change resilience building and adaptation:** Members of OKACOM should work towards strengthening the organization's capacity, make systematic use of its capacities in transboundary water resource planning, and strengthen its mandate to address climate change related to basin-wide issues.
- **Advance infrastructure solutions that reduce vulnerability and help build resilience:** It is recommended that authorities involved in infrastructure planning integrate resilient, nature-based infrastructure solutions, such as smaller scale distributed water storage, into the mainstream of their development plans.
- **Pursue smart climate finance:** Water infrastructure development should specifically and proactively target financing mechanisms such as the Green Climate Fund that are designed for projects that mitigate risk and build resilience across a range of possible climate futures.
- **Socialization of infrastructure planning:** Ensure that infrastructure planning processes actively and transparently engage stakeholders, including particularly local communities and the most vulnerable in society in both the early stages and throughout the process of infrastructure planning to understand and address risks and maximize benefits for all.
- **Development of climate resilient development pathways**: By building on the results achieved so far and by taking into account new insights gained through this project, the Okavango basin countries could aim to move towards a climate resilient LSx scenario that best meets not only their needs but also the needs of future generations.
- **Sequencing development** - In order to better manage uncertainty and the chance of significant adverse impact of developments, proposed developments should be carefully sequenced. If one of the MISOA scenarios with significant infrastructure components is selected, it should be implemented in stages so that its impact on the Delta can be evaluated and adjustments in future plans be made, with future climate changes considered as they occur.
- **Scale and operate infrastructure for conservation -** It is recommended that all infrastructure proposals are developed keeping in mind conservation purposes alongside economic and social purposes. Operation of the dams and irrigation infrastructure should take into consideration the views of all riparian states.
- **Better understanding of the value of the natural capital to inform the approval of developments in the basin** – Natural capital accounts should be prepared for the basin to help inform future assessments of development proposals. This could also build on existing initiatives regarding innovative sources of financing (such as trust funds, impact offsets or even a possible PES scheme) to help finance more pro-poor climate resilient, transboundary developments. These innovative sources of finance should enable member states to assist one another to either forgo some infrastructure, develop alternative development options, or to develop and operate infrastructure it in a way that benefits the whole basin, including conservation. Monitoring capacity to create the evidence base for such innovative payment schemes should be developed.

- **Targeting local beneficiaries** - Approval of individual infrastructure projects should be contingent on local beneficits and supply chains being understood and agreed by all key stakeholders

1. Introduction

The Climate Resilient Infrastructure Facility (CRIDF) is an international development assistance program of the UK Department of International Development (DFID) to help the countries of Sub-Saharan Africa prepare for and address the challenges associated with the impacts of climate change on socio-economic development and environmental sustainability. The program recognizes the critical role of infrastructure, both as significant infrastructure gaps that represent a barrier to poverty reduction, but also through the potential impacts of climate change on existing and planned infrastructure.

Even by global standards, the African continent stands out as particularly vulnerable to the effect of climate change. Mean annual temperature increases are projected to exceed 2°Celsius in some areas and warming of arid regions will likely exceed the global average. While impacts on the water cycle in Sub-Saharan Africa are uncertain and highly variable due to differences in topography and land cover, increases in extreme precipitation are likely by the end of the century. Climate change will amplify the impact of increasing demand on water resources, and its effects will combine with other impacts of global change, creating complex and new risk and vulnerability environments (Niang et al. 2014).

Recognizing the importance of water for sustainable development in the region, hydraulic infrastructure has been identified as a central focus of CRIDF. Hydraulic infrastructure is considered underdeveloped in contrast with needs, challenges (such as climate change) and the sector's potential, and represents major opportunities for investment, as expressed at the political level through SADC's Regional Infrastructure Development Programme (SADC n.d.). The implications of the region's water potential cut across essentially all sectors, from energy to agriculture, tourism, industry, municipal water supply, public health and others.

Addressing social and economic ambitions through large scale infrastructure development without consideration of ecological sensitivities and poverty reduction needs associated with water would carry significant risk. Water is essential for the healthy functioning of regional ecosystems in southern Africa that range from extreme wet in the North to extreme dry below the Intertropical Convergence Zone (ITCZ) and represents an important part of current natural capital and perhaps future climate resilience. The ecosystems of the region and local communities adapted to them rely on established water quality, quantity, spatial and temporal availability and variability regimes that evolved through millennia. Climate change and large-scale infrastructure development affect these patterns and can create a double exposure for national economies, communities and ecosystems. The interactions of globalization in the form of infrastructure development, tourism, trade, etc. and climate change create complex impact patterns that need to be considered in decision-making together to maximize benefits and minimize or manage risks (O'Brien et al. 2000).

Southern Africa is home to several major water basins that represent a logical unit of analysis for assessing the impacts of hydrological infrastructure development options and climate change (Figure 1). In reality, the issues that affect hydrology cut across multiple scales. Climate patterns affecting the region are part of larger, continental and global level systems with sharp divides created on the ITCZ frontier. River basins are often segmented by national boundaries and countries with varying political, institutional and physical environments and different development strategies and ambitions. At a lower level, differences between upstream and downstream interests, differences in water availability for communities and local industries create diverse opportunities for collaboration but may also result in conflict. Navigating this complex, multi-scale web is a significant conceptual, methodological, socio-economic and political challenge.

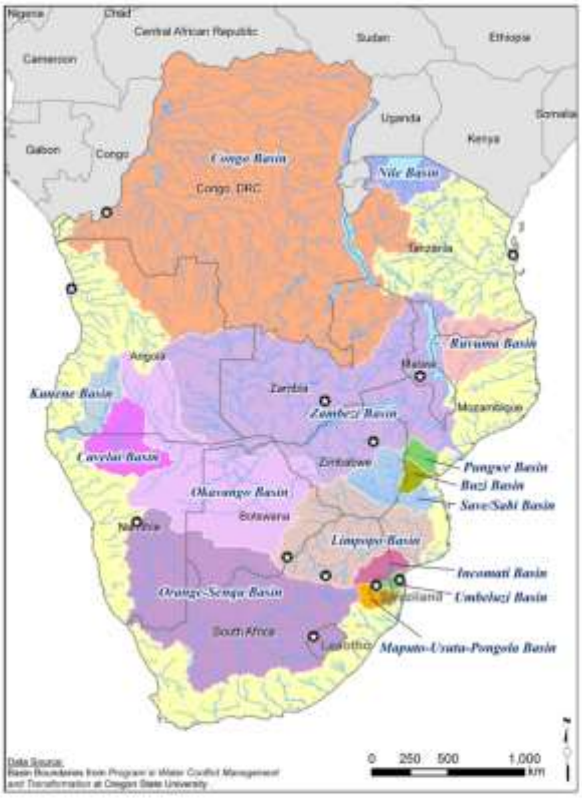


Figure 1 **The River basins in the SADC region**

In order to develop and pilot test an approach to strategic resilience planning, CRIDF chose to work in the Okavango river basin, where a constellation of needs and interests created an opportunity for involvement. The basin is home to a diverse and unique ecosystem. The flood-pulse system of the Okavango River originating in the wet Angolan highlands sustains the unique endorheic Okavango delta with over 200,000 large mammals, more than 400 species of birds and 71 species of fish. The Delta is a Ramsar Site and since 2014 also carries a World Heritage Site designation (Ramsar Convention Secretariat 2014). Other parts of the basin, particularly the Highlands, are also exceptionally rich in biodiversity, for example with the second highest number of endemic plant species in Africa, but the level of protection is low and ecosystems are under threat due to a variety of actors such as poaching, and deforestation (USAID 2008). There is consensus among sector representatives that investment in 'foundation' livelihoods to facilitate the transition from vulnerable/unsustainable subsistence to more resilient/sustainable enterprise opportunities is the most important 'no-regret' option as the foundation for the sustainability of all/any other investment and development programmes.

Like many others in the region, the Okavango basin is shared by several countries, mainly Angola, Botswana, and Namibia. It has a well-functioning basin wide institution in the Permanent Okavango River Basin Water

Commission (OKACOM) and is going through an ambitious water infrastructure planning process through the World Bank's Multi-Sector Investment Opportunity Analysis (MSIOA). Through their reliance on the river, the countries of the river basin are tightly interconnected, yet their different histories, climatic, socio-economic and ecological conditions create differences in interests that lead to different views on \development pathways. The sharp divide along the ITCZ boundary also means possible differences in terms of climate change patterns, further coloring the risks and opportunities that countries need to weigh in when determining their pathways. Due to these conditions the Okavango river basin not only represents an opportunity for the integrated analysis of climate resilient development pathways, but also serves as a useful illustration of the potential of the approach before its application elsewhere.

The climate resilient development pathways (CRDP) approach that was developed and piloted in the Okavango is a science-policy exercise that combines technical, science-based methods with participatory elements described in detail in Section 2 of this report. Its science-based components build on vulnerability assessment methods and resilience theory to analyze a set of scenario assemblies that combine hydraulic infrastructure development options developed through the MSIOA with alternative climate change projections associated with various representative concentration pathways (RCPs). A technical assessment using expert inputs is used to develop an evidence base for each scenario assembly, using a seven-point scale rating of social, economic and ecological impacts using a purpose-built rating tool. Results from the technical work were reviewed through a workshop-based participatory process with stakeholders from the three OKACOM member states to identify significant differences in risks and opportunities associated with the different development options. Besides fine-tuning the results from the expert process, the purpose of stakeholder participation was to help understand the sensitivity of development options to climate change and to compare and rank them based on their impact profile. It also helped consider whether and how the lessons from this assessment could serve as a basis for hydrological infrastructure development strategies that are resilient to climate change – essentially a new development scenario.

This report provides an overview of the CRDP approach, then introduces the results of the expert-based and participatory phase of the project, and provides a conclusion for both the Okavango basin and its broader application in river basins across the SADC region and beyond.

Brief overview of the climate resilient development pathways (CRDP) approach

Background

The CRDP approach was developed to establish a regionally appropriate process for informing the creation of climate resilient water infrastructure development and investment planning by river basin organisations (RBOs) and member states of SADC. CRDP is a science-policy informing process, and focused on the following objectives:

- Enable decision-makers to systematically take into account the projected impacts of climate change on strategic infrastructure development, planning and management alongside other, traditional development criteria.
- Enable decision-makers to manage the trade-offs between multiple, water dependent sectors.
- Use a combination of qualitative and quantitative methods to help inform the process of selecting the most climate resilient development pathway for a river basin.

The approach is informed by an awareness of the purpose, characteristics, strengths and weaknesses of existing tools and methods relevant for assessing the climate resiliency of infrastructure investments in Southern Africa's transboundary watersheds (e.g. the AMCOW 2012[2]). It is also informed by the broader science and practice related to several fields, including but not limited to integrated assessment and integrated risk and *vulnerability* assessment; resilience of socio-ecological systems; integrated water resources management (IWRM); and the broader field of impact assessment focused on social, economic and ecological factors in the water basin context. While keeping the broader context of river basins in the SADC region in mind, the development of the approach was informed by the specific context of the Okavango basin as a test case, and as such built on a review of relevant OKACOM, MSIOA and CRIDF documents.

Development pathway planning at the scale of transboundary river basins is always an integrated, multi-dimensional exercise that must take a wide range of socio-political, techno-economic, administrative and ecological conditions into account. By definition, the time horizon of development pathways at this scale extends to multiple decades. While rooted in established baselines, it must factor in risks and uncertainties that may emerge along the path. A key assumption underlying the CRDP approach is that climate change will result in shifting baselines and a materially different risk environment that strategy development and planning processes must anticipate and to which they much adaptively respond. Resilience in the context of the CRDP is thought of as a result of successful adaptation. Instead of being a static end-point, it is thought of as a dynamic attribute of the river basin's socio-ecological complex with inherent capacities for anticipating and recognizing risk and implementing course correction.

[2] Online: [Water Security and Climate Resilient Development: Strategic Framework". Prepared by GWP, CDKN and AMCOW (2012]

Stages of the CRDP approach

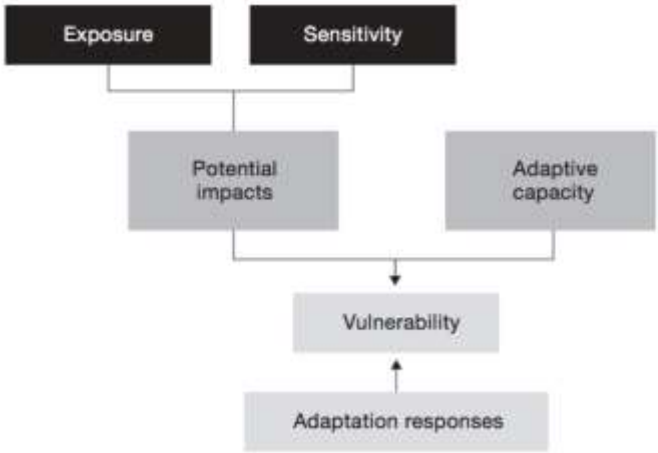


Figure 2 **Representation of the components of vulnerability to climate change and their interlinkages (Allen Consulting reported in Bizikova et al. 2009)**

At the heart of the approach is a well-established conceptualization of vulnerability and adaptation that envisions vulnerability as an outcome of exposure and sensitivity as factors producing impact and eliciting responses that require adaptive capacity. Vulnerability is thus a product of impacts that are beyond adaptive capacity, and include effective adaptation responses, as shown on Figure 2.

The generic CRDP process includes five stages as shown on Figure 3 (see page 20). The approach is designed to provide stakeholders of a given transboundary river basin (TRB) with a perspective on the climate vulnerability and resilience of policy and planning frameworks related to the development of hydraulic infrastructure that are in place either at the national and/or basin level. As such it does not include a stage in which these plans will be generated or even revised in detail, but it does envision that based on the results of the assessment, alternative development options could be compared and perhaps ranked in view of advantages / disadvantages identified through the impact assessment. The assessment of existing policy options may also result in insights that could inspire and inform the construction of new scenarios and implementation strategies.

The CRDP approach pilot tested in the Okavango river basin combined preparatory background work by experts and participatory review and validation by stakeholders from Angola, Botswana and Namibia. The following is a brief description of the five stages; their more detailed descriptions can be found in the CRDP methodology manual.

Stage 1: Scoping

Scoping started with defining the purpose and mandate of the assessment, which focused on identifying the risk, vulnerabilities and adaptation options associated with the pre-developed suite of selected MSIOA scenarios. The exact geographic boundaries of the study area were identified and the selected time horizons for the projections were identified as: the present baseline, 2016-2035 and 2046-2065. It was agreed that the assessment would be carried out separately for the Okavango Highlands and Delta, due to significant differences in climatic, hydrological, and socio-economic conditions. Relevant stakeholders as participants for a review and validation workshop were discussed with the OKACOM Secretariat and it was decided to target mainly senior level technical advisors from the three member states. As the final element of Stage 1 the transboundary, national and sub-national policy contexts were analyzed to identify elements relevant for the CRDP study.

Stage 2: Information and data gathering for baseline analysis and projections

This stage involved constructing the specific analytic framework for the assessment. Out of the MSIOA scenarios developed by the World Bank, three were selected for their range across all the possible options. The details of their relevant infrastructure development measures were noted and the scenarios are discussed in Section 3. With regards to climate change, three projections were included, one assuming no change in the present climate (base case), two high-probability scenarios, including one representing a higher probability outcome with moderate change, and another a lower probability projection with higher-end changes in both temperature and precipitation (less evaporation) patterns. Details of the selected climate projections are discussed in Section 5. Finally, an extreme scenario with a much lower probability of occurrence than the two main change scenarios was also selected but it was only assessed qualitatively due to a limitation in time and resources for climate and hydrological modelling. Based on the three MSIOA scenarios and three main climate projections selected for the study nine *scenario assemblies* were constructed for both the Highland and Delta part of the river basin. Modeling approaches for the climate projections and hydrological impacts were discussed and agreed upon with experts.

Stage 3: Impact assessment of baseline and projections

Climate change projections were calculated for the three projections using the tools and methods agreed in Stage 2. Climate model runs produced a set of climate-related indicator outputs that served as an input for the Pitman hydrological model that recalculated *annual* flow projections with climate change now taken into account, for all *scenario assemblies*. An Excel-based climate impact and vulnerability assessment tool was developed to allow the scoring of impact indicators on a seven-point scale from strong positive to strong negative and the aggregation of the scores at the thematic level and across all themes by scenario assembly. Assessment experts for the social, economic and environmental themes identified a small number (2-5) of impact indicators per theme and established scores taking the results of climate and hydrological projections and the results of prior impact assessments into account. The methods used to assign impact scores to individual indicators varied to some extent by theme and they are described in detail in Sections 7, 8 and 9.

Based on the indicator-specific impact scores and their thematic aggregates, experts analyzed the patterns of impacts in terms of significance, consequences for underlying socio-ecological issues and potential policy implications. Based on the comparison of aggregate results across themes, cross-theme interlinkages, tradeoffs, synergies and contradictions were identified. The results of model-based climate and hydrology projections, thematic and cross-theme impact assessments were packed along with information on the MSIOA and CRDP process and vulnerability for presentation to stakeholders in Stage 4.

Stage 4: Participatory review, validation and adjustment

The review and validation of initial results took place in a workshop in Windhoek, Namibia on March 8-9, 2017 with stakeholders from Angola, Botswana and Namibia. During the event participants reviewed climate and hydrological projections and the results of thematic impact assessments. They also discussed results by scenario assembly and compared the impacts and implications through the lens of MSIOA scenarios, taking elements of adaptive capacity into account. Stakeholder review involved discussions about a scenario that meets human development aspirations while minimizing climate risk and vulnerability and resilience and implications of the findings of the CRDP process for institutions in the region.

Stage 5: Conclusions and lessons for implementation

Conclusions were synthesized for presentation in the current report.

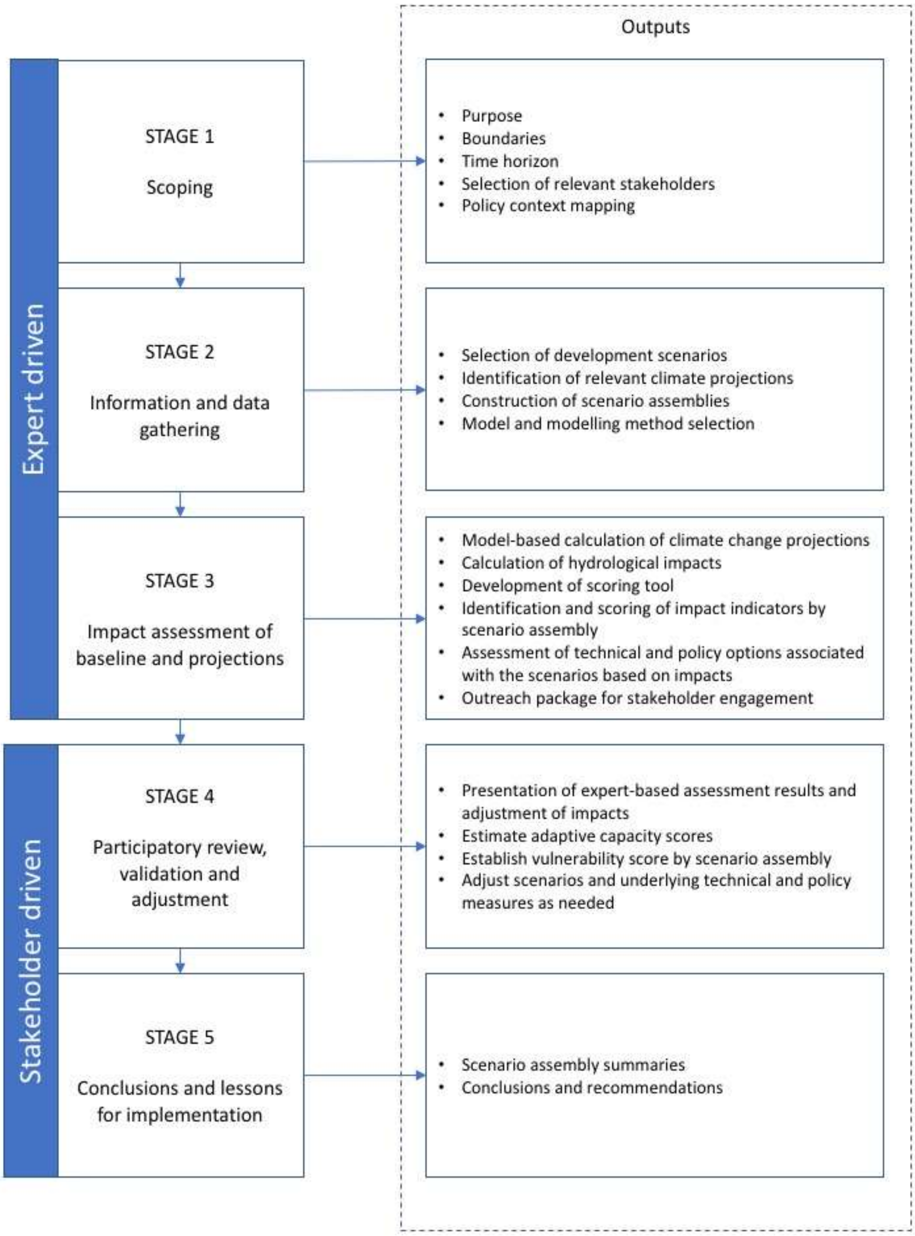


Figure 3 **Outline of the CRDP process**

Overview of the scoring tool

The Excel-based scoring tool developed for and used in the CRDP process has been referred to as the Climate Impact and Vulnerability Assessment Tool (CIVAT). CIVAT is based on a simplified approach to interpreting vulnerability in socio-ecological systems (SES) as shown on Figure 2. The tool requires the identification of a small number of high-level indicators that can measure the combined impact of climate change and non-climate related contextual factors in ecological, economic and social themes. The indicators were selected based broadly on standard selection criteria described in the CRDP guidance.

The indicators are scored on a 7-point scale ranging from strong positive to strong negative; they capture the indicator name and unit of measure, type of number, baseline and projected indicator values and scores for two future time slices as shown on the example in Figure 4.

CRDP *SOCIAL* IMPACTS SCORING SHEET FOR THE OKAVANGO BASIN: HIGHLANDS			
Scoring key			
Score	**Impact**	**Color scheme**	
3	strong positive		
2	positive		
1	weak positive		
0	neutral		
-1	weak negative		
-2	negative		
-3	strong negative		
Average of indicator scores is calculated using equal weight.			
MSIOA scenario: LS1			
Climate: No climate change			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values** 2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	direction from	No disruption in land and	Weak disruption of land
		0	-1
Average impact scores / time period		0	-0.25

Figure 4 **Screenshot to illustrate the structure of a thematic section of the CRDP scoring tool.**

The scoring tool aggregates individual indicator scores by theme, scenario assembly and Highlands or Delta section of the Okavango river basin using simple arithmetic average in the absence of a more rigorous science-based approach to establish differentiated weights in the project. Aggregate impacts are also shown on a summary sheet without indicator details where the impacts associated with scenario assemblies can be visually compared in workshop settings.

As the last element, the tool can also capture scores related to the elements of adaptive capacity using the IPCC's categorization: economic resources, technology, information and skills, infrastructure, institutions and equity. Scores for elements of adaptive capacity are also aggregated by scenario assembly and then combined with the overall impact score to produce an overall score for adaptive capacity adjusted vulnerability.

Some of the weaknesses of aggregating scores are well known such as potentially hiding critical granularity on the scores. Consequently, the CIVAT tool includes all the sub assessment sheets. This enables the aggregated scores to act as a window to the rest of the assessment, allowing stakeholders to investigate further in order to fully understand the final scoring.

Overview of the MSIOA scenarios

Background

The Multi-Sector Investment Opportunity Analysis (MSIOA) process was initiated in the Okavango Basin in mid-2014, when OKACOM entered the 'options analysis' phase of their development, and embarked on a process to design a diagnostic tool to help decision makers assess the potential for Basin development scenarios (and associated investment opportunities) across the three Member States. The Terms of Reference for the assignment (modelled on a prior MSIOA in the Zambezi Basin, modified to take account of the OKACOM context) took some time to develop, and were agreed in early 2015. The funding was provided via the Cooperation in International Waters in Africa (CIWA), from a DFID grant, with implementation being carried out through the World Bank. The World Bank procured professional services to deliver the programme, following a tender procedure carried out in the first half of 2015. Activities commenced in mid-2015, and have continued to present. They are due to be completed later in 2017.

OKACOM Sustainable and equitable climate resilient investment programme

The MSIOA analysis, and the CRDP process, are embedded in the 'options analysis' phase of OKACOM, as represented in the schematic below. Figure 5 shows the five OKACOM 'phases', the details of the activities in each phase, and the stage of cooperative action in the shared waters cooperation continuum (from dialogue to benefit sharing). CRIDF had already supported the OKACOM member states in completing its previous visioning phase.

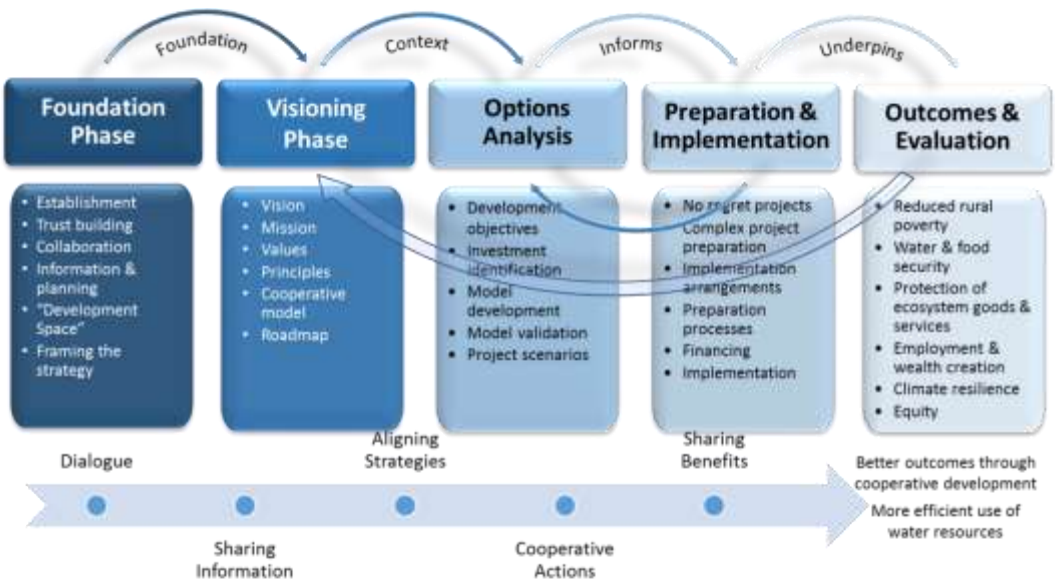


Figure 5 **Structure of the OKACOM climate resilient investment programme.**

MSIOA Objectives

The objective of the MSIOA analysis is ***'to undertake a multi-sector analysis of proposed investment options in the Cubango-Okavango River Basin and provide (word missing here) options to meet the development needs of the riparian countries in such a manner as to safeguard the ecological status of the basin. The analysis will be regional in nature including potential resources outside of the Cubango-Okavango River Basin in order to offset demands within the basin'.***[3]

In order to meet the objective, the Terms of Reference specified the following activities:

- Identify potential investment options in various sectors which align to the countries' and basin's development objectives and make an initial assessment of the economic, hydrological, social and environmental implications of such options.
- Assess the costs, benefits and distribution of the benefits from cooperative and joint investments compared with unilateral development within the Okavango River Basin in order to meet the national and the basin level development objectives.
- Assess the costs and benefits of cooperative and joint investments compared with unilateral development beyond the Okavango River Basin in order to meet the national and the basin level development objectives.
- Assess the institutional and policy requirements for cooperation and joint development options.

The approach and principles were stated as follows:

- Water resources development is not an end in itself but a means to an end. The sustainable use of water for productive purposes is intended to support Government's efforts to sustain economic growth and address poverty reduction.
- The analysis will be undertaken from a hydro-economic development perspective in order to better integrate the economic implications of the development of water-related infrastructure for different sectors into the broad economic development and growth objectives of the riparian countries, the basin as a unit and the broader Southern African Development Community.
- The guiding principles to the approach are based on incremental contributions to the body of information available in the basin. This includes the data and models developed as an input to the TDA and the SAP, and by other programs such as SAREP. These should promote sustainable economic growth with consideration of equity and equality among the member states.
- The Development Space has been defined as a hypothetical construct to inform the potential growth trajectories within the basin.

[3] Cubango-Okavango River Basin Multi-Sector Investment Opportunities Analysis - Terms of Reference issued 22nd January 2015

The MSIOA Processes and outputs

The following processes, and related deliverables, were stated in the Terms of Reference. They are arranged into four specific 'Tasks' as follows. Task A - Analytical Definition and Investment Identification. Task B - Integrated Hydro-Economic Modelling. Task C - Multi-Sector Investment Opportunity Analysis. Task D - Final Report and Dissemination of Results. Details of each task are provided below:

Task A - Analytical Definition and Investment Identification

Inception Report that includes:

- definition of national development objectives
- definition of basin development objectives
- identification of national investment projects
- identification of basin level investment projects
- identification of regional investment projects

Task B - Integrated Hydro-Economic Modelling

Preliminary Report – detailing the Hydro-Economic Model, outlining the initial findings and giving details of the proposed synthesis methodology.

Task C - Multi-Sector Investment Opportunity Analysis

- Report on MSIOA to be used in consultations
- Prioritized list of potential investment opportunities
- Video-conference to present and discuss findings of Task C

Task D - Final Report and Dissemination of Results

Final Report (being produced and validated in April 2017)

MSIOA Scenarios

Table 1 below provides a summary of the full range of scenarios and their key features from the MSIOA process. The scenarios which are highlighted in red are those that were selected for detailed analysis in the CRDP process.

Table 1 **Summary of all MSIOA scenarios**

Scenario	Scenario Details	Namibia Irrigation (ha)	Angola Irrigation (ha)	Total (ha)	Dams	Total Abstraction (mm^3/yr)
LS1	Development Scenario LS1 (Improved livelihoods plus CAN)	2549	170	2719	Nil	134
LS2	Development Scenario LS2 (Irrigation 66,720 ha, 1 dam - Malobas, Urban Abstractions 2040)	11,660	55,060	66,720	Malobas	698
LS3	Development Scenario LS3 (Irrigation 66,720 ha, 1 dam – Mucundi, Urban Abstractions 2040)	11,660	55,060	66,720	Mucundi	698
LS4	Development Scenario LS4 (Irrigation 66,720 ha, 1 dam – Cuito Cuanavale, Urban Abstractions 2040)	11,660	55,060	66,720	Cuito	698
LS5	Development Scenario LS5 (Irrigation at 131,685 ha and 2 dams – Malobas and Cavango, Urban Abstractions 2050)	11,660	120,525	131,685	Malobas, Cuvango	1,559
LS6	Development Scenario LS6 (Irrigation at 131,685 ha and 4 dams – Malobas, Mucundi, Cuito Cuanavale and Cavango, Urban Abstractions 2050)	11,660	120,525	131,685	Malobas, Cuvango, Mucundi, Cuito	1,559
LS7	Development Scenario LS7 (Irrigation at 222,261 ha and 2 dams – Malobas and Cavango, Urban Abstractions 2050)	18,201	204,060	222,261	Malobas, Cuvango	2,542
LS8	Development Scenario LS8 (Irrigation at 302,701 ha and 2 dams – Malobas and Cavango, Urban Abstractions 2050)	18,201	284,500	302,701	Malobas, Cuvango	3,557

Scenario	Scenario Details	Namibia Irrigation (ha)	Angola Irrigation (ha)	Total (ha)	Dams	Total Abstraction (mm^3/yr)
LS9	Development Scenario LS9 (Irrigation at 100,660 ha and 4 dams – Malobas, Mucundi, Cuito Cuanavale and Cavango, Urban Abstractions 2050)	13,160	87,500	100,660	Malobas, Cuvango, Mucundi, Cuito	1,301
LS10 (CC)	Development Scenario LS10 (Irrigation at 100,660 ha and 4 dams – Malobas, Mucundi, Cuito Cuanavale and Cavango, Urban Abstractions 2050) with Climate Change Influence	13,160	87,500	100,660	Malobas, Cuvango, Mucundi, Cuito	1,301

Other Options?

There is general consensus that improving local livelihoods In the Basin is an urgent priority and that it could be done without a major decline in the health of the river system. After that, the trajectory of change for the basin could range from modest small-scale support for local communities to large-scale development of infrastructure and high water use Some of (Figure 6). Between these two options lie many possible permutations of small and large-scale development that could include a mix of solar energy for irrigation and urban areas, local small-scale developments, small offstream water storage, rainfed agriculture and high-end tourism.

The CRDP processs will evaluate the selction of MSIOA highlighted in table 1 and it will also provide recommendations on whether more senarios should be looked at.

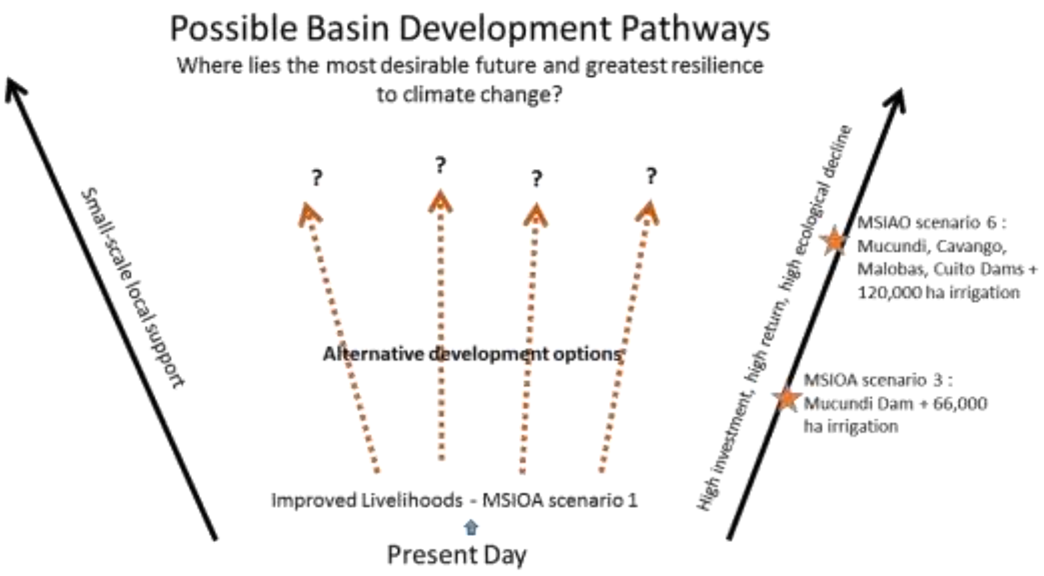


Figure 6 **Possible trajectories of development for the Okavango Basin**

Current vulnerability of the Okavango Basin

The Cubango-Okavango Rivers originate in the Angolan highlands, travel through the semi-arid eastern part of Namibia, and drain into the Okavango Delta in Botswana (Hughes, Kingston & Todd, 2011) (see Figure 7). Its basin is an endorheic (internally draining) watershed, covering approximately 704,000 km^2. Ninety five percent of runoff in the Cubango-Okavango River Basin (CORB) is generated in Angola. The basin is largely undeveloped; potential infrastructure development in the basin is being planned to meet regional water, energy, agriculture and other needs.

Virtually the whole river system is in a near-pristine condition: the upper basin is still largely undeveloped and sparsely populated while the lower basin has created a significant ecotourism industry centred on the Delta in Botswana and the Namibian river reach immediately upstream. The National Action Plans of the three countries make it clear that development of the water resources of the river system is inevitable. Much of this is likely to be in Angola, where the topography is most amenable to hydropower and other dams, and in Namibia. As virtually all of the water flowing into the Delta originates in Angola, the potential for transboundary impacts as development proceeds is high.

The CORB is globally renowned for its abundance of plant and animal life, with densities highest in the Delta and to its north-east, where up to a quarter of a million large free-roaming mammals have been counted in recent years. Few other places globally offer such a concentration of large wildlife. Numbers decline upstream for a range of reasons, mostly related to human activities. Water birds and other river-dependent wildlife are abundant and diverse but fish stocks are naturally low. The welfare of all of them is highly linked to the timing, magnitude, duration and frequency of the various flows that make up the flow regime, particularly the perenniality of flow in the dry season and the nature of the annual flood.

The current population of the CORB is estimated to be 922,000 people, of which approximately two-thirds reside in rural areas and one-third in one of the CORB's four urban centres (OKACOM, 2011).[4] Although population densities in the basin remain low, the number of people living in the region is growing; its population is projected to reach 1.28 million people by 2025 (OKACOM, 2011). The region is also witnessing a trend toward greater urbanization and an associated expansion of its existing urban centres (OKACOM, 2011). The basin's rural majority relies on livelihood activities that are very dependent on natural resources (King & Chonguica, 2016). Population growth is placing pressure on available natural resources (water, land, forest resources, wildlife) and the need to generate employment opportunities in the basin.

Agriculture and tourism play an important role in the basin's economy from the perspectives of employment and economic returns. Crop production is a primary source of income in the basin; in the Botswana portion of the basin, more than 30% of "very poor households" and over 60% for the "better-off" households rely on their own crop production to support household food income (Botswana Vulnerability Assessment Committee

[4] The largest share of this population lives in Angola (estimated to be 57.3%), followed by Namibia (24.8%) and Botswana (17.9%) (OKACOM, 2011).

[BVAC], 2009).[5] Tourism opportunities are growing in the region. Revenue earned from this sector is of particular importance to Botswana, which derives an estimated minimum of US$400 million per year from tourism in the Okavango Delta (OKACOM, 2011). Other economic sectors relevant to basin planning include hydroelectricity, irrigation, fisheries, mining and urban development (Food and Agriculture Organization [FAO], 2014; OKACOM, 2011; United States Agency for International Development [USAID] & OKACOM, 2014).

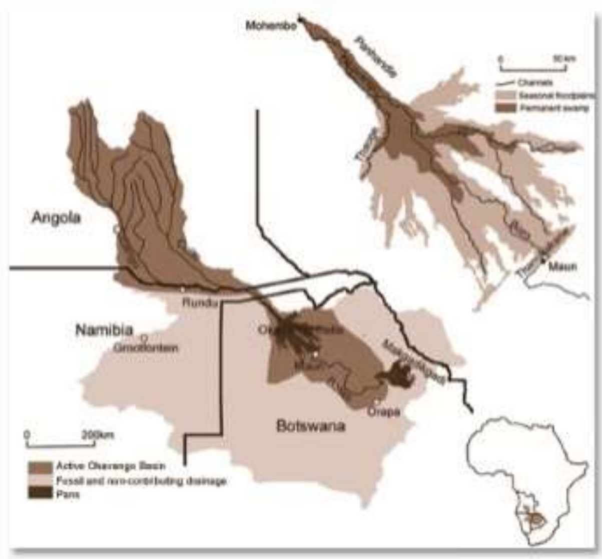


Figure 7 **Map of the Okavango river basin (Source: OKACOM)**

Understanding "vulnerability"

The dependence of the people and economy of the CORB on natural resources, amongst other factors, leaves them vulnerable to climate-related risks such as drought, floods, and pest and disease outbreaks. Within the context of climate change, vulnerability is understood to be a function of a system's (e.g. a river basin's) (IPCC, 2014):

- **Exposure**, or the extent to which there are "people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected" by a climate-related risk (IPCC, 2014, p. 1765).
- **Sensitivity**, or the degree to which a system is affected by the direct or indirect impacts of a climate risk, either adversely or beneficially.
- **Adaptive capacity,** or the ability of a system to adjust to change, to moderate potential damage, to take advantage of opportunities, or to respond to the consequences of a climate-related event.

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[5] Poor and very poor households use 20% to 30% of their annual income to purchase food. Income is earned through on-farm (e.g. weeding) and off-farm income earning activities (BVAC, 2009).

The vulnerability of the CORB is closely linked to the development status of Angola, Botswana and Namibia. Non-climatic factors such as weak health care systems, degraded ecosystems, poor governance institutions, underdeveloped economies and inequality of opportunity between genders and cultural groups limit adaptive capacity and therefore increase vulnerability to climate change. The six determinants of adaptive capacity, namely economic resources, access to technology, presence of information and skills, adequacy of infrastructure, strength of institutions and degree of equity (IPCC, 2007), are the principal levers for reducing the vulnerability of a system to climatic risks. Any CRDP approach must actively consider these social, economic, political and cultural factors.

Vulnerability in the Okavango Basin

The vulnerability of the people and economy of the Okavango Basin is shaped in part by the broader situation in Angola, Botswana and Namibia. The relative vulnerability of these countries to climate risks, as well as their readiness to address climate-related risks, can be seen in Table 2. Each of these countries is highly vulnerable to climate risks due to common characteristics such as low levels of agricultural capacity, low numbers of medical staff per capita and lack of infrastructure such as paved roads, water storage dams and access to electricity (Notre Dame Global Adaptation Index, 2017). For example, 37.0% of Angola's, 47.3% of Namibia's 53.2% and of Botswana's total population had access to electricity in 2012 (World Bank, n.d.); rural access is generally lower than in urban areas. Differences in the levels of vulnerability between the three countries stem from factors such as rural access to improved water sources. While rural access in Botswana and Namibia are relatively high (92.3% and 83.6% respectively), only 28.2% of Angolans living rural area had access to improved water sources in 2015 (World Bank, n.d.).

There is greater differentiation between Angola, Botswana and Namibia with respect to their readiness to respond to climate risks, with Angola's response capacity being lower than that of its regional counterparts - and among the lowest in the world. Lower education scores, lower access to information and communication technologies and its post-conflict status contribute to Angola's lower readiness capacity compared to its neighbours (Notre Dame Global Adaptation Index, 2017). The readiness in all three countries is hindered by their relatively high levels of social inequality.[6]

[6] In Angola, the share of income or consumption by the richest 10% of the population was 32.4% (in 2009). In Botswana, the richest 10% consumed 49.6% of income (in 2009); in Namibia, they consumed 51.8% of income (in 2010) (African Development Bank, 2015).

Table 2 **Angola, Botswana and Namibia's vulnerability to climate change and readiness to respond**

Country	Vulnerability*			Readiness**			Overall		
	World rank	Score	Trend	World rank	Score	Trend	World rank	Score	Trend
Angola	156	0.567	=	170	0.29	↑	164	36.2	↑
Botswana	138	0.51	↓	74	0.494	↑	104	49.2	↑
Namibia	150	0.548	↓	101	0.443	=	122	44.8	↑

* Lower score indicates lower vulnerability. Vulnerability is measured based on indicators associated with the following sectors: food, water, health, ecosystem services, human habitat and infrastructure.
** Higher score indicates higher degree of preparedness. Readiness is measured by looking at indicators related to the economy, governance systems and social readiness.
*** Higher score indicates higher degree of preparation to deal with global challenges such as climate change.

Source: Notre Dame Global Adaptation Index (2017).

Overall, as indicated in Table 2, in general the countries of the CORB are reducing their vulnerability and increasing their readiness to respond. Consequently, in all three countries there is a trend toward greater preparation to address climate-related risks.

The vulnerability of the CORB to existing climate hazards is also influenced by the factors that determine its adaptive capacity, exposure and sensitivity. These factors include:

- **High dependence on rain-fed agriculture.** Basin income and employment remain strongly dependent on rain-fed crop production and only a negligible portion of farming is irrigated. This leaves many in the region sensitive to changes in rainfall patterns and regular occurrence of drought, both from food security and income perspectives. The high dependence of Angola, Botswana and Namibia on food imports also indicates the existing food insecurity in the CORB.[7]
- **Low household incomes.** In the rural areas of the CORB, low levels of agricultural production combined with limited access to markets contribute to low household incomes (OKACOM, 2011). Consequently, rural households often have few economic resources (e.g. savings) to rely upon when exposed to climate shocks and stresses.
- **Access to water.** It is estimated that average domestic water use in the CORB is 53.9 litres per capita per day (comparable to countries with the lowest use in the world), but unevenly distributed between the three basin countries (FAO, 2014). At the national level, per capita daily domestic use of water in Angola was estimated to be 12.4 litres compared to 102.8 litres in Botswana and 119.0 litres in Namibia (FAO, 2014). Periodic dry periods significantly influence access to safe water sources, with negative consequences for human health, livestock and crop production, and water quality.

[7] In Namibia, for example, only 1% of the country is comprised of arable land (World Bank, n.d.) and it is required to import 50% of its cereal requirements (Namibia Ministry of Environment and Tourism, 2010).

- **Limited access to social services.** "In general, the people of the basin are poorer, less healthy and less well educated than other groups in their respective countries" (OKACOM, 2011: p. 35). This situation stems in part from the basin's remote location compared to the main economic centres in surrounding countries (OKACOM, 2011). The population are at greater risk of morbidity and mortality during times of extreme weather events (e.g. floods) and to climate-related and climate-influenced diseases (e.g. malaria, dengue fever, cholera, yellow fever and bilharzia [Urquhart & Lotz-Sisitka, 2014]) due to their limited access to health services.
- **Loss of forested lands.** The CORB's forested lands are being converted to agricultural land, spurred in part by population growth, continued use of traditional agricultural practices (e.g. slash and burn agriculture), overgrazing (OKACOM, 2011), continued reliance on traditional energy sources such as charcoal and fuelwood and expansion of the tourism and mining industries (World Bank, n.d.; Botswana Ministry of Environment, Wildlife and Tourism, 2012).[8] Loss of forests reduces the capacity of the basin to maintain water quality and buffer hydrological change and leaves the region more vulnerable to climate hazards, such as heavy rains and floods. Loss of forest cover also limits access to wild foods and non-timber products (e.g. medicines) that can become more important in times of drought.
- **Governance capacity.** Transboundary planning and analysis is occurring in the region under the auspices of OKACOM, which provides a basin forum for cooperation and coordination. Opportunities remain, though, to strengthen coordination between government spheres and across sectors (OKACOM, 2011) and integrate transboundary basin level goals and implementation with national development, climate adaptation and water planning (FAO, 2014). Stronger governance capacity at the local, national and transboundary levels would increase the capacity of people and institutions in the CORB to respond to climate-related hazards (USAID & OKACOM, 2014).

Demonstration of past vulnerabilities

The climate in southern Africa is characterized by temperature and rainfall levels that vary from year-to-year and on decadal and multi-decal timescales. The region has experienced significant shifts between wetter periods (e.g. in the 1970s) and drier periods (e.g. in the 1990s) (Spear et al., 2015). For example, Botswana has experienced drought conditions in 1998-99, 2002-2006 and from 2011-2013 (Manthe-Tsuaneng, 2014). Periodic droughts have a direct effect on rural livelihoods and revenue, particularly vulnerable populations, as they lead to reduced crop yields and livestock weights and yields and death due to low pasture production and increased distances to water (Masike & Urich, 2008; Mogotsi et al., 2010).

[8] For example, in Botswana, about 77% of rural households continue to rely on fuel wood to meet their cooking needs (Botswana Ministry of Environment, Wildlife and Tourism, 2012).

Drought in 2011-2015

In 2013, Namibia and neighbouring countries, including Botswana, experienced a challenging and debilitating period where drought threatened the agricultural sector and the country's food security (Reliefweb, 2013; IFRC, 2016). Botswana experienced drought from 2011-2013 (Manthe-Tsuaneng, 2014). In addition, Angola experienced extreme dryness in years between 2011-2012 (FEWS NET, 2015). Gaborone dam in Botswana lay dry and the city experienced severe water shortages.

Consequences/Impacts: Impacts of the 2011-2015 drought included a significant rise in malnutrition. In 2013, crop yields decreased by 42% from 2012 yields, leading one district hospital in the Ohangwena region of Namibia to report a 76% increase in paediatric malnutrition (Reliefweb, 2013). Prolonged dry spells followed by extensive flooding characterized the planting season and resulted in delayed planting and destroyed crops. As a result, the 2014-15 crop production yields were 46% below average, putting parts of Namibia at high risk of food insecurity. Angola experienced an outbreak of foot-and-mouth disease, limiting movement of pastoralist farmers and causing cattle deaths. Prices for crops such maize went up by up to 21% in parts of Angola (FEWS NET, 2015).

Flooding in 2008

All 11 natural disasters that occurred in Botswana between 1974 and 2003 were hydro-meteorological—seven droughts, three floods and one windstorm (Urquhart & Lotz-Sisitka, 2014). From January through April 2008, heavy and lasting rainfall resulted in serious flooding in Northern Namibia and Southern Angola (UNWFP, 2008).

Consequences/Impacts: According to the PDNA report (2009), the households that experienced acute transitory food insecurity were mostly headed by subsistence farmers that lost mahangu stocks and experienced average estimated losses of 80%. The vulnerable, often female-run households experienced transitory acute flood insecurity as a direct result of the floods (UNWFP, 2008). Flooding has also affected wider populations, both rural and urban. Malaria outbreaks in times of floods, particularly in parts of Botswana, are very high. Other disease including dengue fever, cholera, yellow fever and bilharzia also increase with increased rainfall and flooding (Urquhart & Lotz-Sisitka, 2014). Vulnerability to these events is exacerbated by high levels of pre-existing chronic food insecurity due to HIV/AIDS, structural poverty, etc. Flooding has also caused crop pests, such as army worms and birds, and extensive damage to crops.

Examples of past actions taken to improve adaptive capacity and coping with extreme events, such as floods and drought include (Mathe-Tsuaneng, 2014; FEWS NET, 2015; NBC, undated):

- **Establish relief programmes:** Due to a persistent, long-standing drought in Namibia, the government administered a drought relief programme, with an estimated $916-million dollars spent towards drought relief between April 2015 to March 2016 (NBC, undated);
- **Increase access to potable water:** Options include water conservation, water recycling, rainwater harvesting, desalination of ground water, incorporation of water demand in national development

projects, increased investment in water infrastructure development, improved water use efficiency, review of existing national and sectoral policies, importing water, and inter-basin transfers;

- **Improve agricultural productivity:** Practices include minimum soil tillage for soil and water conservation, early drought warning systems, such as the Famine Early Warning System in Angola (FEWS NET, 2015);
- **Strengthen health services:** Systematic monitoring of child malnutrition, improved health structures, improved capacity of rural clinics and hospitals;
- **Improve early warning and drought monitoring systems:** Botswana has an organized drought monitoring system. This includes a strong network of stakeholders and organizations dealing with drought monitoring and mitigation such as the National Early Warning Technical Committee, Inter-Ministerial Drought Committee and Rural Development Council (Manthe-Tsuaneng, 2014).

Climate projections

Introduction

The IPCC's Fifth Assessment Report (AR5)[9] states that future climate change will have a wide range of impacts across Southern Africa – including changes in ecosystems, water stress and agricultural systems. In addition, there is a high confidence that managing risk and developing adaptive capacities for ensuring food security, managing health vulnerabilities and governance systems will be insufficient to deal with the predicted impacts of climate change in the short (2025) and medium (2055) term.

Future patterns of atmospheric circulation in Southern African are not well known, but it is widely recognised and accepted that the zonal circulation within the Hadley cell, the ITCZ location and dynamics, the passage of cyclones from the Atlantic and Indian oceans, and the impacts of changing El Nino strength, are important as climate drivers in Southern Africa. This has been examined in numerous studies, where the climate impacts on key aspects of sustainability in Southern Africa (primarily food and water security) have been examined.

IPCC findings indicate that the extent, type and intensity of hydro-climatological hazards will differ significantly across the southern African region; the region should therefore not be viewed as a single climatic zone, but rather as 5 sub-regional zones (see Figure 8 below) based on the Koppen Climate classification[10]. The boundaries between adjacent zones are particularly sensitive to change; there is thus highest climate variability and predictive uncertainty in these areas.

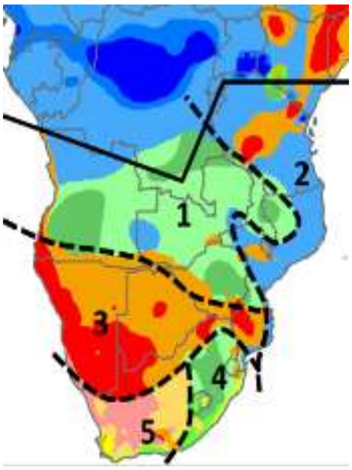

Figure 8 **Climatic Zones in SADC**

- ***Region 1, Summer ITCZ (Intertropical Convergence Zone) region****. Angola, Zambia, and Malawi, central and NE Zimbabwe - This is a temperate/tropical region with dry winters (subtropical high pressure cells) and rainy summers (tropical lows driven by seasonal migration of the ITCZ).*
- ***Region 2, Summer Indian Ocean cyclone/monsoon zone.*** *Mozambique, Tanzania - Tropical/seasonal monsoon climate characterized by incoming cyclones from the Indian Ocean.*
- ***Region 3, Arid descending arm of Hadley cell.*** *Namibia, Botswana, SW Zimbabwe, S Mozambique - This region has a negative hydrological balance, low and variable precipitation and seasonally high temperatures.*
- ***Region 4, Temperate cyclonic zone****. E South Africa, Swaziland, and Lesotho - This region has a wet summer regime with thunderstorms and subtropical cyclones.*

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[9] [online: https://www.ipcc.ch/report/ar5/mindex.shtml]

[10] [online: http://global.britannica.com/science/Koppen-climate-classification]

- ***Region 5, Semi arid/winter rainfall zone.*** *W South Africa - This region is characterized by a steppe climate inland with winter rainfall and fog at the coast*

The map of climate zones in Figure 8 shows that the rainfall climatology of the Cubango/Okavango river basin can be split into two distinct zones:

- Angolan highlands as source section of the basin
- Namibia and the Botswana as the Delta section of the basin.

The differences between the two zones manifest themselves in slight differences in timing of the rainfall; the positions of the two sections with respect to the main atmospheric systems providing the rainfall, and the topographies of the two sections. It is also known that the Angolan highlands contribute 95% of the water in the Cubango/Okavango river basin. Consequently, projections were developed for the two regions of the basin separately.

Creating future climate scenarios

Around 36 climate models (GCM) were used in the projections for the IPCC AR5 (2013). It is well understood that the temperature and precipitation ranges across these GCMs do not form a normal distribution; hence taking a simple mean of their combined values is not an optimum strategy in terms of determining a likely future scenario. CRIDF has instead used a statistical technique called *self-organising maps* to determine whether there are statistical relationships between groups of GCM results. Figure 9 shows a typical scatter graph for the Angolan Highlands. The plot shows GCM results in terms of rainfall (less evaporation) and temperature, while the blue and red triangle indicates that there are two possible groups of GCM results that have a statistical relationship. It also shows the extremes of the GCM (Note: in AR5 it is estimated that the GCM results cover 95% of possible future climate change outcomes. In other words a 1 in 20 chance exists that the eventual level of climate change will fall outside this range). The extremes seem to indicate that there could be a 20% increase in rainfall (less evaporation) or a greater than 50% decrease. Temperature changes could range from less than 1ºC to nearly 4ºC.

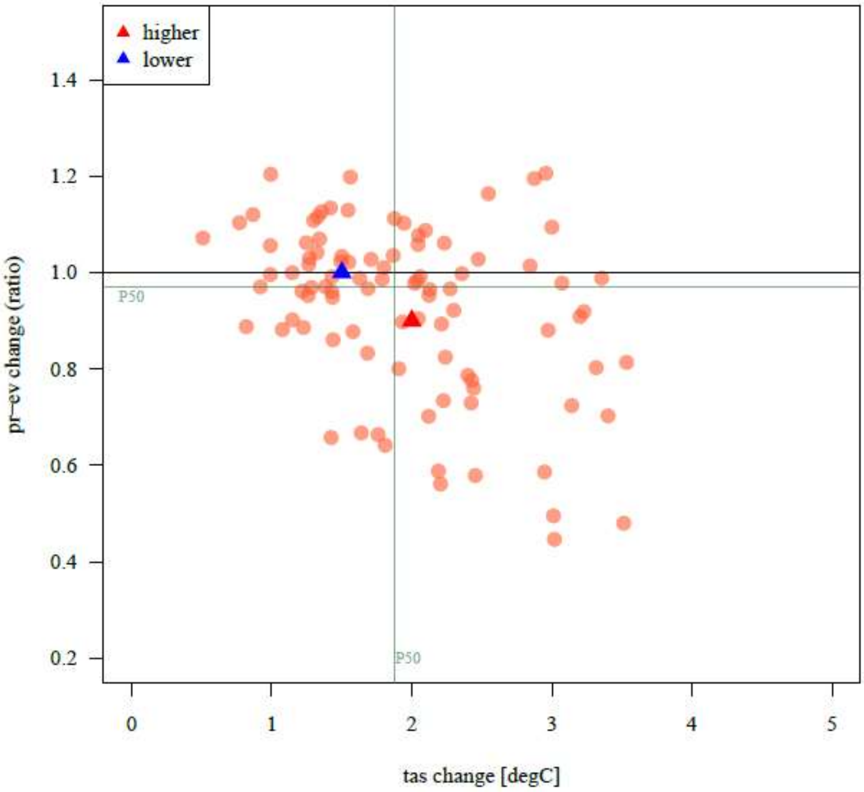

Figure 9 **Scatter graph showing temperature and rainfall plots for all RCPs and GCMs for the Angolan Highlands**

The SOMs analysis of the all 36 GCMs suggests there are two main climate scenarios (Table 3 and 4). The scenarios are based on temperature and rainfall less evaporation and are based on a weighted combination of RCPs. These scenarios are also split geographically between the highlands (upper basin) which accounts for the vast majority of water supply to the river and the delta (lower basin). This split was particularly important as an input to the hydrological modelling but was also useful to consider in workshop discussions. There is also nominally some difference in likelihood of these two scenarios occurring based on the number of GCMs that agree with them. Annex 1 provides information on the methodology behind the creation of the scenarios.

Table 3 **Temperature scenarios (for the upper [Source] and Lower [Delta] Basin)**

Section	Likelihood	2025	2055	2090
Source	Higher	0.75°C	**1.50°C**	2.00°C
Delta	Higher	1.00°C	2.00°C	2.25°C
Source	Lower	1.25°C	**2.00°C**	2.50°C
Delta	Lower	1.00°C	1.50°C	2.00°C

Table 4 Rainfall scenarios – less evaporation (for the upper [Source] and Lower [Delta] Basin) (

Section	Likelihood	2025	2055	2090
Source	Higher	1.00	1.05	1.05
Delta	Higher	0.80	0.80	0.80
Source	Lower	0.75	0.75	0.75
Delta	Lower	1.05	1.10	1.10

Below we have developed four scenarios from this information. The first one is the current climate. The next two are based on the information from the SOMs- depicting high likelihood clusters, while the fourth is an extreme scenario based on results from the 36 models but is more an outlier with only one or two models agreeing with this extent of potential climate change.

Scenario 1- current climate (no climate change)

As discussed above, the basin can be split into two main climatic regions: the headwater areas in southern Angola, with higher elevation areas, orographic rainfall, a high river drainage density, falling within the Inter Tropical Convergence Zone ITCZ which is a summer rainfall zone with dry winters; the rest of the basin lies within the arid climate zone of the descending arm of Hadley cell, with low and variable precipitation, high temperatures, and a negative water balance. This covers the part of the basin in Namibia and Botswana. The hottest months In the Okavango are December to February where average daytime temperatures can be as high as 40°C and humidity is high. The Delta experiences heavy afternoon thunderstorms during this period accounting for most of the annual rainfall. March to June temperature cools down and average temperatures reach around 30°C. The winter months of June to September are dry and cold with night-time temperate dropping to close to freezing[11].

Scenario 2 – higher likelihood

By 2025 the average annual temperature in the upper basin will be 0.75ºC higher than the average annual temperature between 1986 and 2005. The delta experiences slightly warmer conditions (1.0 ºC) during the same period. This rises to 1.5 ºC by 2055 in the highlands and 2.0ºC in the delta. The rainfall (less evaporation) remains the same or may slightly increase during these two time periods in the highlands but experiences a 20% reduction in the delta from 2025 onwards. In most emissions pathways there are more variations in the early season rainfall than in the late season. In addition the late season better reflects the full season. There are likely to be substantial increases in warm spells suggesting extended droughts. Unsurprisingly, there are decreases in cold spells which mean there are fewer days with reduced evaporation. Similarly, three of the indicators of flood seem to indicate that there could be both increased and reduced

[11] Read more: http://www.wordtravels.com/#ixzz4cu0TL0vx

flood risk. On the other indicators of flood there is a slight bias to reduced flood risk from rainfall less evaporation. Furthermore, there could be a 36% increase to the dry season length.

Scenario 3: lower likelihood

By 2025 the average annual temperature is 0.75 ºC higher than the average annual temperature between 1986 and 2005. This rises to 1.25 ºC by 2055. The rainfall less evaporation in the upper basin reduces by 25% by 2025 from the 1986 – 2005 average and maintains this reduction though to 2055 and beyond. In most emissions pathways there are more variations in the early season rainfall than in the late season. In addition, the late season better reflects the full season. There are likely to be substantial increases in warm spells suggesting extended droughts. There are decreases in cold spells which mean there are fewer days with reduced evaporation. Three of the indicators of flood seem to indicate that there could be an increase in flood risk due to rainfall intensity and maximums of between 3 and 30%. On the other indicators of flood there is a slight bias to reduced risk. Furthermore, there could be a 36% increase to the dry season

In short there is over 25% difference in the rainfall between the lower and higher options. Temperature differences only vary by 0.25ºC. There seems to be more potential variation in scenario 1 than 2 where scenario 2 suggests a clearer reduction in rainfall (less evaporation).

Scenario 4: Extremes

By 2025 average annual temperatures could be approaching 2.0ºC above the 1986-2005 average, 5.0ºC by 2055 and over 7.0 ºC by 2090. Rainfall could see up to a 55% reduction or a 50% increase by 2055 through to 2090.

While the extreme projections fall outside of the higher and even lower probability scenarios, they are *not unfeasible*. It is also clear that temperature increases and precipitation variability within this range would fundamentally alter the conditions for ecosystem and livelihood sustainability and the operation of infrastructure designed according to historic and present day framework conditions in the Okavango basis

Finally, a summary of extreme indices for the Cubango/Okavango river basin is shown in Annex 2. These indices are standard and were used in IPCC reporting. They use indicators such a maximum daily rainfall maximum dry spell to indicate changes in drought and flood magnitude and frequency. Some information from them has been incorporated into the scenarios above.

Projections and impact literature reviews

The two most likely recommended scenarios (Scenarios 2 and 3) outlined above might be termed ‘conservative’, and indeed are intended to be so; examination of the SOMs charts will readily identify projections with larger future departures than those recommended here (hence the purpose of the extremes scenario) (see Scenario 4). In order to obtain a broader perspective on climate change scenarios for the CORB a brief literature survey has been conducted, as follows

A brief web-based survey was conducted to find documents reporting climate change projections and impacts for the Okavango Delta. Although this may not be a representative survey, the survey showed that there are fewer such documents for the CORB than that for other areas with similar surveys; many reports emerge from major projects such as "The Future Okavango" and thus are repetitive. A sample is given below:

- Declining rainfall in future - http://www.scidev.net/global/climate-change/news/climate-change-threatens-botswana-s-main-tourist-attraction.html
- Longer drought episodes, changes in rainfall patterns, outbreaks of crop diseases that affect the most important sector for rural households and subsistence agriculture - http://www.bw.undp.org/content/botswana/en/home/ourwork/environmentandenergy/successstories/botswana-embarks-on-ambitious-plan-to-tackle-climate-change-.html
- Increased rainfall in south, decreased in north and east, more rain days but decreases in rain/day and in maximum daily falls, earlier start of season in south, later start in north, later end of season everywhere, longer and more severe droughts - http://unfccc.int/resource/docs/natc/bwanc2.pdf [this is the Second National Contribution to the UNFCCC; Botswana has not submitted a NAPA to date]
- Reduced DJF rainfall, increase in heavy daily rainfall, shorter rainfall season - http://africaclimateconference.org/wp-content/uploads/2013/11/B6-09_Weber.pdf
- Decreased rainfall, especially for the upper part of the catchment - http://www.future-okavango.org/downloads/TFO_Report_engl_compiled_small_version.pdf

In terms of projected rainfall (all agree on higher temperatures if not necessarily the magnitude of the increase) decreases and increases are both proposed for all parts of the Basin. The list above includes the Second National Contribution to the UNFCCC of Botswana (No. 3). Angola also contributed a National Contribution in 2012 – http://unfccc.int/resource/docs/natc/agonc1.pdf - but this includes no climate change projections, in part because the substantive collapse of the climate observations network during Angola's civil war inhibits calibration of model simulations. In summary of the above, there are a number of inconsistent projections published, with most options of decreases or increases in rainfall covered. Lack of clarity also exists in the impacts on river flow, although the main reference above (5) suggests a decrease later in the century.

More information on the possible impacts of climate change from the literature is included in Annex 3. The two tables in the Annex cover rainfall events and temperature events respectively and are based on the two most likely scenarios only, with reference to the IPCC AR5. They include insight gained from calculating the 'extremes' as listed in Annex 2; as a reference some details of these 'extremes' as defined by the IPCC can be found in Annex 1 that covers impacts in the areas of water resources, agriculture/food security and health. Column 1 lists the specific rainfall events. The summary in column 2 is split into a number of individual aspects.

Hydrology

To gain a better understanding of the potential impact of climate change on the flow regime within the Cubango/Okavango System the projections from the two main climate scenarios described in the previous section (Scenarios 2 and 3) were fed into an existing hydrological model for the basin. Extensive hydrological modelling was undertaken as part of the MSIOA Project, for the upper parts of the basin (i.e. up to the Panhandle/inlet to the delta) using the Pitman Rainfall Runoff Model. The CRDP study made use of this existing Pitman Model for the Basin to generate a simulated streamflow time series using data from the Projections carried out as part of CRDP (see section 5 above). This enabled the analysis of the potential impacts of climate change on flows within the system, as well as making inferences about the potential environmental, social and economic impacts of climate change.

The Pitman Model

Since its original design and use in 1973 (in South Africa) the model has undergone a number of transformations. There are many publications associated with the scientific aspects of the model and even more consultancy reports that illustrate the successful application of the model in various parts of southern Africa, as well as in a few other parts of the world. The main features of the model are the following:

- Spatial distribution system: The model uses a semi-distributed, sub-basin approach with individual sub-basins having their own climate driver (rainfall and potential evapotranspiration) inputs and their own parameter sets.
- Temporal modelling resolution: The model operates on a monthly time-scale; however, some parts of the model operate with four time steps per month to avoid large changes in some of the water balance components during high rainfall input periods.
- Natural sub-basin hydrological processes: The model includes algorithms for all the natural hydrological processes that are expected to occur within southern African drainage basins (with the exception of snowmelt). Thus, it includes interception losses, surface runoff due to either impervious areas, exceedance of soil moisture storage or high rainfall leading to infiltration and/or excess runoff. The model includes a soil moisture storage, which is incremented by rainfall that is not subject to surface runoff or interception and decremented by interflow runoff to river channels, groundwater recharge (Hughes, 2004) and evapotranspiration. The groundwater recharge volume is added to a groundwater storage, which supplies streamflow through groundwater drainage. Some of the groundwater storage can also be lost to riparian evapotranspiration and some can be transferred to groundwater storage in downstream sub-basins. If the groundwater level reduces to below the river channel, a transmission losses routine allows water to move from the river channel to the groundwater store. Finally, there are routines that allow the runoff to be routed through the sub-basins (catchment routing) or from one sub-basin to the next (channel routing).
- Accounting for human impacts applicable to this study:

- Direct abstractions from the river channel: These are dealt with as simple volumes of abstraction if there is sufficient water to meet demand, while return flows can also be included.
- Main reservoirs: They can be supplied by streamflow generated in sub-basins upstream of the one in which the reservoir exists. These simulations represent a simple water balance approach where inputs come from the upstream streamflow and the outputs are abstractions, net evaporation (accounting for rainfall) and downstream spillage. It is possible to add different levels of operating rules such that abstractions can be curtailed on the basis of the relative level of storage in the dam. It is also possible to specify controlled releases from the dam for compensation flows using a fixed annual volume and monthly distribution, or to specify a time-series of variable environmental flow requirements.

While various versions of the Pitman Model exist, this study used the “Uncertainty” version of it (Hughes, 2006; Kapangaziwiri et al., 2009; 2012). Within the current modelling project for the Okavango River Basin, a two-stage approach to allow for uncertainty in the parameter sets used for each of the sub-basins has been incorporated.

Calibration of Model

The calibration of the model was undertaken in two separate stages. The first step was to determine the typical pitman parameters for each sub-basin, which is done in the single-run environment within the model (i.e. not using the uncertainty configuration in the initial stage). This process is the same as that used in the original Pitman Model (Pitman, 1973). However, once this initial stage is done, the uncertainty aspects of the model are introduced into the calibration. This is in the form of constraints, which constrain the model to a range of outputs for which multiple variances in the parameters and parameter combinations are simulated, with the aim of achieving 5 000 behavioral ensembles for the Phase 2 analyses.

Despite the paucity of observed streamflow data for calibration, the calibrations were considered to be acceptable as the simulated stream flows represented the observed data in a satisfactory manner (mainly in terms of the frequency of flows).

Baseline Hydrology

The baseline hydrology (or present day hydrology) of the river basin was generated during the MSIOA Project and became the reference point in that study against which each of the MSIOA scenarios were compared. This was used to assess the impact of the various levels of development on the hydrology of the system. A sub-basin layout plan that was used in the modelling is provided in Figure 10.

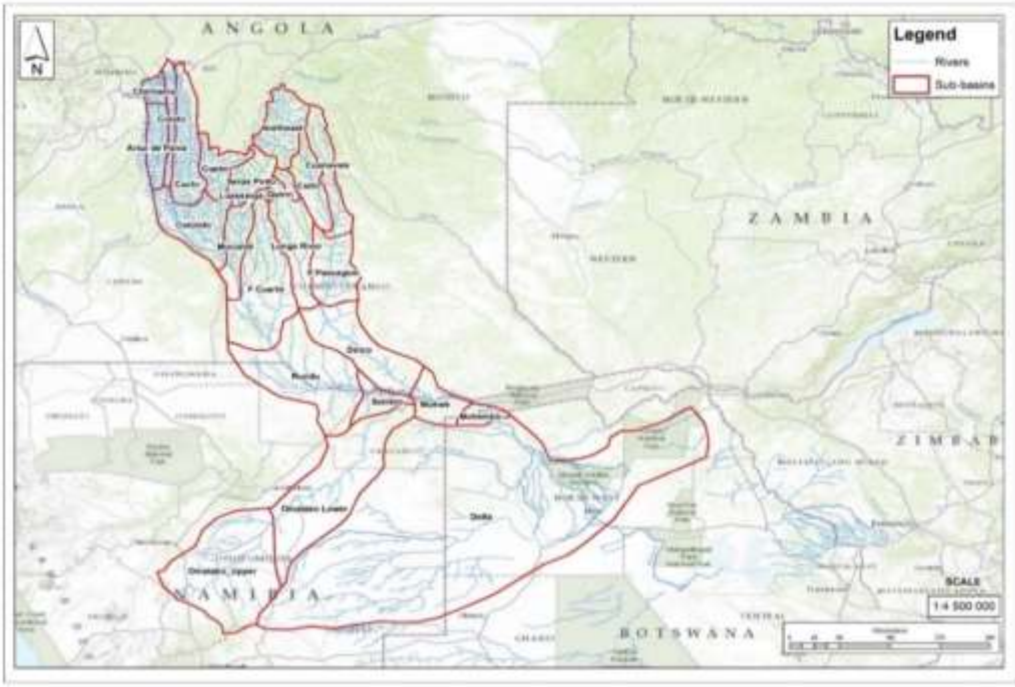

Figure 10 **Cubango Okavango River Basin – Sub-basins**

Table 5 presents the accumulated simulated streamflow results for the system, up to Mohembo, for the baseline (present day) scenario. This table shows a greater accumulated Mean Annual Runoff (MAR) down the western Cubango catchment, when compared to the eastern Cuito catchment. The accumulated results also present a small decrease in MAR from Mukwe to Mohembo, which is evident when comparing the observed records at these sites, and is thought to be primarily as a result of transmission losses in the dry season and a very small incremental streamflow contribution.

Table 5 **Accumulated Simulated Streamflow Results**

Sub-Basin	Average Accumulated Streamflow (million m³)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Chinhama	8.4	22.0	83.0	83.6	74.1	114.9	90.6	53.5	30.5	18.0	10.8	7.0	596.3
Cutato	12.8	20.7	82.1	84.5	81.0	131.5	101.5	59.7	34.9	22.4	16.0	12.8	659.9
Cuchi	26.7	45.2	168.7	184.1	169.5	285.6	210.4	119.0	69.1	43.1	29.7	23.9	1 374.8
Cuelei	16.5	23.0	67.4	94.9	76.7	113.7	73.9	43.3	30.9	23.2	18.2	15.3	596.9
Serpa Pinto	30.6	34.6	51.5	68.8	60.3	75.3	62.7	51.0	45.4	40.3	35.6	31.4	587.6
Artur de Paiva	22.4	43.2	197.9	195.5	181.6	310.2	229.3	134.7	81.9	52.2	34.1	23.3	1 506.4
Calundo	79.5	137.8	590.2	640.3	588.8	934.9	654.0	370.2	225.9	146.7	101.2	76.8	4 546.3
Mucundi	100.3	148.9	543.4	715.7	689.9	960.5	795.4	485.8	298.1	198.4	139.9	105.8	5 182.2
F Cuartir	99.9	126.2	391.4	676.4	732.8	869.3	865.9	609.2	371.5	236.6	161.0	116.8	5 257.0
Rundu	111.3	108.9	221.3	544.3	800.3	837.9	887.5	782.8	534.3	331.8	213.9	146.8	5 521.1
Sambio	109.5	107.6	220.5	552.6	805.0	838.2	885.2	780.0	531.8	329.6	211.9	145.0	5 516.9
Luassinga	3.6	4.0	4.7	5.8	5.8	6.8	6.3	5.5	5.0	4.5	4.1	3.7	59.8
Longa	4.5	4.9	5.8	7.3	7.2	8.4	8.0	7.2	6.6	6.0	5.4	4.8	76.1
Quiriri	11.6	12.5	14.8	18.5	19.0	21.7	20.8	18.5	16.7	15.1	13.6	12.1	194.8
Longa River	25.1	28.7	43.7	67.0	79.6	82.9	78.3	64.5	54.3	46.8	38.9	30.7	640.3
Northeast	117.5	126.0	164.2	194.6	210.0	233.2	215.4	190.4	170.3	153.3	137.4	123.5	2 035.6
Cuito	182.5	194.6	244.7	298.4	313.2	344.2	319.8	285.4	258.3	234.9	212.7	192.5	3 081.3
Cuanavale	217.9	233.2	294.6	367.5	379.0	415.1	384.0	342.9	311.5	283.5	256.4	230.9	3 716.5
P Passagem	221.7	229.1	284.2	364.8	397.2	425.7	409.1	365.0	327.4	296.2	267.0	239.6	3 827.0
Dirico	254.3	252.5	302.7	409.1	478.6	505.3	498.0	451.1	398.5	356.1	318.3	282.2	4 506.7
Omatako Upper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Omatako Lower	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mukwe	353.7	353.0	514.6	955.8	1 277.6	1 333.2	1 369.6	1 216.8	918.0	674.4	519.5	416.9	9 903.0
Mohembo	349.9	349.2	510.4	953.1	1 276.2	1 331.6	1 366.4	1 213.1	914.0	670.8	515.7	413.0	9 863.4

Modelling of Projected Climate Changes

It is commonly accepted that changes in climate are amplified in the hydrological cycle (e.g. a small change in precipitation has a larger proportional impact in streamflow). For this reason, it is useful, to simulate climate change projections using a hydrological model. The results obtained through this exercise are able to provide indications of what the hydrological impacts of various climate change projections will be.

No climate change specific time series input from the climate projections were available during this study for the hydrological model, (i.e. projected month by month time series of changes in rainfall and evaporation); instead, the projected average changes, based on the climate scenarios, to the rainfall less evaporation were applied in a uniform manner across the historical time-series dataset used in the MSIOA study. In other words, if the average projected change in rainfall was a five percent increase, then every monthly value in the historical time-series was increased by five percent.

The benefit of using the time series data for monthly evaporation and rainfall, direct from a climate model, is that potential future variability in rainfall, including *intra*-annual variability is better represented. This would likely be especially useful for better understanding the impact of projected climate change on the intra-seasonal variability, and ultimately, this would result in improving the confidence in the simulated change in high and low flows (including extreme events).

This approach would have a further benefit in that the variability of a system directly impacts the sustainable yield of that system. Thus, a more sophisticated understanding of the potential change in variability would provide more insight into the long-term impacts on system yields. Nevertheless, using the average change and applying it consistently across the months still provides a very useful insight into the potential changes in water availability within the river basin under different future climate change scenarios.

The range of change for the various climate change scenarios, based on the Rainfall Less Evaporation climate modelling scenarios, were as per Section 5. It should be noted that no hydrological scenarios were modelled for the 2090 projection.

Table 6 Projected rainfall less evaporation and temperature results

	2025	2055	2090
Highlands (Source) section			
Scenario 1 – higher likelihood	0.75ºC/1.00	1.50ºC/1.05	2.00ºC/1.05
Scenario 2 – lower likelihood	1.25ºC/0.75	2.00ºC/0.75	2.50ºC/0.75
Delta section			
Scenario 1 – higher likelihood	1.00ºC/0.80	2.00ºC/0.80	2.25ºC/0.80

Scenario 2 – lower likelihood	1.00ºC/1.05	1.50ºC/1.10	2.00ºC/1.10

Three MSIOA scenarios were assessed in this study, as described in Section 3 i.e. LS1, LS3 and LS6. The following section presents selected results of hydrological analysis using the Pitman model from these combined scenarios.

Results

Selected results are provided in the following sub-section. These results highlight typical trends obtained during the study. The results are presented in terms of a table of percentage change, as well as diagrammatically via mean monthly hydrographs and flow duration curves (FDC's).

MSIOA Scenario	Climate Change Scenarios	Percentage Deviation of Mean Flows from MSIOA Scenario (Not Status Quo)												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
MUCUNDI														
LS1	Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Higher 2055	12.8%	16.7%	18.8%	19.1%	17.7%	17.9%	14.9%	11.1%	9.6%	9.5%	9.9%	10.6%	15.8%
	Lower 2025	-55.9%	-60.6%	-66.1%	-65.9%	-62.0%	-61.0%	-55.7%	-49.8%	-46.8%	-46.7%	-48.9%	-52.2%	-58.6%
	Lower 2055	-55.8%	-60.5%	-66.0%	-65.9%	-61.9%	-60.9%	-55.7%	-49.8%	-46.9%	-46.7%	-49.0%	-52.2%	-58.6%
LS3	Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Higher 2055	14.5%	16.2%	17.3%	20.7%	21.2%	19.2%	16.9%	12.6%	12.1%	14.3%	15.0%	15.4%	17.3%
	Lower 2025	-57.3%	-57.1%	-69.5%	-71.1%	-70.3%	-68.2%	-63.1%	-57.9%	-55.4%	-57.1%	-57.5%	-57.2%	-64.1%
	Lower 2055	-57.3%	-57.1%	-69.4%	-71.1%	-70.3%	-68.3%	-63.1%	-57.9%	-55.4%	-57.1%	-57.5%	-57.2%	-64.1%
LS6	Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Higher 2055	11.4%	13.3%	18.4%	22.6%	22.5%	25.4%	18.6%	13.1%	10.8%	11.0%	11.2%	11.2%	18.0%
	Lower 2025	-65.0%	-64.3%	-71.6%	-78.4%	-76.3%	-73.0%	-70.3%	-66.0%	-63.9%	-64.8%	-65.0%	-65.0%	-70.4%
	Lower 2055	-65.0%	-64.3%	-71.6%	-78.4%	-76.3%	-73.0%	-70.3%	-66.0%	-63.9%	-64.8%	-65.0%	-65.0%	-70.4%
KAPAKO														
LS1	Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Higher 2055	12.0%	14.7%	18.3%	19.8%	20.0%	19.4%	18.3%	16.2%	13.2%	11.1%	10.5%	10.9%	17.0%
	Lower 2025	-58.1%	-63.0%	-67.7%	-69.4%	-68.7%	-66.3%	-63.1%	-59.1%	-54.3%	-51.1%	-51.0%	-53.7%	-62.4%
	Lower 2055	-58.1%	-63.0%	-67.6%	-69.3%	-68.6%	-66.2%	-63.0%	-59.1%	-54.3%	-51.2%	-51.0%	-53.7%	-62.3%
LS3	Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Higher 2055	16.1%	15.5%	18.6%	20.5%	21.8%	22.7%	19.9%	18.4%	14.6%	13.1%	14.7%	15.5%	18.7%
	Lower 2025	-60.7%	-60.9%	-64.2%	-73.9%	-73.9%	-74.0%	-71.2%	-67.3%	-62.0%	-59.1%	-60.5%	-60.8%	-67.9%
	Lower 2055	-60.7%	-61.0%	-64.2%	-73.9%	-73.9%	-74.0%	-71.2%	-67.3%	-62.1%	-59.2%	-60.6%	-60.9%	-67.9%
LS6	Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Higher 2055	11.9%	12.4%	15.4%	19.9%	23.3%	23.8%	26.8%	20.4%	15.6%	12.6%	12.0%	11.8%	19.3%
	Lower 2025	-67.5%	-67.6%	-70.4%	-76.5%	-80.2%	-79.3%	-76.9%	-74.9%	-69.8%	-67.1%	-67.8%	-67.8%	-74.0%
	Lower 2055	-67.5%	-67.6%	-70.4%	-76.5%	-80.2%	-79.3%	-76.9%	-74.9%	-69.8%	-67.1%	-67.8%	-67.8%	-74.0%
MOHEMBO														
LS1	Higher 2025	-1.8%	-2.2%	-1.8%	-2.2%	-1.4%	-0.8%	-0.6%	-0.5%	-0.5%	-0.6%	-0.9%	-1.4%	-1.1%
	Higher 2055	6.1%	7.1%	11.8%	14.2%	15.6%	15.7%	14.9%	12.9%	10.2%	8.2%	7.1%	6.3%	12.4%
	Lower 2025	-38.6%	-41.7%	-51.3%	-57.6%	-59.1%	-57.5%	-54.9%	-50.9%	-45.4%	-41.1%	-38.9%	-38.2%	-51.0%
	Lower 2055	-38.5%	-41.5%	-51.1%	-57.0%	-58.7%	-57.2%	-54.8%	-50.8%	-45.3%	-41.0%	-38.7%	-38.1%	-50.8%
LS3	Higher 2025	-1.0%	-1.3%	-1.7%	-3.2%	-1.8%	-1.2%	-0.8%	-0.6%	-0.5%	-0.7%	-0.8%	-1.1%	-1.2%
	Higher 2055	9.6%	9.4%	12.1%	13.1%	15.9%	17.3%	15.5%	14.2%	10.9%	9.1%	9.1%	9.3%	13.2%
	Lower 2025	-45.7%	-46.2%	-50.8%	-56.9%	-60.8%	-61.6%	-59.5%	-56.2%	-50.2%	-45.7%	-45.0%	-45.4%	-54.2%
	Lower 2055	-45.6%	-46.1%	-50.6%	-56.2%	-60.4%	-61.4%	-59.4%	-56.1%	-50.1%	-45.6%	-44.9%	-45.3%	-54.0%
LS6	Higher 2025	-3.1%	-3.2%	-2.3%	-3.4%	-1.7%	-1.0%	-0.6%	-0.6%	-1.1%	-1.6%	-2.4%	-2.9%	-1.7%
	Higher 2055	7.7%	8.0%	11.0%	12.8%	17.1%	18.3%	19.9%	15.8%	11.8%	9.3%	8.4%	7.9%	13.9%
	Lower 2025	-51.2%	-50.9%	-55.0%	-58.1%	-65.2%	-65.8%	-63.6%	-62.1%	-55.8%	-50.9%	-50.2%	-50.7%	-58.8%
	Lower 2055	-51.0%	-50.7%	-54.7%	-57.3%	-64.7%	-65.5%	-63.5%	-62.0%	-55.6%	-50.7%	-50.0%	-50.5%	-58.5%

Table 11 presents the percentage change of the climate change scenario relative to each of the original MSIOA scenarios (i.e. the no climate change MSIOA scenario and not the Present Day Scenario). This allows for the assessment of the impact of climate change on a certain level of development, as contained within the MSIOA scenarios. Percentage Change of Climate Change Scenarios Relative to Each Original MSIOA Scenario (i.e. NOT the Status Quo Scenario). The results are presented for three of the EFlow sites used in the MSIOA Study i.e. Mucundi (middle to upper basin on the Cubango River in Angola), Kapako (middle basin on the Namibia and Angola border just upstream of Rundu) and Mohembo (at the entrance to the Panhandle in Botswana).

It is important to understand the limitations of the sensitivity analysis approach (as mentioned above) and thus focus more on the trends that are shown rather than focusing on the actual numbers. The following observations are evident from the above results:

- The higher likelihood scenario for 2025 shows little to no change across all the selected MSIOA scenarios, as there was no projected change in precipitation in the Highland Portion of the basin (which contributes the majority of the streamflow; *cf.* earlier this section) for this scenario. The reason for the small change in values at the Mohembo site is because of the projected 20% reduction in rainfall in the Delta Region of the system for this scenario. This contrasts to the no change in streamflow for each of the Mucundi and Kapako EFlow sites, which are positioned higher up in the system and only affected by changes in precipitation in the Highland Portion of the basin, which was projected to have no change in precipitation in this scenario.
- The higher likelihood scenario for 2055 shows a small to moderate increase in streamflow, depending on catchment location (i.e. the sites closer to the Highlands show higher increase), due to the projected 5% increase in rainfall in the Highlands. In the context of the MSIOA scenarios, this increase in streamflow could offset some of the reduction in streamflow caused by abstractions associated with the potential developments contained within each MSIOA scenario. This could reduce the environmental impact of the developments and could potentially create more room for development within the basin.
- Both lower likelihood scenarios (i.e. 2025 and 2055) show a significant decrease in intra and inter-annual streamflow due to the significant decrease (25%) in the projected precipitation in the Highland Portion of the basin. This projected decrease in rainfall in the Highlands results in a decrease in streamflow of between 58% and 66% at the entrance to the Delta. These are drastic decreases and will have large environmental, economic and social impacts, as discussed in **Section 7**.

  For LS1 (low levels of development) under the lower likelihood scenarios there is an estimated decrease in streamflow of up to 58% in the wetter months. Similarly, for LS6 (moderate to high levels of development) there is an estimated decrease in streamflow of up to 66% in the wetter months. This indicates that the impacts of climate change for a scenario, where there is a 25% reduction in precipitation in the Highlands, will be far more severe than the impacts of development.
- The results from the table show how the impact of a reduction in rainfall in the Highlands Portion of the basin is more severe than that of a decrease in the Delta Portion of the basin. This reemphasises that the Cubango Okavango River Basin is driven by rainfall occurring in the Angolan highlands.

Figure 11 presents the mean monthly hydrographs for the projected climate scenarios for MSIOA scenario LS1 and LS3 at the Mucundi EFlow site.

The following points can be gleaned from the selected mean monthly hydrographs:

- The impact on streamflow of the potential developments in LS3 is evident i.e. difference between status quo (Present Day; blue line) and LS3 (orange line). This indicates a reduction of flow in the wet season and an increase in flows in the dry season. The decrease in the wet season is expected, but the increase in the dry season is a result of the inclusion of a large dam, on the Cubango River at Mucundi in the simulation. This dam was simulated to generate hydropower throughout the year and it is the dry season releases for this power generation that result in the increase in monthly flows in the dry season. This increase in flows at this time of the year is not a natural phenomenon and could potentially have negative environmental impacts if not managed or offset by abstractions for developmental purposes.

  The graph, and the evident increase in dry season flows, provide an indication of the increased resilience that a storage structure can introduce to a system by improving the yields and reliability of supply in the low flow periods. This resilience may allow for the mitigation of the environmental (and potentially the related socio-economic) impacts as a result of the LS3 developments, or an increase in potential development levels back to the LS3 environmental impact level, assuming that this level of environmental impact was acceptable.
- For both scenarios, it is clear that there is no change between the initial MSIOA scenario and the higher likelihood 2025 as the lines are super imposed on top of each other (reflecting the 0% change shown in **Table 11**).

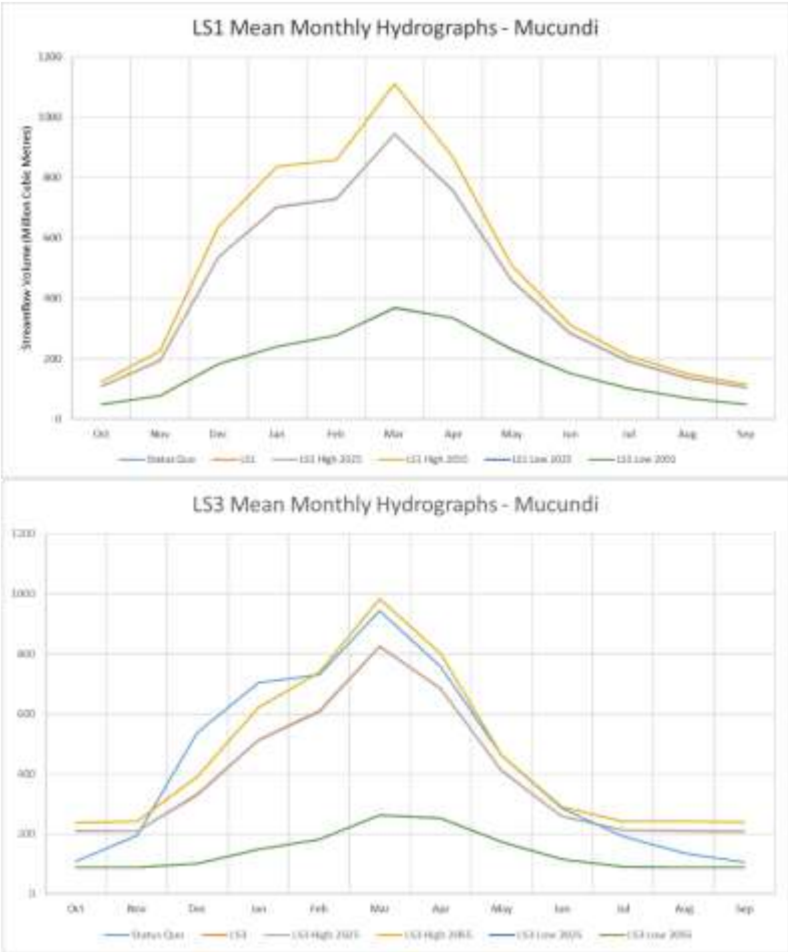

Figure 11 **Mean Monthly Hydrographs for LS1 and LS3 at Mucundi Under Varying Climate Projections**

- The increased flows simulated for the higher likelihood 2055 scenario is clearly reflected by the yellow line on the graphs. For LS1 it is clear how there is significantly more water in the system when compared to the MSIOA scenario, which consisted of very low levels of development. Of more interest is the trend observed for LS3, under this scenario, where the hydrograph shows how the increase in streamflow (as a result of the increase in precipitation) generates a mean monthly hydrograph very similar to the present day situation i.e. offsetting/mitigating the reduction in flow as a result of approximately 66 000 ha of irrigated agriculture and the generation of hydropower through a large dam at Mucundi.
- Significant flow reduction is experienced under the drying projections of both lower likelihood scenarios, with both LS1 and LS3 showing a significant decrease in stream flows, especially in the wet season. The decreasing trend is exacerbated from LS1 to LS3, even with the inclusion of the Mucundi Dam, which may suggest that the impacts resultant from the climate change projections outweigh any anthropogenically introduced resilience. Hence, development levels, and possibly the type and scale of developments, may need to be reassessed under this type of climate projection (i.e. significant drying).

- The resilience introduced by the storage dam in LS3 is shown to be exceeded by the severe reduction of inflows under the lower probability scenarios. This is reflected by the large reduction in the dry and wet season months (as shown by the green line).

The trends described above are further confirmed in the FDC's depicted in **Figure 11**. The FDC's do however show the varying impact on high and low flows more clearly. In addition to the trends already described above the following points of information can be gleaned from the FDC's in **Figure 12**:

- The increase in low flows as a result of the Mucundi Dam in LS3 are evident.
- The severe decreases in flow for the lower likelihood scenarios across the wet and dry season flows are clearly shown by the green line. This indicates a decrease in high flows of up to 60 to 70%.

  It should however be considered that had a time series of rainfall and evaporation data been available, this may have yielded different results in terms of the shape of the FDC's and the quantum of the high and low flows simulated. Linked to this would have been better representation of the intra-seasonal variability, which is currently not evident within the FDC's nor the mean monthly hydrographs.

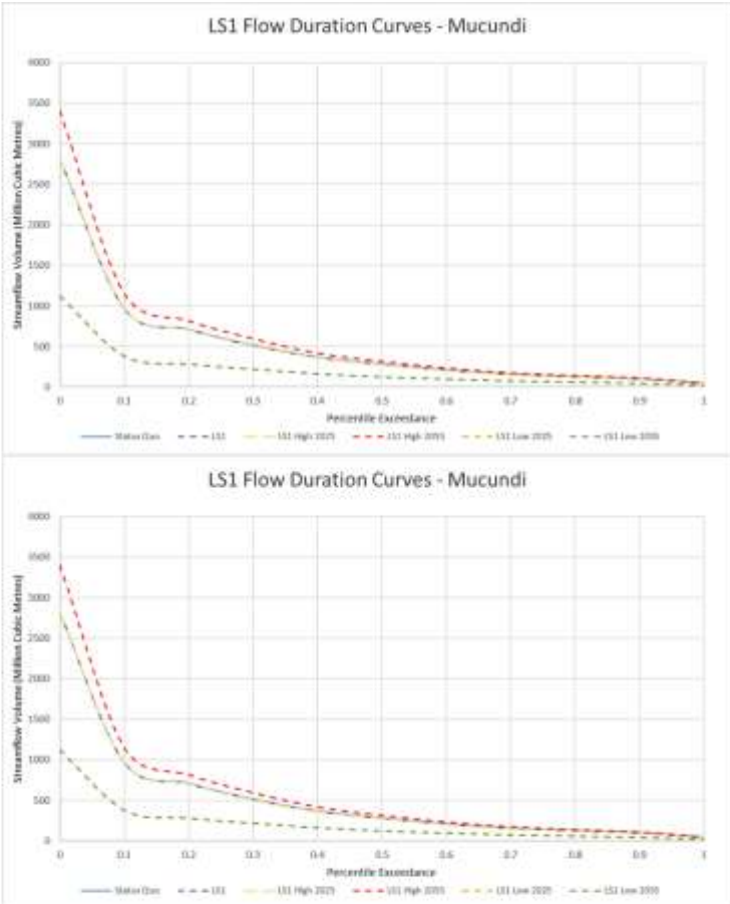

Figure 12 **Flow Duration Curves for LS1 and LS3 at Mucundi Under Varying Climate Projections**

Extremes

The results presented in this section have focused only on the two most likely scenarios which came out of the climate modelling exercise. The possibility does still exist (although with a significantly lower likelihood) for more extreme projections to come to fruition. As discussed in **Section 5** these extremes may consist of an increase in temperature of up to 6 degrees Celsius and a decrease in precipitation of up to 55%, or alternatively an increase in precipitation of up to 50%. These are two very different extremes that would have very different impacts on the corresponding hydrology. The most significant impact of these changes has been shown to occur if these conditions happen in the Highland Portion of the basin.

Although no actual simulations were undertaken for these extreme projections, it is possible to make qualitative inferences about what may happen under these conditions.

With a large increase in temperature and a 55% reduction in rainfall, one could expect the following:

- A massive decrease in streamflow to levels that would likely be non-sustainable from many perspectives, including the environment. From the simulations presented above a 25% reduction in rainfall results in severe reductions in streamflow. Based on this, a 55% reduction would lead to a far more significant reduction in streamflow.
- Large-scale economic benefit, because of water consumptive development, would likely decrease significantly (i.e. hydropower production severely impacted, large-scale irrigation schemes could fail, etc.).
- Assurance of supply to urban areas will reduce significantly.
- Large dams that may already be in place would become non-viable and ineffective. This is confirmed through simulations presented above. This anthropogenically introduced climate resilience would not be sustainable under these extreme conditions.
- There would likely be change in habitats throughout the system with a major change in the Delta. Previous simulations show that with an increase in development and a corresponding reduction in streamflow there is an encroachment of savannah and grasslands into the delta and a large reduction in wetland type ecotopes.
- There could potentially be a shift from large scale commercial operations within the basin to those focussed more on food security and community self-sufficiency to sustain lifestyles. Linked to this may be changes in crop types to less water intensive, higher value crops as well as changes in land use practices. Large dams may become less effective and the focus may shift to a greater number of smaller dams positioned closer to beneficiaries to improve localised supply for these smaller interventions.

With a large increase in rainfall of up to 50%, one could expect the following:

- Simulations of a potential 5% increase in rainfall in the Highlands Portion of the basin have shown an increase in flows of 10 to 25%, depending on the development levels of the scenario being analysed. Therefore, an increase in rainfall of 50% would result in significantly more water being available. This will would likely result in more frequent and larger flooding

- This would potentially create more room for large scale development projects (i.e. more water available without altering flows from present day). This could lead to large economic benefits (more potential for hydropower and more potential for irrigated agriculture downstream of the Angolan Highlands). The Angolan Highlands would not need to develop irrigation infrastructure and could be reliant on rain-fed agriculture, which is less capital intensive.
- Existing infrastructure within the basin at that time may be under capacitated and at risk of damage (i.e. dam spillways under capacitated; bridges for access etc.).
- In the same manner that there is potential for a large change in habitat because of a drying of the system, there is also the same potential for change under these extreme wetting conditions. The changes would be different but could be equally damaging to the tourism industry in Botswana. Additional flooding of the Delta would make large areas inaccessible and would hinder the movement of large mammals.

Conclusions

The hydrological modelling and analysis of climate change scenarios has produced varying results. In summary, the analysis has clearly shown that changes of climate within the Highlands Portion of the basin have far bigger impacts on streamflow than in the lower Delta Portion of the basin. The analysis indicates that a 25% reduction of rainfall in the Highlands Portion of the basin is likely to result in a much larger reduction in streamflow (65 to 80%) throughout the basin, including the Okavango Delta. These reductions will lead to a significantly altered system as a result of the severe change in the flow regime and reduction in water availability. However, the scenario showing a 5% increase in rainfall in the Highlands Portion of the basin is likely to result in significant increases in flows and water availability.

When comparing the climate change scenarios back to the original MSIOA scenarios (i.e. no climate change) the impacts are clear. In a wetter future , there is likely to be more room for development and less environmental impact as there is less change from the Present Day flow conditions. However, under a dryer future, the impacts of climate change exacerbate the impacts of the potential developments and result in highly altered river conditions (both flow and environmental), thus reducing the levels of development that would be sustainable within the basin. The analysis also showed that the potential impacts of climate change could have a significantly bigger impact on the system than any of the planned developments within the basin.

It stands to reason that the respective extreme projections, as presented in Section 6.5, will show similar trends to those of the lesser increase or decrease in rainfall, but in a more exaggerated fashion i.e. even more pronounced drying of the system or significantly more water availability.

In terms of the hydrolgical impacts of the different MISIOA scenarios (sees The MSIOA Scenarios section above), in combination with the climate scenarios, the impacts range from significantly adverse to signifcantly positive in terms of water availability and ingrstrucutre development potential in the basin.

In the lower likelihood climate scenario, where a large reduction in rainfall is expected, the implications to the different types of development will be severe. The developments requiring water at the high assurances (98 and 99%) will be severely negatively affected as water availability, particularly in the drier months, will be significantly reduced. This will result in more frequent water restrictions and less possibility for economic growth within the basin. Irrigation schemes will be negatively affected as there will be less rainfall, placing higher reliance on irrigation, which in turn will be more intermittent due to the lower levels of streamflow within the rivers. Hydropower generation will be reduced which may render certain large projects non-financially viable.

In the higher likelihood climate scenario, where an increase in rainfall is expected, the effects on developments will be the complete converse to those discussed above (a scenario where there is a large reduction). In theory the wetter conditions would create more headroom for development within the basin while still being able to maintain an acceptable level of environmental integrity. The increase in rainfall may also make rain fed agricultural projects more viable, which will in turn free up more water for other developments, such as hydropower generation and urban abstractions (Windhoek/CAN and Cuvelai). If infrastructure has been developed by the time this climate projection comes to fruition, this infrastructure will need to be able to cope with higher flood peaks and floods with greater volume. This may lead to inundation and damage of infrastructure and settlements.

In summary, the combination of different types, geographic location and levels of development within the basin can cause varying levels of impact to the system. These factors will need to be carefully planned and monitored by the basin authorities to ensure that the basin is developed in a sustainable and flexible manner that can react to the impacts of the different possible climate projections if and when they occur

Impact assessment: Natural Environment

Introduction: the Okavango River ecosystem

The Okavango River system is one of the world's great natural treasures. Rising in Angola, it flows south and then east between Angola and Namibia and terminates in Botswana. Its waters never reach the sea and instead spread across the flat Kalahari sands in Botswana to form a wetland of global importance that is one of the largest Ramsar sites in the world - the Okavango Delta (5,537,400 ha).

Conceptual approach to the assessment of impacts on the natural environment

In the last 30 years a new discipline has developed to predict the potential consequences of water-resource developments for riverine ecosystems and their dependent social structures. Presently named Environmental Flow (EFlow) Assessments, the discipline recognizes that as rivers are developed through manipulation of their flow regime, the river ecosystems will respond by changing[12]. This change will differ depending on the nature of the development, and on the severity of the transformation of the flow, sediment and water quality regimes of the river. EFlow Assessments use the potential changes in the flow (and sometimes the other) regimes as the starting point to describe the expected change in the other biophysical parts of the ecosystem. The social and economic impacts of a changing river for local river-dependent human communities can also be predicted if these are not covered in parallel economic and social studies.

The present impact assessment builds on the results of a comprehensive EFlows Assessment done as part of a Transboundary Diagnostic Analysis (TDA) in 2008-2010 (PORBWC, 2011), summarised in King et al. 2014. The assessment used 70 biophysical indicators to describe how the river could change with development, and nine social indicators to describe how this would affect dependent human communities (Table 7).

Table 7 **Examples of indicators used in the TDA to predict the biophysical and social impacts of development-driven flow changes (modified from King et al. 2014).**

Discipline	Indicator
Hydrology - river	Dry season onset
Hydrology -Delta	Savanna: dry areas in seasonally flooded zones
Hydrology – Delta outflow	Percent of river length dry
Geomorphology	Sand bars

[12] The discipline is ccomprehensively reported in a Special Issue of Freshwater Biology (Volume 55(1); 2010), and a Special Issue of Hydrological Sciences Journal (Volume 59:3-4; 2014).

Water quality	Conductivity
Vegetation - river	Upper wet bank (trees and shrubs)
Vegetation - Delta	Lower floodplain
Macro-invertebrates	Channel – submerged vegetation habitat
Fish	Large fish that migrate onto floodplains
Birds	Specialists – water lily habitat
Wildlife	Middle floodplain herbivores: e.g. elephant, buffalo, tsesebe, warthog
Social - economic	Household income - reeds
Social - lifestyle	Wellbeing from intangible river attributes

In the TDA three scenarios (Low, Medium and High water use) were used to describe how all 70 biophysical and nine social indicators could change with development, for eight sites along the river (Figure 13). The Delta site was in the eastern perennial swamps, with no site covering the western seasonal swamps that are now thought to be more vulnerable to a drying landscape. None of the TDA projections considered the impacts of climate change.

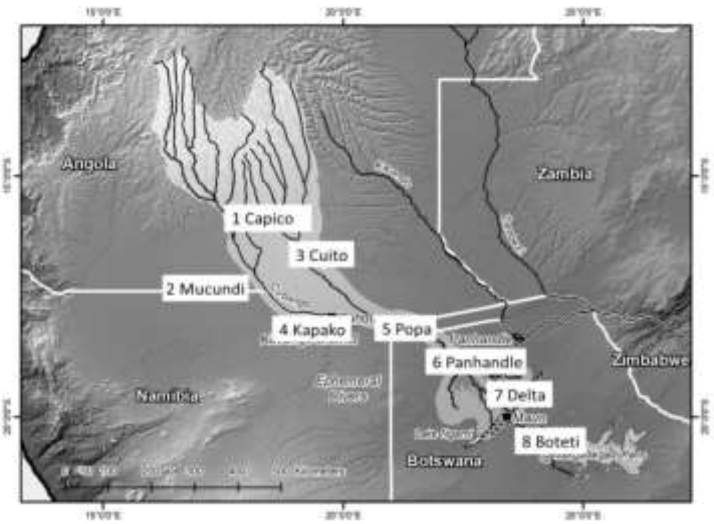

Figure 13 **The Okavango Basin, showing the two main headwater rivers, the Delta and location of the eight EFlow sites.**

The individual scores for indicators were combined to provide a prediction of how the overall ecosystem would change, using five categories of river condition (**Error! Reference source not found.**8). In very general t erms, Category A and B could be seen as upper and lower Conservation rivers, and C and D as upper and lower ‘Working’ rivers. Category E indicates a complete ecosystem change and loss of the original functioning of the river; in most cases it would be seen as unsustainable and not a management objective.

Table 8 **Categories of river condition (after Kleynhans 1996).**

Ecological category	Description of the ecosystem
A	Unmodified. Still in a natural condition.
B	Near natural. A small change in natural habitats and biota, but the ecosystem functions are essentially unchanged.
C	Moderately modified. Loss and change of natural habitat and biota, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions.
E	Seriously modified. Extensive loss of natural habitat, biota and basic ecosystem functions.

It was predicted that through the three stages of basin development considered in the TDA, the Okavango River ecosystem would gradually degrade until some parts of it would be in an E condition (**Error! Reference source not found.**14).

Figure 14 **The Okavango Basin, showing condition of the river**

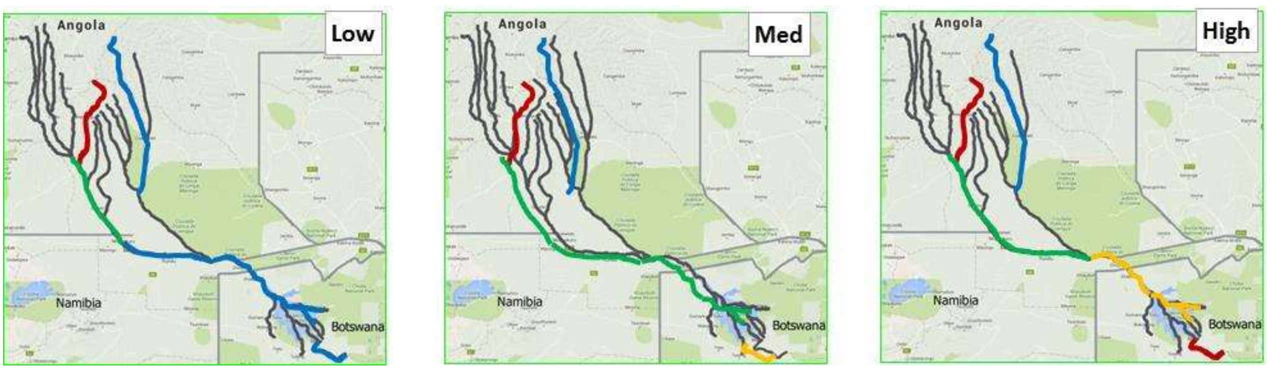

Figure 15 **Summary of expected changes in ecosystem integrity for the TDA’s Low, Medium and High water-use scenarios.**

A (dark blue) =Natural ecosystem; B (light blue) =Largely natural; C (green) =Moderately modified; D (orange) =Largely modified; E (red) =Seriously modified. Present-day ecosystem condition throughout is estimated as A/B. Black reaches were not included in the study. The tributary in Angola that is coded red in all scenarios indicates a hypothetical dam development that would release no water to the downstream river hence turning it from perennial to seasonal (King et al. 2014).

In the 2015-2017 World Bank-funded MSIOA initiative twelve scenarios of increasing water-resource development across the basin were used in the analysis, as described in Section 3 of this report. The major development components of the scenarios were medium to large dams and commercial irrigated agricultural schemes. The database created in the TDA EFlows Assessment, housed in a custom-built Okavango decision support system using DRIFT EFlows software (Brown *et al.* 2013), was used to assess the ecological impacts of each MSIOA scenario for the same eight sites, using the same indicators. The results of this investigation still reside with the World Bank and the Member States.

For the purposes of the present climate resilience project, climate change was superimposed on three of the MSIOA scenarios (Section 5) for three of the river sites: Mucundi, Kapako and Mohembo (shown as Site 6 'Panhandle' in **Error! Reference source not found.**13).

The TDA database was again turned to, to estimate the likely further impacts of climate change on the river system. For each permutation of site and MSIOA scenario, two different climate change predictions (essentially one that predicted a slightly wetter future and one a significantly drier future, as described in Section 5) were considered at two time steps: 2025 (2016-2035) and 2055 (2046-2065).

In the ecological part of the assessment, a site was also added for the Delta and one for the outflow (Sites 7 and 8 in **Error! Reference source not found.**13), because of their great difference in functioning from the r iver.

Assessment method

For the purposes of assessing the impacts on the natural environment 2-3 indicators were selected to predict how they might change from baseline (Present Day) for each site/scenario assembly. Scoring was based on the methodology presented in Section 2 using the CIVAT tool, with a 7-point scale between -3 and +3.

The positive and negative label assumes, in EFlows work, that the system is moving back toward natural (i.e. POSITIVE: a degraded ecosystem is being rehabilitated) or away from natural (i.e. NEGATIVE: the ecosystem is moving away from natural). In the case of the Okavango, which is near natural, most predicted change will be negative.

The decision of how to rate each site/scenario/climate change model/time step permutation was an expert judgement, based on the following information:

- the coarse hydrological predictions (Section 6), which provided:
  - monthly volumes, rather than daily flows as normally used in detailed EFlows work
  - the percent deviation of these monthly volumes from the present-day situation (Annex 4)
  - a summary of how the simulated monthly volumes would probably manifest in terms of hydrological indicators that ecologists can use (Annex 4**Error! Reference source not f ound.**)
  - the TDA biophysical predictions in the DRIFT decision support system as used in the MSIOA project.

The decisions on climate-related change were entered into CIVAT.

Indicators

As the assessment built on the precautionary approach, indicators were chosen that showed a high sensitivity to flow change. In the MSIOA study, colour-coded tables of predicted change for both the flow regime (**Error! Reference source not found.**9) and the 70 biophysical indicators revealed which indicators were likely to change the most (those with red cells). Based on this, three indicators were chosen for the river and two for the Delta/outflow.

Table 9 **Example of colour-coded predicted change in hydrological-hydraulic indicators under 11 MSIOA scenarios; for Kapako EFlow Site 4 (MSIOA study).**

4_Kapako	Units	Present Day	ImpLives	LS2	LS3	LS9	LS5	LS6	LS7	LS8	LS9HIGH	LS9LOW	LS10
Mean annual runoff	Mm^3	5011.73	5005.45	4476.08	4555.18	4129.84	4259.56	4084.27	3876.95	3611.61	5106.63	3422.93	2833.31
Dry Min 5d Q	m^3/s	35.19	35.10	29.78	68.92	64.52	8.63	64.80	0.42	0.00	81.18	70.78	51.37
Dry duration	Days	132.50	135.50	152.00	157.00	173.00	174.00	167.00	177.50	191.00	153.50	129.50	193.50
Dry ave daily vol	Mm^3	4.68	4.70	4.75	6.92	7.17	4.34	7.02	3.43	2.92	8.67	6.36	5.49
DryOnset (HydroWeeks)	Week	46.50	46.37	39.41	44.59	43.61	45.09	43.67	44.03	42.60	44.62	40.87	39.61
Wet Max 5d Q	m^3/s	401.35	401.14	378.93	365.93	323.11	367.81	321.66	356.36	347.92	366.61	281.70	225.16
Wet duration	Days	156.00	156.00	137.50	117.50	101.50	128.50	95.50	119.50	110.50	171.00	63.50	48.50
Wet ave daily vol	Mm^3	24.16	24.13	23.21	23.50	21.30	22.97	21.60	22.40	22.19	21.94	20.38	16.94
WetOnset (HydroWeeks)	Week	17.00	17.00	12.00	19.50	20.00	19.00	20.00	19.00	19.50	15.00	23.00	23.00
Flood volume	Mm^3	3606.54	3603.09	2974.52	2629.22	1785.16	2727.67	1758.03	2508.00	2315.04	2960.95	1328.24	887.37
FloodType	Index	2.50	2.50	2.00	2.00	1.00	2.00	1.00	2.00	2.00	2.00	1.00	1.00
T1 ave daily vol	Mm^3	10.45	10.43	10.92	10.03	10.24	11.31	9.71	11.40	11.36	12.95	6.78	7.01

T2 ave daily vol	Mm^3	9.62	9.62	9.89	9.66	9.75	10.19	9.63	9.58	9.57	11.05	9.02	9.19
T2 recession slope	$m^3/s/d$	-1.58	-1.59	-1.48	-1.85	-1.73	-1.43	-1.76	-1.54	-1.67	-1.55	-1.84	-1.85
Sediment supply	Tons	333 419	332 888	177 839	8 064	6 987	166 166	7 222	119 689	107 462	19 250	0	2 456
Floodplain Area	km^2	46.21	46.20	44.81	44.45	43.82	45.19	43.68	44.91	44.67	44.95	42.03	41.72
Wet: ave FPA <1m	km^2	15.62	15.61	15.99	15.53	15.80	15.82	15.58	15.86	15.87	15.60	15.57	15.63
Wet: ave FPA >1<2m	km^2	6.07	6.07	6.37	6.06	6.26	6.26	6.14	6.30	6.33	6.22	6.13	6.10
Wet: ave FPA >2m	km^2	9.37	9.37	8.79	8.68	8.12	8.97	8.34	8.85	8.75	8.80	7.74	7.42
Wet: ave FPDur <1m	Days	28.45	28.87	21.97	3.03	0.00	30.04	3.47	46.56	44.21	0.00	2.50	3.50
Wet: ave FPDur >1<2m	Days	331.94	331.32	334.65	357.80	366.00	306.57	357.43	271.78	248.67	366.00	355.50	354.00
Wet: ave FPDur >2m	Days	2.87	2.86	2.24	2.22	0.00	2.27	1.89	2.07	1.86	0.00	0.00	0.00
Wet: ave FP depth	m	1.58	1.58	1.51	1.48	1.47	1.54	1.44	1.52	1.51	1.53	1.38	1.35

Change from Present Day: blue – 10-20% change; yellow – 20-40% change; orange – 40-60% change; red - >60% change

Indicators for the Highlands part of the basin

Sites considered: Mucundi, Kapaka and Mohembo

Two major state changes could occur in the river: 1) a change from perennial to seasonal flow; and 2) the loss of floodplains in this flood-pulse driven system. All other changes will be gradual ones around those thresholds. Based on this and the colour coding in Table 14, two hydrological indicators of ecological relevance and one biological indicator were chosen:

Dry season low flow and duration. Almost all aquatic species cannot survive a dry river bed so species would leave the area or their life cycles would fail. There would be no passage to wetter parts of the system, and fish and other species would be fished out of isolated pools. Unit: Change from Baseline (Present Day) of 100.

Flood volume. This is a first indication of whether or not floods are changing in timing, volume or nature, and whether floodplains will continue to be flooded. Without floodplains, there will be a great loss of: groundwater recharge; dry-season flows released into the lower river; and floodplain productivity. Unit: Change from Baseline (Present Day) of 100.

The fish assemblage. Up to a 70% decrease in present-day fish stocks was predicted for some sites under some MSIOA scenarios. Fish reflect the health of the whole system that supports them (geomorphology, chemistry, vegetation and invertebrates) through their habitat and food needs, and are in turn a major food source for the birds and mammals of the system (tourism). An earlier version of this analysis showed that large birds and river-dependent wildlife showed very similar trends to fish through the sites/scenarios. Unit: Change from Baseline (Present Day) of 100.

Delta and outflow (Delta) indicators

Sites considered: Mohembo as inflow, Delta and Boteti

Following the same rationale as for the Highlands, two indicators were chosen:

(1) **Savanna.** The fundamental nature of the Delta is its wetness; any shrinkage of the wetted area is a loss of Delta and all that that implies. As the various wet habitat types of the Delta shrink and expand in the different MSIOA scenarios (**Error! Reference source not found.**), the one clear trend is the advance of a rid savanna grasslands. Unit: percent of total Delta under savanna.

(2) **Delta outflow.** The Thamalakane/Boteti River receives outflows from the Delta and is highly susceptible to the flooding regime of the Delta and the state of groundwater aquifers. It experiences dry and wet years of several years duration. When wet, it provides substantial support to fishing and agricultural activities and wildlife. Unit: percent of 200 km of river length that is dry.

Limitations of the approach /method

With only three indicators for the Highlands and two for the Delta, the results will not necessarily match those from the MSIOA study. There, the responses of up to 23 hydrological and 70 biophysical indicators per site/scenario were combined to provide a prediction of the overall ecosystem shift, although with no consideration of the possible effects of climate change. In doing so some of the greater individual positive or negative results were ameliorated. The approach taken here – to choose noticeably flow-sensitive indicators – loses the nuances of change that would have been provided by the full suite of indicators. To match the MSIOA results as closely as possible, the outcomes for the selected river and Delta indicators were calculated to show their combined value under the MSIOA scenarios – this is the 'no climate change' value shown in each scenario assembly in the next section.

It follows that different single indicators in this study could have produced somewhat different results, but the overall predicted trend is felt to be accurate. Due to time limitations, the ecological model DRIFT was not re-run for the climate change adjusted scenarios and so all predictions of change are based on the MSIOA predictions plus expert opinion.

None of the MSIOA scenarios in TDA included a wetter future and so predictions of change linked to increased rainfall have not been formally analysed. Strictly speaking, increased flows due to climate change, as projected in *some* of the climate scenarios would be a move away from the baseline near-natural situation (i.e. a negative change). Such increases have been here scored as positive; however, as they are relatively small and will probably benefit the system, maintaining the status quo to some extent as abstractions increase.

The three levels of change allowed in the climate change analysis were a coarse measure that did not allow the full nuance of changes to be illustrated.

Predicted impacts of climate change

The predictions of change (Tables 10, 11 and 12; and Annex 4) are shown for:

- Highlands: Mucundi, Kapaka and Mohembo
- Delta: Permanent swamps in the east, plus Boteti outflow.

The results mirror the predictions made in the TDA and MSIOA studies. The complete system could remain in a Conservation A/B condition under the Improved Livelihoods scenario as long as development was undertaken in a careful low-impact way (Table 10). If climate change was towards a slightly wetter future, this condition status could be maintained, but if it was towards a drier climate, the ecosystem would decline to a much poorer condition (condition D: lower Working River) with the river perhaps drying out in its middle reaches for some part of the year and the Delta shrinking so that encroaching savanna could expand to possibly double to treble its present extent.

Table 10 **Predicted change in overall ecosystem condition, with and without climate change, for MSIOA scenario LS1.**

BASIN AREA	MSIOA SCENARIO	CLIMATE PROJECTION	THEME	TIME PERIOD		
				Baseline	2016-2035	2046-2065
Highlands	*LS1*	No climate change	*Environment*	0.00	0.00 A/B	0.00 A/B
		Higher probability	*Environment*	0.00	0.00 A/B	0.00 A/B
		Lower probability	*Environment*	0.00	-3.00 D	-3.00 D
Delta	*LS1*	No climate change	*Environment*	0.00	0.00 A/B	0.00 A/B
		Higher probability	*Environment*	0.00	0.00 A/B	0.00 A/B
		Lower probability	*Environment*	0.00	-3.00 D	-3.00 D

The presence of Mucundi Dam, in scenario LS3, could initiate a flattening or reversal of the flow hydrograph as dam operation manipulated flows to store floods and release water on demand downstream. The dry season releases could double the size of the natural flow, with implications for plants and animals that depend on the quite predictable flows at that time. Habitats, juvenile fish, birds' nests and food organisms could be washed away. People harvesting river resources in the dry season could see these washed away, swamped or inaccessible due to the higher flows. The higher releases in the dry season would be possible because of the storage of floods in the dam's reservoir, which could reduce downstream flood volume by up to 25%. This would reduce flooding (depth, extent, duration) of floodplains with a concomitant loss of their productivity in terms of grazing for livestock and wildlife, other resources used by people, groundwater recharge, and tourism. The river from Mucundi downstream to the Cuito confluence could decline to a borderline B/C condition (condition upstream of the dam is not considered in this analysis), but revers toward a B condition under wetter climate change conditions (Table 11). It is predicted that it would decline to an E condition in a drier future. The delta would fare a little better due to inflows from the Cuito, but would still show a strong decline to Condition E in a drier climate.

Table 11 **Predicted change in overall ecosystem condition, with and without climate change, for MSIOA scenario LS3.**

BASIN AREA	MSIOA SCENARIO	CLIMATE PROJECTION	THEME	TIME PERIOD		
				Baseline	2016-2035	2046-2065
Highlands	*LS3*	No climate change	*Environment*	0.00	-1.33 B/C	-1.33 B/C
		Higher probability	*Environment*	0.00	-1.33 B/C	-1.00 B
		Lower probability	*Environment*	0.00	-3.00 E	-3.00 E
Delta	*LS3*	No climate change	*Environment*	0.00	-1.50 B	-1.50 B
		Higher probability	*Environment*	0.00	-1.50 B	-1.50 B
		Lower probability	*Environment*	0.00	-3.00 E	-3.00 E

Scenario LS6 would further degrade the river ecosystem, from a Condition D with no climate change, to a slight improvement to Condition C under a wetter climate or a decline to a severe Condition E in a drier future (Table 12).

Table 12 **Predicted change in overall ecosystem condition, with and without climate change, for MSIOA scenario LS6.**

BASIN AREA	MSIOA SCENARIO	CLIMATE PROJECTION	THEME	TIME PERIOD		
				Baseline	2016-2035	2046-2065
Highlands	*LS6*	No climate change	*Environment*	0.00	-3.00 D	-3.00 D
		Higher probability	*Environment*	0.00	-3.00 D	-2.00 C
		Lower probability	*Environment*	0.00	-3.00 E	-3.00 E
Delta	*LS6*	No climate change	*Environment*	0.00	-3.00 D	-3.00 D
		Higher probability	*Environment*	0.00	-2.00 C	-2.00 C
		Lower probability	*Environment*	0.00	-3.00 E	-3.00 E

Under that drier future, with four dams and extensive upstream commercial agriculture, potential flows at Mohembo could decline by more than half in every month of the year and by up to 70% in the months January to April. The specifics of Delta condition under this scenario have not yet been modelled.

Conclusion

The environmental analysis shows that the impact of climate change on the basins environment is potentially severe. Even without development if the lower probability climate scenario is realised the Okavango delta will fundamentally change with a significant deterioration in water quality, biodiversity and land cover. Subsequent sections in this report on economic and social impacts will explore the consequences of this in more detail.

The MSIOA development scenarios with greater levels of water abstraction do adversely affect the basin with the river potentially declining from a pristine status to a working river status even if there is an increase in water availability under the more likely climate scenario. This would suggest that in terms of the environment the level and sequencing of development will need to be very carefully looked at in order to mitigate the potential adverse impacts of development in all the most likely future climate scenarios.

As the Okavango Basin stands poised on the brink of possibly quite substantial water-resource development, the three Member States have a rare opportunity to practice truly sustainable development of a near-pristine system (King and Chonguiça, 2016). The descriptions of change in this document do not map a historical decline in a river ecosystem, as it would in so much of the world, but a potential future decline. In doing so, it provides technical information of a nature that has only become available to decision makers in the last 2–3 decades (King *et al*. 2014). It alerts the three Member States to a potential decline in the condition of their shared resource that would be transboundary in nature, and to the basin-wide collaborative planning that would be required to address their national objectives without compromising the Okavango's global and local value. Guiding them is OKACOM's stated objective of an economically prosperous, socially just and environmentally healthy Cubango-Okavango River system and Basin.

Some of the considerations regarding the natural resource base that OKACOM and the countries face as they continue their discourse are (King *et al*., 2014):

- supplying water and sanitation to those who do not have this would have a modest negative impact on the river ecosystem for a high return in human wellbeing;
- irrigated agriculture on highly unsuitable soils would have by far the greatest negative impact on the river system;
- the Okavango system is a vital part of the southern African mosaic of wetlands that supports both resident and migrant birds and other wildlife, and would need to maintain its ecological status to ensure their long-term viability.

Impact assessment: Economics

Introduction

To support climate resilient development planning, it is important that the impacts of projects are considered from an economy-wide perspective (i.e. going beyond the costs and benefits of individual projects to consider how projects will impact on the wider economy). The economy-wide impact of specific adaptation projects, however, is often neglected outside of the use of integrated assessment models (and even here it is very rare) (Productivity Commission, 2012). This contrasts with the standard way in which the economic impact of infrastructure projects is more broadly considered, whereby an assessment of the economy-wide impact of projects using economic models is typically included.

The merging of adaptation and climate resilience thinking into more conventional development planning is complicated by the fact that a consensus on best practice techniques for economic appraisal of adaptation activities has not yet emerged (Watkiss, 2015). This is partly due to the existing differences in general economic appraisal practices in developing countries, and reflects an increased number of stakeholders becoming involved in adaptation activities – many of whom have different views of how economic appraisals should be undertaken. A greater focus on mainstreaming adaptation into existing policy and development planning, as opposed to treating adaptation as a singular activity, however, will lead to greater use of existing sector and development planning practices. This is expected to lead to a greater uptake of existing economic appraisal approaches and methods in these areas being applied to adaptation projects.

For this reason it was decided to use a fairly standard economic modelling approach to consider the possible impact a number of development options could have on the overall development trajectory of the CORB, and to consider how climate change could alter the expected impact of these development options over time. The impact of individual MSIOA development scenario options were translated into changes in the size of economic sectors in Angola, Namibia and Botswana. These impacts were further adjusted based on climate change projections.

Methodology

Information from the MSIOA process was used to estimate the impact of development projects on economic sectors.[13] The impact of development projects on the following sectors was considered:

- **Agriculture** – The production of cereals, rice, sugar and fruits/vegetables and nuts (also including horticulture) increased via irrigated agriculture projects (Angola and Namibia)
- **Water distribution** – An increase in urban abstraction increased the volume of formal sector water sales (Angola, Namibia and Botswana)

[13] All information used to calculate the likely impact of MSIOA scenarios on sectors, the value of tourism in Botswana linked to the CORB, and the value of livelihoods income within the CORB was obtained from MSIOA content shared with the project team.

- **Electricity** – The size of the electricity sector increased by the estimated KWh output from hydropower projects linked to multipurpose dams (Angola)
- **Tourism** – The tourism sector in Botswana was impacted by reduced water flow rates in the delta (Botswana)

Furthermore, the spending power of households in Angola, Namibia and Botswana was increased due to the value of safe drinking water reducing health care costs and increasing their productivity. The monetary values used to calculate this increase in spending power (USD/m3) were taken from the MSIOA documentation. The livelihoods value of the CORB was also captured by adjusting the spending power of households within the three countries, as assumed to be impacted by changes in water flow within the three countries.

In all cases, the impact of sectors were scaled using external data sources (referenced in Annex 5) to only reflect the value of activities in the CORB. Increases in agriculture, for example, were scaled in relation to the total hectares of the relevant crop already being grown in a country.

The possible impact of climate change on the different MSIOA development scenarios was considered by using the changes in water flow under the different climate change projections, generated via hydrological modelling, to scale the impacts of the development projects on the economic sectors and household income. It was assumed that the all impacts varied in direct relation to changes in water flow in the relevant country.

The impact of the proposed activities was modelled using the multi-region Global Trade Analysis Project (GTAP) Computable General Equilibrium (CGE) model. CGE models are widely used in policy analysis and development planning, and are increasingly being applied to modelling the economy-wide effects of planned adaption activities ((Liu, Hertel, & Taheripour, 2016; ECONADAPT, 2016). CGE models simulate the functioning of an economy by explicitly considering the links between different sectors. A change to one sector effects both the sectors that provide goods and services to the sector in question, and the sectors that use the goods and services produced by a sector (in addition to economic actors like households, governments etc. that derive income from all of these sectors). An overview of the economic model is provided in Annex 5.

The GTAP model generated six indicators that were used to measure the economic impact of the different scenario assemblies.

- **Change in real Gross Domestic Product (GDP).** Despite its shortcomings from a sustainability perspective (e.g. ignoring externalities and changes in natural capital), GDP growth is still the main metric used to measure economic performance. The change in GDP was calculated in real (i.e. excluding the impact of inflation) USD millions, and expressed as a percentage of the baseline GDP for the country/region.
- **Change in welfare**. The impact of interventions on national welfare is calculated using the Equivalent Variation (EV) indicator. Any significant change within an economy leads to decisions that impact resources utilisation, resources rents and costs, lending and borrowing rates, and whether to use local or imported inputs. Depending on the structure of the economy and the nature of the intervention, these changes could enhance or reduce welfare. The EV calculates the equivalent direct cash injection (or withdrawal) in nominal millions of USD that would be required to mimic the welfare

impact because of the abovementioned choices. For the purposes of the current analysis, the EV was expressed as a percentage of the baseline GDP of the relevant country/region to be directly comparable. The EV is considered a more holistic indicator of the welfare of the residents of a country than GDP.

- **Change in government revenue**. Apart from the obvious importance of government revenue to provide government services, adapting to climate change is expected to place an increased burden on government finances. The GTAP model generates change in net government revenue (taxes minus subsidies) in nominal USD millions. The change in revenue was expressed as a percentage of the baseline government revenue in the country/region to be comparable.
- **Change in trade balance**. A deterioration in a country's trade balance (exports minus imports) can lead to a shortage of foreign exchange required to service foreign currency-denominated debt and fund the imports of goods and services that cannot be competitively produced within the country. The trade balance is measured in nominal millions of USD. A negative change indicates that imports have increased relative to exports, whereas a positive change indicates that exports have increased relative to imports. As with the other indicators, the change in the trade balance is expressed as a percentage of the original trade balance in the country/region.
- **Change in unskilled labour**. This indicator measures the amount of unskilled labour that is utilised within an economy. Labour quantities within the GTAP model are provided as normalised units of labour per dollar in wages to be comparable between countries. While it is not possible to directly compare the 'units' of labour, the normalised nature of the units means that it is possible to compare the percentage change between countries. The indicator is therefore presented as a percentage change in the supply of unskilled labour (which is fully utilised within the model) within a country or region. An increase in this indicator indicates a reduction in unskilled unemployment, whereas a reduction signifies an increase in unskilled unemployment.
- **Change in proportion of wage income to unskilled labour.** This indicator was included in the analysis in response to a request at the OKACOM workshop during March 2017 that the impact of the development scenarios on equity be considered. This indicator measures the proportion of income to all labour that is paid out to unskilled labour (a description of the different labour categories is provided in Annex 5). The indicator is calculated by comparing the proportion of total wage income paid to unskilled labour before and after the interventions included in the MSIOA development scenarios, and then expressing the change in proportion as a percentage of the original proportion. For example, a change from 30% to 20% would be shown as a 33.3% reduction in the proportion of wage income paid out to unskilled labour.

The table below shows the rating scale used to assign rating scores to indicators. Any values that fell by more than 2.5%, but less or equal to 3.5% was assigned a rating score of '-3' (strong negative), for example, whereas any indicator values that increased or decreased by less than half a percent received a score of '0' (neutral). This rating scale was used for all indicators except 'Change in government revenue'. For this indicator, a larger scoring range was used to account for the fact that governments often experience relatively large variations in tax revenue over time. The table below was used to score changes in government revenue.

Indicator change thresholds - Change in government revenue	Indicator score	Indicator change thresholds - other indicators	Indicator score
-7.0%	-3	-3.5%	-3
-5.0%	-2	-2.5%	-2
-3.0%	-1	-1.5%	-1
-1.00%	0	-0.50%	0
1.00%	1	0.50%	1
3.00%	2	1.50%	2
5.00%	3	2.50%	3

As with the environmental and social impact analyses, the colour code system described in Section 2 was used to denote the magnitude of impacts.

Limitations and possible future refinements to the economic impact methodology

A limitation to the current assessment approach is that the full value of natural capital and ecosystem services (beyond livelihood values) has not been considered. Impacts associated with some of the broader ecological impacts mentioned in Section 7 (e.g., impact of large scale irrigation on soils, encroachment of savanna in the Okavango Delta) were not yet considered. The results of the economic impact assessment should thus be considered together with that of the social and environmental assessments, and this approach should be seen as an intermediate step to conducting economy-wide impact analysis that includes natural capital[14] (and possibly social value of ecosystems) in the analysis.

Furthermore, national-level GCE models only provide an indication of the economy-wide impact of interventions. It is thus not possible to speculate what proportion of a given impact will be felt within the CORB as opposed to the wider national economies. As a rule of thumb, however, the more underdeveloped an area

[14] In order to facilitate the study of water scarcity, the water-focused GTAP-BIO-W variant of the standard GTAP model was created that includes information on rain-fed versus irrigated agriculture coverage, cropland area and yields, and water use by river basin (Taheripour, Hertel, & Liu, 2013; Liu, Hertel, & Taheripour, 2016). The Okavango river basin, however, is not currently included in the GTAP-BIO-W database. This is possibly due to the fact that while Namibia and Botswana are included in the latest GTAP database Angola, is grouped with the Democratic Republic of the Congo (DRC).

(as is the case with most of the CORB), the smaller the proportion of the nationwide impact that is expected to materialise in the area. The reason for this is that most of the inputs, goods and services required by new developments are likely to come from more developed areas (or from imports). The additional employment linked to a greater demand for fertilizer spurred by agricultural developments in rural areas, for example, is more likely to materialise in more industrialised parts of a country where fertilizer factories are likely to be located (like the capital), than in the rural area where agricultural activities are located. This contrasts with the increase in employment linked to the agricultural activities themselves, which will happen where the projects are located. For activities that require specialised skills or experience, however, even the location of projects may not benefit the local communities as much as expected as most jobs would most likely go to more skilled immigrants (in the absence of dedicated programmes to upskill local labour). **It may thus be useful in the future to consider the economic impact of development projects by scoring both the local and economy-wide economic impacts of development options.**

Unfortunately, the capital investments linked to the interventions included in the MSIOA development scenarios were not available, and could therefore not be included in the economic modelling. Investment costs typically have large impacts in GCE models as they tend to support capital accumulation and productivity increases within sectors. Investments also tend to create stronger links to other sectors within the economy than simply assuming an increase in the size of a sector. The reason for this is that while the latter option only increases the amount of typical inputs used by a sector, large investments also lead to increased demand for capital goods and other investment-linked goods and services in addition to the typical inputs used by certain sectors. **The inclusion of investment costs in future modelling exercises would thus provide a more accurate indication of the true expected economic benefit of development options.**

Due to time and information constraints, it was only possible to use the static version of the GTAP model in the current analysis. Static models effectively calculate the impact of interventions within a single period and do not allow for capital accumulation and continued productivity growth over time. Dynamic versions of the GTAP model explicitly allow for endogenous capital accumulation and productive growth over time, and can currently generate impacts stretching out to the year 2100. While the results for the period 2016-2035 is likely to be relatively accurate (particularly since it is not clear when many of the proposed activities will be undertaken) using the static GTAP model, the model is not able to provide an accurate estimation of the impacts of actions over the 2046-2065 period. The information requirements for using dynamic CGE models is however much more onerous than for static models, and requires the development of a baseline development trajectory over time (as opposed to a static baseline for a point in time for static models). Also, given the central role of capital accumulation over time, it is important that both the size and timing of investments are available. These issues notwithstanding, **it may be useful in future to use a dynamic CGE model to consider the very long term development impacts of different development scenarios.**

An additional possible area of improvement relates to how a changing climate change impacts different sectors and activities. During the current assessment, only changes in water flow was considered, and a linear relationship between water flow and impacts were assumed (so a 10% reduction in water flow in Botswana reduces livelihood values by 10% and causes a 10% contraction in the tourism sector within the Delta). In future, it may be useful to consider the expected impact of climate change on economic activities in more detail drawing on local knowledge and expertise. The tourism sector may be influenced more by the environmental integrity of the CORB (as highlighted by the environmental impact assessment in Section 7), for example than by changes in water flows. Some activities like agriculture and power generation may be less sensitive to small changes in water flow than say rural livelihoods, but subject to thresholds effects that lead to large discrete impacts. Furthermore, climate impacts other than average water flow (like the length of the rainy season or temperature extremes) may also have a significant impact on activities like agriculture and tourism. **Closer interaction with local sector exports, and the teams undertaking the social and environmental assessments, could allow a more sophisticated analysis of the expected impact of climate change on key economic sectors, which would lead to more accurate economic impact assessments.**

Lastly, it may be possible to reflect policymakers' preferences more accurately in the scoring of economic impacts using multi criteria decision analysis techniques. The current analysis assumed that policymakers placed equal weights on all six economic indicators, and that the preferences of policymakers in the Highlands and the Delta were similar. It would be useful to test these assumptions in the future *before* the analysis is undertaken. Furthermore, equal importance was assigned to similar sized impacts in the different countries. Given the fact that the GDP per capita in Botswana is much higher than in Angola or Namibia, it is possible that development gains of a similar magnitude may be valued more highly in the Highlands than in the Delta. Policymakers may also have asymmetric loss functions, and may value larger impacts exponentially more than smaller impacts, or the risk of a large negative impact may carry more weight for decision-making than the possibility of an equally sized positive impact. These effects, should they exist, could be reflected both in the indicator weightings and the constructed scales used assign ratings to changes in indicator values.

Economic impact by scenario assembly

The economic impact scoring of the different scenario assemblies used the CIVAT tool and methods described in Section 2 and summarised below. The detailed scoring of the expected impacts of each assembly on the Highlands (Angola and Namibia) and the Delta (Botswana) are shown in Annex 5, as are the absolute indicator values generated (expressed as a percentage of baseline values) that were transformed to indicator ratings as described in the previous section. The changes in the size of sectors as a result of the scenario assemblies that were fed into the model as inputs to generate the modelling results are also shown in Annex 5.

Table 13 **Summary of economic impact of LS1 scenario assemblies**

BASIN AREA	MSIOA SCENARIO	CLIMATE PROJECTION	THEME	TIME PERIOD		
				Baseline	2016-2035	2046-2065
Highlands	*LS1*	No climate change	*Economic*	0.00	0.00	N/A
		Higher probability	*Economic*	0.00	0.00	N/A

		Lower probability	*Economic*	0.00	0.00	N/A
Delta	*LS1*	No climate change	*Economic*	0.00	0.00	N/A
		Higher probability	*Economic*	0.00	0.00	N/A
		Lower probability	*Economic*	0.00	-0.83	N/A

The LS1 development scenario is not expected to lead to any significant impacts on the development trajectories of the Highlands or the Delta in the absence of climate change, or under the Higher Probability climate projection. Under the Lower Probability climate projection, however, a weak negative impact on the Delta is expected (whereas the impact on the Highlands remains neutral). The weak negative impact on the Delta is driven by a weak negative reduction in GDP, welfare and the proportion of total wages going to unskilled labour. There is also negative impact on the utilisation of unskilled labour, which points to an increase in unskilled unemployment under the Lower Probability climate projection. These impacts are driven by a reduction in the size of the tourism sector and a reduction in household income (because of reduced livelihood income values), which is linked to a reduction in water flow in the Delta in this scenario assembly.

Table 14 **Summary of economic impact of LS3 scenario assemblies**

BASIN AREA	MSIOA SCENARIO	CLIMATE PROJECTION	THEME	TIME PERIOD		
				Baseline	2016-2035	2046-2065
Highlands	*LS3*	No climate change	*Economic*	0.00	1.17	N/A
		Higher probability	*Economic*	0.00	0.83	N/A
		Lower probability	*Economic*	0.00	0.17	N/A
Delta	*LS3*	No climate change	*Economic*	0.00	0.00	N/A
		Higher probability	*Economic*	0.00	0.00	N/A
		Lower probability	*Economic*	0.00	-1.00	N/A

The LS3 development scenario (Table 14) is expected to have a significant positive impact on the Highlands under all climate projections, ranging from a weak positive impact under the Lower Probability climate projection to a positive impact under the No Climate Change projection. It should be noted, however, that the input values to consider the economic impact the LS3 assemblies with the No Climate Change and Higher Probability climate change projections were identical for Angola and Botswana. They did however differ for Botswana. The difference in impact ratings under the No Climate Change and Higher Probability climate change projections is thus expected to be driven by trade linkages between Angola, Namibia and Botswana. This is borne out by the fact that the Change in Trade Balance indicator value is strongly positive for the Highlands under the No Climate Change projection ('3') and only positive ('2') under the Lower Probability climate projection. The change in unskilled labour supply is also reduced from a positive ('2') impact under the former projection to a weak positive one ('1') under the latter projection. Given the similarity in the input values underlying the impact modelling for these two assemblies, it is also likely that at least part of the difference in outcome is explained by the uncertainty inherent in the modelling process.[15] For this reason, it is probably most useful to consider the likely impact of LS3 on the Highlands as positive or weak positive.

The Delta is not expected to be significantly impacted under the No Climate Change and Higher Probability climate change projections, but could experience a weak negative impact under the Lower Probability climate projection. This weak negative aggregate impact is generated by a weak negative reduction in GDP, fall in welfare, and reduction in the proportion of total wage income that goes to unskilled labour. It also includes, however, a strongly negative fall in unskilled employment.

Table 15 **Summary of economic impact of LS6 scenario assemblies**

BASIN AREA	MSIOA SCENARIO	CLIMATE PROJECTION	THEME	TIME PERIOD		
				Baseline	2016-2035	2046-2065
Highlands	*LS6*	No climate change	*Economic*	0.00	1.50	N/A
		Higher probability	*Economic*	0.00	1.50	N/A
		Lower probability	*Economic*	0.00	0.33	N/A
Delta	*LS6*	No climate change	*Economic*	0.00	-0.17	N/A
		Higher probability	*Economic*	0.00	-0.33	N/A
		Lower probability	*Economic*	0.00	-1.50	N/A

Unsurprisingly, the scale of the economic impacts of the LS6 development scenario increases across the climate change projections as increased water abstraction from the CORB compounds the variability in water flow created by the impacts of climate change (Table 15). The positive impacts on the Highlands ranges from

[15] While CGE models do not include a stochastic term, and are thus by definition deterministic, they do require the simultaneous solving of numerous non-linear equations. The choice of solving algorithm, the size of the shock modelled the structure of the underlying economy and so forth can all affect the accuracy of the modelled results. For more information see https://www.copsmodels.com/webhelp/rungtap/index.html?hc_solmethod.htm. The Gragg solving method was used to increase model accuracy.

weak positive in the Lower Probability climate projection to positive in the No Climate Change and Higher Probability climate change projections.

The aggregate economic impact on the Delta, by contrast, varies from weak negative (under the No Climate Change and Higher Probability climate change projections) to negative (under the Lower Probability climate projection). All the individual indicators for the Delta also show negative ('-2') impacts, except for Change in Government Revenue (which is neutral) and Change in Unskilled Labour (which is exhibits a strong negative impact ('-3')). The strong negative impact on unskilled employment is expected given that the reduction in water flow is assumed to reduce the size of the tourism industry. Tourism is typically a sector that absorbs a relatively large amount of unskilled labour.

Conclusion

No nationally significant economic benefit to the countries in the basin is expected to materialise due to the activities included in the **LS1 development scenario** under any of the climate projections in either the Highlands or the Delta. Under the Lower Probability climate projection (with its accompanying significant reduction in water flow along the CORB), however, there is the risk that it may have a weak negative economic impact on the Delta. Considering only the economy-wide economic impact, thus, this development scenario assembly creates the risk of a weak negative impact within the Delta without any tangible benefits to offset this risk. From a purely national economic perspective, this does not seem to be an attractive development scenario.

The **LS3 development scenario** is expected to generate a positive or weak positive economic impact on the development trajectory of the Highlands under all the climate change projections. The Delta is not expected to experience any significant economic impacts under the No Climate Change and Higher Probability climate change projections, but could be a weak negative impact should the Lower Probability climate projection materialise. Positive or weak positive economic impacts in the Highlands are thus traded-off against no or weak negative impacts in the Delta. Although it is true that the aggregate impacts mask more significant negative impacts in specific areas (like unskilled employment in the Delta), LS3 does at least offer the possibility of positive impacts in the Highlands without significant negative economic impacts in the Delta. It thus seems to present a more balanced development option with limited downside risk in the Lower Probability climate future. Having said that, the Lower Probability climate future is a realistic possible future outcome. It would thus be wise to consider ways in which the potentially negative individual economic impacts on the Delta can be addressed. This is particularly true of a reduction in unskilled employment, which is likely to be politically problematic.

The **LS6 development scenario** performs similarly to LS3 in terms of the benefits expected to accrue to the Highlands (ranging from weak positive to positive), but creates a wider range of possible negative economic impacts on the Delta. Under this scenario the Delta is negatively impacted under all the climate change projections, ranging from weak negative under the No Climate Change and Higher Probability climate change projections to negative under the Lower Probability climate projection. Also, unlike in LS3, there is no possibility of a positive impact on the Highlands without a corresponding negative impact on the Delta.

Furthermore, whereas the worst outcome under LS3 was close to a neutral impact between the two basins (with a weak positive impact in the Highlands and a weak negative impact on the Delta), there is a greater change of a net negative impact under the Lower Probability climate projection for LS6 as this would lead to a weak positive impact on the Highlands and a negative impact on the Delta. Given the range of probable climate change outcomes, LS6 does thus seem to be an inferior option to LS3 as it includes the same expected positive impact on the Highlands combined with a larger expected negative impact on the Delta.

LS3 does seem to be the most climate resilient development option when considering economic impact in isolation and not considering thresholds (a state where infrastructure become non-viable). It includes the same possible development benefit to the Highlands across all climate projects as LS6 (and is superior to LS1), but includes a smaller expected negative impact on the Delta in the event of the less beneficial climate projection becoming reality.

When considering the results above, however, a few caveats are in order. Economy-wide (national) economic impact analysis downplays the impact of developments on the local communities. Consider the impact of a 52% reduction in streamflow (from status quo) for the Delta. Given the assumption of linear impacts, this means that the tourism industry within the Delta will halve under this assembly. Considered from a country perspective, however, there is a much smaller impact. Based on MSIOA and World Travel and Tourism Council (2017) data, the Delta is responsible for 21.2% of the tourism sector's contribution to GDP in Botswana. This means a 52% reduction in the size of the tourism sector within the Delta, which will have a devastating impact on local communities, only reduces the size of the tourism sector within Botswana with 11% - which in turn has a much less severe impact on the wider Botswanan economy. The same is true for the livelihood value that households derive from the CORB. The MSIOA analysis shows the livelihoods income from the Delta $38m per annum. But this is less than 1% of household income in Botswana. So while halving this will have dire consequences within the Delta, it has a trivial impact on the wider Botswanan economy. The very factors that make households in the Delta so vulnerable to the impacts of climate change, the fact that they are poorer than average and have "few economic resources to rely upon when exposed to climate shocks and stresses" (see Section 9), also mean that changes in their incomes are difficult to observe in national data. This is the main reason why the large economic impacts posited in the hydrology section (Section 6) to accompany the drastic expected decreases in streamflow do not show up in the economic impact modelling.

Two more caveats related to the environmental impact modelling are also relevant. Firstly, because of the assumption of linear impacts, reductions in streamflow lead to predictable, constant and continuous impacts on sectors. Consequently, moving from LS1 to LS3 under the Lower probability climate projection leads to a relatively small negative modelled economic impact on the Delta. According to the natural environment impact assessment in Section 7, however, the Delta drops a category from a 'D' (Largely modified) to an 'E' (Seriously modified) ecosystem rating. So not only is this a significant impact change, but it is debatable what the remaining value of the Delta is to certain sectors like tourism (particularly when compared with other tourist destinations within Botswana and the region). Secondly, average annual streamflow was used as a proxy for climate change impact on sectors, and an increase in streamflow was assumed to have a positive impact on sectors and a reduction in streamflow a negative impact. This ignores the fact that annual averages may (and does in this case) hide changes significant season impacts. And as highlighted in both the hydrology and the environmental impact sections, a reduction in streamflow during the wet season and an increase in flow during the dry season can have significant economic impacts (either indirectly via a change in habitat or directly via impacts on agriculture and tourism).

Therefore, while analysing economic impact at a national level is appropriate when considering the impact that interventions within the CORB may have on the development trajectories of the OKACOM member countries, it is more useful for comparing different development options than considering the extent of impacts within the CORB. In future, thus, it may be desirable to combine economy wide and local economic impact analysis to generate a more balanced set of indicators that address both national development aspirations and the welfare of local communities.

Impact assessment: Social

Introduction

This section explores the projected social impacts of the three MSIOA development scenarios and the three corresponding climate change projections. Understanding potential social impacts of water infrastructure development is critical for ensuring that the proposed infrastructure is not only environmentally sound and benefits national economies, but also uplifts individuals, households, communities and villages in a culturally appropriate, equitable, and inclusive manner. Understanding and planning for social impact management is a central goal in the case of the CORB water infrastructure development because of the high rate of poverty and marginalization that already exists in this area.

Large infrastructure projects, including those proposed by the MSIOA scenarios, such as dams, commercial agriculture, and urban water supply, can have a wide range of both positive and negative social impacts. In terms of positive social impacts, these projects can create access to clean drinking water and sanitation, electricity, provide flood control, access to roads and transportation, income and employment opportunities, improved health and nutrition. All of these positive impacts can catalyse further positive outcomes like improved levels of education, commercial activity, and ultimately improved standards of living and well-being.

However, large infrastructure projects can also generate a range of negative social impacts, mostly related to increased economic activity and land-use, which can disturb social cohesion, catalyse rapid cultural change, and displace households and communities from their land, disturbing livelihoods and placing the most vulnerable individuals at an especially high risk of negative social outcomes. Potential social impacts can vary at different spatial scales (upstream, downstream, village, national level), and at different times (during planning and design, during construction, during operation).

The effects of climate change can further exacerbate negative social impacts and lessen the effects of positive social impact through direct climate effects (e.g., heat stress) and resource scarcity on households and associated communities. This can manifest through an increase in the frequency of extreme weather events, such as droughts or floods, and general degradation of natural resources which the community might rely on, such as fish stocks, medicinal plants, drinking water, soil, and others. These climate change impacts can create social stress and undermine social cohesion and wellbeing.

In this exercise, four social indicators were chosen with aims to generate a holistic picture of potential positive and negative social impacts of the MSIOA development scenarios and climate change projections.

Methodology

The exploratory social impact assessment carried out provides a high level starting point and structure for further distilling the potential social impacts of each of the MSIOA development scenarios under different levels of climate change. The assessment of social impacts could not benefit from the availability of model based or measured indicator data to the same extent as the assessment of economic and environmental impacts, and relies more heavily on practitioner experience with similar projects globally, as well as engagement with key stakeholders and key experts in the climate, environment and economics domains.

The following four social indicators were chosen to represent potential social impacts of the development scenarios:

1. Access to electricity
2. Urban access to water
3. Influx
4. Land and housing disruption

The first two indicators aim to measure the extent of positive impact of large-scale infrastructure on communities, while the latter two highlight the extent of potential negative consequences for communities, with a focus on highlighting potential impact on the most vulnerable and rural segments of society, which may have more barriers than others in being able to benefit from proposed development. This mix of positive and negative indicators aims to create a balanced and holistic picture of the social impacts of the proposed infrastructure projects.

Rationale, definitions, scoring and limitations

The following is a more detailed description of each indicator and the methods for assessment. For each of the four indicators the rationale for choosing the indicator is presented along with definition and scoring approach, and finally a brief overview of limitations.

Indicator 1: Access to electricity

Rationale for indicator: Electrification was chosen as one of the two positive indicators because it is one of the most pressing needs of the communities living with the Cubango/Okavango Water Basin. Widespread household electrification in the basin would have a substantial positive impact on living standards in this area, allowing households to have a higher standard of living by enabling economic activity, education, communication, secure access to a safe energy source, etc. Electrification would also have positive environmental impacts by removing the major cause of small-scale deforestation and would lead to positive health impacts, by removing the need for cooking via fuel-burning stoves within the home. Electrification also enables wider economic growth by allowing enterprise development and enabling tourism.

Definition and scoring approach: Access to electricity calculations were based on the extent of proposed MW capacity within each MSIOA scenario, for each country. The indicator assumes a positive linear relationship between increase in MW capacity and extent of access to electricity for communities. This is clearly dependent on the details of the actual development when it occurs and assumed that local communities will benefit from large regional/national level infrastructure as well as smaller locally focused interventions. It is not always the case that large scale infrastructure benefits local populations, so specific recommendations will need to be made and met.

Climate change impacts generally lessen the positive impacts of electrification from hydropower by introducing higher uncertainty and variability in the energy supply due to the destabilization of climate. As a result, scenarios that contain significant climate change impacts (as outlined in Section 7) include a slight scoring discount to account for the negative impacts of climate change.

Limitations: Due to lack of more detailed information, the indicator assumes equitable supply of electricity to all communities. It is important to note that in reality, more remote communities or those less represented by an organized and networked leadership, and/or those with political influence, may not benefit as much as others from electrification. In fact it may be cheaper to use off grid electricity solutions to provide access to remote rural communities. It could also manifest through gaining access to electricity much later than others, experiencing a higher likelihood of power outages during scarcity, or not gaining access to electricity at all.

The scoring approach is also unable to take into account any electricity-sharing between countries, because no estimates for such an arrangement are available. As a result, since all dams within the proposed scenarios would be located in Angola, all electricity access benefits are accounted for in Angola only, and therefore only show up in the Source portion of the basin.

Indicator 2: Urban access to water

Rationale for indicator: Access to water and sanitation is the second positive social indicator. Access to clean water and sanitation presents a variety of connected and knock-on positive impacts, such as improved health and time saved from fetching water, both of which support higher rates of education, gender equality, economic productivity, etc.

Definition and scoring approach: Urban access to water was calculated by using the urban water abstraction figures presented in each MSIOA scenario. A positive linear relationship was assumed between million cubic meters of urban water abstracted and extent of urban water access.

Impacts of climate change are accounted for in the scoring of this indicator similarly to the methods of the first indicator (electricity access). The final social impact score for each climate change projection is discounted where climate change impacts are the most severe, reflecting the possibility of water shortages, which would lead to a decreased level of water access, despite the extent of the infrastructure. Particularly if there are nexus type trade-offs between energy, food and water that need to be resolved.

Limitations: As for the access to electricity indicator, due to the lack of more detailed information, the urban access to water indicator assumes equitable supply of electricity to all communities and is not able to account for any potential inequities or differentials in potential water supply.

Indicator 3: Influx

Rationale for indicator: Influx is not necessarily a positive or a negative phenomenon, but when not managed well, it can place significant stress on natural resources, social services, infrastructure and structures within a community or settlement. Influx is typically triggered by hopes for employment (e.g. during dam construction), and/or as an attempt to secure improved standards of living associated with the positive changes brought about by the project. Influx management is critical to managing the negative impacts of increased population numbers. When managed well, influx can bring economic growth and positive social change to a community. However, when unmanaged, it can have a profound negative impact on community members' wellbeing. As a result, for the purposes of this assessment, influx was chosen as a negative indicator.

Definition and scoring approach: The influx indicator measures the potential extent of in-migration into existing communities as a result of improved access to electricity (based on proposed dam MW), water (based on proposed urban water abstraction), and increase in availability of unskilled employment (based on calculations from the economic assessment).

A positive linear relationship was assumed between increase in water access, electricity access, and unskilled job creation, and level of potential influx.

Climate change impacts were accounted for in scoring via the unskilled employment figures, which had already embedded impacts of climate change. Therefore no additional discounting was implemented to account for the potential impacts of climate change.

Limitations: Electricity access, water access, and job availability are only rough indicators of influx, and do not account for many other factors that may contribute to influx. As a result, this indicator should be interpreted as a rough indication of the possibility of influx, rather than a certain one.

In addition, as noted above, influx on its own does not necessarily only have a negative social impact. This is only the case if/when influx is not carefully managed. For the purpose of this exercise, it is assumed that no influx management is undertaken.

Indicator 4: Land and housing disruption

Rationale for indicator: Land and housing disruption refers to the negative impact that can be experienced by individuals, households, and entire communities due to either economic or physical displacement from their land, due to land needs of large-scale infrastructure projects, such as commercial farming or dam construction. This can be caused by projects that require land, thus causing the involuntarily or voluntarily displacement of households (via relocation) or restricted access to natural resources previously used for livelihoods (grazing land, pathways and routes used daily for economic activity, access to water, etc.). Displacement can have detrimental economic and psychological impacts on households and individuals, and can also lead to speculative activity and opportunistic influx into the area from individuals wanting to be compensated. Households and individuals without land deeds or rights to their land are especially vulnerable and risk not being compensated adequately to ensure long-term livelihood sustainability.

More specific social impacts of displacement include potential conflict between family members and/or households, psychological effects such as loss of sense of place or cultural identity, long-term livelihood implications, decreased marketability of skills in host communities, and many others.

Definition and scoring approach: This indicator relies on the extent of the projected land use of large-scale water infrastructure to calculate social impact. More specifically, the scoring takes into account the land to be used for commercial agriculture and the size of proposed dams, to project the extent of physical and economic displacement that may result. A positive linear relationship is assumed between the amount of land to be used for commercial agriculture, the capacity of the dam, and the potential extent of land and housing disruption.

Climate change impacts do not manifest within this indicator, as the decision to displace households in order to develop infrastructure does not directly interact with the effects of climate change. As a result, this indicator does not use any discounting to account for negative climate change impacts.

Limitations: As with the first negative indicator (influx), the proposed commercial agriculture land and dam capacity are not perfect indicators of potential displacement. Size of population around the proposed projects is not taken into account. Therefore, this indicator is a rough indication of potential impact rather than a precise calculation.

Scoring

Each indicator is scored on a 7-point scale, with zero indicating no change from the baseline state, -3 indicaitng a strong negative relative to other options and +3 indicating a strong positive relative to other options. This scoring is as described further in Section 2. Within the social impact analysis all score values are relative, rather than absolute. The scores only indicate potential movement towards more positive or more negative impacts, in relation to impacts of other scenarios, within each given indicator and country. As a result, scores are comparable with one another within each country and within the indicator category. However, scores are not comparable between different countries or between different indicators, as such a comparison would require absolute values for indicators. Comparing scores between different countries, or between different indicators, is akin to 'comparing apples to oranges'.

Further, a score of 3 does not indicate an absolute highest positive social impact, but rather the highest positive social impact possible within the given range of the three MSIOA scenarios. Negative scores must also be viewed similarly – a -3 score does not indicate an absolutely worst outcome, but rather an outcome that is the most negative only in relation to the other scenarios.

Discussion of impacts

The following section presents the findings of the social impact analysis. The findings are divided into two parts – the Highlands and Delta.

Social Impacts in the Source

Table 16 **Summary of social impacts in the Highlands**

MSIOA SCENARIO	CLIMATE SCENARIO	THEME	TIME PERIOD	
			Baseline	2016-2035
LS1	No climate change	*Social*	0	-0.25
LS1	High probability	*Social*	0	-0.25
LS1	Low probability	*Social*	0	-0.25
LS3	No climate change	*Social*	0	-0.5
LS3	High probability	*Social*	0	-0.5
LS3	Low probability	*Social*	0	-1
LS6	No climate change	*Social*	0	0
LS6	High probability	*Social*	0	-0.25
LS6	Low probability	*Social*	0	-0.75

Table 16 provides a summary view of estimated net social impacts in the Highlands for each MSIOA scenario and each climate scenario. The scores for each of the four social indicators are averaged and presented in the above table as 'net impact' score for each assembly. Social impacts of most assemblies indicate net zero impact (slightly negative scores such as -.25 and -.75, count as zero, since they do not reach -1).

According to this aggregation of scores, MSIOA scenario LS6 under no climate change results in the **best social impact outcome of net zero effect**. On the other hand, MSIOA scenario LS3 under low probability climate change projection results in the **most negative social impact of -1**.

It is important to note that much of the granularity of the social impacts in this summary table is not visible due to two positive scores cancelling out the two negative scores, resulting in a near-zero average for each scenario.

The two positive indicators – access to electricity and urban access to water – generally increase (in a positive direction) as we go from LS1, to LS3, to LS6. This is because additional infrastructure creates capacity to serve an increasing number of people. Some of these positive benefits are stifled in the Low Probability Climate Change Projection due to the negative effects of climate change, however.

The trends for the positive social indicators in the Highlands can be summarised by the following:

- In all LS1 assemblies (no climate change, high probability and low probability), electricity access scores 0 and urban water access scores 1.
- In LS1, no major difference was reflected between no climate change, higher probability and low probability climate change, as it was estimated that the positive livelihoods impacts of this scenario outweigh the impacts of climate change. However, it is important to note that in this scenario, under lower probability climate change, ecosystem conditions are projected to be at D (a “working” river condition, see Section 7), which, although not reflected in the scoring as it is not granular enough, could in reality lead to worse social impacts.
- In the L3 assemblies, under no climate change and under high probability climate change, electricity access scores 1 and urban water access scores 2. In the low probability climate change urban water access drops back down to 1, due to climate change impacts discounting (in this case ecosystem conditions drop to ‘E’, an unacceptable level).
- In the LS6 assemblies, under no climate change and under high probability climate change, electricity access scores 2 and urban water access scores 3. Under the low probability climate change projection both of the indicators drop, with electricity access at 1 and urban water access at 2 (this is, again, due to ecosystem conditions dropping to the unacceptable level ‘E’).

The two negative indicators – influx and land and housing disruption – generally increase (in a negative direction) as we go from LS1, to LS3, to LS6. This is because additional infrastructure and the land that it takes up and commercial activity it generates tends to increase the probability of influx and land and housing disruption.

The trends for the negative social indicators in the Source can be summarised by the following:

- In all LS1 assemblies (no climate change, high probability and low probability), influx and land and housing disruption score -1.
- In the L3 assemblies, under no climate change and under high probability climate change, influx scores -2 and land and housing disruption scores -3. In the low probability climate change both indicators drop to -3 (due to level ‘E’ ecosystem conditions).
- In the LS6 assemblies, under no climate change influx scores -2 and land and housing disruption scores -3. Under both of the climate change projections both of the negative social indicators drop to -3.

Social Impacts in the Delta

Table 17 **Summary of social impacts in the Delta**

MSIOA SCENARIO	CLIMATE SCENARIO	THEME	TIME PERIOD	
			Baseline	2016-2035
LS1	No climate change	*Social*	0	0
LS1	High probability	*Social*	0	0
LS1	Low probability	*Social*	0	0
LS3	No climate change	*Social*	0	0.25
LS3	High probability	*Social*	0	0.25
LS3	Low probability	*Social*	0	0.25
LS6	No climate change	*Social*	0	0.75
LS6	High probability	*Social*	0	0.75
LS6	Low probability	*Social*	0	0.5

Table 17 provides a summary view of estimated social impacts in the Delta for each MSIOA scenario and each climate scenario. Social impacts of all assemblies indicate net zero impact (slightly positive scores such as .25 and .75, count as zero, since they do not reach 1).

According to this aggregation of scores, MSIOA scenario LS6 under no climate change and MSIOA scenario LS6 under high probability climate change result in the **best net social impact outcomes** with scores of 0.75 out of a possible 3.00.

The electricity access indicator remains 0 in all assemblies in the Delta, due to no dams being built in Botswana. For urban water access, the previous trend of a positive increase from LS1, to LS2, to LS3 is true in the Delta, except for under the low probability climate change scenario, where urban water access scores begin to decrease in LS3 and LS6 due to the impacts of climate change (where ecosystem conditions are projected to reach level 'E').

Land and housing disruption indicator remains 0 in all assemblies in the Delta, due to no dams or commercial agriculture plans in any of the scenarios. The influx indicator is -1 in some of the LS1 and LS3 scenarios, but becomes neutral (0) in LS 6.

The scores for the Delta are slightly more positive than the scores for the Highlands. This is because the majority of the infrastructure projects that would have a significant impact on land use and would cause an increase in commercial activity are located in the Highlands. In fact, there are no dams or commercial agriculture schemes planned in the Delta portion of the basin. Therefore, negative social impacts in the Delta tend to be much less significant. Positive social impacts are also slightly less significant than in the Highlands, due to no anticipated electricity access benefit, since dams are located in Angola.

It is important to reiterate that scores are relative to one another, and do not represent an absolute level of ‘acceptability’ of a certain scenario in terms of social impacts. This is especially evident in how the scoring represents the potential impacts of climate change. Overall, the impacts of climate change as represented in the scoring could be viewed as underestimated. Social impact scores take into account unacceptable levels of ecosystem conditions as caused by climate change (i.e. projected level ‘E’ ecosystem conditions) through discounting of scores by 1, however, this discounting is not able to fully represent the true and far-reaching repercussions of this level of environmental change. Therefore, for a fuller understanding of potential environmental changes of the development scenarios, it is important to read the social impacts section along with Section 7 and Section 8, and not treat it as a stand-alone or comprehensive assessment.

Conclusion

In terms of achieving some of the most pressing societal needs, namely access to water and electricity as a proxy, the MSIOA scenario LS6 appears to be the most attractive option, followed by LS3, for both areas of the basin. However, when combined with the Low Probability climate change scenario, LS6 begins to lose some of its advantage, due to the significant climate change impacts.

LS6 and LS3 come with the greatest potential negative social impacts, mainly due to the large land requirements of the projects and likelihood of increased influx into the project area and associated settlements. These negative social impacts, however, can be mitigated to a certain extent through sound stakeholder engagement and impact and risk management tailored to the local context and specific project. Potential environmental impacts of climate change, however, may not be possible to mitigate once a certain ecological threshold is crossed, and therefore these impacts should be very carefully considered within LS3 and LS6 scenarios.

As mentioned above, both negative and positive social impacts appear less significant in the Delta than they do in the Highlands, indicating that special attention may need to be paid to management of social impacts in the Angolan and Namibian parts of the basin.

It is also crucial to reiterate that positive and negative social impacts of large infrastructure projects do not have homogenous impacts at national, regional, local, and household levels. This analysis has largely considered national-level impacts (especially within the water access and electricity access indicators), due to the lack of more detailed data. However, it is equally important to undertake more detailed local impact assessments to understand how existing local political, economic, cultural, and socioecological conditions might impact the ability to fully benefit from the proposed infrastructure development of the various groups existing within the Okavango delta area. The land & housing disruption and influx indicators are more representative of potential impacts at a local level and provide a starting point for further, more detailed analysis.

In terms of the breadth of indicators chosen, this exercise has aimed to provide a rough indication of the possible social impacts of the chosen assemblies. A more detailed and evidence-based study would be required to understand in more granularity how the proposed assemblies might affect other important societal outcomes.

Aggregate impacts

Hydraulic infrastructure development projects count as some of the most ambitious undertaken by humans, requiring major effort and investment, promising significant payoffs and producing a web of wide ranging, lasting and complex impacts. The development options envisioned through the World Bank's MSIOA initiative fit this description well. Except for the LS1 scenario that is closest to baseline, the LS3 and LS6 scenarios examined in this project involve large-scale, ambitious interventions with the intention to address some of the key economic and human development priorities of the three countries in the Okavango river basin.

As illustrated by the possible impacts revealed by the thematic assessments, the impacts are diverse, in several cases very significant and sometimes contradictory. They also indicate that taking the consequences of climate change into account when considering the impacts and operating conditions of infrastructure is a must. The assessments showed that climate change particularly at the higher-end (though rated as less likely) RCPs can produce impacts that may require a reassessment of the desirability of some of the development scenarios or call for the development of new ones.

However, thematic assessments alone provide a fragmented picture. In reality, impacts would be closely coupled, synergistic and combined for which the rules of cumulative impact assessment would apply. One must consider "the total impacts of multiple actions on a receptor", where a receptor could be a geographical area with its baseline and future framework conditions, an action could be a plan or programme or a social trend, and actions could have occurred in the past, present or future (Therivel 2005).

Discussing cumulative or aggregate impacts from this perspective requires, among others, the consideration of the patterns of impact across climate and development scenarios and scenario assemblies; changes in the positive or negative status and severity of impact and the direction of change over time where projections are available; synergies or contradictions between impacts across the different themes; and any significant differences in terms of the projected magnitude of impact. Furthermore, there is also a need to consider differences in impact between the Highlands and Delta section of the river. While climate projections were limited to a higher and lower probability RCP cluster, the possibility of climate outcomes that go even beyond the lower probability (i.e., more intensive) climate future were also touched and their aggregate consequences would need to be weighed.

Aggregate impacts are discussed based on the summary sheet in CIVAT that both presents the combined results of thematic assessments and produces an aggregate of their results (Table 18 and 19). Aggregated impact results have been calculated for all scenario assemblies but only for the 2016-2035 time period, as due to data and methodological limitations (and time constraints) economic and social projections were not available for 2046-2065. In calculating the aggregate scores, a simple average of environmental, economic and social components was used with equal weights, as there was no rigorous basis for the establishment of differential weights. Differential weighting and other more complex details relevant for considering vulnerability and resilience of the Okavango river basin as a dynamic, complex adaptive system, such as non-linear connections between the different parameters, tipping points, critical thresholds and levels of uncertainty could be considered through a more detailed investigation (Folke et al. 2003).

The following are some high-level observations with regard to key patterns observable across the thematic assessments or their aggregate results.

Table 18 **Aggregate scores for Highlands for all scenario Assemblies**

MSIOA SCENARIO	CLIMATE SCENARIO	THEME	TIME PERIOD		
			Baseline	2016-2035	2046-2065
LS1	No climate change	*Environmental*	0.00	0.00	0.00
LS1	High probability	*Environmental*	0.00	0.00	0.00
LS1	Low probability	*Environmental*	0.00	-3.00	-3.00
LS3	No climate change	*Environmental*	0.00	-1.33	-1.33
LS3	High probability	*Environmental*	0.00	-1.33	-1.00
LS3	Low probability	*Environmental*	0.00	-3.00	-3.00
LS6	No climate change	*Environmental*	0.00	-3.00	-3.00
LS6	High probability	*Environmental*	0.00	-3.00	-2.00
LS6	Low probability	*Environmental*	0.00	-3.00	-3.00
LS1	No climate change	*Economic*	0.00	0.00	
LS1	High probability	*Economic*	0.00	0.00	
LS1	Low probability	*Economic*	0.00	0.00	
LS3	No climate change	*Economic*	0.00	1.17	
LS3	High probability	*Economic*	0.00	0.83	
LS3	Low probability	*Economic*	0.00	0.17	
LS6	No climate change	*Economic*	0.00	1.50	
LS6	High probability	*Economic*	0.00	1.50	
LS6	Low probability	*Economic*	0.00	0.33	
LS1	No climate change	*Social*	0.00	-0.25	
LS1	High probability	*Social*	0.00	-0.25	
LS1	Low probability	*Social*	0.00	-0.25	
LS3	No climate change	*Social*	0.00	-0.50	
LS3	High probability	*Social*	0.00	-0.50	
LS3	Low probability	*Social*	0.00	-1.00	
LS6	No climate change	*Social*	0.00	0.00	
LS6	High probability	*Social*	0.00	-0.25	
LS6	Low probability	*Social*	0.00	-0.75	
LS1	**No climate change**	***Combined***	**0.00**	**-0.08**	
LS1	**High probability**	***Combined***	**0.00**	**-0.08**	
LS1	**Low probability**	***Combined***	**0.00**	**-1.08**	
LS3	**No climate change**	***Combined***	**0.00**	**-0.22**	
LS3	**High probability**	***Combined***	**0.00**	**-0.33**	
LS3	**Low probability**	***Combined***	**0.00**	**-1.28**	
LS6	**No climate change**	***Combined***	**0.00**	**-0.50**	
LS6	**High probability**	***Combined***	**0.00**	**-0.58**	
LS6	**Low probability**	***Combined***	**0.00**	**-1.14**	

Significant differences between thematic scores - As an overall pattern, one of the most striking features of the thematic impact assessments is the significant difference between economic, social and environmental scores. The pattern applies equally to both the Highlands and Delta and affects mainly LS3 and LS6, the two MSIOA scenarios with more aggressive infrastructure development portfolios. There is agreement across thematic assessments with regards to the impacts of LS1 being largely neutral, except for a mild negative impact on social conditions in the Highlands and except under low probability scenarios where impacts would go from neutral to highly negative in both the Highlands and Delta, indicating a potential nonlinear impact.

***Geography matters* –** Not surprisingly, there is a rather striking difference between the sensitivity of the Highlands and Delta sub-region to climate change and the way they react to development options. At the overall level the Delta is more sensitive, and apart from the almost uniformly neutral combined effect of climate and development in the baseline and lower climate scenarios, it exhibits a higher degree of negative impact. Impact of a reduction in rainfall in the Highlands Portion of the basin is more severe than that of a decrease in the Delta Portion of the basin.

Climate change matters – The project provides conclusive evidence that climate change is a critical factor that can fundamentally change the impact profile and desirability (or at the extreme end even feasibility) of hydrological infrastructure development projects. Almost without exception, the negative impact of climate change increases along the baseline → lower probability climate change → higher probability climate change trajectory. The only difference here is that under LS6 and high probability climate change in the Delta the impacts may be slightly moderated due to the possible increase of precipitation in the Highlands that moderates the impact on the Delta's water supply.

In terms of achieving some of the most pressing societal needs, namely access to water and electricity, the MSIOA scenario LS6 appears to be the most attractive option (as long as local beneficiaries are identified and protected by law in the final project designs) , followed by LS3, for both areas of the basin. However, when combined with the Low Probability climate change projection, both scenarios lose some of their advantage due to the possibility of significant negative climate change impacts.

While climate change can result in significant impacts, at some point it becomes a major disruptive force. One such possibility is that under the lower probability projection precipitation in the Highlands area may decrease by 25%, resulting in an 58-66% reduction in streamflow at the entrance to the Delta. These are dramatic reductions that are far more severe than the impact of any level of the studied levels of development. These may also tip the threshold below which large expensive infrastructure becomes a significant stranded asset.

Table 19 Aggregate scores for Delta for all scenario assemblies

MSIOA SCENARIO	CLIMATE SCENARIO	THEME	TIME PERIOD		
			Baseline	2016-2035	2046-2065
LS1	No climate change	*Environmental*	0.00	0.00	0.00
LS1	High probability	*Environmental*	0.00	0.00	0.00
LS1	Low probability	*Environmental*	0.00	-3.00	-3.00
LS3	No climate change	*Environmental*	0.00	-1.50	-1.50
LS3	High probability	*Environmental*	0.00	-1.50	-1.50
LS3	Low probability	*Environmental*	0.00	-3.00	-3.00
LS6	No climate change	*Environmental*	0.00	-3.00	-3.00
LS6	High probability	*Environmental*	0.00	-2.00	-2.00
LS6	Low probability	*Environmental*	0.00	-3.00	-3.00
LS1	No climate change	*Economic*	0.00	0.00	
LS1	High probability	*Economic*	0.00	0.00	
LS1	Low probability	*Economic*	0.00	-0.83	
LS3	No climate change	*Economic*	0.00	0.00	
LS3	High probability	*Economic*	0.00	0.00	
LS3	Low probability	*Economic*	0.00	-1.00	
LS6	No climate change	*Economic*	0.00	-0.17	
LS6	High probability	*Economic*	0.00	-0.33	
LS6	Low probability	*Economic*	0.00	-1.50	
LS1	No climate change	*Social*	0.00	0.00	
LS1	High probability	*Social*	0.00	0.00	
LS1	Low probability	*Social*	0.00	0.00	
LS3	No climate change	*Social*	0.00	0.25	
LS3	High probability	*Social*	0.00	0.25	
LS3	Low probability	*Social*	0.00	0.25	
LS6	No climate change	*Social*	0.00	0.75	
LS6	High probability	*Social*	0.00	0.75	
LS6	Low probability	*Social*	0.00	0.50	
LS1	**No climate change**	***Combined***	**0.00**	**0.00**	
LS1	**High probability**	***Combined***	**0.00**	**0.00**	
LS1	**Low probability**	***Combined***	**0.00**	**-1.28**	
LS3	**No climate change**	***Combined***	**0.00**	**-0.42**	
LS3	**High probability**	***Combined***	**0.00**	**-0.42**	
LS3	**Low probability**	***Combined***	**0.00**	**-1.25**	
LS6	**No climate change**	***Combined***	**0.00**	**-0.81**	
LS6	**High probability**	***Combined***	**0.00**	**-0.53**	
LS6	**Low probability**	***Combined***	**0.00**	**-1.33**	

Choice of development options matter – At the overall level there is a clear gradient in terms of overall impact between the MSIOA scenarios. With the exception of LS1 under baseline of high probability conditions in the Delta, all other scenario assemblies have a negative score. Based on the aggregate level the LS1 scenario appears to be the most favourable, LS3 is the same or more negative, while LS6 is almost without exception and with a significant gradient received the lowest score. As mentioned earlier, these aggregates of course hide significant differences that are an important part of the story. For example, increased precipitation in the Highlands under some climate projections can to some extent offset the effects of downstream water abstraction for irrigation.

Of more interest is the trend observed for LS3, under this scenario, where the hydrograph shows how the increase in streamflow (as a result of the increase in precipitation) generates a mean monthly hydrograph very similar to the present day situation i.e. offsetting/mitigating the reduction in flow as a result of approximately 66 000 ha of irrigated agriculture and the generation of hydropower through a large dam at Mucundi. Likewise, under certain conditions reservoirs can help even out intra-annual streamflow variability in the Delta.

While environmental scores for LS3 and LS6 are alarmingly low for both the Highlands and Delta under both higher and lower probability climate change, economic scores in the Highlands under both climates are the positive range. Without questioning the plausibility of the thematic projections, this is clearly an area for further investigation to understand trade-offs and the interlinkages between different parts of the same system. The question is whether economic (and social) progress can be positive under sharply negative ecological conditions, or whether there are economic development strategies within these MSIOA scenarios that can mitigate ecological impacts by using suitable technological solutions. The question of how to plan expensive infrastructure in such uncertainty is difficult when the less likely potential negative impacts are profound and the more likely positive benefits minor when examined at the national level

Implications of extreme climate – As discussed earlier, the two SOM-based climate change projections used in the scenario assemblies (along with the present day climate) are believed to be likely with higher or lower degrees of certainty based on current knowledge. However, as it was also indicated in both the climate and hydrology sections, climate change intensity and impacts outside of the higher end of these projects are although not very likely, also not implausible. Considering the significantly and almost uniformly negative aggregate impacts of climate change on the trajectory of the scenario assemblies and the fact that climate impact associated with the lower probability climate shows a potential nonlinear gradient (i.e., the impact increment associated with more intensive climate change is higher at the margin), long-term infrastructure development may need to broaden the range of climate and related hydrology futures considered in its planning process.

Conclusions regarding the MISOA Scenarios

The hydrological modelling and analysis of indicated that a 25% reduction of rainfall in the Highlands Portion of the basin as indicated by the lower likelihood scenario (but still supported by a significant number of climate models) is likely to result in a much larger reduction in streamflow (65 to 80%) throughout the basin, including the Okavango Delta. These reductions will lead to a significantly altered system as a result of the severe change in the flow regime and reduction in water availability. However, the higher likelihood scenario showing a 5% increase in rainfall in the Highlands Portion of the basin is likely to result in significant increases in flows and water availability.

When looking at different components within the MSIOA scenarios the following observations can be made

- The urban abstractions, even those potential abstractions for Windhoek and the Central Area of Namibia and the Cuvelai, are small in comparison to large scale irrigation development. However, despite this, the initial MSIOA analysis had indicated that there is greater headroom for development within the basin than initially thought, including some areas of irrigation.
- The climate change analysis conducted under this CRDP process has indicated that under a scenario where there is reduction in rainfall the reductions in streamflow are amplified. In this context large scale irrigated agriculture will have an increasingly negative impact on the system. Under these conditions water availability in general will be significantly reduced and large abstractions, of any kind, will have to be carefully considered and planned, taking cognisance of the environmental and social requirements of the river. Consideration could be given to strategically positioned dams in order to create additional yield in the system to sustain abstractions for development. This, however, would have its own environmental impacts which would need to be considered and mitigated.
- Anomalies occur when large hydropower dams are introduced, especially those containing the Mucundi Dam on the main stem Cubango River (LS3, LS6 and LS9). The dam has negative and positive impacts depending on the levels of development within the system. It creates additional yield in the system which can be used to regulate flows and offset some of the abstractions upstream of it and sustain flows such that certain abstractions downstream are met. In addition, it can be used to regulate flows and maintain acceptable levels of environmental integrity. It should however be noted that large dams have their own environmental impacts such as alteration of flow regime and reduction of bed load sediment within the river.
- The thematic assessments all suggest that whilst the MSIOA option LS1, the programme of small local development, has the least negative impact in terms of environment, economy and social themes. It also has the least positive national impact in terms of the economy. Social impact analysis suggests that the high development options LS3 and LS6 have both the highest negative and positive impacts. The environmental analysis is unambiguous that the high development options will lead to severely negative impacts on the quality of the river. This negative environmental impact is qualitatively picked up in the economic analysis as potentially having a significant impact on tourism, but it is not picked up by the economic modelling due to a limitation in the methodology. Consequently, decisions on optimum level of development and the preferred MSIOA option come down to choices, between promoting local economic growth (LS1) vs maximising potential national economic growth (LS3, 6 and 9); adverse local environmental and social impacts in the delta and national economic development (LS3, 6, 9).
- Climate change analysis suggests there is a significant risk associated with high development scenarios (LS3, 6, 9) due to the lower likelihood climate scenario. If this climate scenario is realised (Note: it is supported by several individual climate models) then all the projected national economic

benefits of LS3, 6 and 9 will not be realised. Furthermore, the adverse climate impacts will be exacerbated under these development scenarios. In this case perhaps the development focus should shift to identifying a range of measures to protect the environmental integrity of the basin and its dependent livelihoods in the face of climate change, rather than maximising economic growth? In the event of the higher likelihood climate scenario then national economic development potential is maximised and there is additional room for development. However potential negative environmental and social impacts will need to be carefully considered.

- The ideal type of development within the basin is one that uses small amounts of water and generates a high level of economic benefit to the people within the basin. Through interaction with stakeholders within the basin these types of developments are not common. However, adaptive measures can be implemented to traditional development projects in order to make them less water intensive while still providing an economic benefit. These range from crop and irrigation method selection, rain fed agriculture, water conservation and demand management projects, to design measures in large dams to ensure environmental releases are met. All of this will improve the adaptive capacity of developments and improve the levels of climate resilience within the basin.

Recommendations for the MSIOA and related strategic planning

This project subjected selected hydrological infrastructure investment options developed through the World Bank's MSIOA process to an integrated assessment of their sensitivity and vulnerability to climate change. The technical analysis revealed new evidence indicating a pattern of impacts across a range of climate and development scenario assemblies discussed in the previous sections of the report. Based on these results a number of policy-relevant recommendations can be formulated for relevant stakeholders, including the governments of Angola, Botswana and Namibia, the OKACOM Secretariat (OKASEC), the MSIOA team and perhaps most importantly the communities and people of the Okavango basin who most directly experience the positive and negative consequences of development and climate change in their daily lives.

- **Options to reduce the potential impact of climate change on the basin should be developed**

  The climate projections and in particular the SOM based scenarios and extremes suggest there is a significant risk that the impacts of future climate change on the water availability in the CORB will be greater than the impact of even the most intense development scenarios prepared under the MSIOA project. *A study should be commissioned to look at options to reduce the impact of climate change on the Okavango basin. This study would need to look at institutional, green, blue and hard infrastructure solutions. It will also need to take into account the development scenarios prepared under the MSIOA project, as well as other relevant development proposals and plans within the basin. Finally, it would need to assess the level of their preparedness / adaptive capacity for institutions and stakeholder groups in the basin, which would enable capacity building to be targeted more efficiently*.

- **Require taking climate change impacts into account in infrastructure development planning**

  The analysis of global climate models covering the Okavango basin and the hydrological modeling based on these climate models provided new evidence about the possible impacts of climate change on the hydrology and broader environment of the region. Based on this evidence the impacts on both the social, economic and ecological system are likely to be significant, especially under the conditions of the lower probability (but more severe) climate change scenario. *Based on this, it is recommended that relevant authorities of the three countries should require any major future hydrological infrastructure development proposal to systematically consider the impacts of climate change as a matter of routine and from the beginning of the planning process*.

- **Strengthen and make use of cooperative frameworks for climate change resilience building and adaptation**

  As already outlined in the founding documents of OKACOM, the countries of the water basin recognized the importance of collaborative decisions making regarding matters that affect the region. Given the increasing risks and potentially significant impacts because of climate change and potential new infrastructure development, the need for such institutions will likely increase. *The recommendation is that the OKASEC and Member State representatives work towards strengthening the organization's capacity,* *make systematic use of its capacities in transboundary water resource planning, and strengthen its mandate to address climate change related to basin-wide issues.*

- **Advance infrastructure solutions that reduce vulnerability and help build resilience**

  The study revealed significant differences in the vulnerability profile of climate and development scenario assemblies depending on the type of hydrological infrastructure solutions they used. Given persistent poverty in the region, development is a must. But when advancing infrastructure development programs, nature based, ecosystem-friendly solutions such as locally controlled micro water-storage reservoirs that offer robust solutions across a wider range of climate futures at a reduced cost could be considered. *Authorities involved in infrastructure planning are recommended to integrate resilient, nature-based infrastructure solutions into the mainstream of their development plans.*

- **Smart climate finance**

  The project showed that due to changes in flow rates, pieces of large scale hydrological infrastructure can become stranded, non-producing assets. Building climate risk proactively into strategic plans not only helps reduce the exposure to potential large financial liabilities in the future, but also attract financing from donors and investors interested in climate finance with favourable conditions. *It is recommended that water infrastructure development should specifically and proactively target financing mechanisms such as the Global Climate Fund that are designed for projects that mitigate risk and build resilience across a range of possible climate futures.*

- **Socialization of infrastructure planning**

  As shown by the results of the project, countries, industries and communities in the Okavango basin benefit from infrastructure development and exposed to the risks of climate change in different ways – they are everyone's business. They require the active, timely and meaningful engagement of many, experts and non-experts in understanding their exposure, envisioning and elaborating development plans with their location, technical design, financing, operation and impacts all covered. *The recommendation is to ensure infrastructure planning processes to actively and transparently engage stakeholders, including particularly local communities and the most vulnerable in society in early stages and throughout the process of infrastructure planning to understand and address risks and maximize benefits for all.*

- **Development of climate resilient development pathways**

  The evaluation of the scenario assemblies building on the MSIOA scenarios and climate change projections showed significant differences in the risk profile and attractiveness of the different options. LS1 was attractive for its limited impact on ecosystem integrity, but left some of the acute social and economic needs inadequately addressed. LS2 performed worse on the ecological front but delivered more for social well-being and economic prosperity. At least under the present or high probability future climate LS3 did well on social and economic performance, but at a very high cost to ecosystem integrity. Based on the results of the project, it seems human needs cannot be adequately addressed at the present level of infrastructure development, however, infrastructure needs to be developed in a way that helps maintain water availability both in the Delta and Highlands at or close to historic levels, even under the conditions of climate change. *As these conditions didn't fully align in any of the scenario assemblies, the project team recommends that the stakeholders of the region build on the results achieved so far, and by taking into account new insights gained through this project they aim to move towards a climate resilient LSx scenario that best meets not only their needs but also the needs of the children and grandchildren.*

- **Sequence development**

  This CRDP assessment has shown that there is significant uncertainty around the extent of climate change. Furthermore one of the two more likely future climate scenarios would lead to a profound change in water availability in the basin. *Consequently in order to better manage uncertainty and the chance of significant adverse impact of developments, proposed developments should be carefully sequenced. If one of the MSIOA scenario's with significant infrastructure components is selected it should be implemented in stages so that its impact on the delta can be evaluated and adjustments in future plans made and the future climate changes considered as they occur*.

- **Scale and operate infrastructure for conservation**

  The hydrological modelling has shown that water availability will dramatically decrease throughout the year in most scenarios, time periods and parts of the basin. It is also likely that precipitation and temperature will become more variable and extreme. Consequently some additional storage in the upper catchment could become beneficial to the delta if it is operated in a way that is conducive to conservation. Infrastructure should be scaled and operated in such a way that sustainable levels of environmental flows are guaranteed in both in the upper and lowers sections of the Basin *It is recommended that all infrastructure proposals are developed keeping in mind a conservation purpose alongside economic and social purposes. Operation of the dams and irrigation infrastructure should take into consideration the views of all riparian states.*

- **Better understanding of the value of the natural capital to inform the approval of developments in the basin**

  The Okavango is practically a pristine river system with a unique contribution to global biodiversity. This contribution should be better understood and be used to inform the approval of different development scenarios in the basin. It is recommended that natural capital accounts be prepared for the basin in conjunction with strengthening monitoring capacity that can provide the evidence base for such accounts. This can also inform the need for infrastructure to increase climate resilience of the conservation value of the basin

  Natural capital accounts should be prepared for the basin to help inform future assessments of development proposals. This could also build on existing initiatives regarding innovative sources of financing (such as trust fund, impact offsets or even a possible PES scheme) to help finance more pro-poor climate resilient, transboundary developments. These innovative sources of finance should enable member states to assist one another to either forgo some infrastructure, develop alternative development options, or to develop and operate infrastructure it in a way that benefits the whole basin including *conservation. Monitoring capacity to create the evidence base for such innovative payment schemes should be developed.*

- **Targeting local beneficiaries**

  The positive benefits identified in the economic and social assessment chapters are largely dependent on the CORB area and poorest both benefiting from the development of the basin. It is well known that less developed areas and local people often do not benefit from large scale national infrastructure projects. *Approval of individual infrastructure projects should be contingent on local benefits and supply chains being understood and agreed to by all key stakeholders.*

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Annex 1: Projections

Climate Change Assessment for the Okavango Delta, Botswana, based on Self-Organising Maps

Background

The Okavango Delta, the world's largest inland delta, lies in the north-western corner of Botswana. The Delta itself lies in a relatively arid region, with semi-desert surrounding the area irrigated directly by the Okavango River; in rare, unusually wet, rainfall seasons water can escape from the Delta first into Lake Ngami to the south west, and in exceptional circumstances on to the Makgadikgadi Pans further south east, but otherwise all water entering the Delta either evaporates or sinks into the ground within the immediate region of the Delta.

Rainfall over the Delta itself is seasonal, as in most of southern Africa, but is insufficient to maintain the volumes of water. The main source of supply comes from the wetter highlands in central Angola (in the region near the city of Huambo), the river there being named the south-east flowing Cubango, before crossing the Caprivi Strip of Namibia and being renamed Okavango on entering Botswana.

A chart of the entire Cubango/Okavango drainage system, Figure 1 below, illustrates the extensive southern area of the system that rarely sees substantive flowing water. The current analysis is focussed, therefore, on the main source in Angola and the Delta within Botswana.

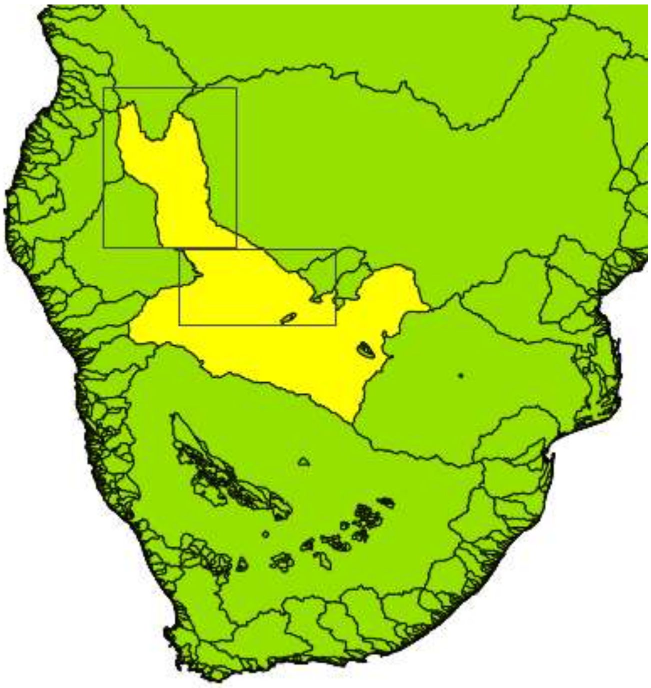


Figure 1. The Cubango/Okavango drainage basin, outlined in yellow. The black boxes outline the locations of the two analysis areas, the Source section in the north and the Delta section in the south.

The rainfall climatology of the Angolan Source section of the basin is somewhat different to that of the Botswana Delta section, not least in slight differences in timing of the rainfall, the positions of the two sections with respect to the main atmospheric systems providing the rainfall, and the topographies of the two sections. Given that, climate change scenarios have been created independently for the two regions outlined in Figure 1, the Source region in the north and the Delta section to the south.

The full set of global climate models within CMIP5, the grouping on which most of the major conclusions of the latest IPCC Assessment Report, the AR5, were based, has been used to calculate the scenarios. In other words, downscaling has not been used, including through the regional climate models (RCMs) of CORDEX AFRICA. RCMs have been demonstrated to provide some additional spatial and temporal information over mountainous terrain (perhaps relevant in the Source section) and near coasts (not pertinent here), but given the current state of development of these RCMs caution is recommended. For several climate change scenarios created previously for other regions the self-organised maps (soms) approach (see the Detailed Text document for a technical description of soms) was used in parallel for both the CMIP5 and the relevant CORDEX projection sets, with the consistent result that no further information not provided by the global models was made available by the RCMs. But with frequent exceptions in regards to certain results regarding rainfall projections, and in all cases these exceptions raised issues regarding the validities of the RCM projections. Development work continues with the RCMs, but at the present time these have not reached states such that they provide additional useful information over the global models, at the least within a soms analysis.

Earlier climate change scenarios derived through the soms approach have been created based on joint temperature and rainfall projections for all of the CMIP5 models. A modified methodology is used here with rainfall replaced by ‘rainfall less evaporation’, perhaps more useful in that it measures the water retained in the system. The change has been made based on certain recent analyses that suggest that, even in areas where rainfall is projected to increase in future, water availability might be reduced through increased evaporation associated with the higher temperatures. Nevertheless in order to provide a consistent background with earlier scenarios, the soms approach has been used additionally with just the rainfall.

Using model-calculated evaporation might introduce new uncertainties into the calculations (the main reason for also examining the standard temperature-rainfall soms as a comparison). As a rule of thumb, global climate models handle temperatures well in comparison to other parameters they are required to calculate, with rainfall being a rather more complex challenge. Calculating evaporation increases the difficulties yet again. According to the IPCC AR5 WGI Report (see p 791):

> However for specific data-rich sites, current land surface models still struggle to perform as well as statistical models in predicting year-to-year variations in latent and sensible heat fluxes and runoff.
>
> There are few evaluations of the performance of land surface schemes in coupled climate models, but those that have been undertaken find major limitations associated with the atmospheric forcing rather than the land surface schemes themselves.

Together these two statements effectively suggest that evaporation projections require care in their use – but the same can be said for the temperature and rainfall projections also!

The IPCC Background to Climate Change for the Cubango/Okavango Basin

In order to obtain an overview of the CMIP5 projections for the Okavango region Figures 2, 3 and 4 have been reproduced from Chapter 22 of the IPCC AR5 WGII Report (Fig. 2) and Chapter 12 of the IPCC AR5 WGI Report (Figs 3 and 4). Note that, following IPCC requirements, the full diagrams and captions have been reproduced; this includes some diagrams not relevant here and mention of certain Figures and Boxes of pertinence only within the IPCC reports themselves.

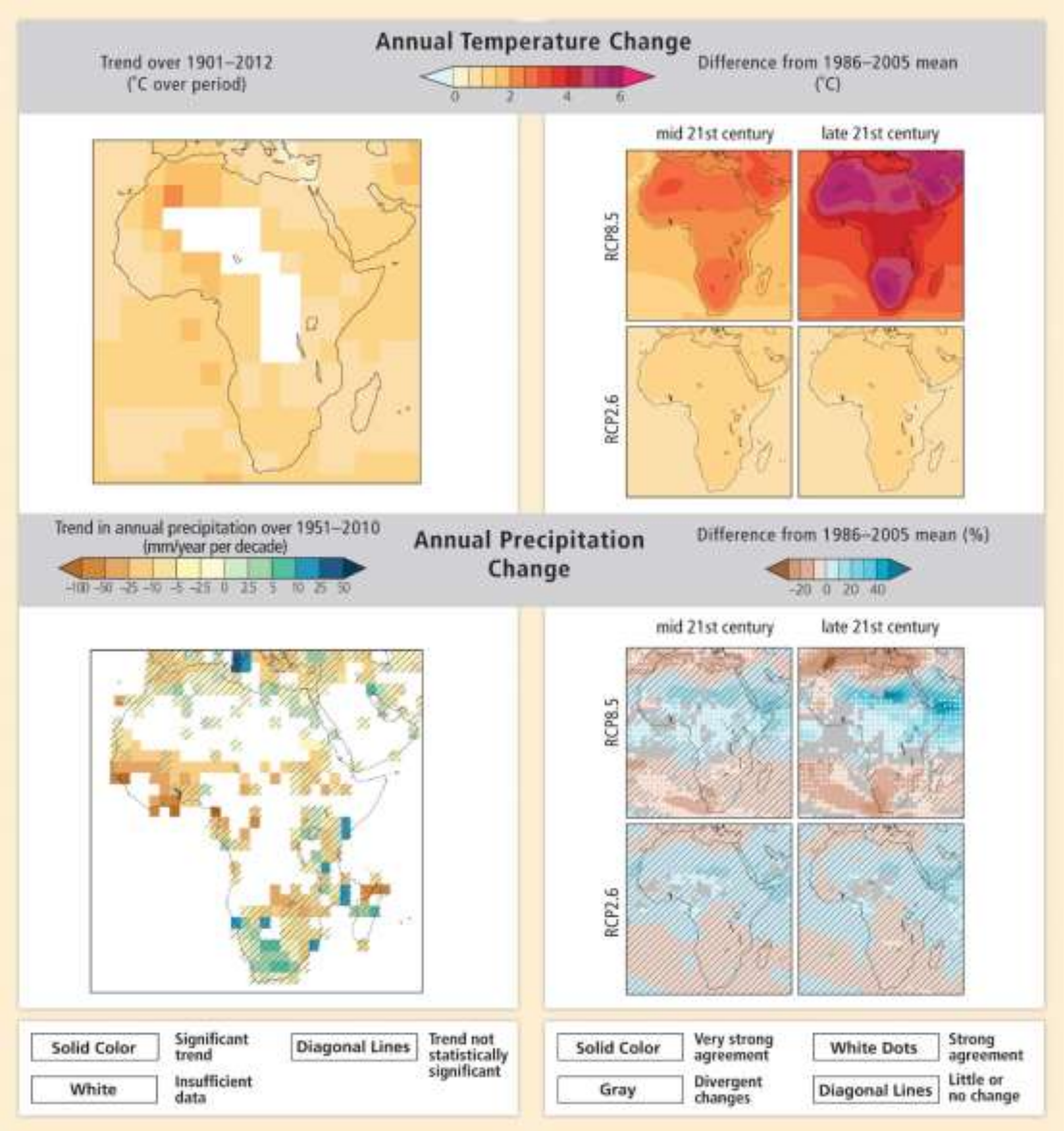


Figure 2. Observed and projected changes in annual average temperature and precipitation. (Top panel, left) Map of observed annual average temperature change from 1901–2012, derived from a linear trend. [WGI AR5 Figures SPM.1 and 2.21] (Bottom panel, left) Map of observed annual precipitation change from 1951–2010, derived from a linear trend. [WGI AR5 Figures SPM.2 and 2.29] For observed temperature and precipitation, trends have been calculated where sufficient data permit a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Solid colors indicate areas where trends are significant at the 10% level. Diagonal lines indicate areas where trends are not significant. (Top and bottom panel, right) CMIP5 multi-model mean projections of annual average temperature changes and average percent changes in annual mean precipitation for 2046–2065 and 2081–2100 under RCP2.6 and 8.5, relative to 1986–2005. Solid colors indicate areas with very strong agreement, where the multi-model mean change is greater than twice the baseline variability (natural internal variability in 20-yr means) and ≥90% of models agree on sign of change. Colors with white dots indicate areas with strong agreement, where ≥66% of models show change greater than the baseline variability and ≥66% of models agree on sign of change. Gray indicates areas with divergent changes, where ≥66% of models show change greater than the baseline variability, but <66% agree on sign of change. Colors with diagonal lines indicate areas with little or no change, where <66% of models show change greater than the baseline variability, although there may be significant

change at shorter timescales such as seasons, months, or days. Analysis uses model data and methods building from WGI AR5 Figure SPM.8. See also Annex I of WGI AR5. [Boxes 21-2 and CC-RC]

The top right-hand diagram of Figure 2 indicates that temperatures will rise over the Cubango/Okavango Basin, more so under RCP8.6 than under RCP2.6, and gives an indication that rainfall may decrease (lower right); the decrease under RCP2.6 is non-significant, but under RCP8.5 it does approach significance.

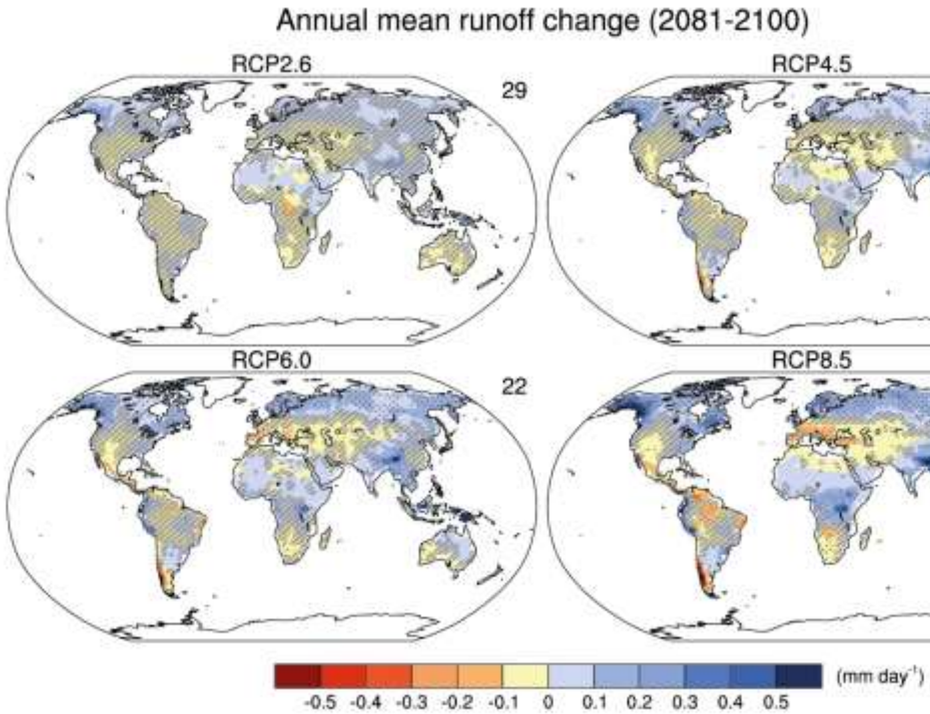


Figure 3. Change in annual mean runoff relative to the reference period 1986–2005 projected for 2081–2100 from the CMIP5 ensemble. Hatching indicates regions where the multi-model mean change is less than one standard deviation of internal variability. Stippling indicates regions where the multi-model mean change is greater than two standard deviations of internal variability and where at least 90% of models agree on the sign of change (see Box 12.1). The number of CMIP5 models used is indicated in the upper right corner of each panel.

Runoff has been illustrated in Figure 3, even though it is not being assessed directly in this analysis, but because the focus is on flow in the river. Across all RCPs there is a suggestion of a decrease in flow, but this becomes significant only at the higher RCPs, with a nominal value of an annual-average decrease equivalent to roughly 0.1mm/day of rainfall (about 35mm/year, or approximately 3.5% of the annual rainfall in the Source section).

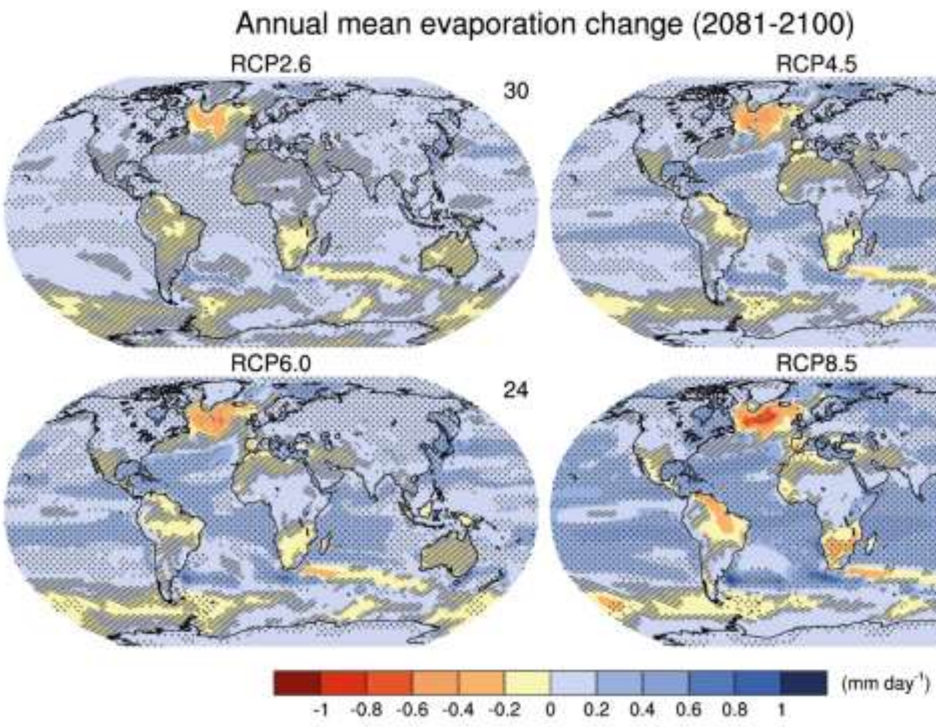


Figure 4. Change in annual mean evaporation relative to the reference period 1986–2005 projected for 2081–2100 from the CMIP5 ensemble. Hatching indicates regions where the multi-model mean change is less than one standard deviation of internal variability. Stippling indicates regions where the multi-model mean change is greater than two standard deviations of internal variability and where at least 90% of models agree on the sign of change (see Box 12.1). The number of CMIP5 models used is indicated in the upper right corner of each panel.

Evaporation decreases on average through the year (Figure 4) for all RCPs, but with significance only for RCP8.5. The decrease is nominally equivalent to about 0.1mm/day, a similar figure to the decrease in runoff according to Figure 3.

Thus in summary all three assessments, of rainfall in Figure 2, of runoff in Figure 3, and of evaporation in Figure 4, all point to a reduction in annual water availability by the end of this century, with no consideration of other factors, with a preliminary estimate of a reduction by about 5%, more so with the higher RCPs. Note however these estimates are based on ensemble means, and do not adequately reflect the more detailed assessments created using the soms approach.

Overview of analysis process

Calculations have been made using all CMIP5 projections for both sections, Source and Delta, independently, covering:

- All four emissions scenarios used in the IPCC AR5 – from 'low' to 'high' RCP2.6, RCP4.5, RCP6.0 and RCP8.5
- Three future time slots centred around 2025, 2055 and 2090
- Two separate areas – the Source section over Angola (12º15'-18º00'S, 16º15'-20º00'E) and the Delta section over Botswana (18º00'-20º30'S, 18º15'-24º00'E)
- Analyses across the full rainfall season of November to April, together with analyses for the early rainfall season of November to January and for the late rainfall season of February to April

- For temperature, maximum temperature, daily temperature range, rainfall and evaporation projections, ensemble means and standard deviations (the latter as a simple indicator of spread, with much improved indications of spread shown in the soms charts)
- SOMs analyses for both temperature against rainfall and for temperature against rainfall less evaporation
- A number of IPCC-defined 'extreme' measures calculated from the projections, as listed in the tables provided in the 'Detailed Text' document

Most of the extensive results sets are summarised in the 'Detailed Text' document supported by the various documents illustrating results (separately for the ensemble means, the standard deviations, and the two soms sets). The discussion within the 'Detailed Text' document begins with some considerations of the use of climate change projections, including discussion of their limitations, in a manner that provides essential background that should be borne in mind when reviewing the results. Only a broad outline of the main conclusions is provided below, together with a list of the recommended climate change scenarios (see the 'Detailed Text' document for details of the derivations of these scenarios).

In summary, the process followed has been:

- Calculate ensemble mean change values for all RCPs over both the Source and the Delta sections for temperature, maximum temperature, daily temperature range, rainfall, evaporation, and rainfall less evaporation – these are presented in the 'Ensemble Means Changes Diagrams' document and are discussed in the 'Detailed Text' document
- Calculate standard deviations of change across the ensemble for all RCPs over both the Source and the Delta sections for temperature, maximum temperature, rainfall, evaporation, and rainfall less evaporation – these are presented in the 'Ensemble Standard Deviations Diagrams' document and are discussed in the 'Detailed Text' document
- Calculate soms for rainfall together with temperature for all RCPs separately:
    - Individual soms charts (for specific sections – Source or Delta – and individual RCPs) are presented in the 'Soms Rainfall Temperature Diagrams' document
    - Tables are provided together with the soms charts that list the subjectively assessed scenarios for that specific section/RCP followed by a brief summary of the results; the intent is to characterise the main sequences in time through all three time slots as represented by the groupings of projections revealed by the soms – as this process is subjective there are occasions when different scenarios might be identified by a different analyst, but this is unlikely to adjust the overall results; the values given for temperature and rainfall in the tables are rough averages for all projections within a group, and thus extrema do not appear in the tables but are readily identified if required from the soms charts
    - A subjective quantitative assessment of likelihood for each scenario is provided also in the tables based on the tentative assumption that likelihood is represented by the numbers of projections within each sequence – use with caution
    - Based on the above, a summary table of scenarios is provided in the 'Detailed Text' document for each section and RCP separately, in which the main scenarios are listed but the quantitative likelihood values have been adjusted to qualitative statements such as 'Higher' and 'Lower'; a summary of the results and justification for the process providing the shortened results accompanies each table
    - Additional tables in the 'Detailed Text' document then summarise the scenarios by section and by higher and lower likelihood, to provide an overview of results from the previous scenario summary tables
    - From these tables the main scenarios as represented at higher and lower likelihood for each section are then provided in the 'Detailed Text' document – consistent with prior similar analyses it is possible to produce overarching scenarios that to a large

    extent capture the main sequences in time of all projections largely independent of RCP
  - Assess through a similar subjective process values to attach to each scenario of certain IPCC 'extremes; because of noisy variables done only for the full rainfall season and only in ranges (for detailed 'extreme' values by time slot see the 'Soms Temperature Rainfall Diagrams' document, and for assessment of these and incorporation into the final scenarios see the 'Detailed Text' document)
- Calculate soms for rainfall less evaporation together with temperature for all RCPs separately in an identical process to that for rainfall together with temperature as outlined immediately above (does not include calculation of the IPCC 'extremes' because of similarity of results to those from the other soms analysis)

Summary of Main Results

In brief:

- **The ensemble means** results are instructive, but use simply of ensemble means (even with standard deviations thereof) fails to reveal the detailed structure amongst the various projections uncovered by the soms approach; in summary:
  - Temperatures increase progressively through the century, more so over the Delta section; similar changes in early and late rainfall seasons
  - Similar changes for maximum temperatures to those for average temperature
  - Diurnal temperature ranges tend to decrease by and large (perhaps indicating greater increases in minimum than in maximum temperatures, but this has not been assessed)
  - Rainfall declines in general, but with increases in the north-west of the Source section; pattern of declines most apparent in the late rainfall season, suggesting that declines in the early season may be more intense than those in the later season
  - Evaporation (a complex parameter to model, resulting in elimination of 6 projections from all analyses involving evaporation) in general decreases, although exceptions are present over the Source section in the late rainfall season and over the Delta section under certain RCPs – overall a complex picture [the IPCC attributes reduced evaporation even given higher temperatures to reduced inputs from rainfall]
  - Rainfall less evaporation decreases in general, but may increase over the north-west – substantial similarities between the three sets of ensemble means for rainfall, for evaporation, and for rainfall less evaporation
- **Standard deviations across ensembles** reveal marked spreads across projections, and are of magnitudes to suggest non-linearities in many of the fields, a suggestion confirmed by consideration of the soms charts
- As has been determined in prior analyses, projections are readily grouped in general (some exceptions) into scenarios through the **soms approach** to which indications of higher and lower likelihoods may be attached given certain assumptions:
  - By and large higher and lower likelihood scenarios are reasonably consistent in terms of temperature/rainfall/rainfall less evaporation changes across all RCPs for a given section (Source or Delta) and thus overarching scenarios, largely independent of RCPs, may be defined with some confidence that capture the essence of the groupings revealed by the soms; exceptions that do occur are related to the lesser-populated RCP2.6 and, especially, RCP6.0, and may therefore be related to sample sizes or biases introduced by fewer projections; nevertheless there are extrema that may be identified from the soms charts if required
  - Results are similar within the precision available for rainfall-temperature soms and (rainfall less evaporation)-temperature soms, and so a position may be taken in the future of whether it is beneficial or not to calculate both sets

- There are significant differences between scenarios for the two sections, with higher likelihood scenarios for the Source section indicated little change or around a 5% increase in rainfall or rainfall less evaporation and for the Delta section decreases of 10-20%
- Equivalently, lower likelihood scenarios for the Source section are for decreases of about 5-10% if using rainfall and of 25% if using rainfall less evaporation, and for the Delta section of little change or perhaps a 5-10% increase
- **NB:** soms for the Delta section have been calculated using rainfall, evaporation and temperatures specifically for that section; the models do provide estimates of river discharge from the Source section into the Delta section, discharge included in the evaporation calculations only, and thus not all water input to the Delta section is covered by the rainfall less evaporation calculations thus perhaps negatively biasing the results for this section to an extent
- Overall, therefore, scenarios for the two sections are approximate mirror images of each other, higher/lower likelihood water scenarios being for (little change/increase)/decrease over the Source section and decrease/(little change/increase) over the Delta section
- Some differences are present in soms results for the two sub-seasons (overall scenarios have been estimated taking these into consideration):
    - By and large the picture for the full rainfall season is better reflected in that for the late rainfall season
    - Some results for the early rainfall season are markedly different to those for the full and late rainfall seasons
- **NB:** caution should be taken with results for the sub seasons, as projections are dependent upon the abilities of individual models to adequately simulate local annual rainfall cycles, something achieved variably by the models; overall greater confidence should be placed in results for the full season than those for the sub seasons

Recommend Scenarios for Planning

Based on the rainfall and temperature self-organising models analyses

There are two scenarios for both of the Source and the Delta sections, in either case one with no change in rainfall and the other with a decrease. But likelihoods differ, with higher likelihoods for the scenario with no change in rainfall for the Source section but for the one with reduced rainfall for the Delta section. Decreases in the two relevant scenarios go to about 10%. Temperature changes tend to be higher in those scenarios with decreased rainfall. These scenarios are summarised in the first of following tables, with temperature/rainfall changes from averages for 1986-2005 listed for each time slot (note: both temperature, in ºC, and rainfall changes, as a ratio, are provided only to 0.25ºC/0.05, a precision that might still overstate that available).

All scenarios take most weight from RCP2.6, RCP4.5 and RCP6.0, given recent developments in the UNFCCC, with cuts in global emissions making RCP8.5 appear unduly pessimistic and with RCP2.6 the only emissions scenario (marginally for RCP4.5) consistent with the Paris Agreement. Were RCP8.5 to prove correct, then temperatures could be 2.00ºC warmer than those in the first table.

Changes in 'extremes' as defined by the IPCC, calculated for annual changes only, are listed in the second table following provided as ranges with no details for each time slot (this information can be found in the 'Soms Rainfall Temperature Diagrams' document); certain 'extremes' are not included because they provide no useful information (see the 'Detailed Text' document for definitions of the 'extremes'). Results for many of the 'extremes' are equivocal, with both increases and decreases present; exceptions are noted in the table. The clearest results appear to be those for Scenario 2 for the Delta section, where there is a certain consistency in indicating that rainfall on the heavier events may increase.

	2025	2055	2090
Source section			
Scenario 1 – higher likelihood	1.00ºC/1.00	1.75ºC/1.00	2.25ºC/1.00
Scenario 2 – lower likelihood	1.25ºC/0.95	1.75ºC/0.95	2.50ºC/0.90
Delta section			
Scenario 1 – higher likelihood	1.25ºC/0.90	2.00ºC/0.90	2.50ºC/0.90
Scenario 2 – lower likelihood	1.00ºC/1.00	1.50ºC/1.00	2.00ºC/1.00

Extreme	Comment
CSDI	Decreases in all scenarios – typical value 3 days fewer
WSDI	Substantial increases progressively in time in both cases, over a range 3-230 days (the latter suggestive of extended drought although associated only with RCP8.5)
RX1day	No clear outcome, with both increases and decreases except for Scenario 2 for the Delta section in which all values are for increases (over the range 3-30%)
RX5day	As per RX1day, no clear outcome, with both increases and decreases except for Scenario 2 for the Delta section in which all values are for increases (over a range to 18%)
SDII	No clear outcome as per RX1day and RX5day, with both increases and decreases, although the bias is towards an increase in Scenario 2 for the Delta section
R10mm	Both increases and decreases are present in most Scenarios, but there does seem to be a bias towards decreases
R20mm	Similar to R10mm above
CDD	Probably refers to the length of the dry season, and in all cases indicates an increase of up to 36%
CWD	No distinction, with a range of about -20% to +20%, but with a possible bias towards decreases
R95pTOT	As with other indicators of heavy rainfall events, split between increases and decreases, except for Scenario 2 in the Delta section in which the consensus is for an increase

Based on the rainfall less evaporation and temperature self-organising models analyses

The equivalent results to those immediately above but obtained from the rainfall less evaporation with temperature soms are given in the table below. The scenarios as defined here are similar to those from the rainfall-temperature soms discussed immediately above, with only slight differences in projected temperatures and rainfall.

	2025	2055	2090
Source section			
Scenario 1 – higher likelihood	0.75ºC/1.00	1.50ºC/1.05	2.00ºC/1.05
Scenario 2 – lower likelihood	1.25ºC/0.75	2.00ºC/0.75	2.50ºC/0.75
Delta section			
Scenario 1 – higher likelihood	1.00ºC/0.80	2.00ºC/0.80	2.25ºC/0.80
Scenario 2 – lower likelihood	1.00ºC/1.05	1.50ºC/1.10	2.00ºC/1.10

Conclusions

Scenarios of climate change through the remainder of the 21st Century have been developed using all of the projections underpinning the main conclusions of the IPCC AR5 (of 2013-14) through the approach of self-organising maps. The results differ, perhaps, to those that might have been assumed through consideration of ensemble means across the same projections. All higher-likelihood scenarios include temperature changes of up to 2.25ºC by the end of the century, but differ in the direction of rainfall changes with perhaps a 5% increase over the Source section and 20% decrease over the Delta section. Inversely the lower-likelihood scenarios cover a rainfall decrease of around 25% over the Source section and an increase to up to perhaps 10% in the Delta section.

Annex 2: Extremes

Table 20 **Summary of GCM results in terms of extremes**

Brief Title	Okovango
Warm Spell - a warm spell is of at least 6 days above the 90th percentile for 1961 - 1990:	Substantial increases progressively in time in both cases, over a range 3-230 days (the latter suggestive of extended drought although associated only with RCP8.5)temperatures over the base period, 1961-1990, for that time of year. *A measure of heat, related to increased evaporation.*
Cold Spell - at least 6 days above the 90th percentile for 1961 - 1990 - indicates reduced evaporation	Decreases in all scenarios – typical value 3 days fewer
Max 1 day rain - single day maximum rianfall	No clear outcome, with both increases and decreases except for Scenario 2 for the Delta section in which all values are for increases (over the range 3-30%)*this value, but equally give a more reliable estimate than ones based on fewer grid points*
Max 5 day rain - Total maximum rainfall over 5 consecutive days during the period. One measure of flood potential.	As per RX1day, no clear outcome, with both increases and decreases except for Scenario 2 for the Delta section in which all values are for increases (over a range to 18%)
Simple Rain Intensity - the average rainfall per day (ignores days of 1mm or less) indicated flood potential	No clear outcome as per RX1day and RX5day, with both increases and decreases, although the bias is towards an increase in Scenario 2 for the Delta section
Days with >10mm - counts the number of days with rain above 10mm - a measure of flood potential	Both increases and decreases are present in most Scenarios, but there does seem to be a bias towards decreases
Days with >20mm counts the number of days with rain above 20mm - a measure of flood potentila	Similar to R10mm above
Max dry spell - Maximum number of days where rainfall is less than 1mm. An indicator of drought duration	Probably refers to the length of the dry season, and in all cases indicates an increase of up to 36%
Max wet spell - Maximum number of days where rainfall is more than 1mm. An indicator of flood potential	No distinction, with a range of about -20% to +20%, but with a possible bias towards decreases
Total rain >95% - total annual rainfall on days above 95th percentile indicates flood potential	As with other indicators of heavy rainfall events, split between increases and decreases, except for Scenario 2 in the Delta section in which the consensus is for an increase

Annex 3: Climate Change Impacts

The summaries in the tables are based in part on the SOMs analyses and also on the brief literature review above – numbers in parentheses refer to the documents covered in that review.[16]

Column 1 lists the rainfall-related event, as also in the southern African table. Column 2 provides comments on the event gleaned from the two recommended scenarios and the IPCC 'extremes' data. Column 3 coverts details from Column 2, where possible, into indications of the magnitudes of any changes. Comments on implications are offered in Column 4; numbers in parentheses refer to the above table of documents reviewed. Scientific journal articles are also referred to where appropriate; these are listed in the References section of this report.

Table 21 **Rainfall-related events**

Rainfall-related events for the Cubango/Okavango Basin in Angola and Botswana	Likelihood	Extent of change	Implications

[16] Comments in column 3 are based on several sources.

- For water resources, comments are based on the IPCC AR5, in particular Chapter 12 of the WGI report and Chapters 3 and 22 of the WGII report
- For agriculture/food security, some comments are based on the IPCC AR5, in particular Chapters 7 and 22 of the WGII report, but also include selected details from the FAO GAEZ - http://www.fao.org/nr/gaez/en/. GAEZ is an expanding project to map global crop production, and includes some estimates of future yields under climate change of certain crops. All such calculations have been made only for individual models and for specific emissions scenarios, in all cases those used by WGI in the IPCC AR4. There is no overall assessment available, nor can changes from current yields be assessed. Examples are provided in Table 3 but only from a single model under the high emissions scenario A2, and there is no guarantee that these results are representative.
- For health, comments are based on WHO documents and statistics

Increase in extreme rainfall events	The evidence provides no indication of direction of change, with IPCC 'extremes' suggesting in general both increases and decreases in roughly equal amounts. One exception is for R10mm and R20mm, both of which seem to be biased towards a decrease. The second exception is for Scenario D2, with indicators suggesting an increase in extreme events.	In most cases the range is around ±20% (with no preferred direction of change), but for Scenario D2 any increases might be as high as 30%.	The evidence is inconsistent; from the brief literature survey above there are suggestions also of both increases (4, 5) and of decreases (3). As the evidence is for possible different directions of overall rainfall change in the two sections of the Basin, the implications are unclear for this analysis. It is more appropriate to assume that there may be greater variability and less predictability of precipitation events (total number of extreme events and their severity). (Pinto et al., 2016)
Increase of inter-annual variability in rainfall.	No specific statistics have been calculated for Angola and Botswana to elaborate this aspect, but the earlier CRIDF southern African analysis, together with Figure 22-2 of the IPCC WGII AR5 report, suggest a likely increase in variability.	Based on the IPCC AR5, greater increases in variability might be expected with higher emissions. Likely that greater variability will be experienced at the southern extent of the seasonal ITCZ, thus variations in ITCZ strength and penetration will impact on rainfall totals.	Were variability to increase then the likely outcome is an increase in water stress on vegetation, agriculture and ecosystems, at least in some years. (Suzuki, 2011). May be implications for groundwater recharge, reliability of water resources and sustainability of particular agricultural systems.
Increase of seasonal variability in rainfall.	No specific statistics have been calculated for Angola and Botswana to elaborate this aspect. Li et al. (2015) show a change in summer rainfall by 2029, compared to 1990	Some of the documents surveyed suggest that seasonal variability may increase (2, 3, 4)	Implications for water availability seasonally and in different parts of the river system; implications for agriculture and biodiversity/ecosystems especially in the Delta region.

	values, of -10% to +10% across the region, with a decrease in Okavango River headwater areas and an increase in lowland area (Botswana)		
Increase in drought events/water availability decreases.	The position with droughts is not fully clear from the available statistics – the main measure, CDD, suggests an increase in the length of dry periods, but this most likely relates to a longer dry season (and therefore a shorter rainfall season). The alternate CWD index adds little additional insight as values both increase and decrease.	Cannot be estimated directly from the available evidence.	The difference in direction of rainfall change between the two sections of the Basin, suggested also by (5), means that implications need, of course, to be viewed on a Basin-wide perspective, with perhaps increased inflow to the Delta making up for reduced rainfall in S1/D1, and *vv.* for S2/D2. Implications for water quality of available surface water bodies (rivers, lakes)
Reduced absorption of rainwater to recharge groundwater.	This cannot be estimated directly without the use of modelling. Nevertheless the results based on soms using rainfall less evaporation with temperature provide evidence that evaporation varies in the same direction as rainfall, also a generic conclusion in the IPCC AR5.	Cannot be estimated here.	The implication may be a difference in absorption in the two sections of the Basin along consistent lines with changes in rainfall as indicated in the row immediately above. (see Hassan and Jin, 2016)
Groundwater tables rising.	As immediately above.	Cannot be estimated here.	Impacts on groundwater will be related directly to the absorption issue discussed in the row immediately above. (see Hassan and Jin, 2016)

Run-off increases/decreases.	Based on the soms, the indication is that run-off from the Source section will increase or stay the same under S1/S3, but will decrease under S2/S4. Indeed this is consistent with results presented in the IPCC AR5 (see Figures 3 and 4 in the Executive Text document). The consequence regarding runoff in the Delta section is not immediately apparent without further modelling	A rise/decrease in rainfall of *x*% does not necessarily translate to the same increase/reduction in run-off as other factors are involved.	From the climate perspective alone changes in water stress may differ between S1/S3 and S2/S4, and indeed between D1/D3 and D2/D4. However there are other substantive issues other than climate that determine water stress, many of which point to an increase in stress especially with increased need for irrigated water for agriculture, increased population demand and deteriorating water quality of available water systems
Increase in cyclone/high wind/storm surge events.	There are examples of tropical cyclones entering north-east Botswana on rare occasions, but I am not aware of any that have penetrated as far west as the Delta, and certainly none into Angola. It is plausible that cyclones have merged into and increased the intensities of the low-pressure systems that often sit over the Cubango/Okavango region during the rainfall season, but in general cyclones can be neglected. The main issue is wind related to local, more intense thunderstorms, something possible according to indices such as RX1day; equally strong winds may become less frequent should	Cannot be quantified directly here.	Damage to local ecosystems and infrastructure may increase given stronger storm winds. Increased land surface temperatures during summer may result in more intense thunderstorms (and associated rainfall, wind and lightning)

	fewer such storms develop.		

Temperature-Related Events. Column 1 lists the temperature-related event, as also in the southern African table. Column 2 provides comments on the event gleaned from the two recommended scenarios and the IPCC 'extremes' data. Column 3 coverts details from Column 2, where possible, into indications of the magnitudes of any changes. Comments on implications are offered in Column 4. Scientific journal articles are also referred to where appropriate; these are listed in the References section of this report.

Table 22 **Temperature-related events**

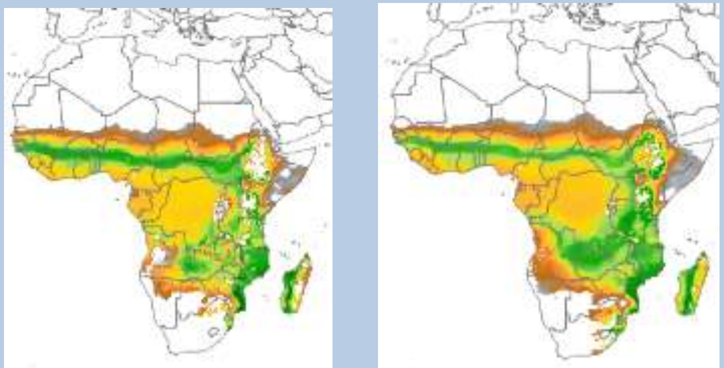
Climate change trends for the Cubango/Okavango Basin in Angola and Botswana	Likelihood	Extent of change	Implications
Increase in temperature/drought events → increased risk of wildfires.	Almost certain that temperatures will increase, with more hot spells according to WSDI and fewer cold spells according to CSDI regardless of scenario. The discussion re droughts (see table above) suggests that an increase is plausible but the supporting evidence is limited. Overall, particularly given the increased temperatures, it is reasonable to suggest that the risk of wildfires will increase – but see final column.	Cannot be estimated directly from the available evidence, although CSDI suggests the reduction in cold spells will be only around 3 days.	One issue to consider may be the cause of fires. Vegetation may suffer more extended drier periods than at present, although this outcome is not certain, but equally it may be surmised that there may be fewer lightning strikes to initiate fires but this may be dependent upon thundercloud climatology, discussed above

Changes in daily/seasonal temperature ranges.	The general consensus is that daily temperature ranges will decrease because minimum temperatures are expected to increase more than maximums, a result consistent (with some exceptions) with data presented in Figures 13-18 of the Ensemble Means Changes Diagrams document. Li et al. (2015) show that summer temperature increases to 2029 for 1990 values are likely to be in the range +0.4-1.0ºC, and winter increases in the range +0.2-0.6ºC.	Typically no more than 1ºC according to Figures 13-18 of the Ensemble Means Changes Diagrams document.	A possible increase in heat stress given reduced relief on some nights. Seasonality is likely to slightly increase as a result of higher summer mean temperatures, resulting in significant heat stress amplified by low surface moisture. (Li et al., 2015)
Decrease in number of frost days.	Almost certain under all future emissions, but hardly an issue in Angola and Botswana, except perhaps in the drier parts in the dry season.		None.
Increase in number of heat waves.	Temperatures will almost certainly increase, even were emissions to cease immediately. Reductions in cold weather, as indicated by CSDI, and extensions of periods of warm weather, with substantial increases according to WSDI for some projections, both under all scenarios, are consistent with an increase in the number of heat waves.	Cannot be estimated directly from the available evidence.	Increased heat stress, affecting all of human populations, crops, livestock, and all aspects of the ecology. Effects include increased heat related deaths, breathing problems and associated health effects.

Column 1 lists activity area, as also in the southern African table. Column 2 provides a summary regarding the area of activity including results from the present analysis, from the IPCC AR5, from the brief literature review above (referenced by numbers in parentheses – the literature reviewed covers mainly the Delta section only), and from UN bodies. Comments are offered in Column 3. Scientific journal articles are also referred to where appropriate; these are listed in the References section of this report.

Table 23 **Impacts on Water Resources, Agriculture/Food Security and Health.**

Activity Area	Summary	Comment
Adjustments in water resources	Results presented in this analysis, with evaporation both included and excluded, suggest the more likely scenario is for an increase in rainfall in the Source section and a decrease in the Delta section, and *vv.* for the less likely scenario. (6) is consistent with the less likely scenario, as is (3) for the Delta section only. However, other studies suggest the reverse pattern (Li et al., 2015). Note the high uncertainty in either case	Some of the reports suggest that increases might occur mainly in the northern part of the Source section, but the evidence is limited. A good overview of water resource variations in Africa under climate change is presented by Kusangaya et al. (2014). The implications for trans-boundary water resource management, especially for this region under the auspices of OKACOM, are discussed by King et al., (2014), Green et al. (2013), Andersson et al. (2006) and Hughes et al. (2011)
	Both increased flooding and droughts are mentioned (3), suggesting an increased hazard risk	A common theme in many reports for a variety of countries, possibly based on generic statements in earlier IPCC Assessments; no equivalent statement has been located in the IPCC AR5
	Increased water stress (1, 2, 3)	The IPCC places increasing water stress generically across Africa in the medium/high risk categories for global temperature increases of 2ºC/4ºC, but emphasises also that this is a compound issue not dependent on climate alone
Changes in agriculture and food security (not including livestock)	Critical impacts on agriculture (2, 3)	The IPCC AR5 (note: impacts in AR5 are largely based on results using CMIP3, rather than CMIP5, and often the A2 emissions scenario) does not commit to providing national adjustments to crop production and food security, but does note appropriate positive and negative effects from temperature increases (can be positive if

		temperatures do not exceed 30ºC), rainfall changes (can be positive or negative) and increases in CO_2 concentrations (generally positive); also emphasises the need for adaptation. Weinzier and Heider (2015) specifically discuss the implications of climate changes on the viability of key staple crops in the Okavango Basin region under climate change. Pearl millet is identified as the crop that is most resilient under different climate change scenarios, whereas maize, sorghum and cow pea are least resilient. Specific case studies of farming resilience to climate variations in the Okavango Basin are presented in Motsholapheko et al. (2011)
	Increases in pests and diseases (2)	The IPCC offers only low confidence in projections of reductions in efficiency of some herbicides, on disease intensity, and changes in geographical ranges of pests and diseases
	Maize: No specific references to changes in maize production have been found in the brief literature review	FAO GAEZ: 

		Left hand map 2020 yield, right hand 2080 yield, both for low-input maize; yields increase in time across Angola (e.g. more intense greens) and possibly over northern Botswana. NB One model only under high emissions A2 scenario and may not be a representative result
	Sorghum: No specific references to changes in sorghum production have been found in the brief literature review	FAO GAEZ: same model and same emissions scenario with same caveats to that above for maize suggests (not illustrated) possible reduced yields over Angola but perhaps little change over Botswana
	Coffee: No specific references to changes in coffee production have been found in the brief literature review	FAO GAEZ: same model and same emissions scenario with same caveats to that above for maize suggests (not illustrated) decreased yields for *Coffee robusta* in northern Angola; not relevant in Botswana
Changes in disease distribution / frequency. The IPCC AR5 lists the follow as health risks within Africa that might be affected by climate change:	Cholera: water borne; outbreaks often associated with heavy rains, therefore risk may vary with scenario as indicated above, but increases in heat may also adversely affect outbreaks	

		WHO Cholera reports 2010-15 – the WHO chart does not record any cases in Botswana, but other sources indicate that outbreaks have taken place in the country, as also in Angola
	Nutrition: dependent on many factors other than climate but availability may decrease if farming practices do not adjust to a changed climate	WHO: An issue throughout Africa
	Malaria: not linearly related to climate change, with decreases above about 28°C, but also dependent on rainfall; more work required	WHO: Decreasing trend in infections in Botswana through intervention, but increasing resistance in mosquito populations in surrounding countries; insufficient data to examine any trends in Angola
	Leishmaniasis: not present in Botswana and Angola as far as is known	WHO: No cases reported in Botswana and Angola (2013 data), but no data for Angola for the visceral form
	Rift Valley fever: mainly in animals but can be transmitted to humans, transported by mosquitos and hence heavy rainfall may increase incidence	WHO: No outbreaks recorded in either Angola or Botswana since 2000, but one did occur in South Africa in 2010, so presumably they might occur also in the two countries
	Air quality: the aerosol loading of the atmosphere might increase under a possible drier climate.	WHO: Limited data suggest that the situation is worst in Angola than in Botswana, with the former ranked with a relatively serious issue, especially in regards to household aerosol loadings
	Ticks and tick-borne diseases: limited research on	WHO: some are endemic throughout Africa

	theleriosis suggests range will expand in southern Africa under climate change	
	Schistosomiasis: numerous factors known to affect distribution, but limited research indicates transmission will increase with climate change; one possible factor leading to increased range of the carrier worms might be irrigation introduced as an adaptation strategy	WHO: present throughout most of Africa, including Angola and Botswana
	Meningococcal meningitis: dry season threat associated with aerosols; speculatively under a drier climate risk might increase	WHO: No data for Angola or Botswana, but a serious issue in neighbouring DRC
	Hanta virus: carried by rodents	WHO: suggests worldwide
	Trypanosomiasis: vector is the tsetse fly which faces a possible range decrease under climate change	WHO: Various strains – endemic in both countries but mainly in different strains
	Heat stress: likely to increase in both Angola and Botswana with increased temperatures	

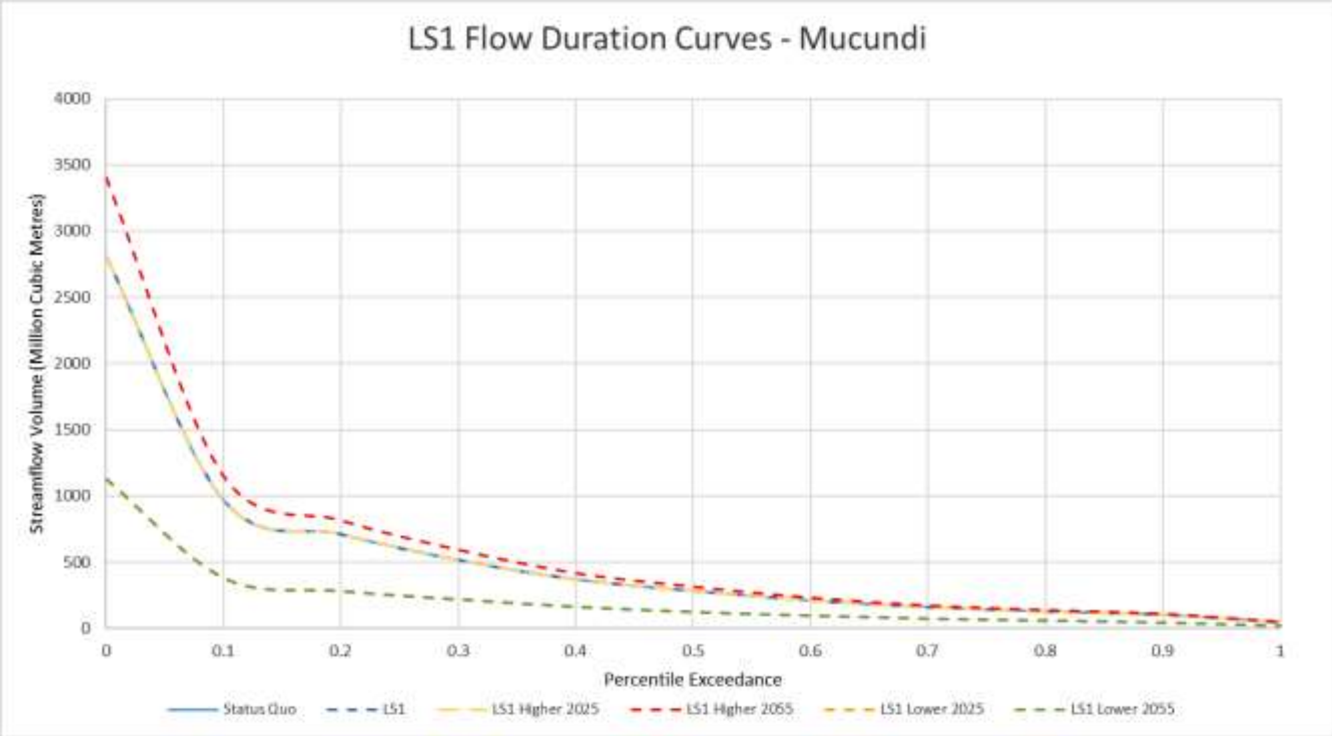
Annex 4: Hydrology Impacts of Climate Projects in the CORB

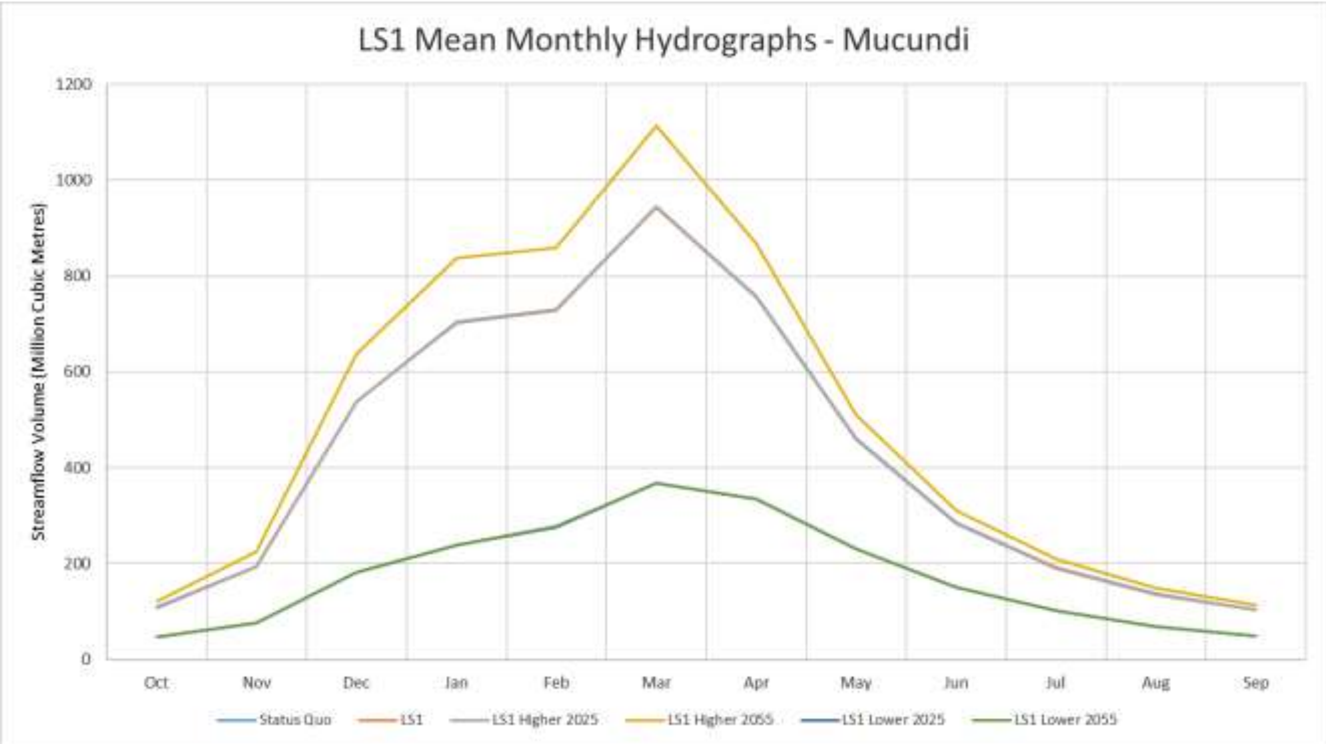
LS1 – MUCUNDI

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	109	195	537	704	730	945	757	461	285	192	137	105	5 158
LS1	108	194	537	703	729	944	755	460	284	191	136	104	5 145
LS1 Higher 2025	108	194	537	703	729	944	755	460	284	191	136	104	5 145
LS1 Higher 2055	122	226	639	837	858	1 113	867	511	312	209	150	115	5 958
LS1 Lower 2025	48	76	182	240	277	368	334	231	151	102	70	50	2 129
LS1 Lower 2055	48	77	182	240	277	369	334	231	151	102	69	50	2 130

Scenarios	Percentage Deviation of Mean Flows from LS1 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS1 Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LS1 Higher 2055	12.8%	16.7%	18.8%	19.1%	17.7%	17.9%	14.9%	11.1%	9.6%	9.5%	9.9%	10.6%	15.8%
LS1 Lower 2025	-55.9%	-60.6%	-66.1%	-65.9%	-62.0%	-61.0%	-55.7%	-49.8%	-46.8%	-46.7%	-48.9%	-52.2%	-58.6%
LS1 Lower 2055	-55.8%	-60.5%	-66.0%	-65.9%	-61.9%	-60.9%	-55.7%	-49.8%	-46.9%	-46.7%	-49.0%	-52.2%	-58.6%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS1	-0.8%	-0.5%	0.0%	-0.1%	-0.2%	-0.1%	-0.3%	-0.4%	-0.4%	-0.5%	-0.7%	-0.9%	-0.2%
LS1 Higher 2025	-0.8%	-0.5%	0.0%	-0.1%	-0.2%	-0.1%	-0.3%	-0.4%	-0.4%	-0.5%	-0.7%	-0.9%	-0.2%
LS1 Higher 2055	11.9%	16.1%	18.9%	19.0%	17.5%	17.8%	14.5%	10.7%	9.2%	8.9%	9.1%	9.6%	15.5%
LS1 Lower 2025	-56.2%	-60.7%	-66.1%	-66.0%	-62.0%	-61.0%	-55.8%	-49.9%	-47.0%	-47.0%	-49.3%	-52.6%	-58.7%
LS1 Lower 2055	-56.2%	-60.7%	-66.0%	-65.9%	-62.0%	-60.9%	-55.8%	-50.0%	-47.0%	-47.0%	-49.3%	-52.6%	-58.7%


LS1 Flow Duration Curves - Mucundi
Streamflow Volume (Million Cubic Metres)
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile Exceedance
Status Quo
LS1
LS1 Higher 2025
LS1 Higher 2055
LS1 Lower 2025
LS1 Lower 2055

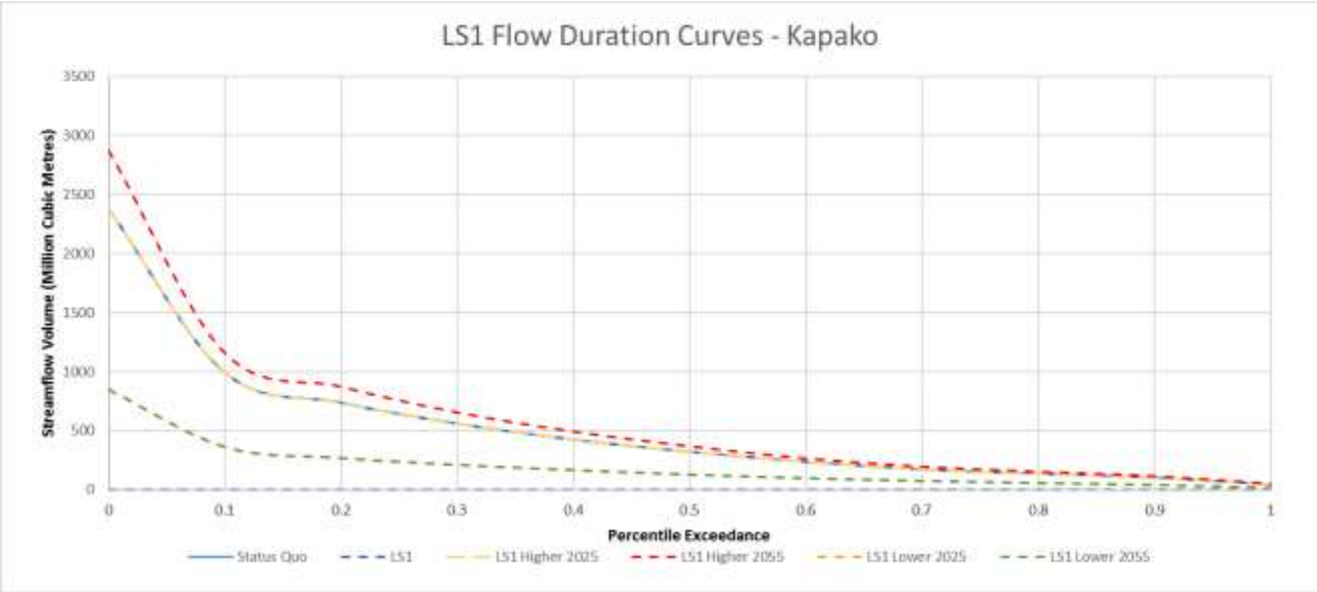

LS1 Mean Monthly Hydrographs - Mucundi
Streamflow Volume (Million Cubic Metres)
1200
1000
800
600
400
200
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS1
LS1 Higher 2025
LS1 Higher 2055
LS1 Lower 2025
LS1 Lower 2055

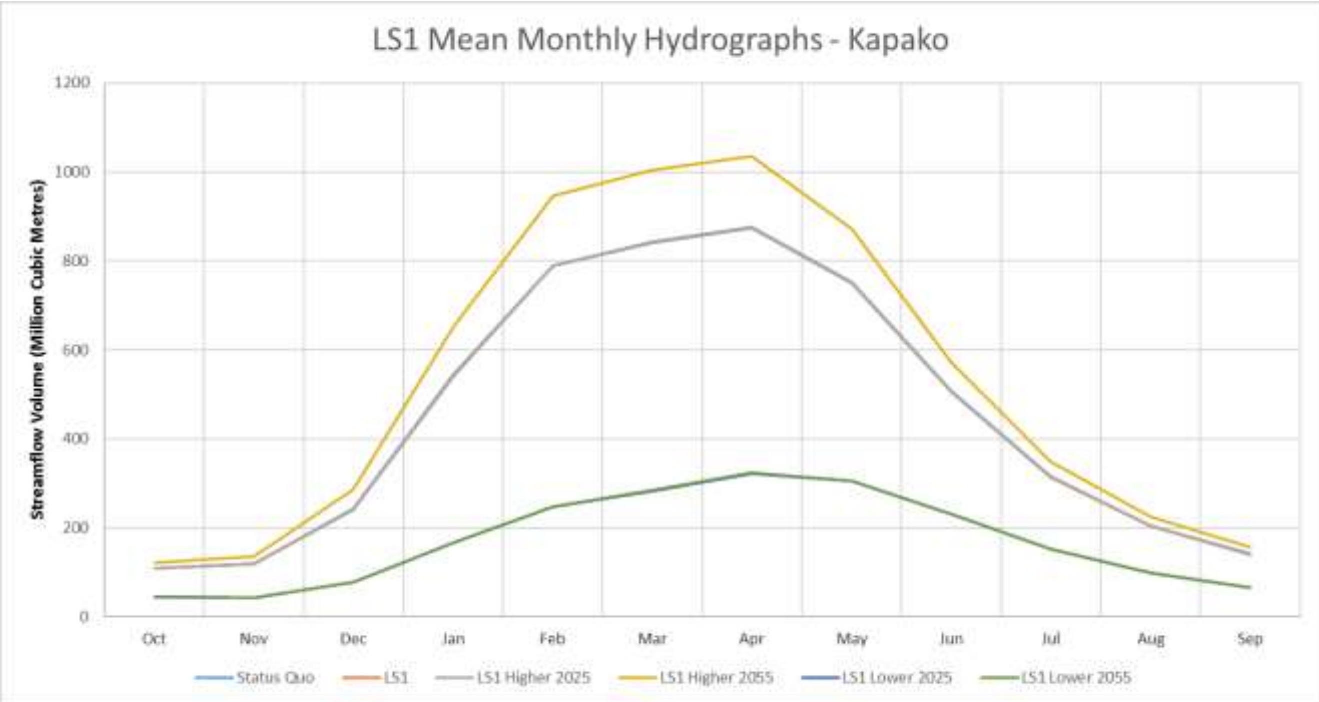
LS1 – KAPAKO

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	110	120	243	545	790	842	876	751	508	316	205	142	5 448
LS1	109	119	243	544	789	841	875	750	506	314	204	141	5 433
LS1 Higher 2025	109	119	243	544	789	841	875	750	506	314	204	141	5 433
LS1 Higher 2055	122	136	287	652	947	1 004	1 035	871	572	349	225	156	6 357
LS1 Lower 2025	46	44	78	167	247	284	323	307	231	153	100	65	2 045
LS1 Lower 2055	46	44	79	167	248	284	323	307	231	153	100	65	2 046

Scenarios	Percentage Deviation of Mean Flows from LS1 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS1 Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LS1 Higher 2055	12.0%	14.7%	18.3%	19.8%	20.0%	19.4%	18.3%	16.2%	13.2%	11.1%	10.5%	10.9%	17.0%
LS1 Lower 2025	-58.1%	-63.0%	-67.7%	-69.4%	-68.7%	-66.3%	-63.1%	-59.1%	-54.3%	-51.1%	-51.0%	-53.7%	-62.4%
LS1 Lower 2055	-58.1%	-63.0%	-67.6%	-69.3%	-68.6%	-66.2%	-63.0%	-59.1%	-54.3%	-51.2%	-51.0%	-53.7%	-62.3%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS1	-1.1%	-0.9%	-0.3%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.4%	-0.6%	-0.7%	-1.0%	-0.3%
LS1 Higher 2025	-1.1%	-0.9%	-0.3%	-0.1%	-0.1%	-0.1%	-0.2%	-0.2%	-0.4%	-0.6%	-0.7%	-1.0%	-0.3%
LS1 Higher 2055	10.8%	13.7%	17.9%	19.7%	19.8%	19.3%	18.1%	15.9%	12.7%	10.4%	9.7%	9.9%	16.7%
LS1 Lower 2025	-58.6%	-63.4%	-67.8%	-69.4%	-68.7%	-66.3%	-63.1%	-59.2%	-54.5%	-51.4%	-51.4%	-54.1%	-62.5%
LS1 Lower 2055	-58.6%	-63.4%	-67.7%	-69.3%	-68.7%	-66.3%	-63.1%	-59.2%	-54.5%	-51.5%	-51.4%	-54.1%	-62.5%


LS1 Flow Duration Curves - Kapako
Streamflow Volume (Million Cubic Metres)
Percentile Exceedance
Status Quo
LS1
LS1 Higher 2025
LS1 Higher 2055
LS1 Lower 2025
LS1 Lower 2055

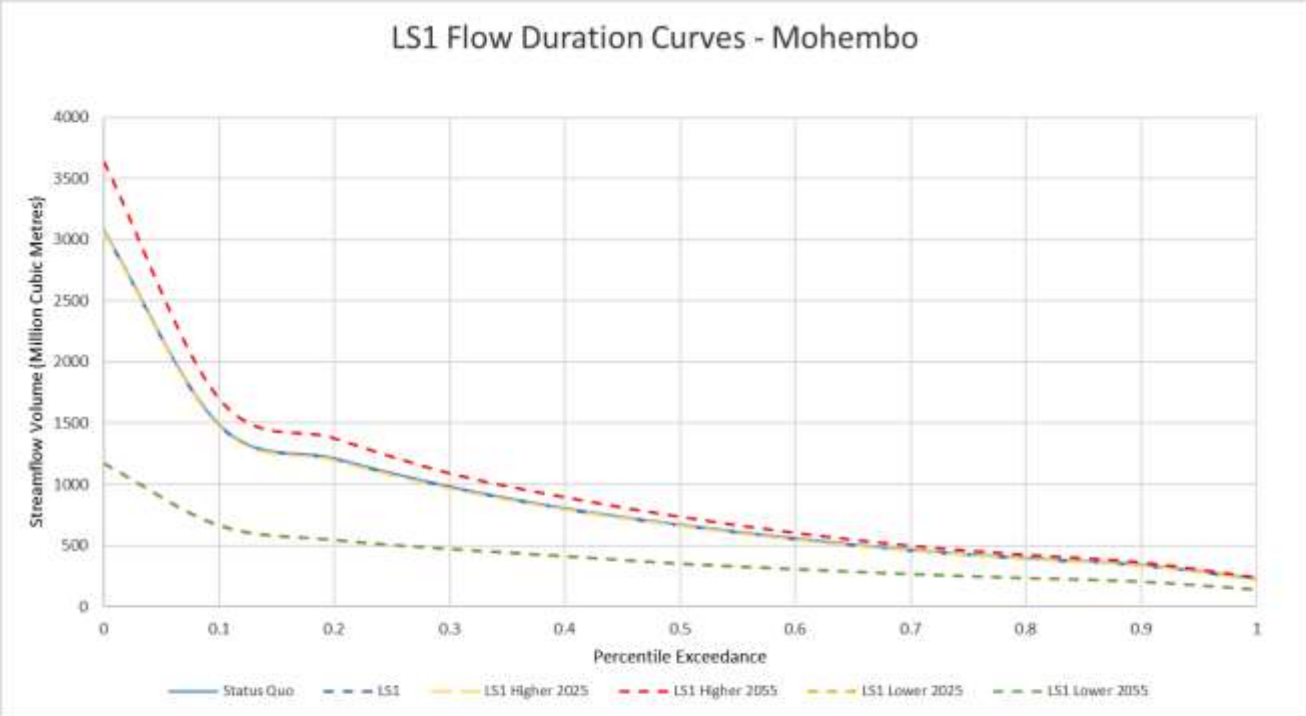

LS1 Mean Monthly Hydrographs - Kapako
Streamflow Volume (Million Cubic Metres)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS1
LS1 Higher 2025
LS1 Higher 2055
LS1 Lower 2025
LS1 Lower 2055

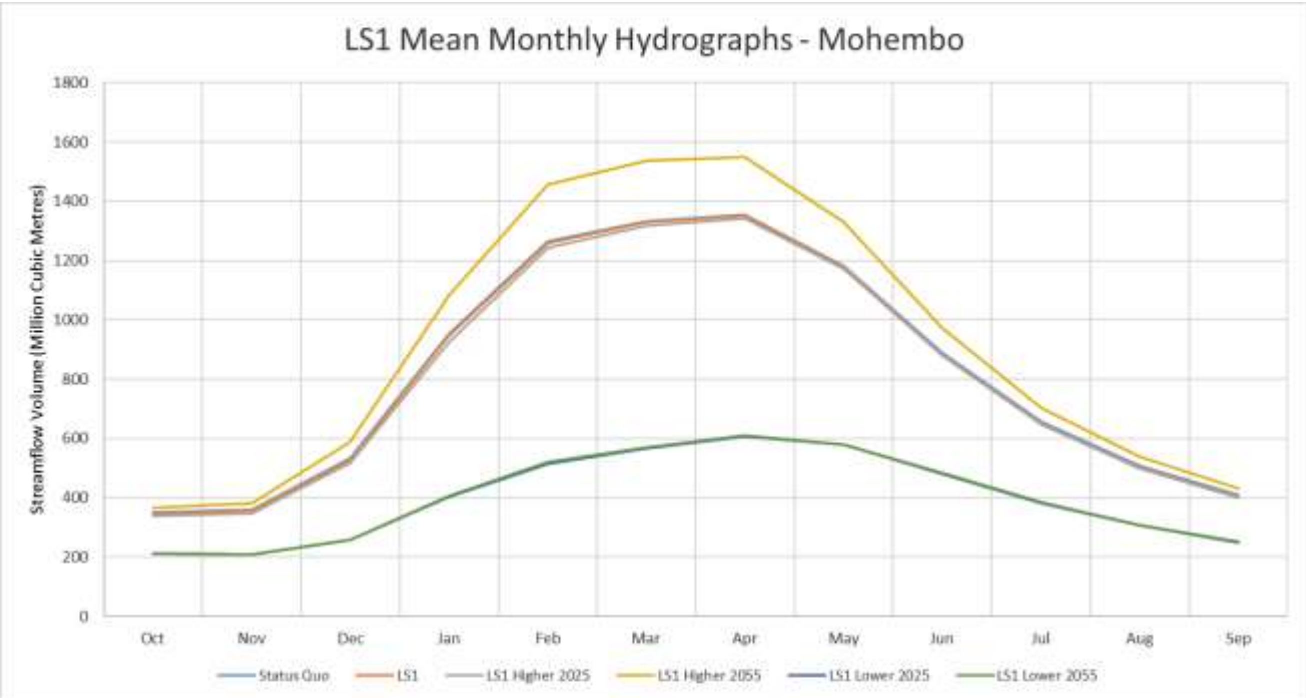
LS1 – MOHEMBO

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
Status Quo	351	361	532	952	1 265	1 335	1 355	1 183	888	656	508	410	9 795
LS1	345	356	527	948	1 260	1 330	1 350	1 177	882	650	503	405	9 733
LS1 Higher 2025	339	348	518	927	1 243	1 319	1 342	1 172	878	646	498	399	9 628
LS1 Higher 2055	366	381	589	1 082	1 457	1 538	1 551	1 329	972	703	538	430	10 937
LS1 Lower 2025	212	208	257	402	516	565	608	578	482	383	307	250	4 767
LS1 Lower 2055	212	208	258	408	521	569	610	580	483	384	308	251	4 790

Scenarios	Percentage Deviation of Mean Flows from LS1 (MSIOA No Climate Change)												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
LS1 Higher 2025	-1.8%	-2.2%	-1.8%	-2.2%	-1.4%	-0.8%	-0.6%	-0.5%	-0.5%	-0.6%	-0.9%	-1.4%	-1.1%
LS1 Higher 2055	6.1%	7.1%	11.8%	14.2%	15.6%	15.7%	14.9%	12.9%	10.2%	8.2%	7.1%	6.3%	12.4%
LS1 Lower 2025	-38.6%	-41.7%	-51.3%	-57.6%	-59.1%	-57.5%	-54.9%	-50.9%	-45.4%	-41.1%	-38.9%	-38.2%	-51.0%
LS1 Lower 2055	-38.5%	-41.5%	-51.1%	-57.0%	-58.7%	-57.2%	-54.8%	-50.8%	-45.3%	-41.0%	-38.7%	-38.1%	-50.8%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Annual**
LS1	-1.5%	-1.4%	-0.9%	-0.4%	-0.3%	-0.4%	-0.4%	-0.5%	-0.7%	-0.9%	-1.1%	-1.3%	-0.6%
LS1 Higher 2025	-3.3%	-3.5%	-2.7%	-2.6%	-1.7%	-1.2%	-1.0%	-0.9%	-1.1%	-1.5%	-2.0%	-2.7%	-1.7%
LS1 Higher 2055	4.4%	5.7%	10.8%	13.6%	15.2%	15.2%	14.4%	12.4%	9.5%	7.2%	5.9%	4.9%	11.7%
LS1 Lower 2025	-39.6%	-42.5%	-51.7%	-57.7%	-59.2%	-57.6%	-55.1%	-51.1%	-45.8%	-41.7%	-39.6%	-39.0%	-51.3%
LS1 Lower 2055	-39.4%	-42.3%	-51.5%	-57.2%	-58.8%	-57.4%	-55.0%	-51.0%	-45.6%	-41.5%	-39.4%	-38.9%	-51.1%


LS1 Flow Duration Curves - Mohembo
4000
3500
3000
2500
2000
1500
1000
500
0
Streamflow Volume (Million Cubic Metres)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile Exceedance
Status Quo
LS1
LS1 Higher 2025
LS1 Higher 2055
LS1 Lower 2025
LS1 Lower 2055

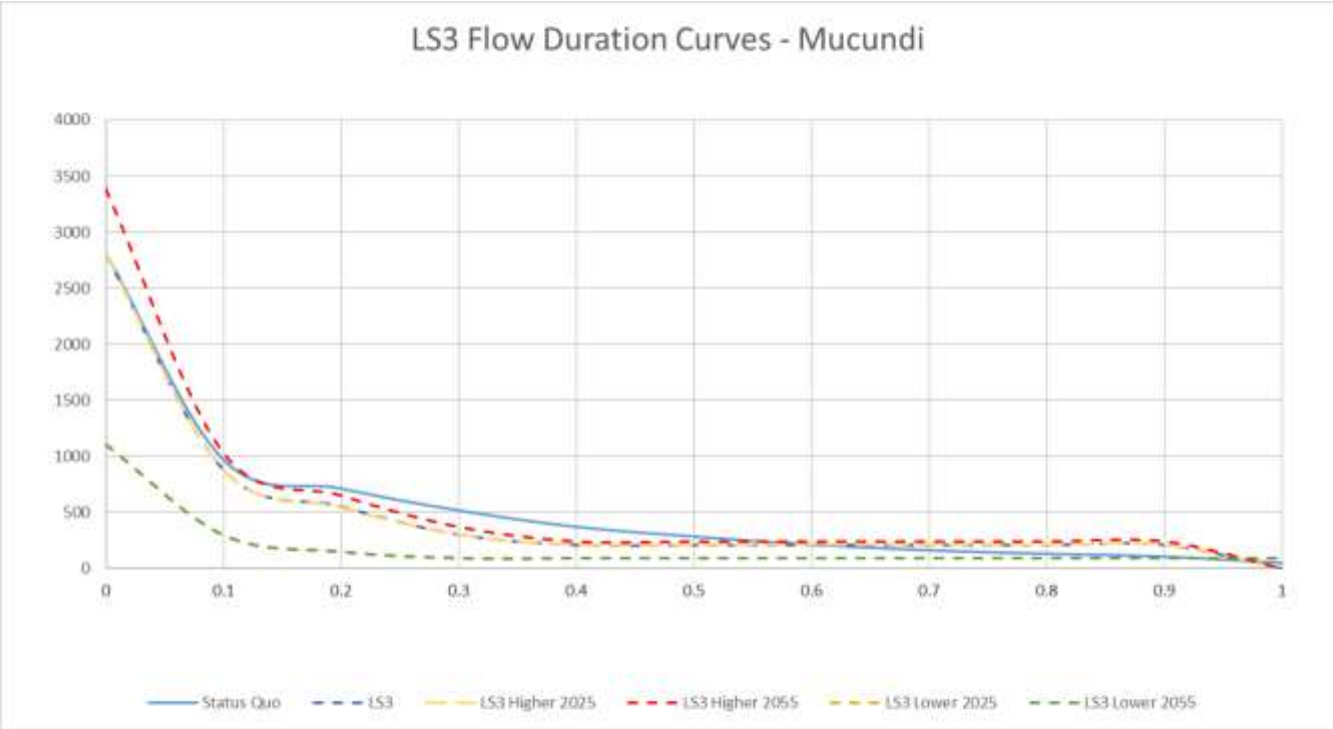

LS1 Mean Monthly Hydrographs - Mohembo
1800
1600
1400
1200
1000
800
600
400
200
0
Streamflow Volume (Million Cubic Metres)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS1
LS1 Higher 2025
LS1 Higher 2055
LS1 Lower 2025
LS1 Lower 2055

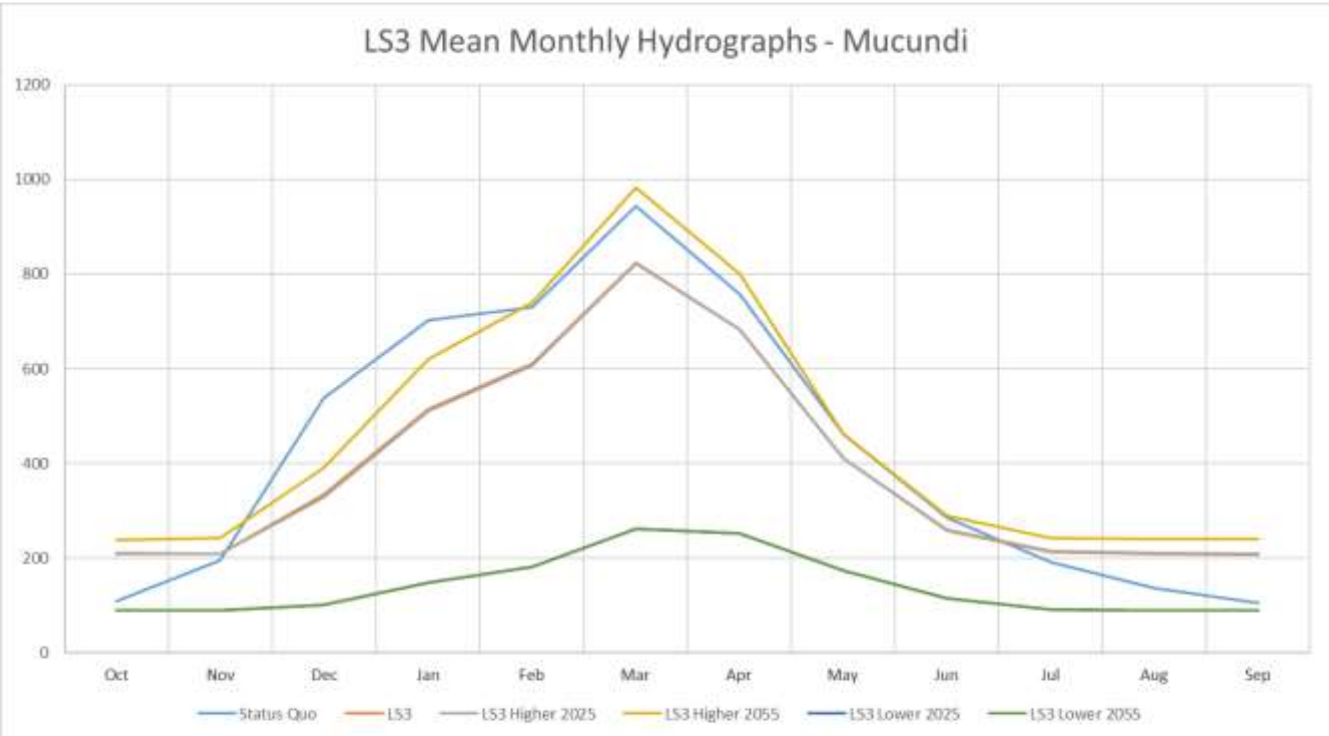
LS3 – MUCUNDI

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	109	195	537	704	730	945	757	461	285	192	137	105	5 158
LS3	208	208	333	514	610	825	684	410	258	212	210	208	4 681
LS3 Higher 2025	208	208	333	514	610	825	684	410	258	212	210	208	4 681
LS3 Higher 2055	238	242	391	620	739	984	800	462	289	242	241	240	5 490
LS3 Lower 2025	89	89	102	149	181	262	252	173	115	91	89	89	1 681
LS3 Lower 2055	89	89	102	149	181	262	252	173	115	91	89	89	1 681

Scenarios	Percentage Deviation of Mean Flows from LS3 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS3 Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LS3 Higher 2055	14.5%	16.2%	17.3%	20.7%	21.2%	19.2%	16.9%	12.6%	12.1%	14.3%	15.0%	15.4%	17.3%
LS3 Lower 2025	-57.3%	-57.1%	-69.5%	-71.1%	-70.3%	-68.2%	-63.1%	-57.9%	-55.4%	-57.1%	-57.5%	-57.2%	-64.1%
LS3 Lower 2055	-57.3%	-57.1%	-69.4%	-71.1%	-70.3%	-68.3%	-63.1%	-57.9%	-55.4%	-57.1%	-57.5%	-57.2%	-64.1%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS3	90.8%	7.0%	-38.0%	-27.0%	-16.4%	-12.6%	-9.7%	-11.1%	-9.5%	10.4%	52.8%	98.3%	-9.2%
LS3 Higher 2025	90.8%	7.0%	-38.0%	-27.0%	-16.4%	-12.6%	-9.7%	-11.1%	-9.5%	10.4%	52.8%	98.3%	-9.2%
LS3 Higher 2055	118.4%	24.3%	-27.2%	-11.8%	1.3%	4.2%	5.6%	0.1%	1.4%	26.2%	75.8%	128.9%	6.4%
LS3 Lower 2025	-18.5%	-54.1%	-81.0%	-78.9%	-75.2%	-72.3%	-66.7%	-62.6%	-59.7%	-52.7%	-35.1%	-15.0%	-67.4%
LS3 Lower 2055	-18.5%	-54.1%	-81.0%	-78.9%	-75.2%	-72.3%	-66.7%	-62.6%	-59.7%	-52.7%	-35.1%	-15.0%	-67.4%


LS3 Flow Duration Curves - Mucundi
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Status Quo
LS3
LS3 Higher 2025
LS3 Higher 2055
LS3 Lower 2025
LS3 Lower 2055

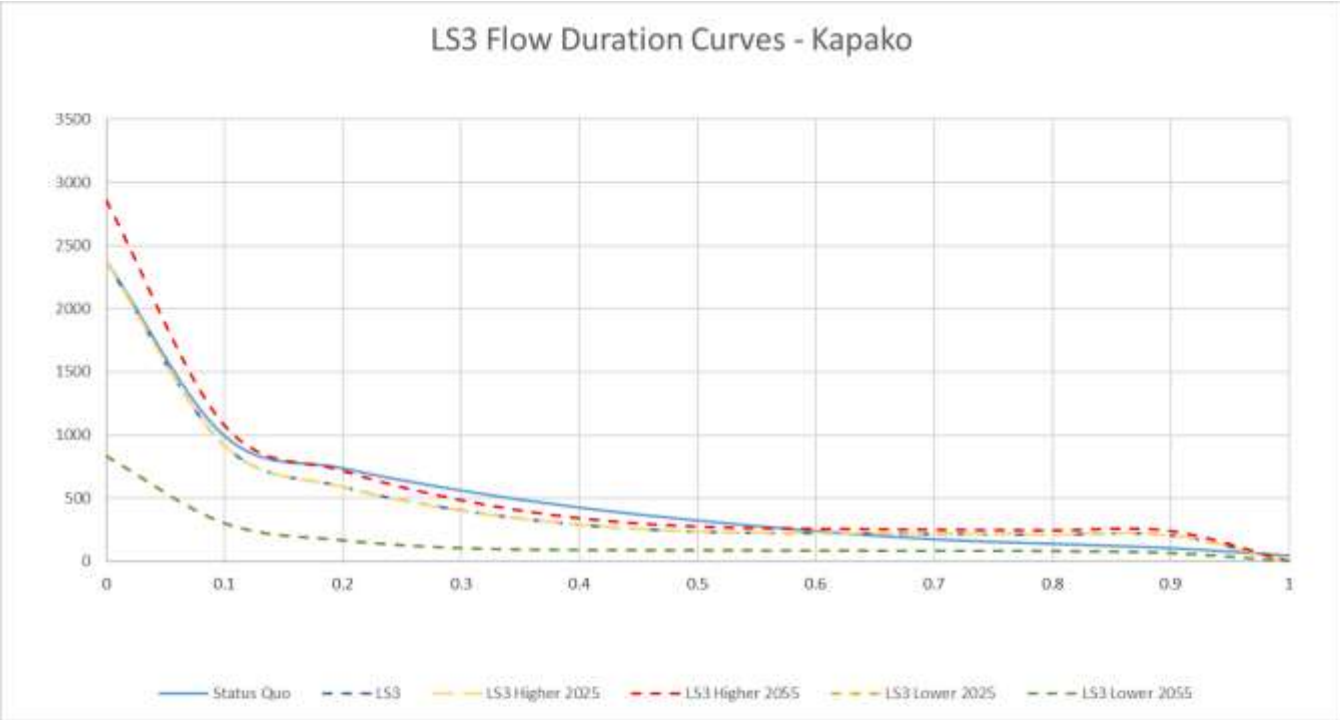

LS3 Mean Monthly Hydrographs - Mucundi
1200
1000
800
600
400
200
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS3
LS3 Higher 2025
LS3 Higher 2055
LS3 Lower 2025
LS3 Lower 2055

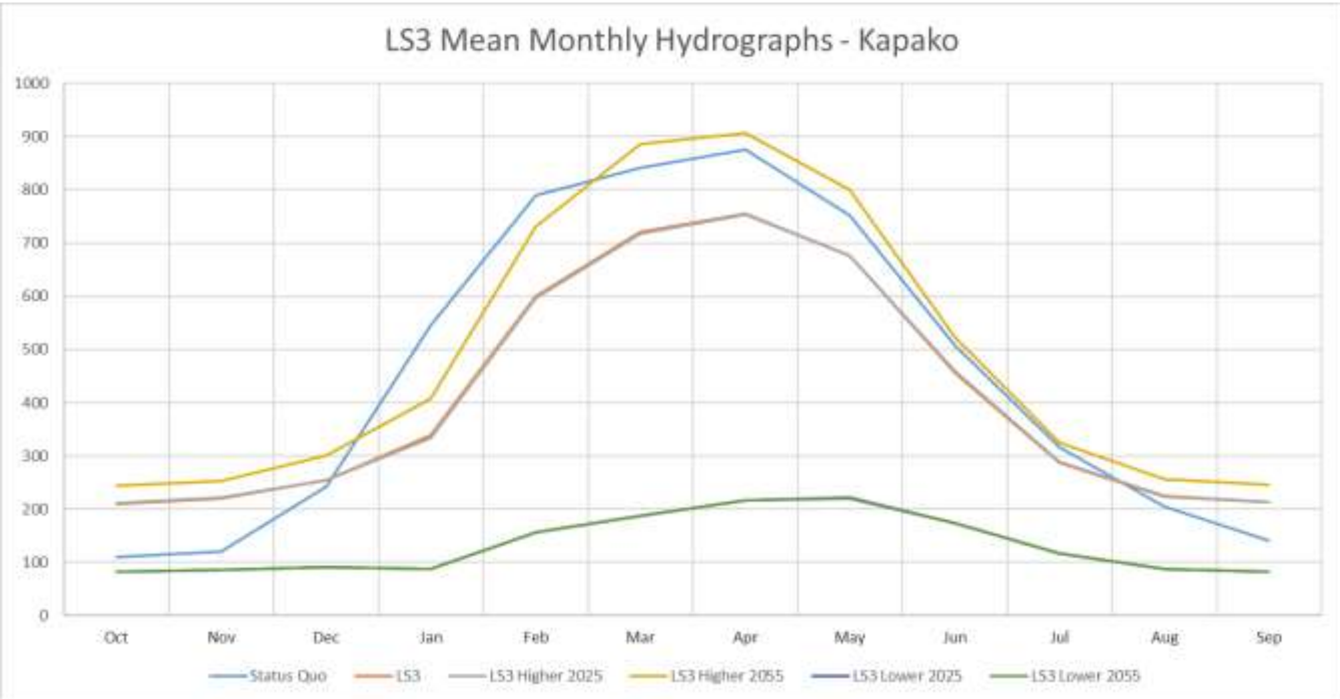
LS3 – KAPAKO

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	110	120	243	545	790	842	876	751	508	316	205	142	5 448
LS3	210	219	254	338	600	722	755	676	456	287	223	213	4 954
LS3 Higher 2025	210	219	254	338	600	722	755	676	456	287	223	213	4 954
LS3 Higher 2055	244	253	302	408	731	886	906	800	523	325	256	246	5 879
LS3 Lower 2025	83	86	91	88	157	187	217	221	173	117	88	83	1 592
LS3 Lower 2055	82	86	91	88	157	187	217	221	173	117	88	83	1 591

Scenarios	Percentage Deviation of Mean Flows from LS3 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS3 Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LS3 Higher 2055	16.1%	15.5%	18.6%	20.5%	21.8%	22.7%	19.9%	18.4%	14.6%	13.1%	14.7%	15.5%	18.7%
LS3 Lower 2025	-60.7%	-60.9%	-64.2%	-73.9%	-73.9%	-74.0%	-71.2%	-67.3%	-62.0%	-59.1%	-60.5%	-60.8%	-67.9%
LS3 Lower 2055	-60.7%	-61.0%	-64.2%	-73.9%	-73.9%	-74.0%	-71.2%	-67.3%	-62.1%	-59.2%	-60.6%	-60.9%	-67.9%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS3	90.4%	82.9%	4.5%	-37.9%	-24.1%	-14.3%	-13.8%	-10.1%	-10.1%	-9.0%	8.9%	49.8%	-9.1%
LS3 Higher 2025	90.4%	82.9%	4.5%	-37.9%	-24.1%	-14.3%	-13.8%	-10.1%	-10.1%	-9.0%	8.9%	49.8%	-9.1%
LS3 Higher 2055	121.1%	111.2%	23.9%	-25.1%	-7.5%	5.2%	3.4%	6.5%	3.0%	2.9%	25.0%	73.1%	7.9%
LS3 Lower 2025	-25.2%	-28.5%	-62.6%	-83.8%	-80.2%	-77.7%	-75.2%	-70.6%	-65.9%	-62.8%	-57.0%	-41.3%	-70.8%
LS3 Lower 2055	-25.2%	-28.6%	-62.6%	-83.8%	-80.2%	-77.8%	-75.2%	-70.6%	-65.9%	-62.9%	-57.1%	-41.4%	-70.8%


LS3 Flow Duration Curves - Kapako
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Status Quo
LS3
LS3 Higher 2025
LS3 Higher 2055
LS3 Lower 2025
LS3 Lower 2055

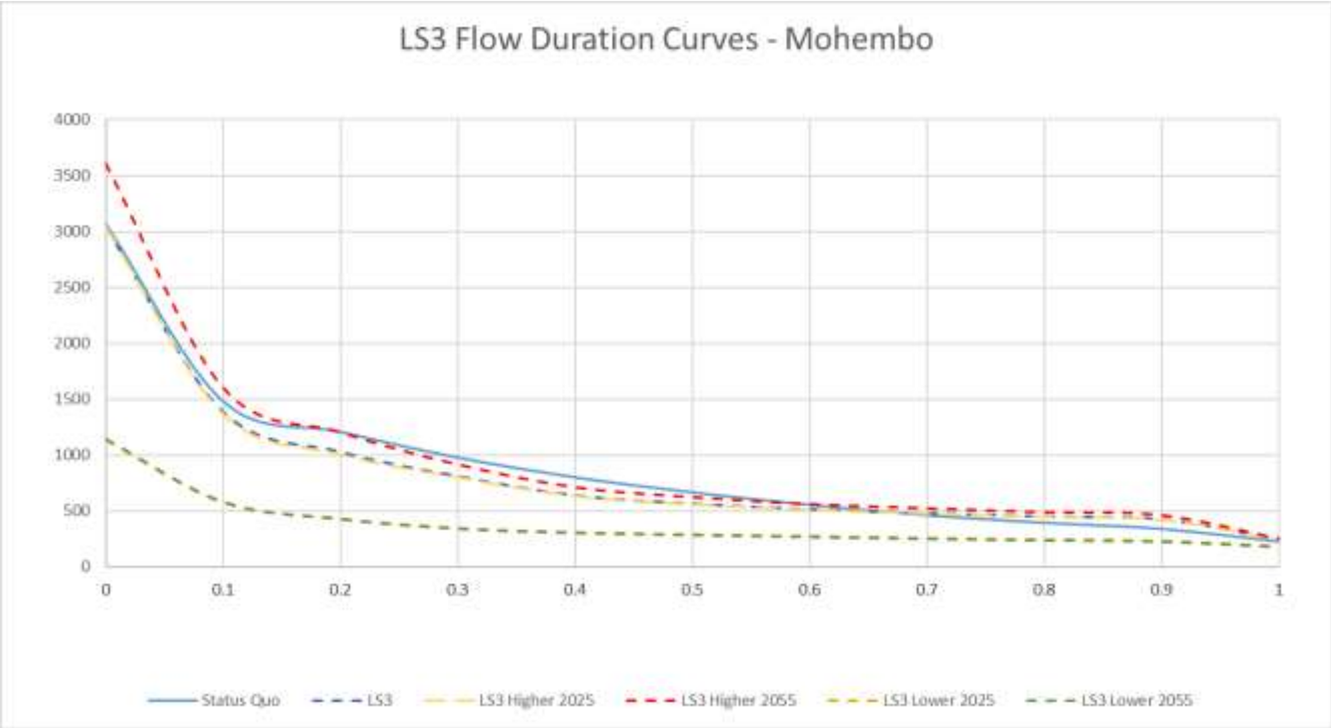

LS3 Mean Monthly Hydrographs - Kapako
1000
900
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS3
LS3 Higher 2025
LS3 Higher 2055
LS3 Lower 2025
LS3 Lower 2055

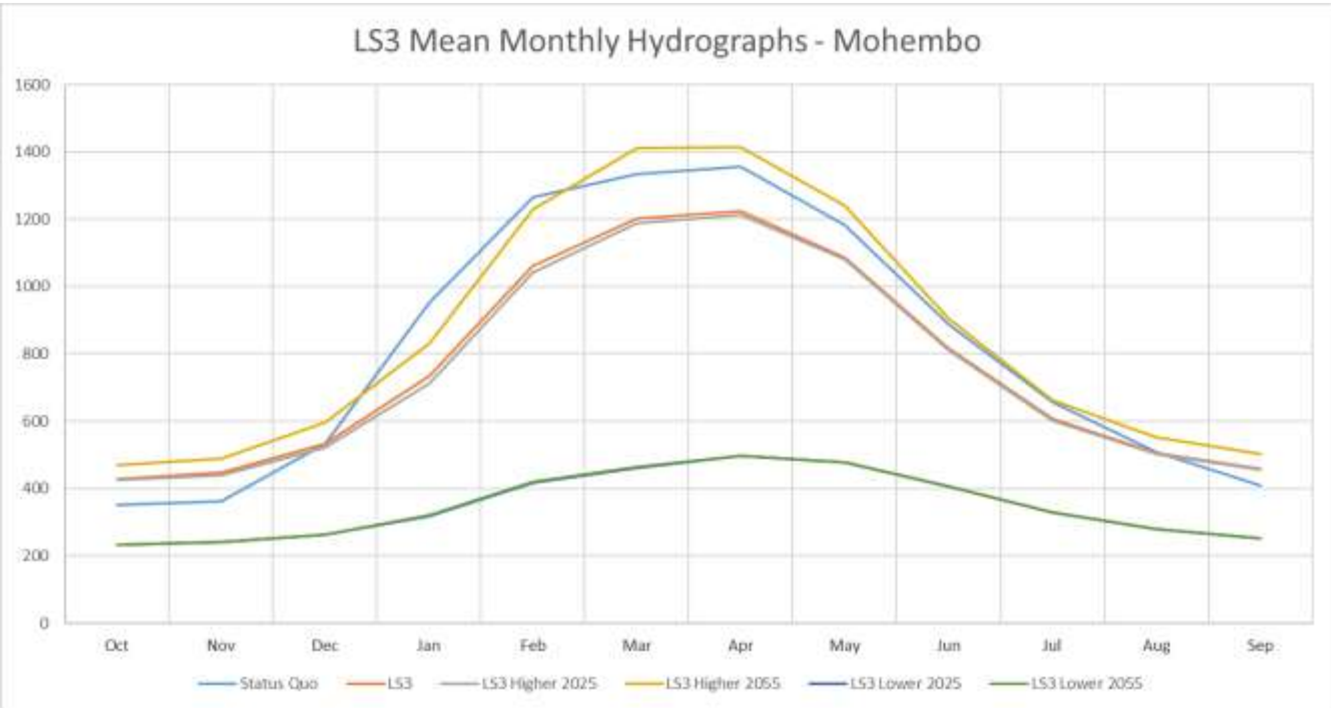
LS3 – MOHEMBO

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	351	361	532	952	1 265	1 335	1 355	1 183	888	656	508	410	9 795
LS3	429	446	532	735	1 062	1 203	1 224	1 087	816	606	506	460	9 105
LS3 Higher 2025	425	440	523	711	1 043	1 188	1 213	1 081	812	602	502	454	8 994
LS3 Higher 2055	470	488	596	831	1 230	1 411	1 413	1 241	905	662	552	502	10 302
LS3 Lower 2025	233	240	262	317	416	461	496	477	406	329	278	251	4 166
LS3 Lower 2055	233	240	263	322	421	464	497	477	407	330	279	251	4 185

Scenarios	Percentage Deviation of Mean Flows from LS3 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS3 Higher 2025	-1.0%	-1.3%	-1.7%	-3.2%	-1.8%	-1.2%	-0.8%	-0.6%	-0.5%	-0.7%	-0.8%	-1.1%	-1.2%
LS3 Higher 2055	9.6%	9.4%	12.1%	13.1%	15.9%	17.3%	15.5%	14.2%	10.9%	9.1%	9.1%	9.3%	13.2%
LS3 Lower 2025	-45.7%	-46.2%	-50.8%	-56.9%	-60.8%	-61.6%	-59.5%	-56.2%	-50.2%	-45.7%	-45.0%	-45.4%	-54.2%
LS3 Lower 2055	-45.6%	-46.1%	-50.6%	-56.2%	-60.4%	-61.4%	-59.4%	-56.1%	-50.1%	-45.6%	-44.9%	-45.3%	-54.0%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS3	22.5%	23.6%	-0.1%	-22.8%	-16.0%	-9.9%	-9.7%	-8.1%	-8.1%	-7.5%	-0.5%	12.2%	-7.0%
LS3 Higher 2025	21.2%	22.0%	-1.8%	-25.3%	-17.6%	-11.0%	-10.5%	-8.6%	-8.6%	-8.2%	-1.3%	10.9%	-8.2%
LS3 Higher 2055	34.2%	35.2%	12.1%	-12.7%	-2.7%	5.7%	4.3%	5.0%	1.9%	0.9%	8.6%	22.6%	5.2%
LS3 Lower 2025	-33.5%	-33.5%	-50.8%	-66.7%	-67.1%	-65.4%	-63.4%	-59.7%	-54.2%	-49.8%	-45.3%	-38.7%	-57.5%
LS3 Lower 2055	-33.4%	-33.4%	-50.6%	-66.2%	-66.7%	-65.2%	-63.3%	-59.6%	-54.1%	-49.7%	-45.2%	-38.6%	-57.3%


LS3 Flow Duration Curves - Mohembo
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Status Quo
LS3
LS3 Higher 2025
LS3 Higher 2055
LS3 Lower 2025
LS3 Lower 2055

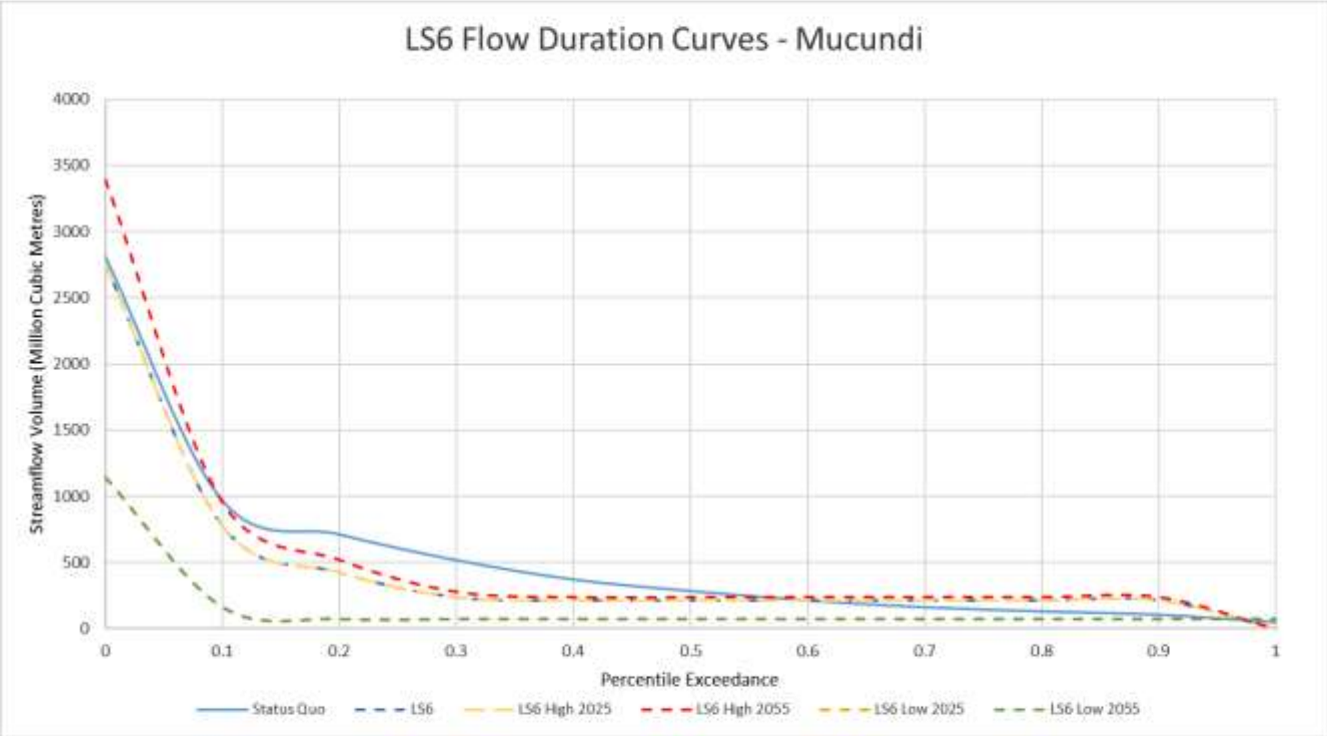

LS3 Mean Monthly Hydrographs - Mohembo
1600
1400
1200
1000
800
600
400
200
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS3
LS3 Higher 2025
LS3 Higher 2055
LS3 Lower 2025
LS3 Lower 2055

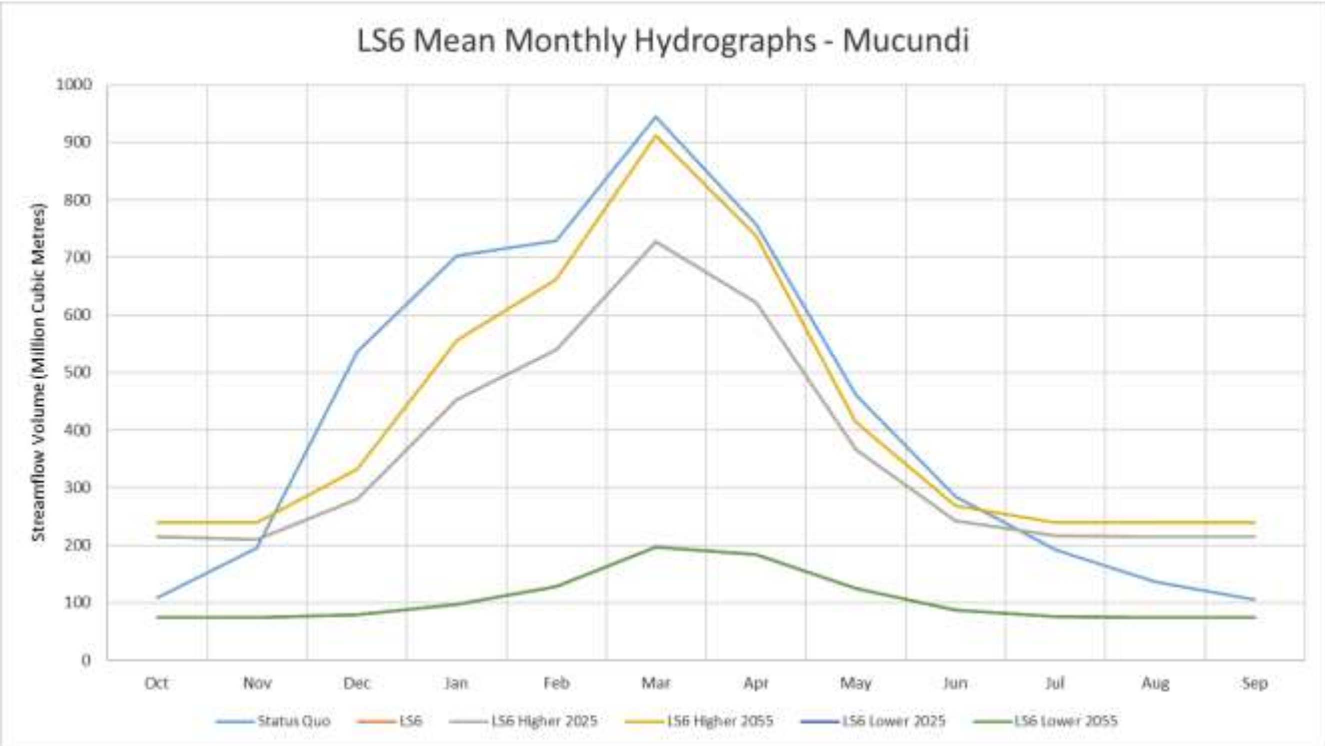
LS6 – MUCUNDI

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	109	195	537	704	730	945	757	461	285	192	137	105	5 158
LS6	215	211	280	453	540	727	622	366	242	216	215	215	4 302
LS6 Higher 2025	215	211	280	453	540	727	622	366	242	216	215	215	4 302
LS6 Higher 2055	239	239	332	556	662	912	737	414	268	240	239	239	5 076
LS6 Lower 2025	75	75	80	98	128	196	185	124	87	76	75	75	1 275
LS6 Lower 2055	75	75	80	98	128	196	185	124	87	76	75	75	1 275

Scenarios	Percentage Deviation of Mean Flows from LS6 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS6 Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LS6 Higher 2055	11.4%	13.3%	18.4%	22.6%	22.5%	25.4%	18.6%	13.1%	10.8%	11.0%	11.2%	11.2%	18.0%
LS6 Lower 2025	-65.0%	-64.3%	-71.6%	-78.4%	-76.3%	-73.0%	-70.3%	-66.0%	-63.9%	-64.8%	-65.0%	-65.0%	-70.4%
LS6 Lower 2055	-65.0%	-64.3%	-71.6%	-78.4%	-76.3%	-73.0%	-70.3%	-66.0%	-63.9%	-64.8%	-65.0%	-65.0%	-70.4%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS6	96.6%	8.3%	-47.8%	-35.6%	-26.0%	-23.0%	-17.9%	-20.6%	-15.3%	12.4%	56.8%	105.2%	-16.6%
LS6 Higher 2025	96.6%	8.3%	-47.8%	-35.6%	-26.0%	-23.0%	-17.9%	-20.6%	-15.3%	12.4%	56.8%	105.2%	-16.6%
LS6 Higher 2055	118.9%	22.7%	-38.2%	-21.1%	-9.4%	-3.5%	-2.6%	-10.3%	-6.1%	24.8%	74.3%	128.1%	-1.6%
LS6 Lower 2025	-31.1%	-61.3%	-85.2%	-86.1%	-82.5%	-79.2%	-75.6%	-73.0%	-69.4%	-60.4%	-45.2%	-28.2%	-75.3%
LS6 Lower 2055	-31.1%	-61.3%	-85.2%	-86.1%	-82.5%	-79.2%	-75.6%	-73.0%	-69.4%	-60.4%	-45.2%	-28.2%	-75.3%


LS6 Flow Duration Curves - Mucundi
Streamflow Volume (Million Cubic Metres)
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile Exceedance
Status Quo
LS6
LS6 High 2025
LS6 High 2055
LS6 Low 2025
LS6 Low 2055

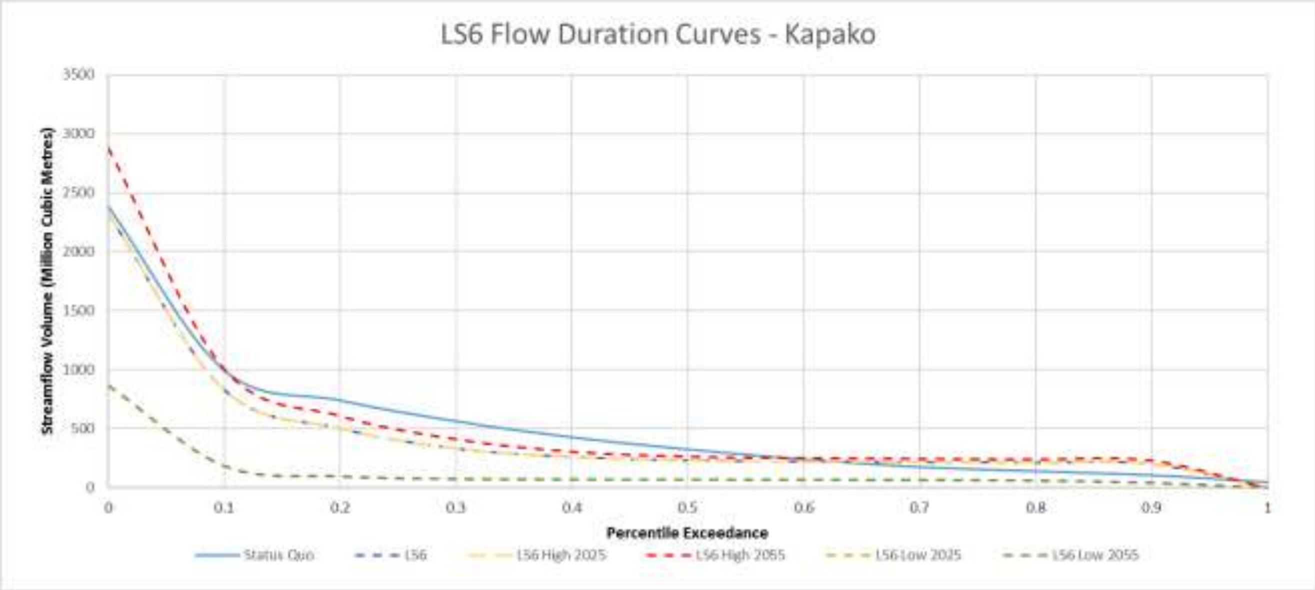

LS6 Mean Monthly Hydrographs - Mucundi
Streamflow Volume (Million Cubic Metres)
1000
900
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS6
LS6 Higher 2025
LS6 Higher 2055
LS6 Lower 2025
LS6 Lower 2055

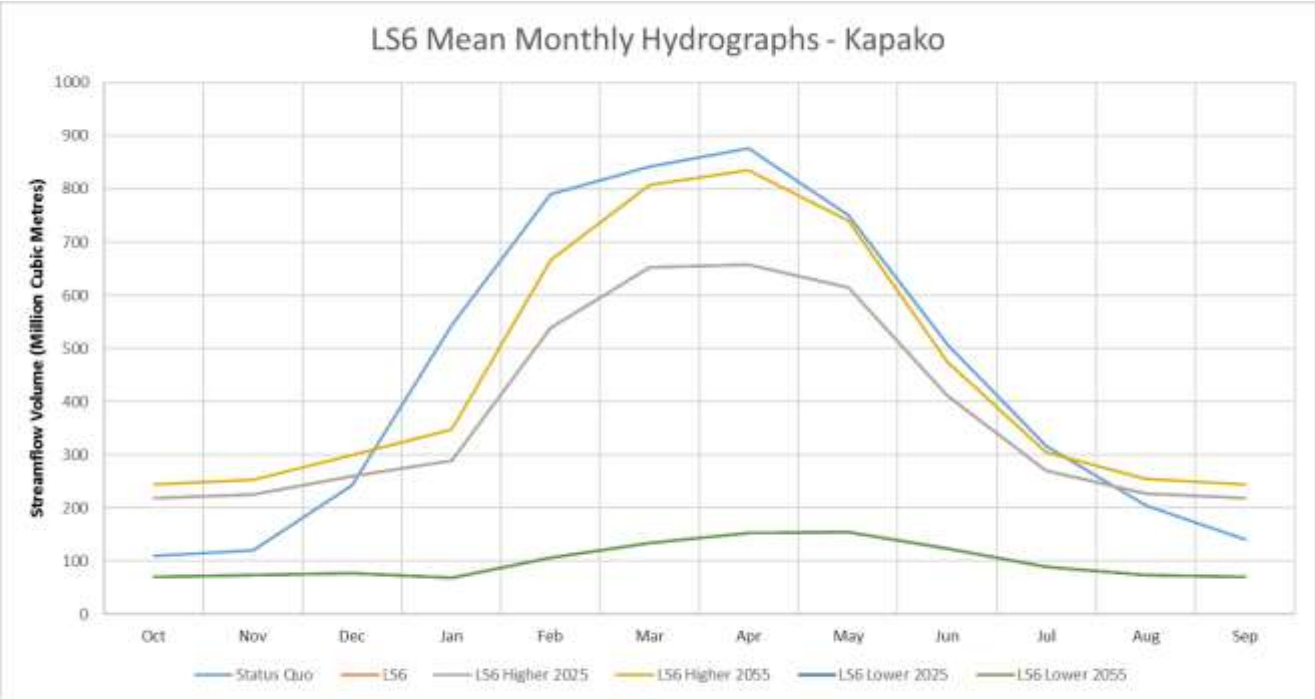
LS6 – KAPAKO

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	110	120	243	545	790	842	876	751	508	316	205	142	5 448
LS6	218	226	259	290	540	652	658	614	411	271	227	218	4 585
LS6 Higher 2025	218	226	259	290	540	652	658	614	411	271	227	218	4 585
LS6 Higher 2055	244	254	299	348	665	808	835	740	476	305	254	244	5 471
LS6 Lower 2025	71	73	77	68	107	135	152	154	124	89	73	70	1 194
LS6 Lower 2055	71	73	77	68	107	135	152	154	124	89	73	70	1 194

Scenarios	Percentage Deviation of Mean Flows from LS6 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS6 Higher 2025	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LS6 Higher 2055	11.9%	12.4%	15.4%	19.9%	23.3%	23.8%	26.8%	20.4%	15.6%	12.6%	12.0%	11.8%	19.3%
LS6 Lower 2025	-67.5%	-67.6%	-70.4%	-76.5%	-80.2%	-79.3%	-76.9%	-74.9%	-69.8%	-67.1%	-67.8%	-67.8%	-74.0%
LS6 Lower 2055	-67.5%	-67.6%	-70.4%	-76.5%	-80.2%	-79.3%	-76.9%	-74.9%	-69.8%	-67.1%	-67.8%	-67.8%	-74.0%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS6	97.6%	88.0%	6.5%	-46.8%	-31.7%	-22.5%	-24.9%	-18.2%	-19.0%	-14.3%	10.9%	53.9%	-15.8%
LS6 Higher 2025	97.6%	88.0%	6.5%	-46.8%	-31.7%	-22.5%	-24.9%	-18.2%	-19.0%	-14.3%	10.9%	53.9%	-15.8%
LS6 Higher 2055	121.1%	111.3%	22.9%	-36.2%	-15.8%	-4.1%	-4.7%	-1.5%	-6.3%	-3.5%	24.1%	72.1%	0.4%
LS6 Lower 2025	-35.7%	-39.0%	-68.4%	-87.5%	-86.5%	-84.0%	-82.6%	-79.5%	-75.6%	-71.8%	-64.3%	-50.4%	-78.1%
LS6 Lower 2055	-35.7%	-39.0%	-68.4%	-87.5%	-86.5%	-84.0%	-82.6%	-79.5%	-75.6%	-71.8%	-64.3%	-50.4%	-78.1%


LS6 Flow Duration Curves - Kapako
Streamflow Volume (Million Cubic Metres)
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile Exceedance
Status Quo
LS6
LS6 High 2025
LS6 High 2055
LS6 Low 2025
LS6 Low 2055

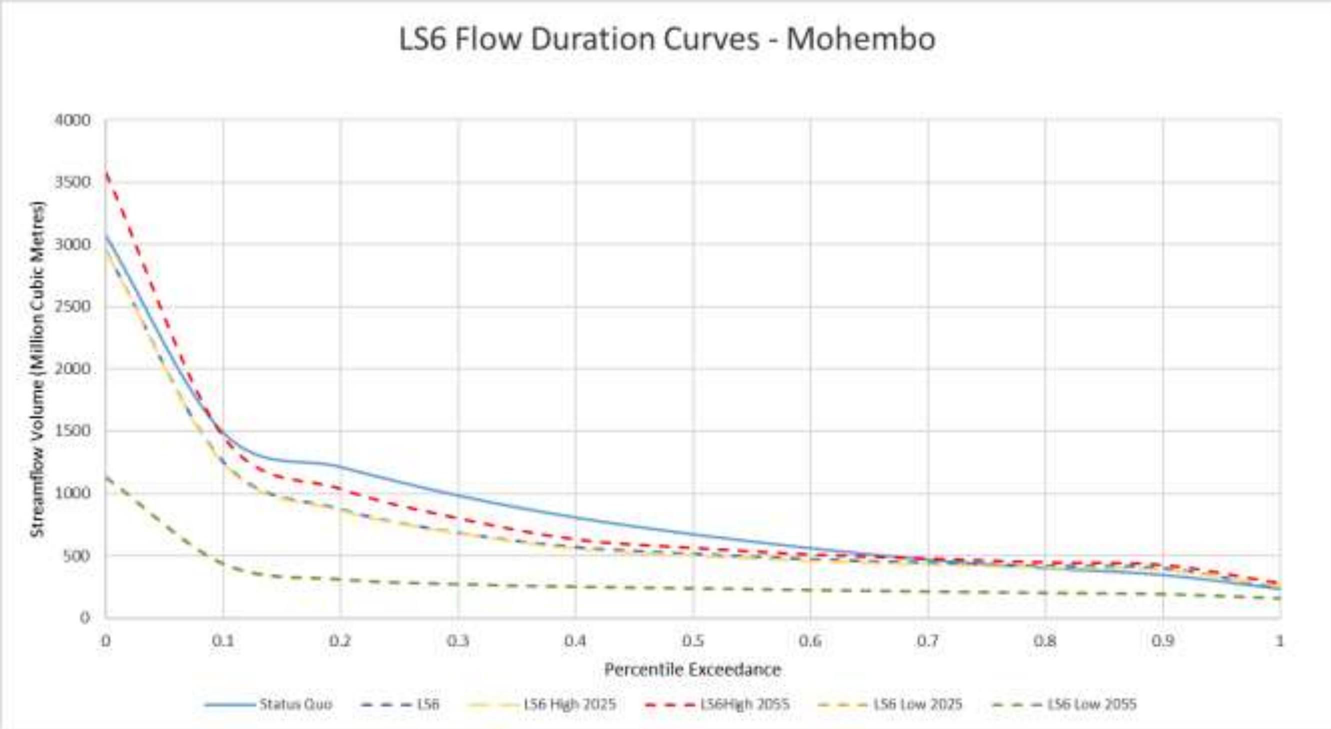

LS6 Mean Monthly Hydrographs - Kapako
Streamflow Volume (Million Cubic Metres)
1000
900
800
700
600
500
400
300
200
100
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS6
LS6 Higher 2025
LS6 Higher 2055
LS6 Lower 2025
LS6 Lower 2055

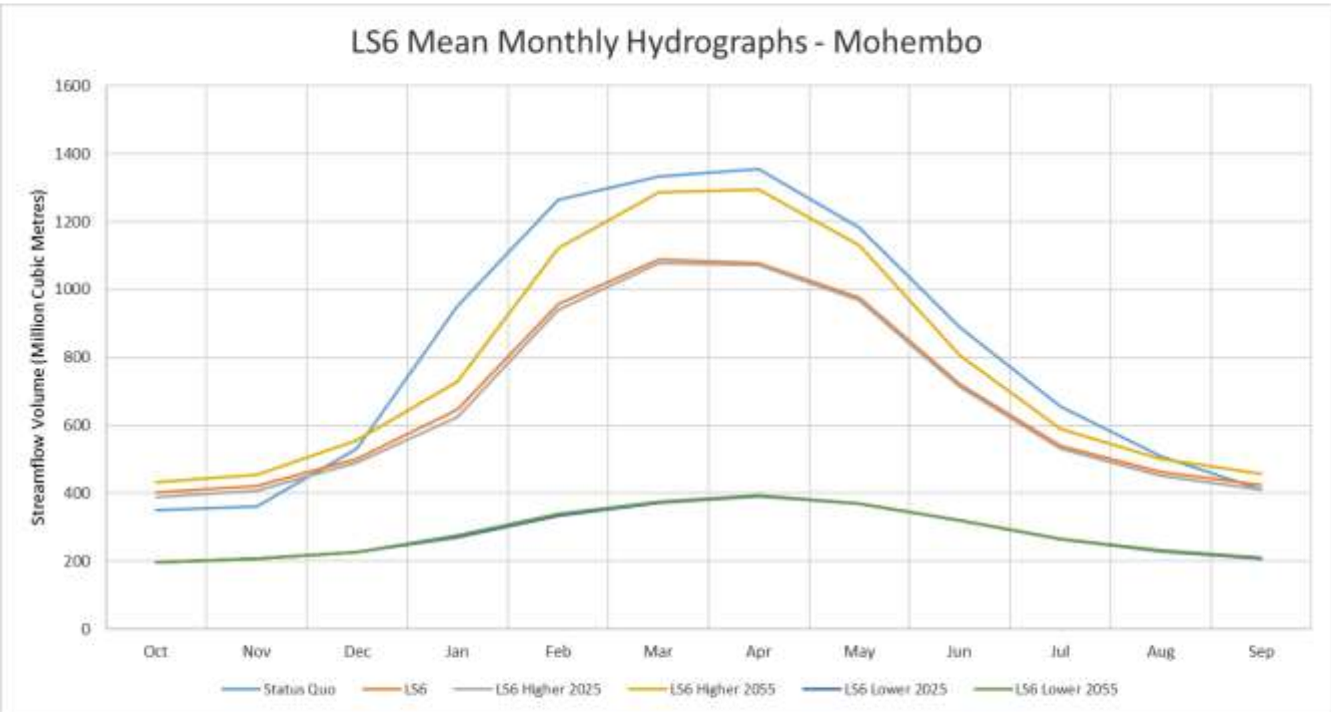
LS6 – MOHEMBO

Scenarios	Mean Flows (Million Cubic Metres)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Status Quo	351	361	532	952	1 265	1 335	1 355	1 183	888	656	508	410	9 795
LS6	401	421	501	646	958	1 088	1 079	975	720	540	462	423	8 215
LS6 Higher 2025	389	408	489	624	941	1 077	1 073	969	712	531	451	411	8 076
LS6 Higher 2055	432	455	556	729	1 121	1 287	1 294	1 129	805	590	501	456	9 357
LS6 Lower 2025	196	207	226	270	334	372	392	370	319	265	230	209	3 389
LS6 Lower 2055	197	208	227	275	338	375	394	371	320	266	231	210	3 411

Scenarios	Percentage Deviation of Mean Flows from LS6 (MSIOA No Climate Change)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS6 Higher 2025	-3.1%	-3.2%	-2.3%	-3.4%	-1.7%	-1.0%	-0.6%	-0.6%	-1.1%	-1.6%	-2.4%	-2.9%	-1.7%
LS6 Higher 2055	7.7%	8.0%	11.0%	12.8%	17.1%	18.3%	19.9%	15.8%	11.8%	9.3%	8.4%	7.9%	13.9%
LS6 Lower 2025	-51.2%	-50.9%	-55.0%	-58.1%	-65.2%	-65.8%	-63.6%	-62.1%	-55.8%	-50.9%	-50.2%	-50.7%	-58.8%
LS6 Lower 2055	-51.0%	-50.7%	-54.7%	-57.3%	-64.7%	-65.5%	-63.5%	-62.0%	-55.6%	-50.7%	-50.0%	-50.5%	-58.5%

Scenarios	Percentage Deviation of Mean Flows from Status Quo/Present Day												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
LS6	14.5%	16.7%	-5.8%	-32.2%	-24.3%	-18.5%	-20.4%	-17.5%	-18.9%	-17.7%	-9.1%	3.2%	-16.1%
LS6 Higher 2025	10.9%	13.0%	-8.0%	-34.5%	-25.6%	-19.3%	-20.8%	-18.1%	-19.8%	-19.0%	-11.2%	0.3%	-17.5%
LS6 Higher 2055	23.4%	26.0%	4.5%	-23.4%	-11.3%	-3.6%	-4.5%	-4.5%	-9.3%	-10.0%	-1.5%	11.4%	-4.5%
LS6 Lower 2025	-44.1%	-42.8%	-57.6%	-71.6%	-73.6%	-72.1%	-71.0%	-68.8%	-64.1%	-59.6%	-54.7%	-49.1%	-65.4%
LS6 Lower 2055	-43.9%	-42.5%	-57.3%	-71.1%	-73.2%	-71.9%	-71.0%	-68.7%	-64.0%	-59.4%	-54.5%	-48.9%	-65.2%


LS6 Flow Duration Curves - Mohembo
Streamflow Volume (Million Cubic Metres)
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile Exceedance
Status Quo
LS6
LS6 High 2025
LS6High 2055
LS6 Low 2025
LS6 Low 2055


LS6 Mean Monthly Hydrographs - Mohembo
Streamflow Volume (Million Cubic Metres)
1600
1400
1200
1000
800
600
400
200
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Status Quo
LS6
LS6 Higher 2025
LS6 Higher 2055
LS6 Lower 2025
LS6 Lower 2055

Annex 5: Economic Impacts of Climate-Water Scenario Assemblies in the CORB

LS1

MSIOA scenario: LS1				
Climate: No climate change				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.28%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	100.28%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	100.03%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.29%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	100.09%	
	Indicator score	0.00	0.00	
Change in proportion of wage of income to unskilled labour	Indicator value	100.00%	99.81%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.00	

MSIOA scenario: LS1				
Climate: No climate change				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.09%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	100.08%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	100.03%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.09%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	100.04%	
	Indicator score	0.00	0.00	
Change in proportion of wage	Indicator value	100.00%	99.91%	

income to unskilled labour	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.00	

MSIOA scenario: LS1				
Climate: High probability				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.28%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	100.28%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	100.03%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.29%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	100.09%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.81%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.00	

MSIOA scenario: LS1				
Climate: High probability				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.06%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	100.05%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	100.02%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.08%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	99.99%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.89%	
	Indicator score	0.00	0.00	

Average impact scores / time period	0.00	0.00	

MSIOA scenario: LS1				
Climate: Low probability				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.14%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	100.15%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	99.95%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.46%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	100.06%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.93%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.00	

MSIOA scenario: LS1				
Climate: Low probability				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	98.91%	
	Indicator score	0.00	-1.00	
Welfare gain / loss	Indicator value	100.00%	98.83%	
	Indicator score	0.00	-1.00	
Change in government revenue	Indicator value	100.00%	99.54%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	99.71%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	97.61%	
	Indicator score	0.00	-2.00	
Change in proportion of wage	Indicator value	100.00%	98.89%	

income to unskilled labour	Indicator score	0.00	-1.00	
Average impact scores / time period		0.00	-0.83	

Modelling output per country

MSIOA Scenario	Climate projection	Variable	Botswana	Namibia	Angola	Highlands
LS1	M	Change in real GDP	0.09%	1.09%	0.18%	0.28%
LS1	M	Welfare gain / loss (% of base GDP)	0.08%	0.99%	0.20%	0.28%
LS1	M	Change in government revenue	0.03%	0.63%	0.01%	0.03%
LS1	M	Change in exports	0.06%	1.07%	0.10%	0.19%
LS1	M	Change in imports	0.05%	1.15%	0.01%	0.13%
LS1	M	Change in trade balance	0.09%	0.88%	0.24%	0.29%
LS1	M	Change in unskilled labour	0.04%	0.59%	0.02%	0.09%
LS1	M	Change in proportion wage of income to unskilled labour	-0.09%	-0.70%	-0.14%	-0.19%
LS1	M	Change in wage income to unskilled labour	-0.07%	-0.13%	-0.16%	-0.16%
LS1	L	Change in real GDP	-1.09%	0.66%	0.08%	0.14%
LS1	L	Welfare gain / loss (% of base GDP)	-1.17%	0.61%	0.09%	0.15%
LS1	L	Change in government revenue	-0.46%	0.24%	-0.06%	-0.05%
LS1	L	Change in exports	-0.54%	0.81%	0.09%	0.16%
LS1	L	Change in imports	-0.70%	0.49%	-0.11%	-0.04%
LS1	L	Change in trade balance	-0.29%	1.60%	0.38%	0.46%
LS1	L	Change in unskilled labour	-2.39%	0.34%	0.02%	0.06%
LS1	L	Change in proportion wage of income to unskilled labour	-1.11%	-0.41%	-0.03%	-0.07%
LS1	L	Change in wage income to unskilled labour	-1.73%	-0.29%	-0.12%	-0.14%
LS1	H	Change in real GDP	0.06%	1.09%	0.18%	0.28%
LS1	H	Welfare gain / loss (% of base GDP)	0.05%	0.99%	0.20%	0.28%
LS1	H	Change in government revenue	0.02%	0.63%	0.01%	0.03%
LS1	H	Change in exports	0.05%	1.07%	0.10%	0.19%
LS1	H	Change in imports	0.03%	1.15%	0.01%	0.13%
LS1	H	Change in trade balance	0.08%	0.88%	0.24%	0.29%
LS1	H	Change in unskilled labour	-0.01%	0.59%	0.02%	0.09%
LS1	H	Change in proportion wage of income to unskilled labour	-0.11%	-0.70%	-0.14%	-0.19%
LS1	H	Change in wage income to unskilled labour	-0.11%	-0.13%	-0.16%	-0.16%

Changes in size of sectors used as modelling inputs

Angola - LS1		**M**	**L**	**H**
	Agric-Cereals	0.00%	0.00%	0.00%
	Agric-Rice	0.45%	0.19%	0.45%
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts	0.00%	0.00%	0.00%
	Household income (Urban)	0.00%	0.00%	0.00%
	Household income (Livelihood)	0.00%	-0.13%	0.00%
	Electricity			
	Tourism			
	Water	1.22%	0.50%	1.22%
Namibia - LS1		**M**	**L**	**H**
	Agric-Cereals	0.71%	0.27%	0.71%
	Agric-Rice			
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts	2.62%	0.99%	2.62%
	Household income (Urban)	0.32%	0.12%	0.32%
	Household income (Livelihood)	0.00%	-0.33%	0.00%
	Electricity			
	Tourism			
	Water	87.62%	32.95%	87.62%
Botswana -LS1		**M**	**L**	**H**
	Agric-Cereals			
	Agric-Rice			
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts			
	Household income (Urban)	0.01%	0.01%	0.01%
	Household income (Livelihood)	0.00%	-0.40%	-0.01%
	Electricity			
	Tourism	-0.13%	-10.93%	-0.36%
	Water	4.80%	2.35%	4.75%

LS3

MSIOA scenario: LS3				
Climate: No climate change				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	101.08%	
	Indicator score	0.00	1.00	
Welfare gain / loss	Indicator value	100.00%	101.12%	
	Indicator score	0.00	1.00	
Change in government revenue	Indicator value	100.00%	100.19%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	102.62%	
	Indicator score	0.00	3.00	
Change in unskilled labour	Indicator value	100.00%	101.80%	
	Indicator score	0.00	2.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	100.04%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	1.17	

MSIOA scenario: LS3				
Climate: No climate change				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.01%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	99.99%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	100.00%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.11%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	99.80%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.73%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.00	

MSIOA scenario: LS3				
Climate: High probability				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	101.01%	
	Indicator score	0.00	1.00	
Welfare gain / loss	Indicator value	100.00%	101.03%	
	Indicator score	0.00	1.00	
Change in government revenue	Indicator value	100.00%	100.15%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	101.90%	
	Indicator score	0.00	2.00	
Change in unskilled labour	Indicator value	100.00%	101.24%	
	Indicator score	0.00	1.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.72%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.83	

MSIOA scenario: LS3				
Climate: High probability				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	99.98%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	99.96%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	99.99%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.10%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	99.74%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.71%	
	Indicator score	0.00	0.00	

Average impact scores / time period		0.00	0.00	

MSIOA scenario: LS3				
Climate: Low probability				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.41%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	100.42%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	99.96%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.92%	
	Indicator score	0.00	1.00	
Change in unskilled labour	Indicator value	100.00%	100.24%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.73%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	0.17	

MSIOA scenario: LS3				
Climate: Low probability				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	98.72%	
	Indicator score	0.00	-1.00	
Welfare gain / loss	Indicator value	100.00%	98.62%	
	Indicator score	0.00	-1.00	
Change in government revenue	Indicator value	100.00%	99.46%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	99.69%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	97.17%	
	Indicator score	0.00	-3.00	
Change in proportion of wage	Indicator value	100.00%	98.66%	

income to unskilled labour	Indicator score	0.00	-1.00	
Average impact scores / time period		0.00	-1.00	

Modelling output per country

MSIOA Scenario	Climate projection	Variable	Botswana	Namibia	Angola	Highlands
LS3	**M**	Change in real GDP	0.010%	1.510%	1.030%	1.078%
LS3	**M**	Welfare gain / loss (% of base GDP)	-0.014%	1.321%	1.092%	1.117%
LS3	**M**	Change in government revenue	-0.003%	0.650%	0.177%	0.191%
LS3	**M**	Change in exports	0.040%	1.577%	0.633%	0.719%
LS3	**M**	Change in imports	-0.003%	1.300%	-0.726%	-0.507%
LS3	**M**	Change in trade balance	0.106%	2.268%	2.642%	2.617%
LS3	**M**	Change in unskilled labour	-0.204%	1.377%	1.858%	1.800%
LS3	**M**	Change in proportion wage of income to unskilled labour	-0.266%	-0.584%	0.111%	0.040%
LS3	**M**	Change in wage income to unskilled labour	-0.299%	0.275%	0.580%	0.548%
LS3	**L**	Change in real GDP	-1.280%	0.790%	0.360%	0.408%
LS3	**L**	Welfare gain / loss (% of base GDP)	-1.383%	0.701%	0.386%	0.420%
LS3	**L**	Change in government revenue	-0.541%	0.214%	-0.051%	-0.043%
LS3	**L**	Change in exports	-0.619%	1.003%	0.208%	0.281%
LS3	**L**	Change in imports	-0.827%	0.488%	-0.205%	-0.130%
LS3	**L**	Change in trade balance	-0.309%	2.287%	0.818%	0.916%
LS3	**L**	Change in unskilled labour	-2.833%	0.598%	0.190%	0.240%
LS3	**L**	Change in proportion wage of income to unskilled labour	-1.343%	-0.342%	-0.264%	-0.271%
LS3	**L**	Change in wage income to unskilled labour	-2.066%	-0.164%	-0.327%	-0.310%
LS3	**H**	Change in real GDP	-0.020%	1.520%	0.950%	1.015%
LS3	**H**	Welfare gain / loss (% of base GDP)	-0.042%	1.324%	0.999%	1.034%
LS3	**H**	Change in government revenue	-0.012%	0.663%	0.137%	0.152%
LS3	**H**	Change in exports	0.028%	1.594%	0.513%	0.612%
LS3	**H**	Change in imports	-0.021%	1.308%	-0.408%	-0.223%
LS3	**H**	Change in trade balance	0.102%	2.305%	1.875%	1.904%
LS3	**H**	Change in unskilled labour	-0.261%	1.381%	1.219%	1.238%
LS3	**H**	Change in proportion wage of income to unskilled labour	-0.289%	-0.582%	-0.247%	-0.280%
LS3	**H**	Change in wage income to unskilled labour	-0.338%	0.284%	0.064%	0.087%

Changes in size of sectors used as modelling inputs

Angola - LS3		**M**	**L**	**H**
	Agric-Cereals	1.37%	0.49%	1.37%
	Agric-Rice	3.77%	1.36%	3.77%
	Agric-Sugar	58.28%	20.92%	58.28%
	Agric-Fruit/Veg/Nuts	0.86%	0.31%	0.86%
	Household income (Urban)	0.00%	0.00%	0.00%
	Household income (Livelihood)	-0.02%	-0.16%	-0.02%
	Electricity	2.70%	0.97%	2.70%
	Tourism			
	Water	4.69%	1.68%	4.69%
Namibia - LS3		**M**	**L**	**H**
	Agric-Cereals	3.28%	1.06%	3.28%
	Agric-Rice			
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts	11.41%	3.67%	11.41%
	Household income (Urban)	0.37%	0.12%	0.37%
	Household income (Livelihood)	-0.05%	-0.40%	-0.05%
	Electricity			
	Tourism			
	Water	101.74%	32.70%	101.74%
Botswana - LS3		**M**	**L**	**H**
	Agric-Cereals			
	Agric-Rice			
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts			
	Household income (Urban)	0.02%	0.01%	0.02%
	Household income (Livelihood)	-0.05%	-0.48%	-0.06%
	Electricity			
	Tourism	-1.49%	-12.97%	-1.75%
	Water	8.53%	3.91%	8.43%

LS6

MSIOA scenario: LS6				
Climate: No climate change				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	101.52%	
	Indicator score	0.00	2.00	
Welfare gain / loss	Indicator value	100.00%	101.56%	
	Indicator score	0.00	2.00	
Change in government revenue	Indicator value	100.00%	100.29%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	102.77%	
	Indicator score	0.00	3.00	
Change in unskilled labour	Indicator value	100.00%	102.00%	
	Indicator score	0.00	2.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.53%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	1.50	

MSIOA scenario: LS6				
Climate: No climate change				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	99.84%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	99.81%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	99.93%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.10%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	99.40%	
	Indicator score	0.00	-1.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.52%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	-0.17	

MSIOA scenario: LS6				
Climate: High probability				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	101.52%	
	Indicator score	0.00	2.00	
Welfare gain / loss	Indicator value	100.00%	101.56%	
	Indicator score	0.00	2.00	
Change in government revenue	Indicator value	100.00%	100.29%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	102.77%	
	Indicator score	0.00	3.00	
Change in unskilled labour	Indicator value	100.00%	102.00%	
	Indicator score	0.00	2.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.53%	
	Indicator score	0.00	0.00	
Average impact scores / time period		0.00	1.50	

MSIOA scenario: LS6				
Climate: High probability				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	99.80%	
	Indicator score	0.00	0.00	
Welfare gain / loss	Indicator value	100.00%	99.76%	
	Indicator score	0.00	0.00	
Change in government revenue	Indicator value	100.00%	99.92%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	100.08%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	99.32%	
	Indicator score	0.00	-1.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.49%	
	Indicator score	0.00	-1.00	

Average impact scores / time period		0.00	-0.33	

MSIOA scenario: LS6				
Climate: Low probability				
Economic impacts - Highlands				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	100.55%	
	Indicator score	0.00	1.00	
Welfare gain / loss	Indicator value	100.00%	100.57%	
	Indicator score	0.00	1.00	
Change in government revenue	Indicator value	100.00%	99.94%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	101.05%	
	Indicator score	0.00	1.00	
Change in unskilled labour	Indicator value	100.00%	100.23%	
	Indicator score	0.00	0.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	99.47%	
	Indicator score	0.00	-1.00	
Average impact scores / time period		0.00	0.33	

MSIOA scenario: LS6				
Climate: Low probability				
Economic impacts - Delta				
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**	
			2016-2035	**2046-2065**
Change in real GDP	Indicator value	100.00%	98.42%	
	Indicator score	0.00	-2.00	
Welfare gain / loss	Indicator value	100.00%	98.29%	
	Indicator score	0.00	-2.00	
Change in government revenue	Indicator value	100.00%	99.33%	
	Indicator score	0.00	0.00	
Change in trade balance	Indicator value	100.00%	99.63%	
	Indicator score	0.00	0.00	
Change in unskilled labour	Indicator value	100.00%	96.52%	
	Indicator score	0.00	-3.00	
Change in proportion of wage income to unskilled labour	Indicator value	100.00%	98.35%	
	Indicator score	0.00	-2.00	

Average impact scores / time period	0.00	-1.50	

Modelling output per country

MSIOA Scenario	Climate projection	Variable	Botswana	Namibia	Angola	Highlands
LS6	**M**	Change in real GDP	-0.160%	1.600%	1.510%	1.516%
LS6	**M**	Welfare gain / loss (% of base GDP)	-0.193%	1.387%	1.580%	1.559%
LS6	**M**	Change in government revenue	-0.068%	0.713%	0.282%	0.295%
LS6	**M**	Change in exports	-0.024%	1.739%	0.826%	0.910%
LS6	**M**	Change in imports	-0.108%	1.470%	-0.507%	-0.294%
LS6	**M**	Change in trade balance	0.099%	2.410%	2.798%	2.772%
LS6	**M**	Change in unskilled labour	-0.597%	1.435%	2.082%	2.003%
LS6	**M**	Change in proportion wage of income to unskilled labour	-0.475%	-0.601%	-0.456%	-0.469%
LS6	**M**	Change in wage income to unskilled labour	-0.601%	0.336%	0.141%	0.162%
LS6	**L**	Change in real GDP	-1.580%	0.750%	0.530%	0.550%
LS6	**L**	Welfare gain / loss (% of base GDP)	-1.710%	0.666%	0.557%	0.569%
LS6	**L**	Change in government revenue	-0.667%	0.184%	-0.069%	-0.061%
LS6	**L**	Change in exports	-0.756%	1.012%	0.248%	0.318%
LS6	**L**	Change in imports	-1.019%	0.452%	-0.230%	-0.157%
LS6	**L**	Change in trade balance	-0.365%	2.408%	0.956%	1.053%
LS6	**L**	Change in unskilled labour	-3.483%	0.548%	0.189%	0.232%
LS6	**L**	Change in proportion wage of income to unskilled labour	-1.652%	-0.320%	-0.551%	-0.526%
LS6	**L**	Change in wage income to unskilled labour	-2.531%	-0.196%	-0.628%	-0.583%
LS6	**H**	Change in real GDP	-0.200%	1.600%	1.510%	1.516%
LS6	**H**	Welfare gain / loss (% of base GDP)	-0.236%	1.387%	1.580%	1.559%
LS6	**H**	Change in government revenue	-0.084%	0.713%	0.282%	0.295%
LS6	**H**	Change in exports	-0.046%	1.739%	0.826%	0.910%
LS6	**H**	Change in imports	-0.133%	1.470%	-0.508%	-0.294%
LS6	**H**	Change in trade balance	0.083%	2.410%	2.798%	2.772%
LS6	**H**	Change in unskilled labour	-0.679%	1.435%	2.082%	2.003%
LS6	**H**	Change in proportion wage of income to unskilled labour	-0.508%	-0.601%	-0.456%	-0.469%
LS6	**H**	Change in wage income to unskilled labour	-0.656%	0.336%	0.141%	0.162%

Changes in size of sectors used as modelling inputs

Angola - LS6		**M**	**L**	**H**
	Agric-Cereals	2.31%	0.69%	2.31%
	Agric-Rice	103.55%	30.69%	103.55%
	Agric-Sugar	77.70%	23.03%	77.70%
	Agric-Fruit/Veg/Nuts	1.50%	0.44%	1.50%
	Household income (Urban)	0.01%	0.00%	0.01%
	Household income (Livelihood)	-0.04%	-0.19%	-0.04%
	Electricity	4.27%	1.27%	4.27%
	Tourism			
	Water	7.34%	2.18%	7.34%
Namibia - LS6		**M**	**L**	**H**
	Agric-Cereals	3.28%	0.86%	3.28%
	Agric-Rice			
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts	11.41%	2.97%	11.41%
	Household income (Urban)	0.45%	0.12%	0.45%
	Household income (Livelihood)	-0.08%	-0.47%	-0.08%
	Electricity			
	Tourism			
	Water	122.84%	31.99%	122.84%
Botswana - LS6		**M**	**L**	**H**
	Agric-Cereals			
	Agric-Rice			
	Agric-Sugar			
	Agric-Fruit/Veg/Nuts			
	Household income (Urban)	0.03%	0.01%	0.03%
	Household income (Livelihood)	-0.13%	-0.58%	-0.14%
	Electricity			
	Tourism	-3.41%	-15.85%	-3.77%
	Water	11.20%	4.62%	11.01%

Economics impact modelling external data sources

INDICATOR	DESCRIPTION	YEAR	SOURCE
NAMIBIA			
Agricultural production baseline	Area harvested (Ha)	2014	(Knoema, 2017)
Urban Abstraction	Summation of towns (Mm^3/yr)	2007	(JG Africa, 2017)
Livelihoods	Household final consumption expenditure (million USD)	2015	(The World Bank Group, 2017a)
Water	Potable water produced (Mm^3)	2008	(NAMWATER , 2008)
BOTSWANA			
Agricultural production baseline	Area harvested (Ha)	2014	(Knoema, 2017b)
Urban Abstraction	Summation of towns (Mm^3/yr)	2007	(JG Africa, 2017)
Livelihoods	Household final consumption expenditure (million USD)	2015	(The World Bank Group, 2017a)
Tourism	Total Tourism Contribution to GDP (million USD)	2016	(World Travel and Tourism Council, 2017)
Water	Potable Water Produced (Mm^3)	2013	(Water Utlities Corporation, 2013)
ANGOLA			
Agricultural production baseline	Area harvested (Ha)	2014	(Knoema, 2017c)
Urban Abstraction	Summation of towns (Mm^3/yr)	2007	(JG Africa, 2017)
Livelihoods	Household final consumption expenditure (million USD)	2015	(The World Bank Group, 2017a)
Electricity	Million kilowatt hours currently produced	2014	(International Energy Agency, 2014)
Water	Municipal water withdrawal (Mm^3)	2011	(Centre for Applied Research, 2012)

Overview of the economic model used

The **Global Trade Analysis Project (GTAP) model** is a multi-region, CGE model. The inter-regional linkages originate from bilateral trade flows, while intra-industry linkages are captured by the regional input-output structure. The associated GTAP database covers bilateral trade data, structure of production, consumption and intermediate usage of commodities and services. Version 9A of the GTAP database provides three reference years for the global economy, 2004, 2007 and 2011. The database divides the world into 140 regions and 57 sectors and contains information on bilateral trade flows for commodities in these regions.

While the GTAP database provides a unique combination of global trade flows and economic data, there are a number of **key limitations** related directly to this study. Particularly, in the latest version of the GTAP model (Version 9A), Angola and the Democratic Republic of Congo (DRC) are aggregated and presented as a single region, as are a number of other regions within Africa. It is therefore not possible to provide disaggregated results for these countries directly from the model.
The analysis that follows for Angola is therefore based on a simplifying assumption. Angola is assumed to have the same overall economic structure as that of the DRC. Percentage changes to any of the identified economic indicators will therefore be identical for either country. To reflect actual (volume or value) changes in the economic indicators, the change has been reflected in proportion to Angola's share of total 2011 GDP of Angola and the DRC combined.

A second limitation relates to the aggregation of tourism-related activities within a broader trade and commercial activity sector. To identify the impact of potential shocks on the tourism sector, simulated shocks on the broader trade sector were undertaken using the implied contribution of tourism to this sector.[17]

The GTAP database was **aggregated into 4 regions** i.e. Botswana, Namibia the combined DRC-Angola region and the Rest of the World. The 57 available sectors were aggregated into 22 sectors, summarised in Table 1. The latest reference year, 2011, was used for the purpose of this analysis.

Table 1 Sectoral aggregation for CGE simulations

Old sector (baseline GTAP)		Aggregated new sector	
No.	Detailed description	No.	Description
1	Paddy Rice: rice, husked and unhusked	2	Paddy rice, processed rice
2	Wheat: wheat and meslin	1	Wheat and cereal grains nec
3	Other Grains: maize (corn), barley, rye, oats, other cereals	1	Wheat and cereal grains nec
4	Veg & Fruit: vegetables, fruitvegetables, fruit and nuts, potatoes, cassava, truffles,	4	Vegetables, fruit, nuts
5	Oil Seeds: oil seeds and oleaginous fruit; soy beans, copra	5	Oil seeds, plant based fibres
6	Cane & Beet: sugar cane and sugar beet	3	Sugar cane, sugar beet, sugar
7	Plant Fibres: cotton, flax, hemp, sisal and other raw vegetable materials used in textiles	6	Plant fibres eg cotton
8	Other Crops: live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds, beverage and spice crops, unmanufactured tobacco, cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets, plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes, sugar beet seed and seeds of forage plants, other raw vegetable materials	7	Crops nec incl flowers
9	Cattle: cattle, sheep, goats, horses, asses, mules, and hinnies; and semen thereof	8	Livestock and meat products
10	Other Animal Products: swine, poultry and other live animals; eggs, in shell (fresh or cooked), natural honey, snails (fresh or preserved) except sea snails; frogs' legs, edible products of animal origin n.e.c., hides, skins and furskins, raw, insect waxes and spermaceti, whether or not refined or coloured	8	Livestock and meat products
11	Raw milk	8	Livestock and meat products
12	Wool: wool, silk, and other raw animal materials used in textile	8	Livestock and meat products
13	Forestry: forestry, logging and related service activities	9	Mining and extraction
14	Fishing: hunting, trapping and game propagation including related service activities, fishing, fish farms; service activities incidental to fishing	9	Mining and extraction
15	Coal: mining and agglomeration of hard coal, lignite and peat	9	Mining and extraction
16	Oil: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)	9	Mining and extraction
17	Gas: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)	9	Mining and extraction
18	Other Mining: mining of metal ores, uranium, gems. other mining and quarrying	9	Mining and extraction
19	Cattle Meat: fresh or chilled meat and edible offal of cattle, sheep, goats, horses, asses, mules, and hinnies. raw fats or grease from any animal or bird.	8	Livestock and meat products

[17] This was done by using tourism's direct contribution to GDP (based on data from the World Travel and Tourism Council (WTTC)) to identify the implied contribution of tourism to the trade sector within the GTAP database.

Old sector (baseline GTAP)		Aggregated new sector	
No.	Detailed description	No.	Description
20	Other Meat: pig meat and offal. preserves and preparations of meat, meat offal or blood, flours, meals and pellets of meat or inedible meat offal; greaves	8	Livestock and meat products
21	Vegetable Oils: crude and refined oils of soya-bean, maize (corn),olive, sesame, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and canola, mustard, coconut palm, palm kernel, castor, tung jojoba, babassu and linseed, perhaps partly or wholly hydrogenated,inter-esterified, re-esterified or elaidinised. Also margarine and similar preparations, animal or vegetable waxes, fats and oils and their fractions, cotton linters, oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; degras and other residues resulting from the treatment of fatty substances or animal or vegetable waxes.	10	Processed food
22	Milk: dairy products	10	Processed food
23	Processed Rice: rice, semi- or wholly milled	2	Paddy rice, processed rice
24	Sugar	3	Sugar cane, sugar beet, sugar
25	Other Food: prepared and preserved fish or vegetables, fruit juices and vegetable juices, prepared and preserved fruit and nuts, all cereal flours, groats, meal and pellets of wheat, cereal groats, meal and pellets n.e.c., other cereal grain products (including corn flakes), other vegetable flours and meals, mixes and doughs for the preparation of bakers' wares, starches and starch products; sugars and sugar syrups n.e.c., preparations used in animal feeding, bakery products, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products, food products n.e.c.	10	Processed food
26	Beverages and Tobacco products	10	Processed food
27	Textiles: textiles and man-made fibres	11	Textiles and clothing
28	Wearing Apparel: Clothing, dressing and dyeing of fur	11	Textiles and clothing
29	Leather: tanning and dressing of leather; luggage, handbags, saddlery, harness and footwear	12	Light manufacturing
30	Lumber: wood and products of wood and cork, except furniture; articles of straw and plaiting materials	12	Light manufacturing
31	Paper & Paper Products: includes publishing, printing and reproduction of recorded media	12	Light manufacturing
32	Petroleum & Coke: coke oven products, refined petroleum products, processing of nuclear fuel	13	Heavy manufacturing
33	Chemical Rubber Products: basic chemicals, other chemical products, rubber and plastics products	13	Heavy manufacturing
34	Non-Metallic Minerals: cement, plaster, lime, gravel, concrete	13	Heavy manufacturing
35	Iron & Steel: basic production and casting	13	Heavy manufacturing
36	Non-Ferrous Metals: production and casting of copper, aluminium, zinc, lead, gold, and silver	13	Heavy manufacturing
37	Fabricated Metal Products: Sheet metal products, but not machinery and equipment	12	Light manufacturing
38	Motor Motor vehicles and parts: cars, lorries, trailers and semi-trailers	12	Light manufacturing
39	Other Transport Equipment: Manufacture of other transport equipment	12	Light manufacturing
40	Electronic Equipment: office, accounting and computing machinery, radio, television and communication equipment and apparatus	13	Heavy manufacturing
41	Other Machinery & Equipment: electrical machinery and apparatus n.e.c., medical, precision and optical instruments, watches and clocks	13	Heavy manufacturing
42	Other Manufacturing: includes recycling	12	Light manufacturing
43	Electricity: production, collection and distribution	15	Elec production distribution
44	Gas Distribution: distribution of gaseous fuels through mains; steam and hot water supply	14	Gas manufacture distribution
45	Water: collection, purification and distribution	16	Water collection distribution
46	Construction: building houses factories offices and roads	17	Construction
47	Trade: all retail sales; wholesale trade and commission trade; hotels and restaurants; repairs of motor vehicles and personal and household goods;	18	Trade incl hotels

Old sector (baseline GTAP)		Aggregated new sector	
No.	Detailed description	No.	Description
	retail sale of automotive fuel		
48	Other Transport: road, rail ; pipelines, auxiliary transport activities; travel agencies	19	Transport and communication
49	Water transport	19	Transport and communication
50	Air transport	19	Transport and communication
51	Communications: post and telecommunications	19	Transport and communication
52	Other Financial Intermediation: includes auxiliary activities but not insurance and pension funding (see next)	20	Finance, insurance, business
53	Insurance: includes pension funding, except compulsory social security	20	Finance, insurance, business
54	Other Business Services: real estate, renting and business activities	20	Finance, insurance, business
55	Recreation & Other Services: recreational, cultural and sporting activities, other service activities; private households with employed persons (servants)	21	Recreation, other services
56	Other Services (Government): public administration and defense; compulsory social security, education, health and social work, sewage and refuse disposal, sanitation and similar activities, activities of membership organizations n.e.c., extra-territorial organizations and bodies	22	Public, social, other services
57	Dwellings: ownership of dwellings (imputed rents of houses occupied by owners)	22	Public, social, other services

The GTAP database aggregates country labour endowments into 5 major groupings, based on the ILO's International Standard Classification of Occupations (ISCO) version 1998 (ISCO-88). This classification is summarised in the table below.

Table 2 Labour endowments in GTAP database

ISCO-88 Major Group	Short GTAP name	Description
1,2	Officials and Mangers	Legislators, senior officials and managers (Major Groups 1), and professionals (Major Group 2)
3	Technicians	Technicians and associate professionals
4	Clerks	Clerks
5	Service / Shop workers	Service workers and shop and market sales workers
6,7,8,9	Agricultural and Unskilled	Skilled agricultural and fishery workers (Major Group 6), craft and related trade workers (Major Group 7), plant and machine operators and assemblers (Major Group 8), and elementary occupations (Major Group 9)

The standard comparative static GTAP CGE model is used, with the exception that agricultural and unskilled real labour unit costs are assumed to be fixed (or "sticky") for Botswana, Namibia and Angola-DRC regions. This allows for the introduction of high levels of unskilled unemployment (an excess supply of unskilled labour) in the model. Through this the supply of unskilled labour is determined endogenously, rather than fixed as an exogenous variable. A second adjustment to the standard model was made to allow for exogenous shocks to output in each of the identified sectors. To make output in each of these sectors exogenous, the productivity parameter for capital was made an exogenous variable in each applicable sector.[18]

[18] This implies that the productivity of capital can adjust as needed in terms of that sectors production function, and is effectively providing each applicable sector an unearned (free) capital productivity boost. Nevertheless, this adjustment allows for the exogenous shock to output.

Annex 6: Social Impacts of Climate-Water Scenario Assemblies in the CORB

MSIOA scenario: LS1			
Climate: No climate change			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Weak disruption of land and housing
		0	-1
Average impact scores / time period		0	-0.25

MSIOA Scenario LS1, High Probability Climate Change

MSIOA scenario: LS1			
Climate: High probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Weak disruption of land and housing
		0	-1
Average impact scores / time period		0	-0.25

MSIOA Scenario LS1, Low Probability Climate Change

MSIOA scenario: LS1			
Climate: Low probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Weak disruption of land and housing
		0	-1
Average impact scores / time period		0	-0.25

MSIOA Scenario LS3, No Climate Change

MSIOA scenario: LS3			
Climate: No climate change			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	Weak positive improvement in electricity access
		0	1
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Positive improvement in urban water access
		0	2
Influx	Relative impact direction from baseline	No change in influx	Increase in influx
		0	-2
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Strong disruption of land and housing
		0	-3
Average impact scores / time period		0	-0.5

MSIOA Scenario LS3, High Probability Climate Change

MSIOA scenario: LS3			
Climate: High probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values** **2016-2035**
Electricity Access	Relative impact direction from baseline	No change in electricity access	Weak positive improvement in electricity access
		0	1
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Positive improvement in urban water access
		0	2
Influx	Relative impact direction from baseline	No change in influx	Increase in influx
		0	-2
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Strong disruption of land and housing
		0	-3
Average impact scores / time period		0	-0.5

MSIOA Scenario LS3, Low Probability Climate Change

MSIOA scenario: LS3			
Climate: Low probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator** **2016-2035**
Electricity Access	Relative impact direction from baseline	No change in electricity access	Weak positive improvement in electricity access
		0	1
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Strong increase in influx
		0	-3
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Strong disruption of land and housing
		0	-3
Average impact scores / time period		0	-1

MSIOA Scenario LS6, No Climate Change

MSIOA scenario: LS6			
Climate: No climate change			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values** **2016-2035**
Electricity Access	Relative impact direction from baseline	No change in electricity access	Positive improvement in electricity access
		0	2
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Strong positive improvement in urban water access
		0	3
Influx	Relative impact direction from baseline	No change in influx	Increase in influx
		0	-2
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Strong disruption of land and housing
		0	-3
Average impact scores / time period		0	0

MSIOA Scenario LS6, High Probability Climate Change

MSIOA scenario: LS6			
Climate: High probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator** **2016-2035**
Electricity Access	Relative impact direction from baseline	No change in electricity access	Positive improvement in electricity access
		0	2
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Strong positive improvement in urban water access
		0	3
Influx	Relative impact direction from baseline	No change in influx	Strong increase in influx
		0	-3
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Strong disruption of land and housing
		0	-3
Average impact scores / time period		0	-0.25

MSIOA Scenario LS6, Low Probability Climate Change

MSIOA scenario: LS6			
Climate: Low probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	Weak positive improvement in electricity access
		0	1
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Positive improvement in urban water access
		0	2
Influx	Relative impact direction from baseline	No change in influx	Strong increase in influx
		0	-3
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	Strong disruption of land and housing
		0	-3
Average impact scores / time period		0	-0.75

MSIOA Scenario LS1, No Climate Change

MSIOA scenario: LS1			
Climate: No climate change			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0

MSIOA Scenario LS1, High Probability Climate Change

MSIOA scenario: LS1			
Climate: High probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0

MSIOA Scenario LS1, Low Probability Climate Change

MSIOA scenario: LS1			
Climate: Low probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	No change in urban water access
		0	0
Influx	Relative impact direction from baseline	No change in influx	No change in influx
		0	0
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0

MSIOA Scenario LS3, No Climate Change

MSIOA scenario: LS3			
Climate: No climate change			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Positive improvement in urban water access
		0	2
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0.25

MSIOA Scenario LS3, High Probability Climate Change

MSIOA scenario: LS3			
Climate: High probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Positive improvement in urban water access
		0	2
Influx	Relative impact direction from baseline	No change in influx	Weak increase in influx
		0	-1
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0.25

MSIOA Scenario LS3, Low Probability Climate Change

MSIOA scenario: LS3			
Climate: Low probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Weak positive improvement in urban water access
		0	1
Influx	Relative impact direction from baseline	No change in influx	No change in influx
		0	0
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0.25

MSIOA Scenario LS6, No Climate Change

MSIOA scenario: LS6			
Climate: No climate change			
Social impacts			
Indicator name & unit of	**Type of number**	**Baseline indicator values and scores**	**Projected indicator**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Strong positive improvement in urban water access
		0	3
Influx	Relative impact direction from baseline	No change in influx	No change in influx
		0	0
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0.75

MSIOA Scenario LS6, High Probability Climate Change

MSIOA scenario: LS6			
Climate: High probability			
Social impacts			
Indicator name & unit of measure	**Type of number**	**Baseline indicator values and scores**	**Projected indicator values**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Strong positive improvement in urban water access
		0	3
Influx	Relative impact direction from baseline	No change in influx	No change in influx
		0	0
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0.75

MSIOA Scenario LS6, Low Probability Climate Change

MSIOA scenario: LS6			
Climate: Low probability			
Social impacts			
Indicator name & unit of	**Type of number**	**Baseline indicator values and scores**	**Projected indicator**
			2016-2035
Electricity Access	Relative impact direction from baseline	No change in electricity access	No change in electricity access
		0	0
Urban Water Access	Relative impact direction from baseline	No change in urban water access	Positive improvement in electricity access
		0	2
Influx	Relative impact direction from baseline	No change in influx	No change in influx
		0	0
Land and Housing Disruption	Relative impact direction from baseline	No disruption in land and housing	No disruption in land and housing
		0	0
Average impact scores / time		0	0.5

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