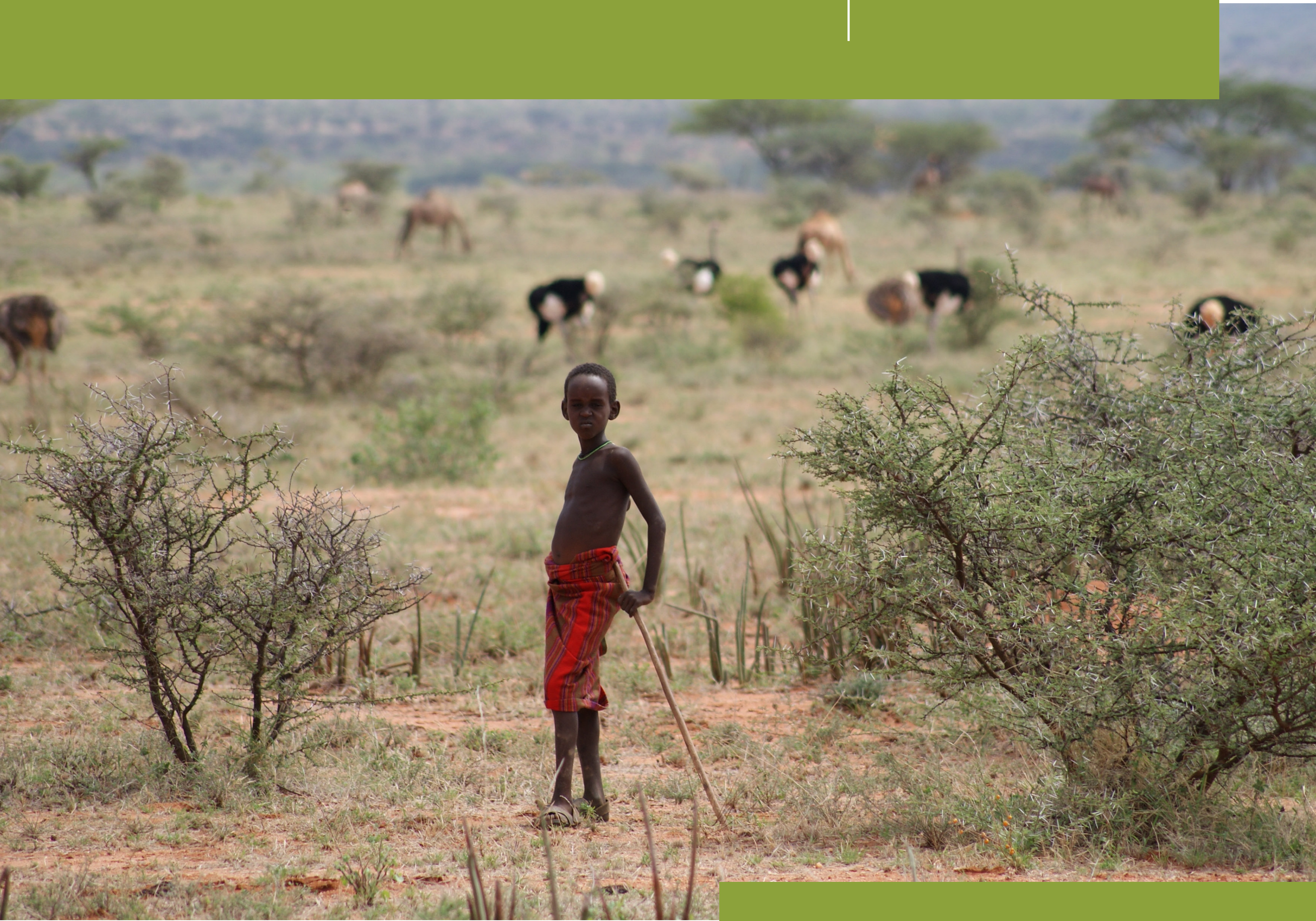
Local economic costs of the proposed Isiolo dam: A scoping study

DISCUSSION PAPER



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Conservation Strategy Fund

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Photo: Peter Chira

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Contents

List of Tables

List of Figures

1 Introduction

Construction of the proposed Isiolo Dam in the Ewaso Ng'iro River has been identified by Kenya's National Water Conservation and Pipeline Corporation as necessary to improve local livelihood by providing water for domestic and livestock use, small irrigation activities, and in the future, for tourists in the proposed Isiolo Resort City. However, there has also been opposition to the proposed construction, on the grounds that the dam will expose herders downstream to drought, negatively affect endangered wildlife, and put the local wildlife-tourism based economy at risk. The Ewaso Ng'iro Basin Stakeholder Forum, composed of conservation sector, business sector, and civil society, has sought further understanding on the risks and opportunities related to the project. The present study represents one such effort, in which the Forum engaged Conservation Strategy Fund (CSF) to conduct an initial desk-based study of potential local costs that could be caused by the Dam. Forum members provided data and factual input, but did not carry out analyses or take a role in generating conclusions or recommendations.

The study focuses on the area downstream of the dam, but also quantifies and describes several important economic changes upstream. Specifically, we address three main topics. First, we quantify change in water supply if the dam is built, and then calculate and compare this to demand in the form of current and expected local water use for agriculture, livestock, and domestic uses; we consider historical river flow data, predicted future growth in water demand, and several river flow scenarios following construction in order to describe the magnitude of changes that could be expected. Second, we quantify the impact of the proposed dam on the daily life of herders, by quantifying their expected economic losses due to increased incidence of drought and therefore to increased livestock mortality and distance to water sources. Third, we evaluate the economic impact of the proposed dam on the existing wildlife tourism sector, considering first the adverse effects on wildlife from the project, and the decline in the number of tourists due to a decline in the willingness to pay for wildlife viewing. These results are necessarily simplified, and do not take into account complex but potentially significant ecological changes and their additional impact on herders, wildlife, and wildlife tourism. However, the analysis included here within the constraints of a desk study suggest that negative local economic impacts may be severe, in turn suggesting that in depth analysis of local ecological and economic impacts is merited prior to proceeding with the project.

The following sections present each of the three main topics of analysis. The final section gives conclusions and recommendations.

2 Water Balance During and After Dam Construction

2.1 Supply

To quantify the extent of the change in river flow resulting from the construction of the proposed Isiolo Dam, we use monthly data from January 1960 to August 2007 to construct historical flow patterns. We use data from two upstream stations: the Ewaso Ng'iro Junction (henceforth AJ) and Ewaso Narok Junction (henceforth AK). These time series were made available by the Center for Training and Integrated Research in ASAL Development (CETRAD).[1] Because there are many missing values for the AK station, we use an imputation procedure to replace missing values with values predicted using the flow from the AJ Junction for the same month and year.[2]

To obtain the unregulated (or natural) downstream flow (i.e., prior to construction of the proposed dam), we sum up the data from both upstream stations. Isiolo County is in the middle and lower catchment of the Ewaso Ng'iro River, which enters the county after the confluence of Ewaso Ng'iro and Ewaso Narok (Figure 1).

[1] ASAL is the acronym for Arid and Semi-Arid Lands.

[2] The prediction is made after estimating a multivariate regression model where the explanatory variables are a cubic polynomial in AJ junction flow interacted with month-specific dummy variables (to account for seasonality in the relationship between the two junctions). The R-squared from this regression is 0.562, implying a sufficiently strong relationship between flows at the two junctions to use flow at AJ to predict flow at AK.

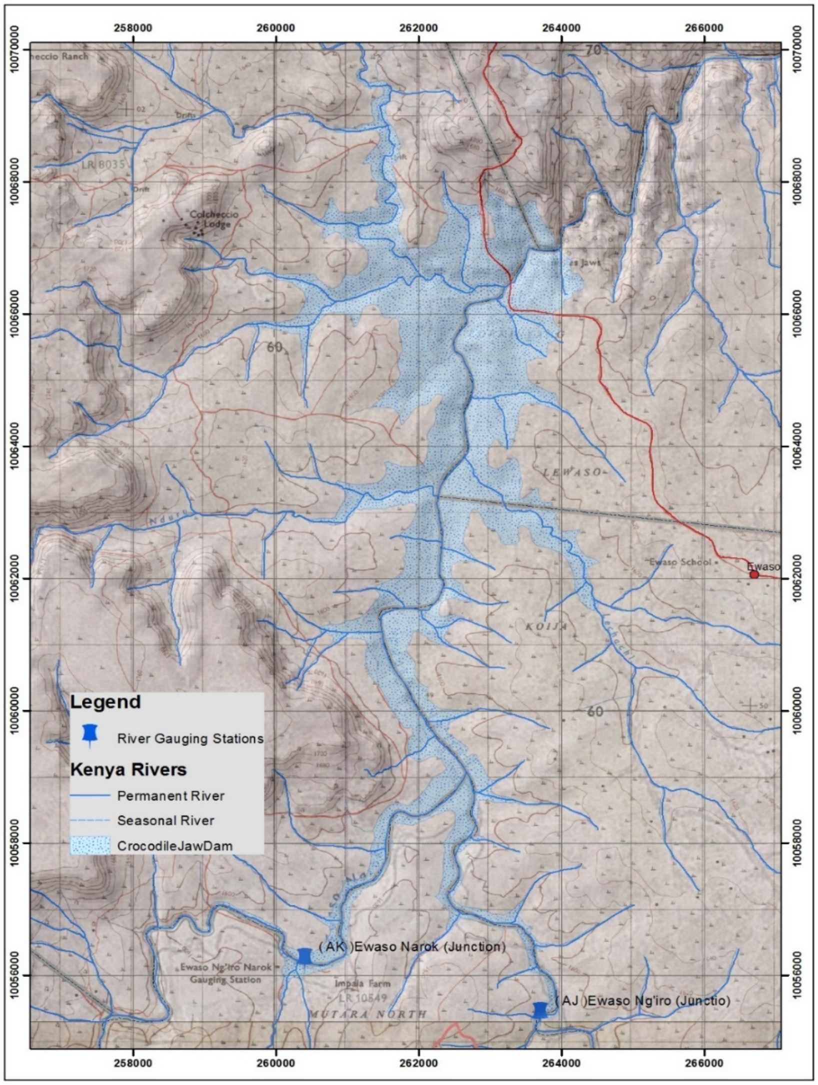

Figure 1 - Crocodile Jaw Map

Source: Center for Training and Integrated Research in ASAL Development, CETRAD

Figure 2 shows the average monthly flow pattern from 1960 to 2007, as well as the flow in the wettest and driest years, 1961 and 1999 respectively. While in 1961 the annual average flow was approximately 56 m^3/s (cubic meter per second), in 1999 the annual river flow average was close to 3.4 m^3/s. Assuming that there is no measurement error, November and December of 1961 were considerably atypical for the region with a flow equal to 337 and 217 m^3/s respectively.[3] For the following calculations, we therefore make use of average or seasonal average flows. The average discharge for the entire study-period is 13.09 m^3/s, which is enough water to fill an Olympic-size swimming pool in just over three minutes.[4]

[3] Because of the flows in November and December, 1961 was the wettest year from 1960 to 2007. However, from January to March the river flow was below the average for the period.

[4] The total volume of an Olympic-size pool is 2,500 cubic meters.

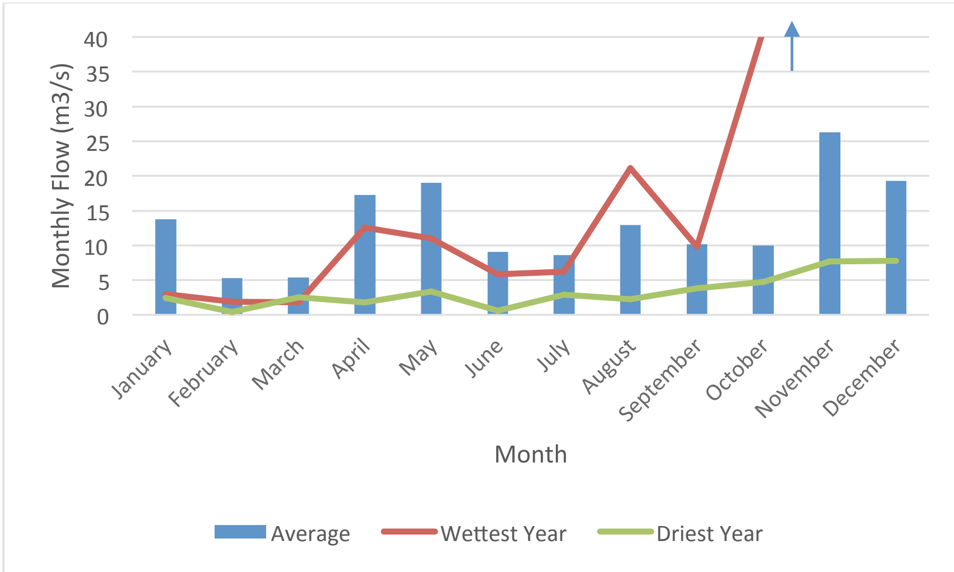

Figure 2 - Monthly River Flow (1960 - 2007) before the Construction of the Proposed Dam
Source: Authors' calculations based on data provided by CETRAD

Figure 3 shows average monthly flow and average rainfall on the left panel, and average monthly river flow and average temperature in Isiolo County on the right panel. Average rainfall and temperature data are taken from World Weather Online from 2000 to 2012. As expected, the correlation between river flow and rainfall is high, because precipitation is one of the most important variables determining river output. The correlation between river flow and temperature is not strong.

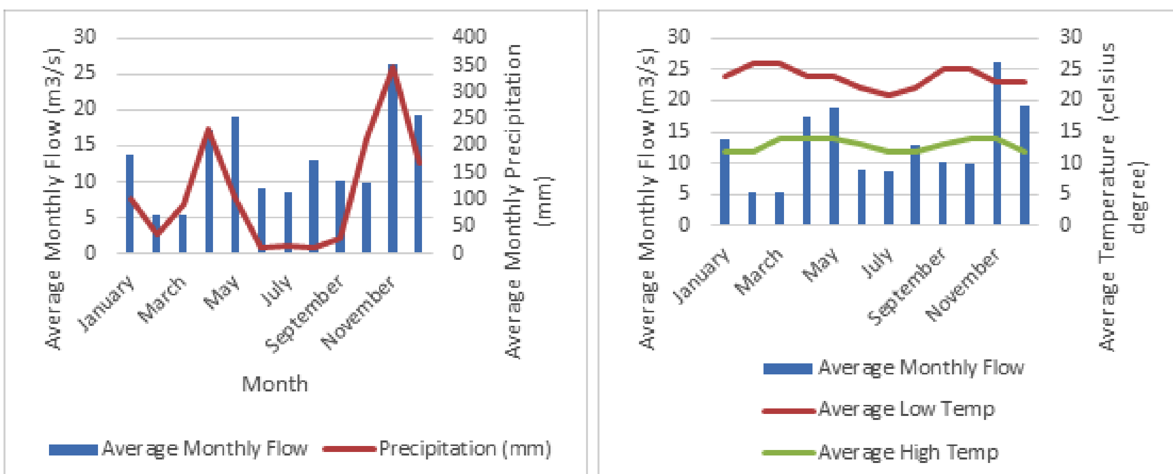

Figure 3 - Average River Flow (1960 – 2007), Precipitation and Temperature (2000 – 2012) in Isiolo County
Source: Authors' calculations based on data provided by CETRAD and World Weather Online

From the average monthly flow and rainfall, we identify two wet seasons and two dry seasons in Isiolo County. During the dry seasons – from January to February and from June to September – the average flow is 9.9 m^3/s, reaching an average low of 5.3 m^3/s in February. In the wet seasons – from March to May, and October to December – the average flow is 16.20 m^3/s and the month with the average highest is November, with 26.3 m^3/s flow, which is almost five times higher than the average low during the dry months.[5] Because of this variability in river flow during the dry and wet seasons, we consider seasonality in our assessment of impacts.

Figure 4 shows the river flow pattern in the dry and wet seasons. The time series for the dry and wet periods are constructed considering the river flow in the dry and rainy months respectively.

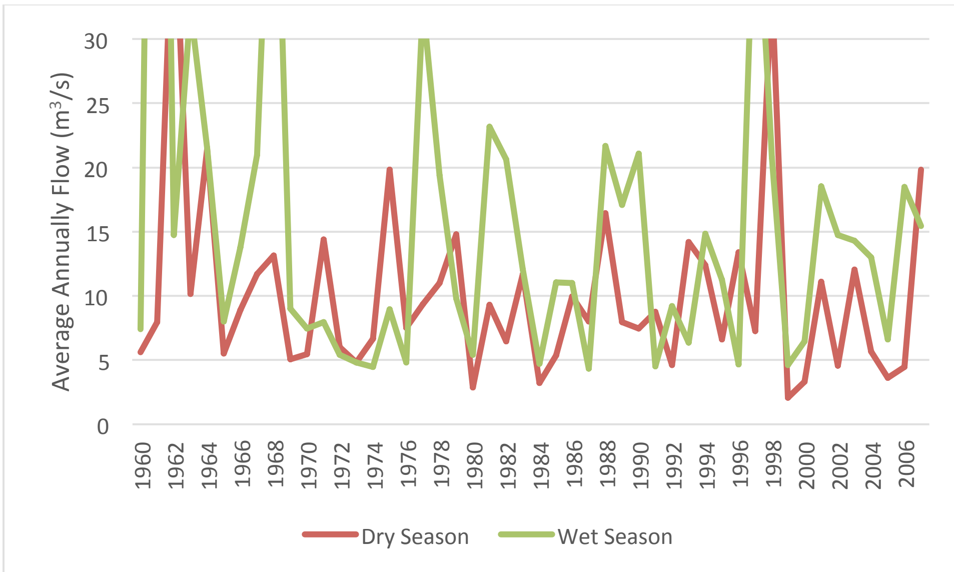

Figure 4 - Unregulated Annual Flow (m^3/s) by Season before the Construction of the Proposed Dam

Source: Authors' calculations based on data provided by CETRAD

Note: We limit the maximum number in the vertical axis to 30 m^3/s for visualization purposes.

To calculate river flow changes due to the construction of the dam, we use the numbers available in the Environmental Impact Assessment (henceforth EIA) Report for the proposed Isiolo Dam project (CAS Consultants Limited, 2014). According to EIA, during the impoundment of the reservoir, 1.92 m^3/s of water will be released for the stated purpose of sustaining the ecosystem downstream of the dam, and, once the reservoir is established, the discharge will be equal to 5 m^3/s.[6] The impoundment period might range from 5.7 to 13.4 months. This range is calculated considering the mean and minimum flows, which, based on EIA calculations, are 16.44 m^3/s and 8.1 m^3/s respectively.[7] Based on our database and

[5] These values were obtained by taking the monthly average throughout the study period.

[6] The discharge of 1.92 m^3/s corresponds to 85 percent of the base flow, which is the technical name for the dry weather flow in a river. The water released during impoundment is known as compensation flow. This information is on pages 73 and 117 of the official document. According to this document, the minimum and the mean flows are 8.1 m^3/s and 16.44 m^3/s. It is unclear how, based on the minimum and mean flows, the value of 1.92 m^3/s was determined.

[7] To find the number of months, the compensation flow (1.92 m^3/s) is subtracted from the minimum and mean flow. The storage volume of the reservoir is 214,261,547 meter cubic.

considering the average flow in the last 10 years, from 1998 to 2007, the impound period is seven months.[8]

Figure 5 shows the relationship between the unregulated river flow and the river flow predicted by the EIA during the impoundment and post-impoundment periods. **Construction of the proposed dam will significantly change conditions downstream by both substantially reducing total river flow and by eliminating seasonal variation. Based on EIA numbers, after impoundment of the reservoir, downstream flow will be fixed at one half of the unregulated dry streamflow, and instead of seasonal flood pulses, the dam will discharge a constant flow throughout the year. During impoundment, flow will be far less than the natural river flow even during the driest months, implying an estimated year-long of severe drought for people and wildlife that depend on the River.[9]**

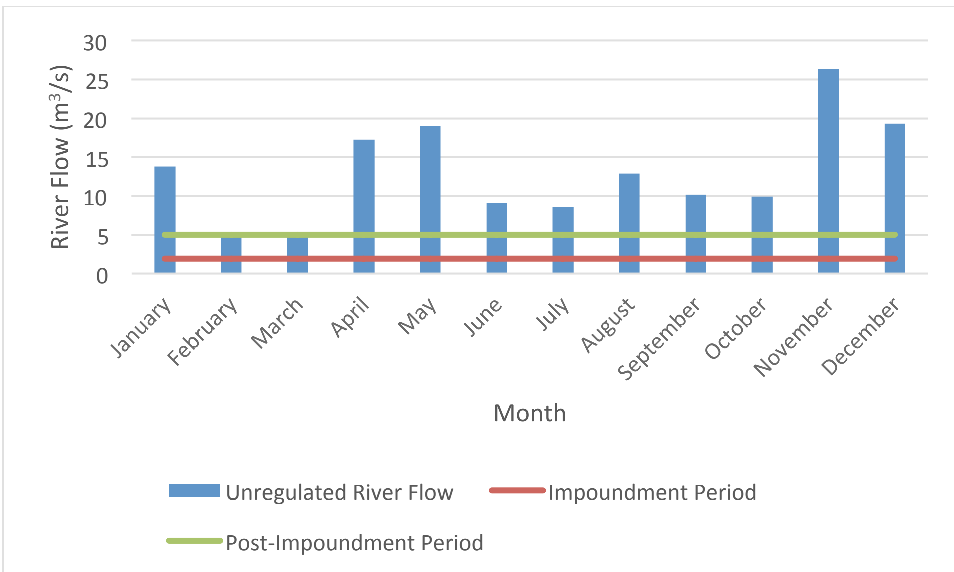

Figure 5 – Average Monthly Flow Pattern during Impoundment and Post-Impoundment
Source: Authors' calculations based on data provided by CETRAD and available on the EIA Report

Table 1 shows the monthly average river flow considering the unregulated and regulated river flow, as well an estimate of the regulated river flow as a percentage of the unregulated flow.[10] The estimates show that **the river flow would be reduced to 15 percent during the impoundment period (assuming impoundment takes place over the course of an average year of river flow), and post-impoundment, the average annual flow would be 38 percent of the unregulated river flow.**

[8] The average river flow in the last 10 years is 11.68 m3/s.
[9] Assuming that impoundment will take 13.4 months.
[10] For each month, we multiply the river flow by 30. Then, we add up these values to obtain yearly measures and, based on these numbers, calculate the percent of the unregulated river flow during the impoundment of the reservoir and post-impoundment. To calculate the annual river flow in m^3/d, one can divide the annual volume by 365.

Table 1 - Monthly Average River Flow (m^3/d) during Impoundment and Post-impoundment

Month	Unregulated River Flow	Regulated River Flow (impoundment period)	Regulated River Flow (post-impoundment period)
January	1,187,166	165,888	432,000
February	460,666	165,888	432,000
March	466,596	165,888	432,000
April	1,492,788	165,888	432,000
May	1,642,397	165,888	432,000
June	784,325	165,888	432,000
July	742,723	165,888	432,000
August	1,115,349	165,888	432,000
September	876,870	165,888	432,000
October	859,371	165,888	432,000
November	2,272,152	165,888	432,000
December	1,668,573	165,888	432,000
Annual water availability (m^3)	407,069,280	59,719,680	155,520,000
Percentage of the unregulated river flow (%)		14.67	38.20

Several other major water sources enter the Ewaso Ng'iro River downstream of the proposed Dam. While incorporating these flows into analysis is beyond the scope of the present study, several conclusions may still be drawn. First, **the area most heavily affected by dam-caused water scarcity is likely to be from the dam to the entry point of the Isiolo River, where people, livestock and wildlife have no alternative water supplies**. Reduction in the Ewaso Ng'iro River streamflow will in turn likely increase demand for water from the Isiolo River and water springs such as the Buffalo Springs, Shaba (Sarova), and Ngotu, which still run during dry seasons and drought events. In section 3.1, we analyze the potential impact of Isiolo Dam on herders' migration routes.

Swarzenski and Mundorff (1977) show that the water from the Ewaso Ng'iro River reaches the lower end of the Lorian Swamp when the flow at Archer's Post (the most downstream gauging station) is greater than 35 to 40 million meter cubic per month. The impoundment period flow as stated in the EIA at 1.92 m^3/s is equal to approximately 5 million cubic meters per month, while post-impoundment, a constant river flow of 5 m^3/s is equivalent to approximately 13 million cubic meters per month. Under these conditions, even **after impoundment, the proposed Dam will release only 37 percent of the minimum flow required to guarantee that the water from the river reaches the lower end of the Lorian Swamp. By comparison, in an average year the unrestricted river flow at the site of the proposed dam is currently 36 million cubic meters per month, sufficient on its own to ensure that water reaches the lower end of the Lorian Swamp.** The Isiolo river and springs mentioned above will still added some volume of water to the Ewaso Ng'iro downstream of the dam, but this volume is unknown. While it is beyond the scope of this paper to evaluate the ecological and resulting economic effects on the Lorian Swamp, it is reasonable to understand that these effects will be major given that basic calculations suggest that water flow to the Swamp will be significantly reduced.

As a result of the low river flow downstream, it is also likely that the amount of water in the Merti Aquifer will decrease. According to Leeuw et al. (2012), although the main recharge areas of the Merti Aquifer are not well known, it has been suggested that significant recharge takes place in the Lorian Swamp (Figure 6).

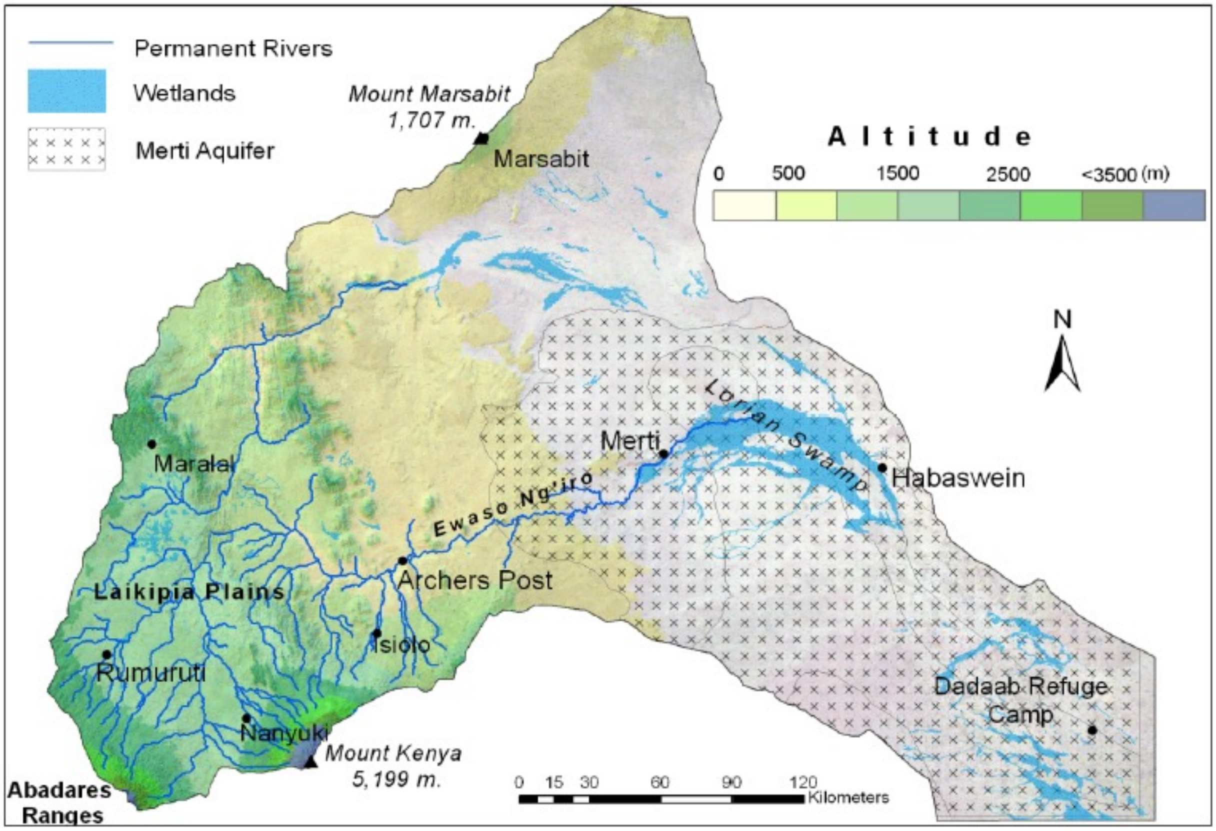

Figure 6 - Map of the Ewaso Ng'iro River Basin
Source: Leeuw et al. (2012)

Upstream, construction of the dam will substantially increase water availability. Considering the mean river flow of 16.44 m^3/s reported in the EIA, the amount of water retained in the reservoir and presumably available for use will be equal to 11.44 m^3/s post-impoundment. This is equivalent to a monthly volume retained of 29,652,480 cubic meter post-impoundment.[11] Per year, the amount of water available upstream would be 356 million cubic meter, which is equivalent to 975 thousand cubic meters per day.[12] This increase is expected to support local development, increasing productivity and

[11] Considering a month with 30 days.
[12] To calculate the annual water volume, we multiply the monthly volume by 12. To obtain water availability per day, we divide the annual volume by 365. Therefore, these number are approximations.

stimulating development, primarily of irrigated agriculture (see section 3.2). However, this development comes at the cost of aggravating water scarcity downstream.

Based on the overall results from the supply analysis, two conclusions can be drawn. First, the construction of the proposed Isiolo Dam will change the downstream river flow dramatically not only by eliminating its variability, but, most important, by reducing the amount of water available downstream. Our calculation shows that, per year, the amount of water available downstream will be 61 and 158 million cubic meters during impoundment and post-impoundment – a reduction of more than 50 percent, which characterizes a water scarce situation.[13] Second, the upstream water availability will increase substantially.

2.2 Demand

The study "Surface and Groundwater Assessment and Planning in Respect to the Isiolo County" (Water Resources Management Authority, 2013) finds that the total demand for water in Isiolo County is likely to grow in the next 40 years. While the total demand for water was 344,531 m^3/d in 2013, the projected demand in 2050 is equal to 661,331 – a growth of 92 percent over the whole period. Water use for irrigation accounts for almost all growth in water demand in Isiolo County (Figure 4 - Unregulated Annual Flow (m^3/s) by SeasonFigure 7). However, although agricultural production is the sector with the highest demand for water (both in the present day and in the future), it is currently not the main economic activity in Isiolo County. According to the Agricultural Sector Development Support Programme (2017), only 1,497 hectares, or 0.06 percent out of the county's total land area, is used for food production.

[13] According to Raskin et al (1997), the ratio between annual water abstraction and annual water supply should not be greater than 20 percent. A ration greater than this percentage means that water stress will be a limiting factor on economic development.

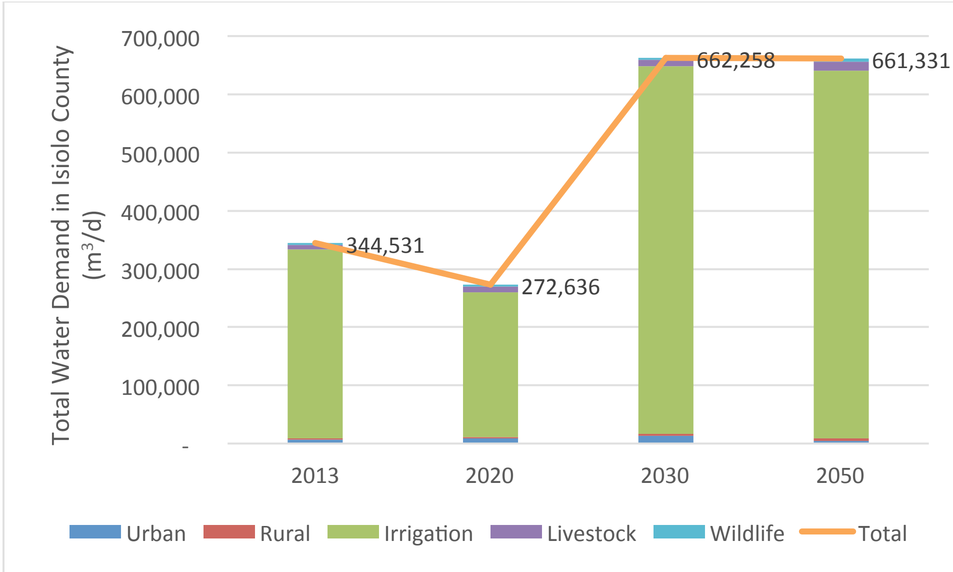

Figure 7 - Water Demand in Isiolo County (m^3/d)

Source: Authors' calculation based on Water Resources Management Authority (2013).

Based on the EIA report (CAS Consultants Limited, 2014), the proposed Isiolo Dam is projected to supply water, by gravity and via pipeline, to Isiolo Town, to the proposed Isiolo Resort City, and to specific rural areas in Laikipia, Isiolo and Samburu counties (Figure 8). Without addressing the important issue of water distribution and the selection of the targeted areas, the total water demand the project aims to supply in 2036 is 113,681 m^3/d, which is only 17 percent of the total projected demand in Isiolo County, by 2030, even under the unreasonable assumption that no water goes to Laikipia or Samburu (Figure 9).

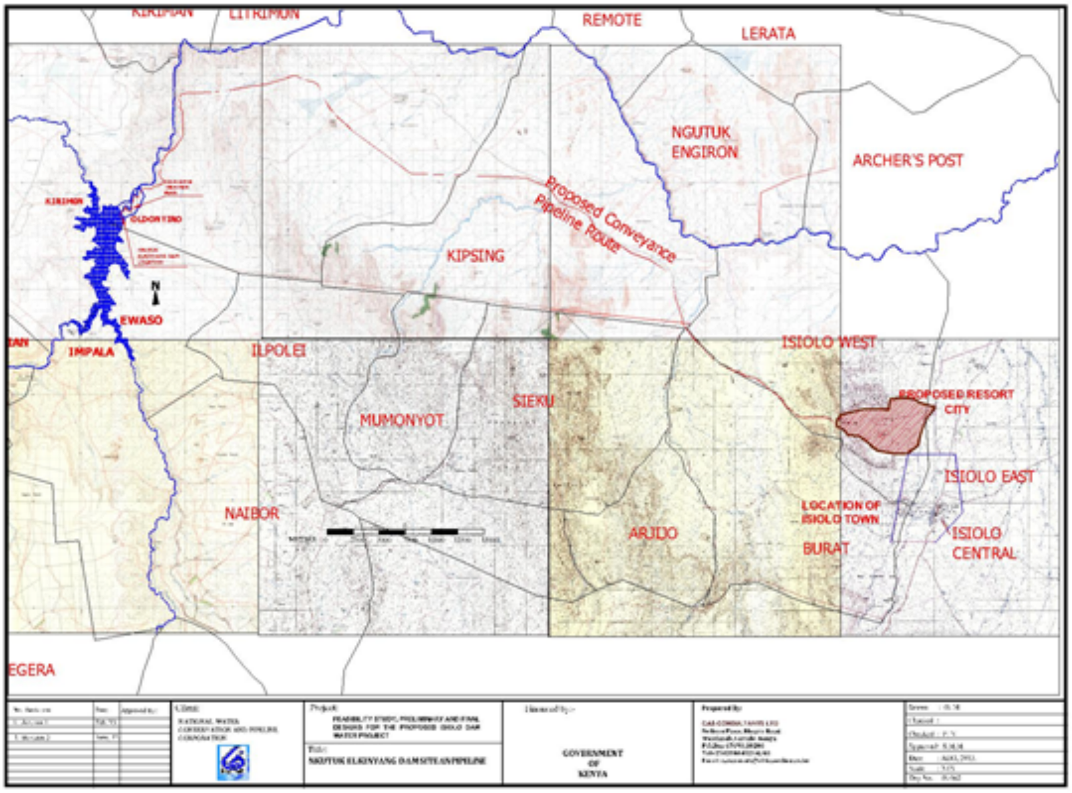

Figure 8 - The Proposed Isiolo Dam and its Components

Source: The EIA report (CAS Consultants Limited, 2014)

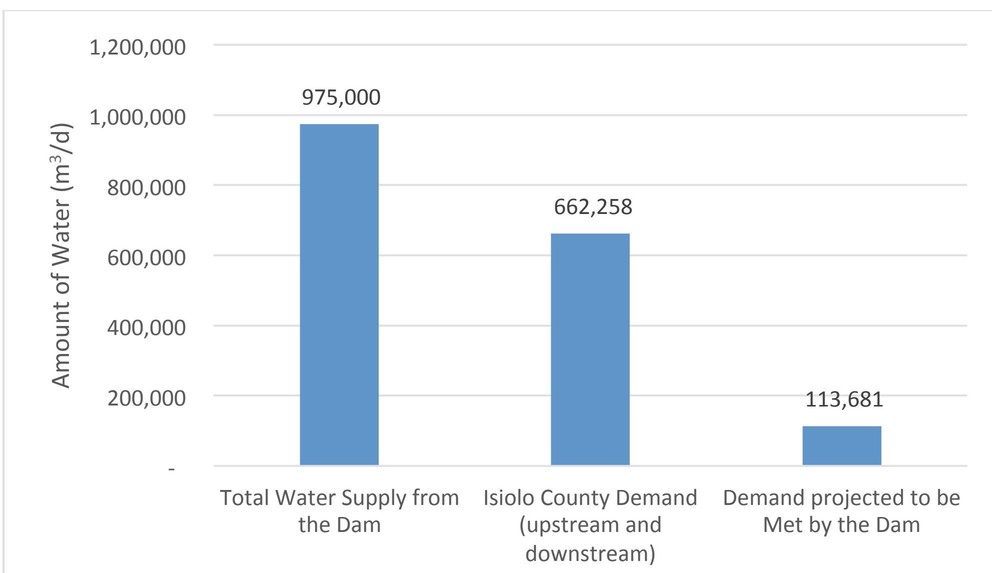

Figure 9 - Water Supply Upstream versus Total Demand in 2030

Construction of the proposed Isiolo Dam can therefore be understood as able to meet demand for users who benefit from piped water. However, for communities downstream that are not part of the target areas, the situation is likely to get worse as the water availability downstream reduces significantly. Furthermore, upstream, increased water volume does not mean that the water needs of all people will be met, and indeed, social changes upstream may compound challenges especially for water users downstream. The socio-economic impacts of changing water availability upstream (via increased economic activity) and downstream (via impacts to livestock and tourism activities) are addressed in sections 3 and 4.

3 Impact on herders

3.1 Daily life of herders downstream

Change in hydrology as described in section two can be expected to have an impact on herders downstream through decreased water availability and decreased ecosystem health. The latter is not addressed here. The former can cause economic losses due to direct livestock mortality, decreased livestock health driven by lower quality forage and increased distance to water sources, change in prices paid, and increased social conflict related to use of scarce water supplies, among other issues.

In depth assessment of these issues is beyond the scope of this study. However, we carry out a basic assessment using the following approach. First, using streamflow data and calculations made above, we investigate how the dam will change the likelihood of drought downstream. Second, based on a literature review, we evaluate how an increase in drought affects herders by calculating the distance traveled to water sources and livestock loss. We also consider price effects. The main assumption here is that the biggest challenge herders face is drought-related livestock mortality.

Regarding the first step, we calculate the probability of drought using river flow data from Archer's Post Gauging Station – the most downstream station. We use the definition of hydrological drought from Yevjevich (1967). According to the author, a drought is defined as an uninterrupted period of streamflow below a particular threshold.[14] To determine the threshold, there are many possibilities, such as using the mean, median or percentile values of the river flow time series. Following the author and Stahl (2001), we use a fixed level equal to the 70 percentile (Q_{70}) flow from the Flow Duration Curve (FDC) to define drought events.[15]

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[14] There is no universal definition of drought. One could have calculated drought by using, for example, precipitation and temperature measures. However, because this study focuses on the Ewaso Ng'iro River, we opt for using hydrologic data.

[15] To calculate the 70^{th} percentile, we took into account the whole time series, meaning that we did not control for seasonality. Because we are using monthly data, a drought event means a month with river flow smaller or equal the threshold value. This allows for the consideration that herders may experience drought even prior to the dam being constructed.

As before, we use monthly data – from January 1960 to December 2011 – to calculate the FDC.[16] River flow data from Archer's Post Gauging Station were made available by CETRAD. An initial analysis of the data shows that the mean river flow is 22 m^3/s, and the minimum and maximum flows are 0.098 m^3/s and 651.7 m^3/s respectively. The driest year was 2000, with an annual river flow average of 4.25 m^3/s. The wettest year was 1961, with an annual average equal to 82.72 m^3/s. The 70th percentile is equal to 5.59 m^3/s, which means that the probability of having a streamflow greater than 5.59 m^3/s is 70 percent. Thus, according to this criterion, a drought event now occurs every year, with an average duration of 3.5 months.[17]

Moreover, calculation of a simple moving average (calculated every 10 years) suggests that the average duration of drought has already been increasing from a low of 1.4 months in the 1960s to a high of 4.8 months in the 2000s. **Thus, even before the construction of the proposed dam, conditions downstream have been getting more critical over the past several decades.**

Figure 10 shows the number of months in which the river flow was smaller or equal to the drought threshold, as well as the moving average. To make this graphic, we summed the months with drought in a year. One can notice that the number of times, as well as the duration, of low streamflow has increased in recent years (especially in the 2000s) of our sample, corroborating the findings from the moving average calculation.[18]

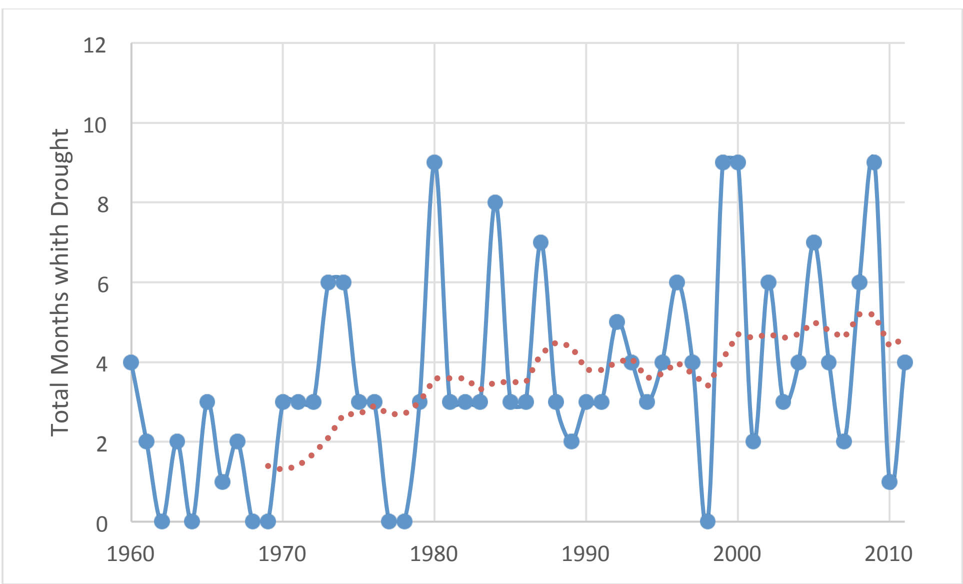

Figure 10 – Number of Months with Drought per Year

Source: Authors' calculation based on CETRAD data

Note: The red dotted line corresponds to the 10-year moving average

[16] Archer's Post has more recent data when compared to AJ and AK gauging stations.

[17] Not necessarily consecutive months.

[18] During 2008 and 2009, the river flow was below the threshold during 10 uninterrupted months -- this was the longest period of low flow in our simple.

During impoundment, with water flow of 1.92 m^3/s, or 15 percent of annual streamflow, the dam will cause a major and continuous drought for those that depend on the river. During operation, the situation will be critical as well. The long term planned discharge of 5 m^3/s is close to the drought threshold of 5.59 m3/s, indicating the likely continuation of drought for those who depend on the river for their main source of water.

Drought affects herders in different ways. In the present study, we focus on two: first, the increase in the distance traveled to water sources; and second, the change in livestock population, as well as herders' decision regarding livestock selling and migration.[19]

Regarding the distance traveled, Siwa (2014) shows – through a field study survey – that the Ewaso Ng'iro River is used by most downstream communities in Isiolo County as an alternative source of water during dry seasons and drought periods. Throughout the year, the main sources of water are boreholes and shallow wells.[20] For most respondents (77 percent), the distance between these water points and their homes is less than a kilometer, implying that, except for dry periods and drought events, water availability is not a problem, although the water quality is far from good and the waiting time (to get water) is between 30 to 60 minutes. Figure 11 shows the distribution of villages within a 15-km distance radius from water sources. About 63 percent of the area lacks access to livestock water and this includes 92 villages, or 38 percent of the total number of villages. Some villages are about 75 km from the nearest water source (Mati, Muchiri, Njenga, Vries, & Merrey, 2005).

[19] Livestock is the sector in the economy most vulnerable to drought, followed by crop farming (Mbogo, Inganga, & Maina, 2014).

[20] Due to data limitations, we are unable to calculate the relationship between the water from the Ewaso Ng'iro River and from the boreholes and shallow wells, but to the extent that the latter depend on the former, impacts will be worse than those calculated here.

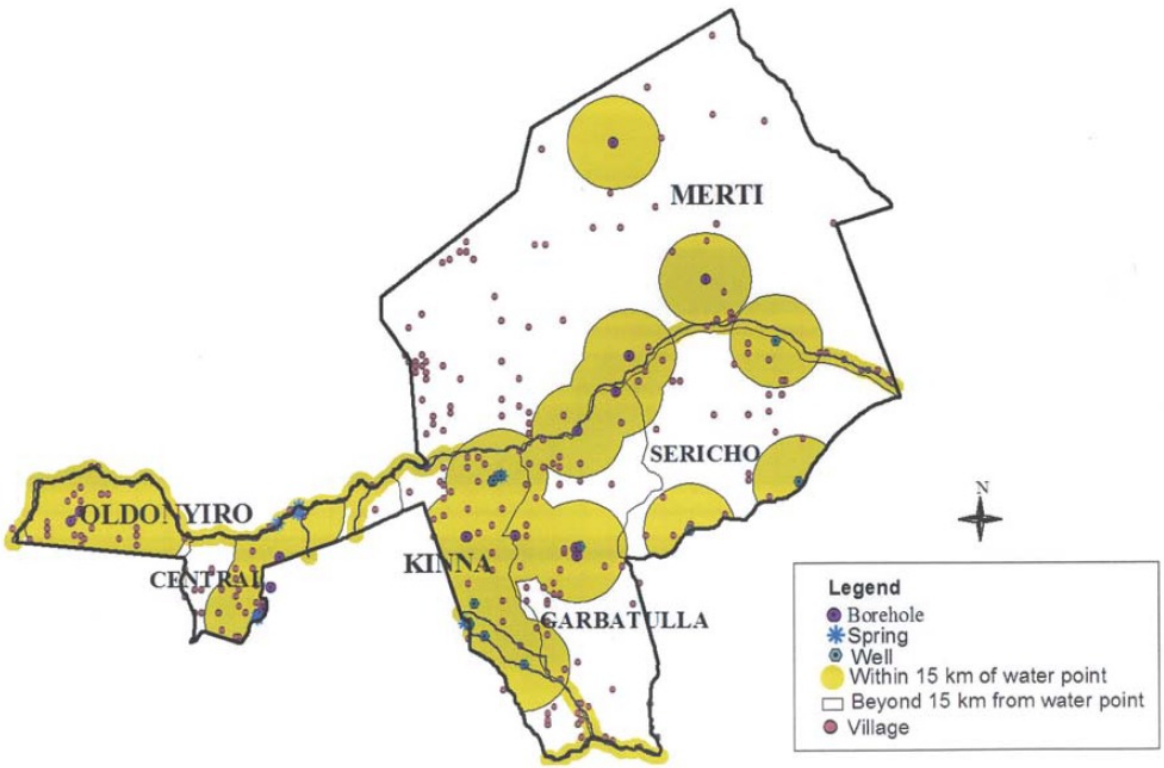

Figure 11 - Water Access during the Dry Season (15 km from Water Sources)
Source: Mati, Muchiri, Njenga, Vries, & Merrey (2005)

Within this context, the reduction of the river flow due to the construction of the proposed Isiolo Dam will specifically affect water availability when downstream communities need it the most. According to Siwa (2014), at times when the river is needed as an alternative water source means distance to water can increase to up to 25 km, which corresponds to the maximum distance residents of Dadacha Basa, in Merti Sub-county (in Isiolo County), have to walk to access this water source. If there is not sufficient water in the Ewaso Ng'iro River during shortages of water from other sources, herders and other residents will have to travel more than 25 km to access other sources of water if these exist. This distance is more than double the normal distance that non water-stressed cattle regularly travel to water (Ericksen, et al., 2011).

Despite the challenge of trekking longer distances, livestock mobility is one method used by herders to reduce the size of losses (both in terms of animal numbers and income) during dry seasons and drought periods. The number of livestock lost depends, as expected, on the severity and duration of the drought, as well as livestock age, sex and breed (Oba (2001) and Huho, Ngaira, & Ogindo (2010)). For example, Oba (2001) shows that livestock mortality can be as high as 90 percent and as low as 20 percent.[21] Huho, Ngaira, & Ogindo (2010) show that the number of livestock lost was approximately 35 percent higher

[21] The 90 percent and 20 mortality rates were found for the period 1991-1992 and 1983-1984 respectively.

during extreme drought when compared to those lost during mild drought. Both studies – as most studies that calculate livestock loss – are field studies.

During dry seasons, besides migrating upstream, herds move towards the Lorian Swamp (downstream). However, the construction of the proposed Isiolo Dam will potentially reduce or entirely eliminate the water available in this wetland water (and vegetation) source as mentioned in the previous section. As a result, herders will have to search for other water sources and grazing sites, most likely upstream or outside the catchment area. Figure 12 illustrates livestock movements during a drought year in Kenya. The white arrows indicate two clear migration routes from outside Ewaso Ng'iro Catchment towards the Ewaso Ng'iro River. There is livestock movement upstream, close to the proposed Isiolo Dam, and downstream, towards the Lorian Swamp. If the dam is built, then the second route (to the Lorian Swamp) will probably cease to be an option to herders in search for water and pasture.

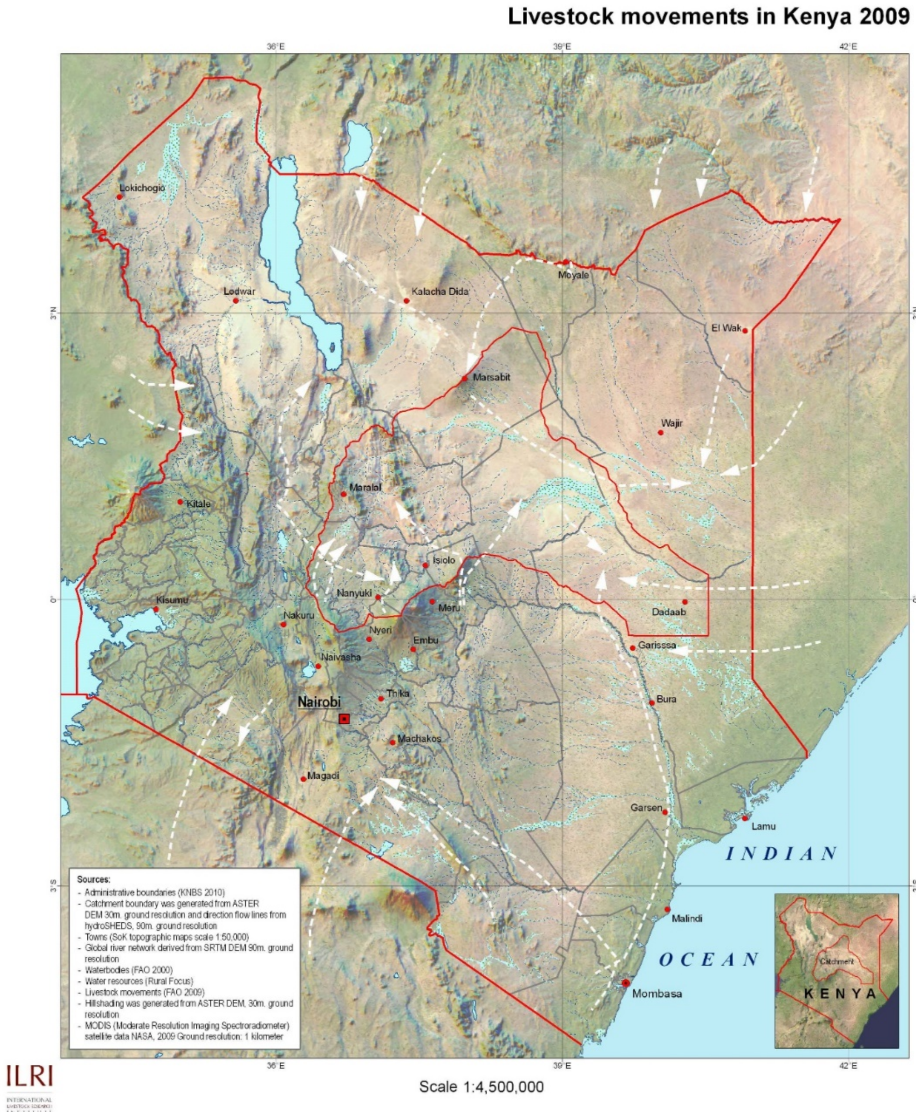

Figure 12 - Livestock Movements in Kenya 2009

Source: CGSpace: A Repository of Agricultural Research Outputs (2016)

Note: 2009 was a drought year

Although the construction of the proposed Isiolo Dam will increase water supply upstream, many herders downstream will not be able to move their cattle so far, without permanently moving. Both seasonal livestock movement and demand for permanent movement to areas of better water availability are likely to increase the likelihood of conflict over water. Currently, residents' perception regarding water use and conflict in the upper Ewaso Ng'iro North Basin is that there are already conlficts (Figure 13).

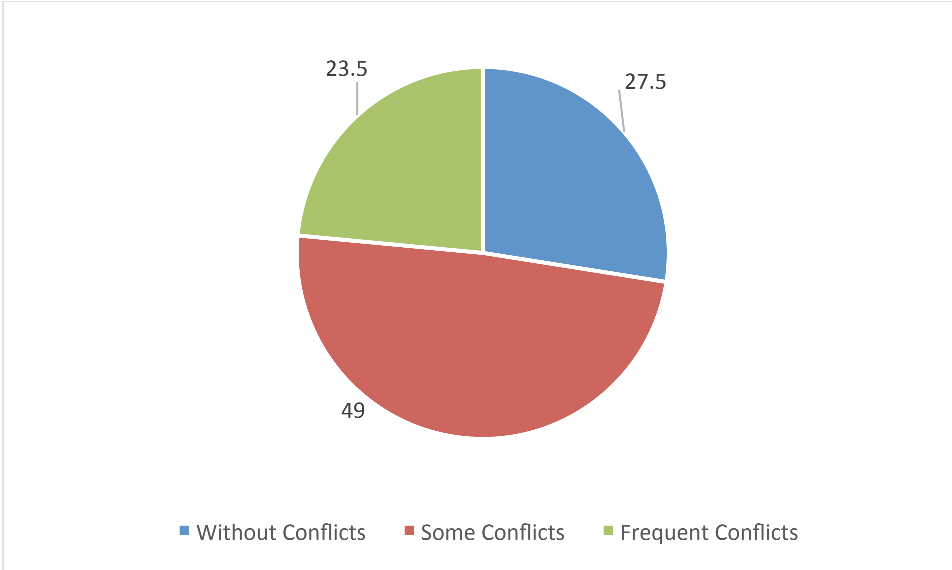

Figure 13 - Opinions of Households Concerning Conflicts over Water Use in the Upper Ewaso Ng'iro North Basin (%)
Source: African Studies Centre (2013)
Note: 150 households were interviewed

Herders that cannot or choose not to migrate face either livestock mortality, or may reduce herd size by selling their animals. As a consequence, the loss of livestock has short- and long-term implications for household welfare. Besides reducing current income, it also reduces future generation of income as herd recovery tends to be slow (Oba, 2001). Additional economic problems include low milk production and lower purchase capacity. Due to migration, milk production can decline as much as 80 percent and milk consumption drops from 3 to 4 liters per day to 1 liter per day (Kenya Food Security Steering Group (KFSSG), 2015).

During drought years, the number of livestock sellers increases considerably while the number of buyers remains approximatelly the same. As a result, livestock prices reduce substantially. From 2014 to 2016, for example, cattle and goat prices reduced by half - from Kenyan Shilling (Ksh) 30,000 to Ksh 15,000 (from USD 288 to USD 144) and from Ksh 8,000 to Ksh 4,000 (from USD 76 to USD 38) respectively (Daily Nation, 2016).[22] Thus, besides animal loss, there is a welfare loss resulting from reduced prices.[23]

We attempt to synthesize this complexity into a basic calculation of economic loss for herders downstream as follows. As will be clear, this calculation captures only a fraction of the likely losses.

First, data from KNOEMA (Livestock Population by Type and District, Kenya, 2009) on livestock population in Isiolo County (Isiolo and Garbatulla) show that in 2009, total cattle and goat populations were 198,424 and 398,900 respectively. Ideally, we would use a map layer to create buffer zones around the Ewaso Ng'iro River of 50 km to better estimate livestock population around the river. However, due

[22] The exchange rate used was 1 USD = 103.9 Ksh (January 18, 2017).
[23] During dry seasons and drought events, herders' vulnerability to price variation increases substantially.

to data and time constraints, we make an educated guess based on Figure 14, which suggests that there is a high concentration of livestock upstream and around the Lorian Swamp. Assuming that 30 percent of the total livestock population is within a 50-km radius of the river, then total cattle and goat populations that might rely on the river are 59,527 and 119,670 respectively. Based on Oba (2001) and estimating conservatively, if 20 percent is lost due to drought in one year, then the economic loss will be equal to Ksh 178 million and 95 million (USD 1.718 million and USD 921 thousand) respectively – assuming that the cattle and goat prices are Ksh 15,000 and Ksh 4,000. There is an additional loss related to the livestock value. Because of the price variation, the remaining livestock is worth only 50 percent of its original value, meaning an additional loss of USD 6.875 million and USD 3.685 million respectively. Thus, **the economic loss resulting from drought caused by the Isiolo Dam can be estimated at USD 13 million per year, which is approximately 3.6 percent of the total income generated by the livestock secto**r.[24,25]

As a point of comparison, based on empirical evidence, Aklilu & Wekesa (2002) show that as a direct result of drought, the estimated economic losses from livestock deaths (sheeps, goats, cattle, and camels) in Kenya as a whole was USD 80 million between 1998 and 2001. A report from the International Livestock Research Institute shows that, from 2008 to 2011, droughts cost to Kenya USD 12.1 billion, with the livestock sector incurring 27 percent of this loss, or approximately USD 3.3 billion (International Livestock Research Institute, 2016).

It is clear that reduction in the downstream river flow due to the construction of the proposed Isiolo Dam has the potential to aggravate the daily life of herders downstream, especially during dry seasons and drought. This is especially true in the Lorian Swamp, which no longer will receive water from the Ewaso Ng'iro River.

Figure 14 shows the average livestock density between 1990 and 2010. If we assume that livestock density in the Lorian Swamp is on average equal to 30 Tropical Livestock Units (TLU) of livestock per km^2, then the total amount of livestock affected by the drought in the swamp is 87,540 TLU.[26] Assuming that each household has on average 20 TLU of livestock, then 4,377 households will be directly affected by the construction of the dam just in this area. If the average household size is 4.5, then **the total number of people affected by the Isiolo dam-related drought in the Lorian Swamp is close to 20,000.**[27] However, the construction of the dam will affect not only the swamp, but all downstream communities, meaning that the the total number of livestock affected by the dam is likely to be higher than the number calculated above.

[24] The percentage value of 3.6 was calculated based on estimations from FAO (2005), which shows that the livestock sector contributed with USD 1,220 million to GDP (Gross Domestic Product).

[25] To calculate this loss, we add up the economic loss resulting from livestock mortality (USD 2.640 million) to the value loss of the remaining livestock (USD 10.560 million).

[26] Tropical Livestock Units is an index representing an animal of 250kg, which allows combining different animals. For the calculation of the total number of livestock affected by the drought, we consider the total area of the swamp to be 2,918 km2 (Leeuw, et al., 2012).

[27] (KIRA, 2014)

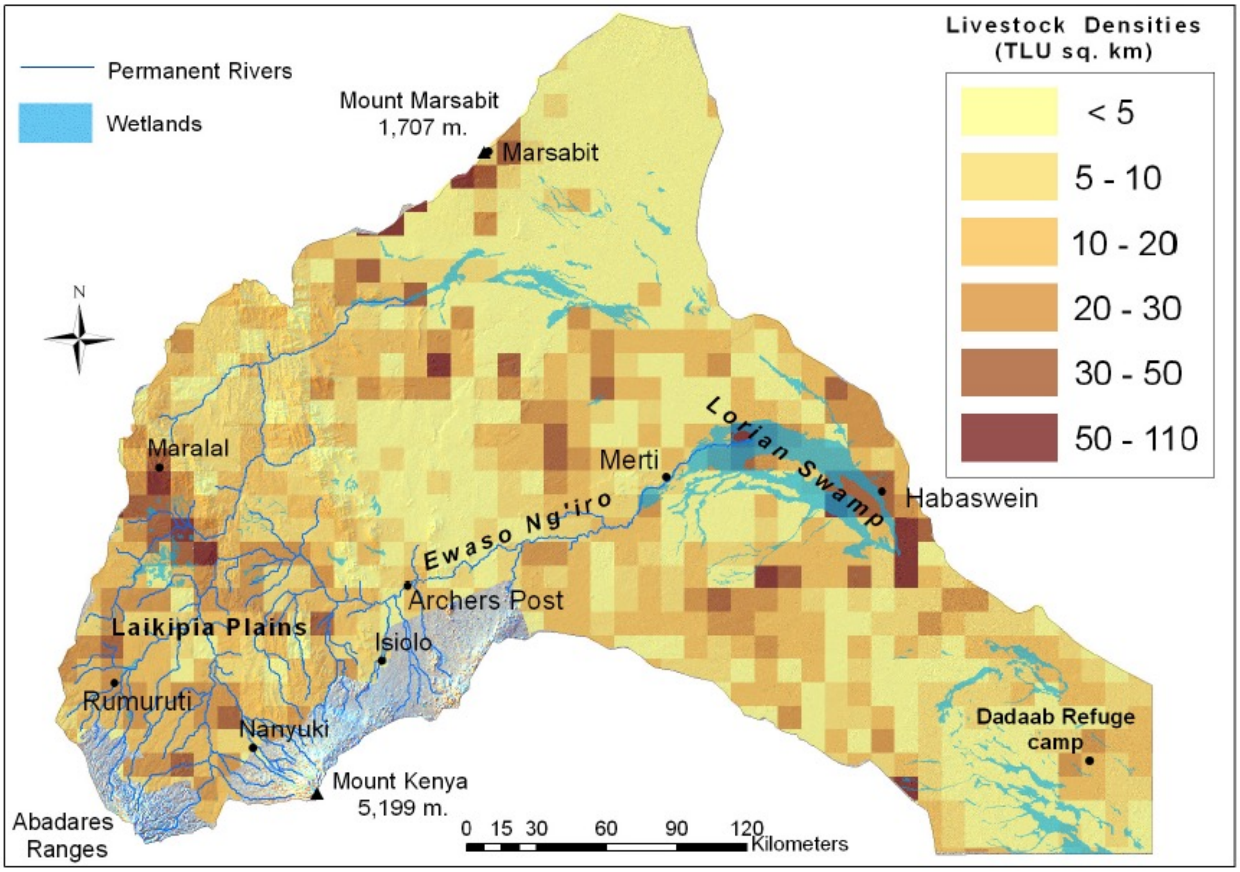

Figure 14 - Average Livestock Density 1990 - 2010 (TLU per km^2)
Source: Leeuw et al. (2012)

3.2 Land-use Upstream

Upon completion of the proposed Isiolo Dam, an area of 2,462 hectares (ha) is expected to be inundated. According to the EIA report (CAS Consultants Limited, 2014), the dam will inundate areas in Oldonyiro, in Isiolo County, and in Kirimon, Impala and Ewaso in Laikipa County (Figure 15).[28]

[28] Page 2 in the EIA report.

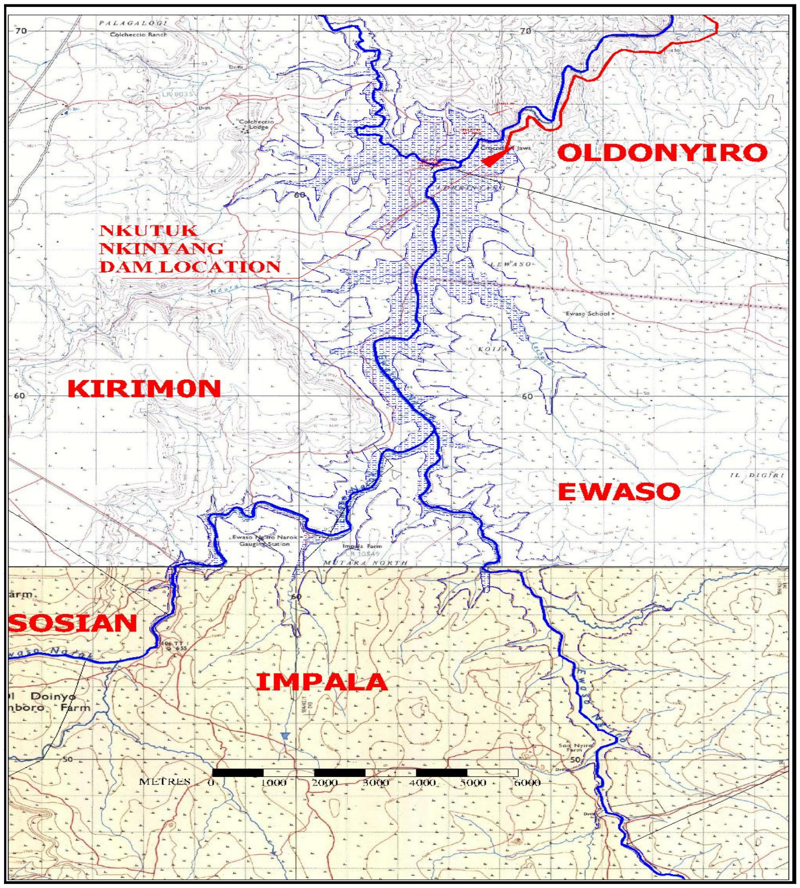

Figure 15 – Inundation Area Map

Source: The EIA Report (CAS Consultants Limited, 2014)

Note: In red, the pipeline to the proposed Isiolo Resort City and the arrow indicating the location of the dam at Crocodile Jaws (Nkutuk Elkinyang)

Figure 16 shows that livestock production is the dominant land use in the area to be flooded, followed by conservancy areas. Mixed crop-livestock production and irrigated crop production do not seem to occupy any significant share of land. However, beyond direct loss of important areas due to flooding, irrigated agriculture is likely to gain prominence due to water availability. In the presence of irrigated agriculture, activities such as livestock and wildlife tourism might not compete economically (Smith, Ojwang, & Mose (2016), Emerton (1997)). **Since cultural traditions such as pastoralism, do not change based on simple economic calculus, the new land distribution could lead to widespread hardship for herders upstream who face increased competition for their lands even though water is more readily available**.

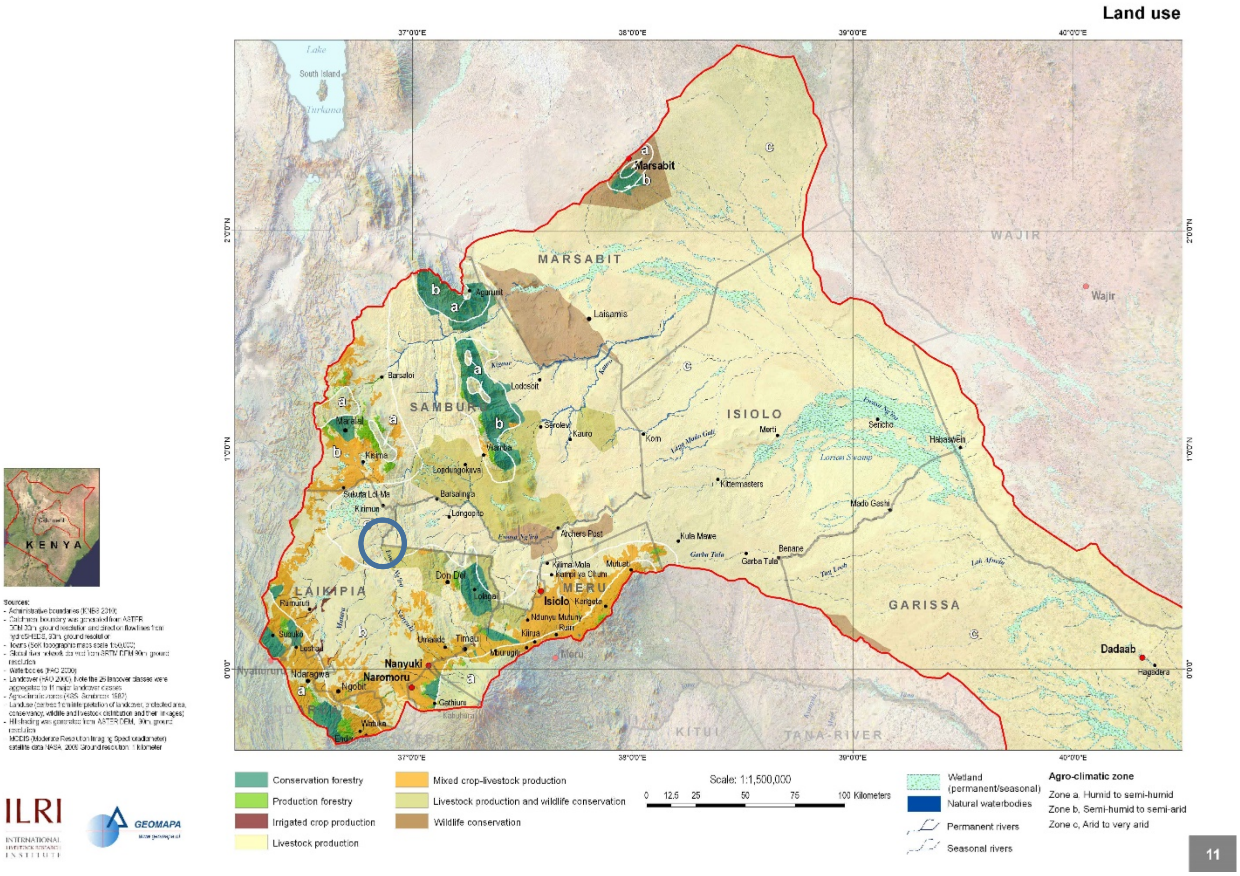

Figure 16 - Land Use Distribution

Source: CGSpace: A Repository of Agricultural Research Outputs (2016)

Note: The circle in blue corresponds to the area where the proposed Isiolo Dam will be constructed

In Laikipia, the area to be flooded is on private ranches (on a freehold basis with title deeds), while in Isiolo County, the reservoir area is communally owned with land tenure being under Trust. However, because private ranches also provide dry season grazing for pastoralists, we estimate the impact of the proposed Dam on herders upstream by applying an estimated livestock density of 30 LTU per km^2 (Figure 14) to the entire flooded area. Under this assumption, close to 740 LTU of livestock will be affected by the dam. If price is Ksh 30,000, (current livestock price) then **the area to be flooded is worth, in terms of livestock, Ksh 22.16 million (or USD 213,230)**. This is a rough estimation that does not take into account longer term disruption to herders, including related to market access. In terms of wildlife, multiple endangered species will lose access to an important habitat area. In an attempt to estimate one element of the economic value of this loss, in the next section, we estimate the impact of the dam on wildlife tourism using a market value approach.

4 Impact on existing wildlife tourism

This section quantifies the impact of the proposed dam on existing wildlife tourism. We begin with a qualitative assessment of the impact on wildlife itself. This analysis gives a perspective on the potential decline in the quality of the tourism products that businesses in Isiolo County will be able to offer if the dam is built. We then calculate economic losses of two types. First, we calculate direct losses from the closure of tourism facilities in the area that would be flooded to fill the dam's reservoir. Second, we estimate additional economic losses resulting from reduced demand by wildlife tourists. We do not analyze the impact of the proposed Isiolo Resort City on wildlife and wildlife tourism.

4.1 Impact on wildlife

The construction of the proposed Isiolo Dam will affect wildlife by eliminating seasonal flooding and greatly reducing the amount of water available downstream. The dam will also flood conservancy areas upstream. In the medium term, it is expected that additional habitat will be lost upstream as increased water availability fuels a transition of the current mix of rangelands and natural habitat into irrigated agriculture. The competition for land, as well as water resources, is documented in a report from Northern Rangelands Trust (NRT, 2015). According to this report, in the last 30 years, wildlife in Kenya has declined significantly because of habitat loss, grazing competition with livestock, and poaching.

Construction of the dam will likely aggravate the already tense situation in Northern Kenya. Of the 2,462 hectares expected to be flooded, approximately 81 percent (1,993 hectares) is in conservancy areas. Although, as stated in the EIA report (CAS Consultants Limited, 2014), this represents only 0.25 percent of the 800,000 hectares dedicated to conservation in the region, the area is particularly important for wildlife as illustrated in Figure 17.

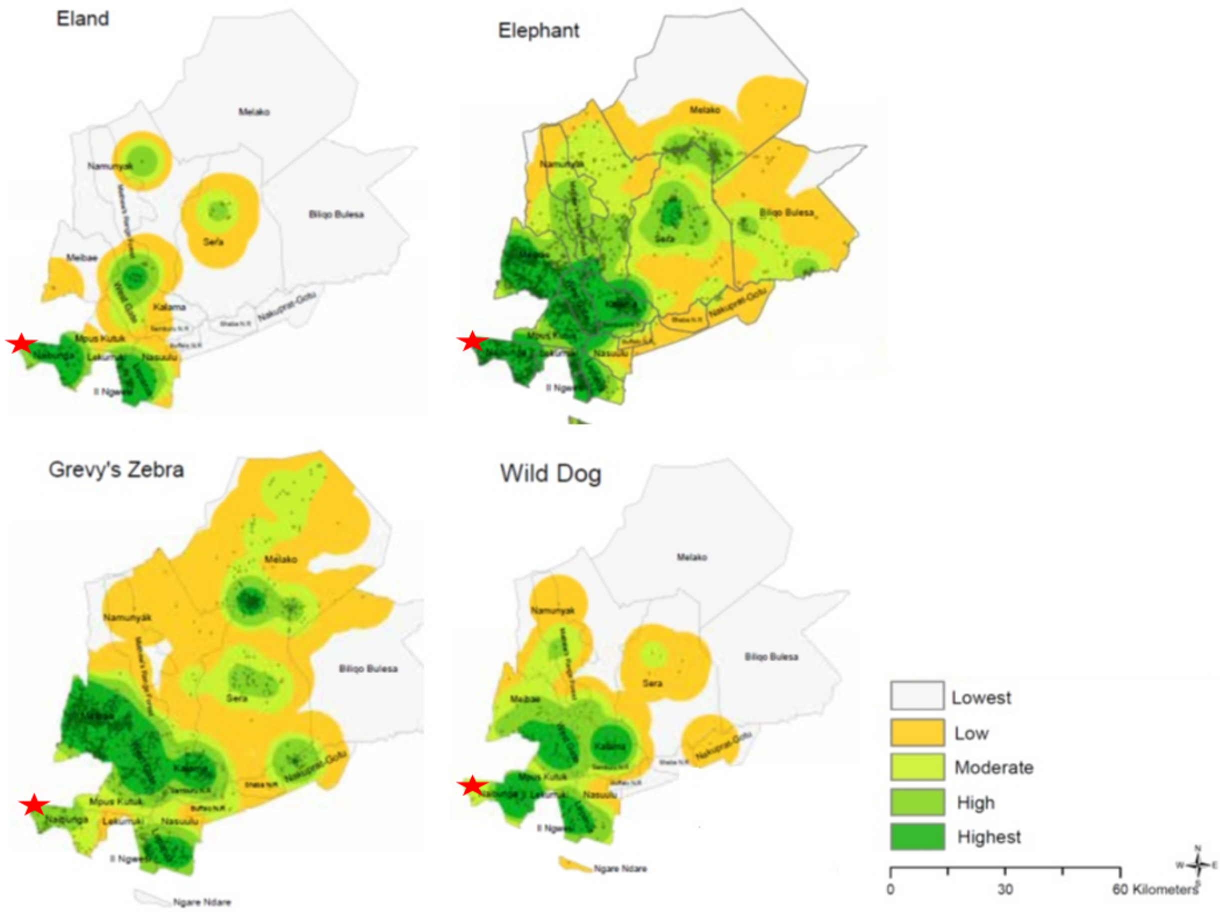

Figure 17 - Concentration of Species Sightings of Wildlife
Source: Northern Rangelands Trust (NRT) (2015)
Note: The red star on the map indicates the location of the proposed dam.

As an example of the more complex phenomena that may occur, Becker et al. (2009) found that elephants move to forests during the dry season in search of forage and water. In doing so, they sometimes cause destruction of farms and human deaths. If the flow of the river is reduced by the dam, elephants may move deeper into the forests and these undesired consequences may become more common.

4.2 Closure of existing tourism facilities due to flooding

This section addresses only those tourism facilities that would be flooded by the Dam reservoir. Impacts downstream are considered in the following section.

Figure 18 shows tourism infrastructure in Laikipia, Samburu and Isiolo. Most of the wildlife facilities are around Isiolo, Nanyuki, and Mount Kenya. According to Emerton (1997), wildlife tourism accounted for five percent of gross domestic product (GDP), or USD 350 million in Kenya in 1995, and represented 70 percent of all gross income from tourism in the country. A more recent study shows that wildlife tourism now accounts for 10 percent of GDP and is largely generated in the ASALs (Ericksen, et al., 2011).

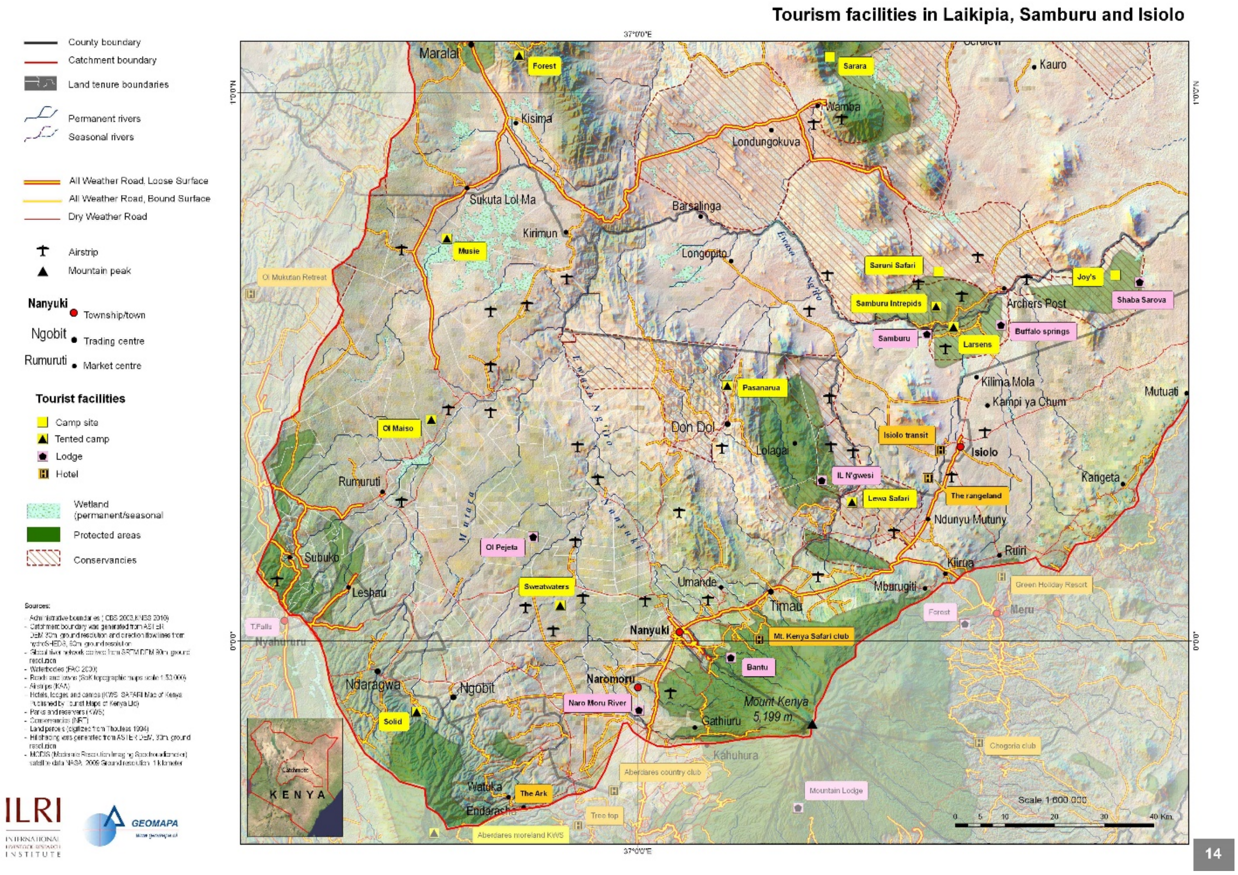

Figure 18 - Tourism Facilities in Laikipia, Samburu and Isiolo

Source: (CGSpace: A Repository of Agricultural Research Outputs, 2016)

Note: Map does not show all existing tourism facilities in the affected region.

Data on tourism facilities from Laikipia County Tourism show that there are 108 tourism facilities in the county. Out of this total, 10 facilities are located in the area which will be flooded in the construction of the Isiolo Dam. The facilities are: Il Polei Campsite, Kiboko Starbeds, Koija Starbeds, Laikipia Wildness, Loisaba Cottages, Loisaba House, Ol Gaboli Bandas, Sabuk Lodge, Suyian Camp, and Tiemamut Campsite.

To quantify the loss in revenue resulting from the closure of these facilities, we use available data on their current prices, occupancy rates, and number of beds. Regarding prices, the facilities are categorized in three groups: low-, mid-, and high-range, as listed in Table 2 (Laikipia Tourism Task Force, 2015). These ranges are defined as less than USD 200 per person per night, between USD 200 and USD 400 per person per night, and more than USD 400 per person per night, respectively. To calculate losses, we assume that prices per person per night are USD 150, USD 300, and USD 600 for these categories.

Table 2 - Tourism Facility Information in Laikipia County

Tourism Facility Name	Location	Number of beds	Price Range
Il Polei Campsite	Naibunga Conservancy	14	Low
Kiboko Starbeds	Loisaba Wilderness Ranch	9	Mid
Koija Starbeds	Loisaba Wilderness Ranch	9	Mid
Laikipia Wilderness	Ol Donyo Lemburo Ranch	10	Mid to high
Loisaba Cottages	Loisaba Wilderness Ranch	8	Mid
Loisaba House	Loisaba Wilderness Ranch		Mid
Ol Gaboli Bandas	Naibunga Conservancy	35	Low
Sabuk Lodge	Sabuk		High
Suyian Camp	Suyian Soul	10	Mid
Tiemamut Campsite	Naibunga Conservancy		Low

Source: Laikipia Tourism Task Force (2015)

We also make three additional assumptions. First, for facilities with no information on the number of beds in Table 2, we assume that there are 10 beds. Second, the number of beds is multiplied by two to estimate capacity in terms of visitors. And third, since the occupancy rate in the last five years has averaged from 15 to 50 percent, we assume an occupancy rate at the average level of 33 percent.[29]

Under these assumptions, **the loss in tourism revenues resulting from the closure of facilities in the area that would be flooded is USD 22,869 per day, or more than USD 8 million per year. This value does not consider the loss in tourist expenditures in the larger area and feedback effects in the local economy. Thus, this estimate should be viewed as a lower bound for the negative effect.**

4.3 Decreased demand for viewing wildlife downstream of the dam

Although we cannot accurately predict wildlife loss, it is reasonable to expect some areas of significant decline. Less wildlife will lead to a reduced willingness to pay for wildlife-based tourism and/or fewer tourists visiting conservancy areas around and especially downstream of the dam. Figure 19 exemplifies a reduction in willingness to pay as the result of a reduction in wildlife. This is shown as a shift in the demand curve to the left, following the blue arrow.

[29] The information on occupancy rate was obtained from Laikipia Wildlife Forum.

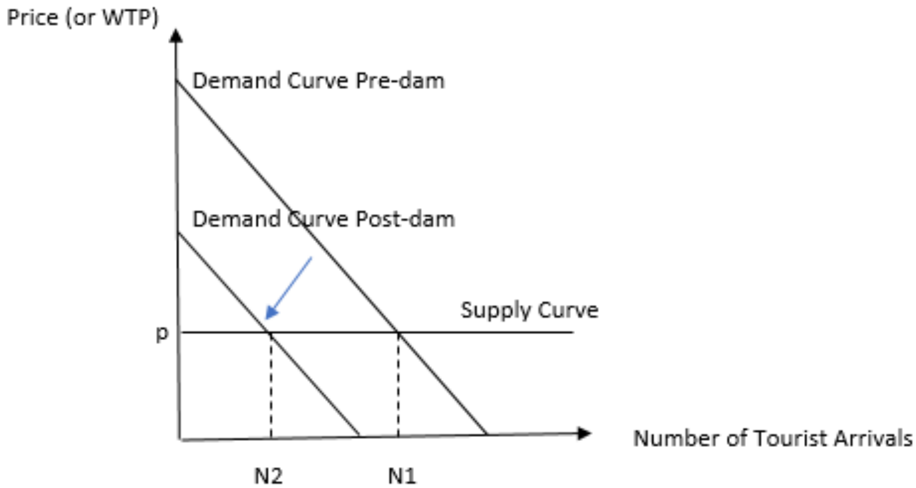

Figure 19 – Hypothetical Demand Curve for Visiting Conservancy Areas

Note: This demand curve does not necessarily represent the real demand curve for visiting conservancy areas. This figure is illustrative to show the relationship between number of visits and willingness to pay

To estimate the relationship between willingness to pay, decrease in tourist visits, and loss of wildlife, we use simple assumptions about demand structure, along with data from the World Travel & Tourism Council (WTTC, 2014) and references to the academic literature. Before turning to the data, we first describe a simple theoretical framework. We assume that total demand (measured in number of tourists, N) has a constant elasticity. Mathematically, $N = Ap^{-\sigma}$, where A is a constant, σ is the elasticity of tourist demand, and p is the price. Our goal is to predict the change in demand following a change in willingness to pay (WTP). In the model, a change in WTP represents a shift in the constant from an initial value A to A'. The size of this change can be obtained using the following expression: $\frac{A'}{A} = \left(\frac{\text{WTP}'}{\text{WTP}}\right)^{\sigma}$, where WTP' is the new willingness to pay after the change. Given that actual prices are constant (that is, the supply curve is assumed to be horizontal), the final change in demand is proportional to the change in the constant A. So, the final expression is $\frac{N'}{N} = \left(\frac{\text{WTP}'}{\text{WTP}}\right)^{\sigma}$.

To use this expression, we need the initial number of tourists, the initial and final WTP's, and the elasticity of demand σ. The WTTC estimates that there were 1,165,000 international tourists in Kenya in 2015, and that the total amount spent by these tourists was Ksh 162.4 billion. This represents total average expenditures USD 1,362.65 per visitor per visit. Assuming that 1 percent of international visitors to Kenya go to tourism facilities downstream of the dam, and that their spending is equal to the national average, the number of local visitors is $N = 11,650$ per year, and total revenues are USD 15,874,877. To obtain the change in willingness to pay, we note that Ericksen et al. (2011) find that the willingness to pay for wildlife viewing varies significantly (Table 3). Assuming that the quality of wildlife affects willingness to pay for wildlife viewing, we set this decrease at USD 34 per visitor per day, equivalent to the difference between the highest value and the lowest value from a Contingent Valuation exercise carried out by Brown et al. (1994), and roughly the average difference between high and low values from two other valuation exercises by Brown et al. (1994) and Navrud and Mungatana (1994). Assuming further that the average tourist in Isiolo spends a week viewing wildlife, the total change in willingness to pay for tourism services for the average tourist in Isiolo is $7 \times 34 = 238$. Finally, the elasticity of demand for tourism is taken from Konovalova & Vidishcheva (2013), who find a value of 1.23 for holiday tourism.

Using these numbers and the theoretical expression above, we estimate that the number of international tourists visiting Isiolo could decline from 11,650 to 9,200, a change of 21 percent. The foregone revenues from these 2,450 "missing tourists" amount to USD 3,338,586 per year.

It is important to mention that the assumptions used in this calculation are conservative. First, we do not include for domestic tourists. Second, and most importantly, we only consider the reduction in spending for wildlife viewing. Consider a potential tourist who would have visited other places in Kenya, but after learning about the decline in wildlife in Isiolo, chooses instead to visit another country. In this case, additional expenditure would also be forfeited, and the final decline in total tourism revenue in Kenya would be substantially larger.

Table 3 - Willingness to Pay for Viewing Wildlife

	Willingness to pay	**Habitat and animals**	**Approach**
Brown et al (1994)	• USD 52-86 per visitor per day (CV) • USD 77-134 per visitor per day (TC)	Game parks, Kenya	Contingent Valuation (CV) and Travel Cost (TC)
Navrud and Mungatana (1994)	• USD 53.25 per visitor per day (CV) • USD 114-120 per visitor per day (TC)	Lake Nakuru, Kenya	Contingent Valuation (CV) and Travel Cost (TC)

Source: Ericksen et al. (2011)

5 Conclusion

This study provides a preliminary assessment of several of the expected local impacts of the proposed Isiolo Dam. Calculations are based on river flow data provided by CETRAD, online data, and a literature review. We focus our analysis on three main topics: water availability, herders and wildlife tourism. Given study limitations, results beyond the hydrological calculations should be understood as an initial scoping of the relevant issues.

Downstream, construction of the proposed Isiolo Dam will change river flow dramatically not only by eliminating seasonal flood pulses, but also by reducing the amount of water available. Using official data, we find that during impoundment and post-impoundment, the river flow will be equal to 15 and

38 percent, respectively, of the current unregulated flow. Flows at these levels are likely to mean long-term drought conditions for those who depend on the river as their major water source, in particular in the area to the west of where the Isiolo River joins the Ewaso Ng'iro. Further, the river will likely cease to reach water points at the lower part of the Ewaso Ng'iro Catchment, or reach them at much reduced volume. These include the Lorian Swamp, which is used as an important alternative water source during dry seasons and drought.

These changes are estimated to cost local herders USD 13 million per year, due to livestock mortality and price changes. The total number of people affected by the Isiolo dam-related drought in and around the Lorian Swamp is close to 20,000. The dam will also negatively impact wildlife downstream, along with the wildlife-based tourism industry. While a detailed treatment of the ecology and economic-decision making involved is beyond the scope of this study, a simplistic calculation suggests that visitation could decline significantly, resulting in lost revenues of several million USD each year.

Upstream, water availability will increase substantially. Livestock production is currently the dominant land use in the area around the dam, followed by conservancy areas. However, because of the change in water availability, irrigated agriculture is likely to gain prominence. In the presence of irrigated agriculture, activities such as livestock production and wildlife tourism may struggle to compete economically. Since livelihood and cultural traditions related to pastoralism do not easily change based on simple economic calculus, conflicts for land upstream could lead to hardship for herders even though water is more readily available. Herders downstream from the dam may also seek to adjust to water shortages by traveling upstream, either seasonally or permanently, further increasing the scope for conflict.

We estimate that lost tourism revenues resulting from the closure of facilities in the area that would be flooded are approximately USD 23,000 per day, or more than USD 8 million per year. This value does not consider the loss in tourist expenditures in the larger area and feedback effects in the local economy, as well as the economic impact on tourism facilities located downstream (e.g. in Samburu and Buffalo Springs National Reserves). In terms of livestock, we found that the area to be flooded is worth USD 213,230.

These findings suggest that the local environmental and economic impacts of the Isiolo Dam may be severe. However, a great deal of complexity related to expected changes remains unaddressed. Accordingly, we believe an in-depth analysis of local ecological and economic impacts is needed before proceeding with the project.

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Appendix

Sensitivity analysis

For the purpose of testing, we make our own estimates regarding the change in the river flow due to the construction of the proposed Isiolo Dam. We apply the method developed by Smakhtin and Anputhas (2006) which is based on the use of Flow Duration Curves (henceforth FDC). This method has been used to estimate river flow change resulting from dams and other major projects in other countries around the world.

The FDC is a cumulative probability distribution function that identifies the probability of the river flow to be greater than a specified value. Analyses typically consider 17 fixed percentiles: 0.01, 0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99, 99.9, and 99.99 percent.[30] The FDC provides critical information for watershed management by representing the variation in the availability and reliability of surface water to supply ecosystem services and satisfy anthropogenic need (Muller, Dralle, & Thompson, 2014).

To get another perspective on changes resulting from the proposed Isiolo Dam, we use the Environmental Flow Assessment method developed by Smakhtin & Anputhas (2006). In this method, six Environmental Management Classes (EMC) are determined according to the expected scope of change to the river. In this study, we consider two out of the six scenarios: the moderately modified and the largely modified scenarios. These two scenarios include change in water quantity and quality due to disturbances associated with “typical” dams and other major infrastructure.

The moderately scenario assumes that habitats and dynamics have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost or reduced, and alien species are present. On the other hand, the largely modified scenario assumes major changes in natural habitat, biota and basic ecosystem functions. In this scenario, alien species prevail, reducing local species richness.

Figure *20* shows the default FDC (i.e., for the unregulated river) and the FDCs for the two scenarios. The hypothetical FDC are determined by shifting the unregulated river curve to the left, along the probability axis. In this study, the default FDCs corresponding to the moderately and largely modified scenarios are shifted by three and four steps respectively – each step being equal to one percentage point. This means that a flow which was exceed 99.99 percent of the time in the original FDC will now be exceed by 95 and 90 percent of the time respectively.

[30] These thresholds are defined by the authors to ensure that the entire range of flows is covered.

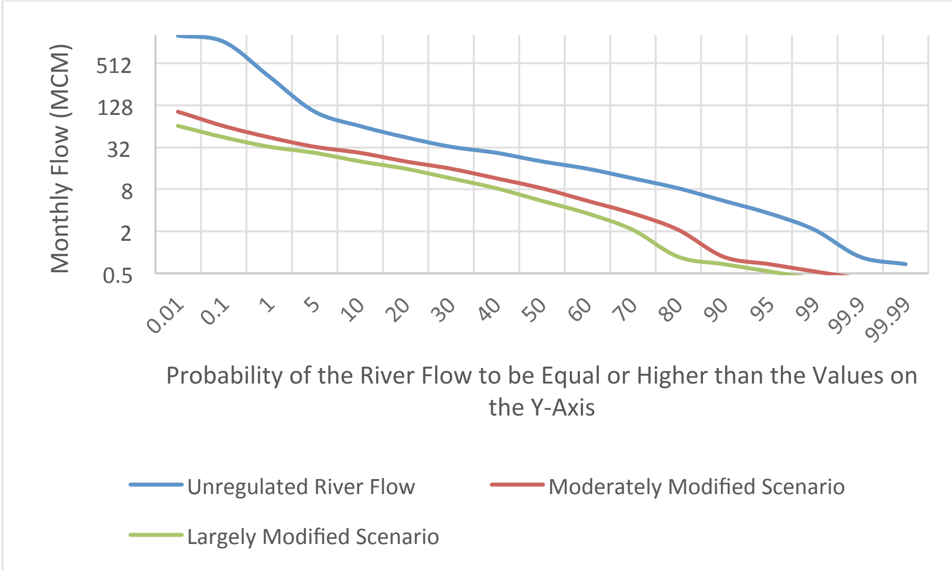


Figure 20 - Flow Duration Curve

Notes: MCM is the acronym for Million Cubic Meters per Month. The vertical scale is in logarithmic base 2 for better visualization.

To have a better understanding of what these two scenarios mean in terms of monthly flow, we use the spatial interpolation procedure described by Hughes and Smakhtin (1996).[31] Briefly, this technique generates a monthly time series using the Flow Duration Curve of both the default and alternative scenarios. The method first identifies for each original observation the corresponding percentile in the associated FDC. Second, it finds the same percentile in the new FDC and the monthly flow associated with this exceed probability. Since the distribution function covers all possibilities, we are able to find a monthly flow correspondence for each probability, and, therefore, establish a hypothetical time series for each scenario.

Figure *21* displays the original data and the river flow resulting in both scenarios. The Ewaso Ng'iro River flow is considerably smaller under both hypothetical scenarios. On average, the river flow reduces by 65 and 76 percent in the first and second scenario respectively. **These reductions are much more significant than the 25 percent predicted by the EIA report for the proposed Isiolo Dam during the impoundment period.**

[31] The procedure is explained in detail in Hughes and Smakhtin (1996). To perform this analysis, we use the software Global Environmental Flow Calculator, which is free to use.

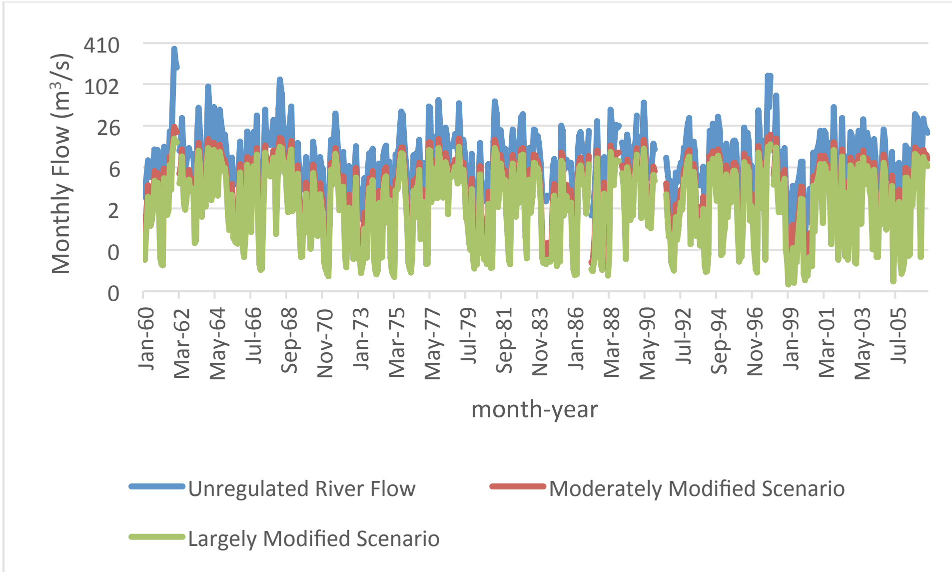


Figure 21 – Unregulated Monthly Flow (m3/s) and Monthly Flow in the Moderately and Largely Modified Scenarios
Notes: The vertical scale is in logarithmic base 2 for better visualization.

The estimates based on the two scenarios show that, regardless the scenario, the river flow will decrease substantially. While the stated constant flow of 5 m^3/s is likely to reduce the river flow to 38 percent according to our earlier calculations, in the moderately and largely modified scenarios, the river flow is likely to diminish to 34 and 25 percent respectively (Table 4)

Table 4 - Monthly Average River Flow under Different Scenarios (m^3/d)

Month	Unregulated River Flow	Regulated River Flow (impoundment period)	Regulated River Flow (post-impoundment period)	Moderately Modified Scenario	Largely Modified Scenario
January	1,187,166	165,888	432,000	226,869	161,802
February	460,666	165,888	432,000	129,905	87,876
March	466,596	165,888	432,000	255,816	188,363
April	1,492,788	165,888	432,000	574,641	429,507
May	1,642,397	165,888	432,000	500,366	375,147
June	784,325	165,888	432,000	318,767	228,344
July	742,723	165,888	432,000	338,966	244,348
August	1,115,349	165,888	432,000	375,509	275,763
September	876,870	165,888	432,000	392,841	286,896
October	859,371	165,888	432,000	461,764	342,626
November	2,272,152	165,888	432,000	569,494	425,214
December	1,668,573	165,888	432,000	432,267	315,191
Annual water availability	407,069,280	59,719,680	155,520,000	137,316,150	100,832,310

(m^3)				
Percentage of the unregulated river flow (%)	14.67	38.20	33.73	24.77

Figure 22 shows the FDC for the dry and wet season. As expected the curve corresponding to the dry season is on the left of the curve associated to the wet season. This means, for example, that the probability of having an average monthly flow equal to 32 m^3/s is approximately 3 percent for the dry season and almost 17 percent for the wet season.

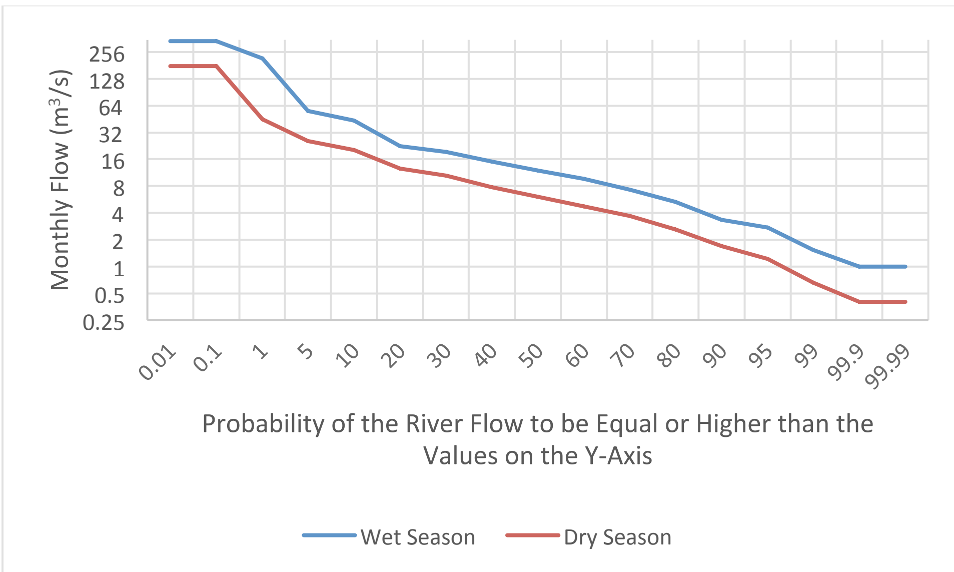
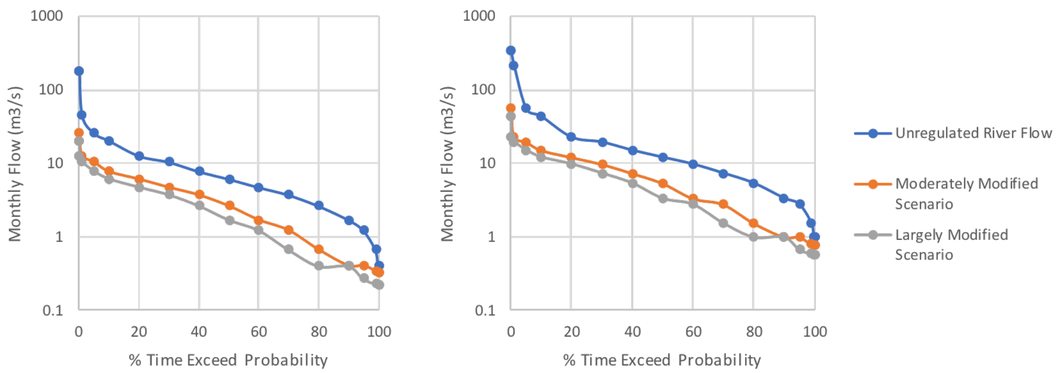


Figure 22 - Flow Duration Curve by Season

Notes: The vertical scale is in logarithmic base 2 for better visualization.

Finally, Figure 23 shows the FDC for the moderately and largely modified scenarios in the dry season on the left panel, and the FDC curves for both scenarios in the wet season on the right panel.



FDC in the Dry Season FDC in the Wet Season

Figure 23 - Flow Duration Curve by Season in two Different Scenarios

As expected the difference between the exceed probability of the current river flow and the flow under both scenarios is higher during the wet season. While the probability of having an average monthly flow equal to 42 m^3/s is 10 percent under the unregulated flow, the probability drops to 0.01 percent in the largely modified scenario. In the dry season, the probability of having an average monthly flow close to 42 m^3/s drops from 1 percent to less than 0.01 percent.