7 Environmental Baseline Situation

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Contents

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Tables

PUBLIC DISCLOSURE AUTHORIZED

Figures

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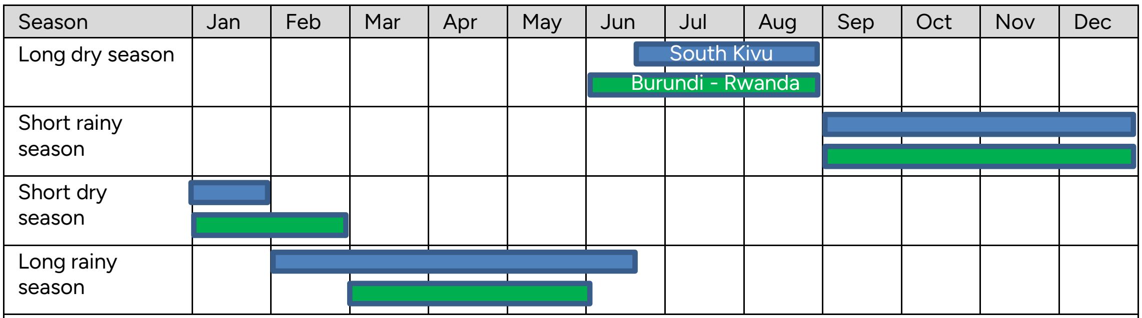
7.1 Climate

The Project is located in a tropical climate area with "dry" and "wet" seasons. Rainfall varies with altitude and follows a four-cycle regime. Uplands receive the most rain and there are many local variations linked to relief and the orientation of slopes. The highest parts of the mountains are not necessarily those with the highest rainfall, but rather the western slopes. The seasonal regime consists of a long and a short dry season, and a long and a short rainy season with varying durations, as shown in Figure 7-1.



Source: SHER, 2021

Figure 7-1 Distribution of Seasons in the Project Area

The distribution of average monthly rainfall at Kamambe airport, the closest meteorological station to the Project, is provided in Figure 7-2. Over the 23 years of available data (from 1991 to 2019, with the exception of 1994 to 1997, 2000 and 2001). There is a clear distribution between the long rainy season (March-May), representing 40% of annual precipitation and the short rainy season (September-December), representing 30% of annual precipitation.

The average annual rainfall for the period from 1991 to 2019 is 1,279 mm, though there are significant inter-annual variations that range from 845 mm (66% of the mean value) to 1,606 mm (125% of the mean) as shown in Figure 7-3. Regional variations in rainfall are illustrated in Figure 7-5.

Moderate temperatures are observed in the Project area (see Figure 7-4), with only small seasonal variations.

Wind is predominantly south-easterly trade winds, though in July these are replaced by very dry north-easterly trade winds. However, local topography influences wind and the corridor formed by the upper Ruzizi Valley, most likely channels the circulation of air from the south to the north. The average wind speed in Rwanda is 1-2 m/s and the maximum monthly wind speeds recorded at Kamembe Airport range from 6-14 m/s from the southeast.

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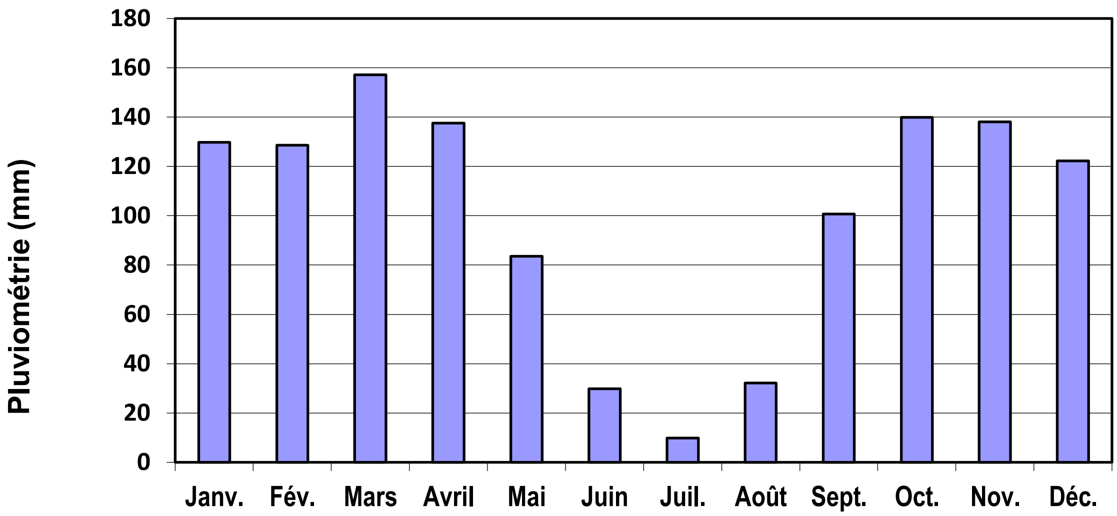
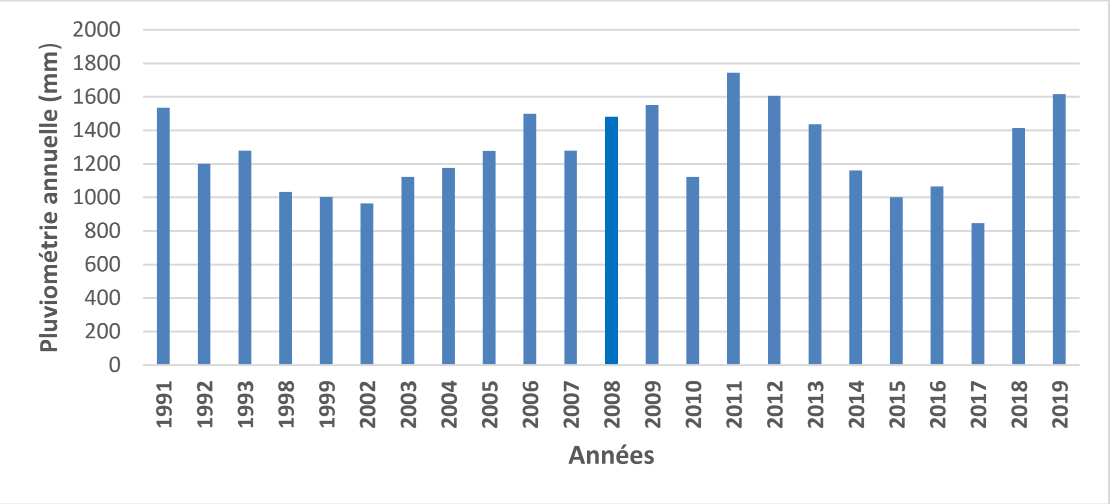


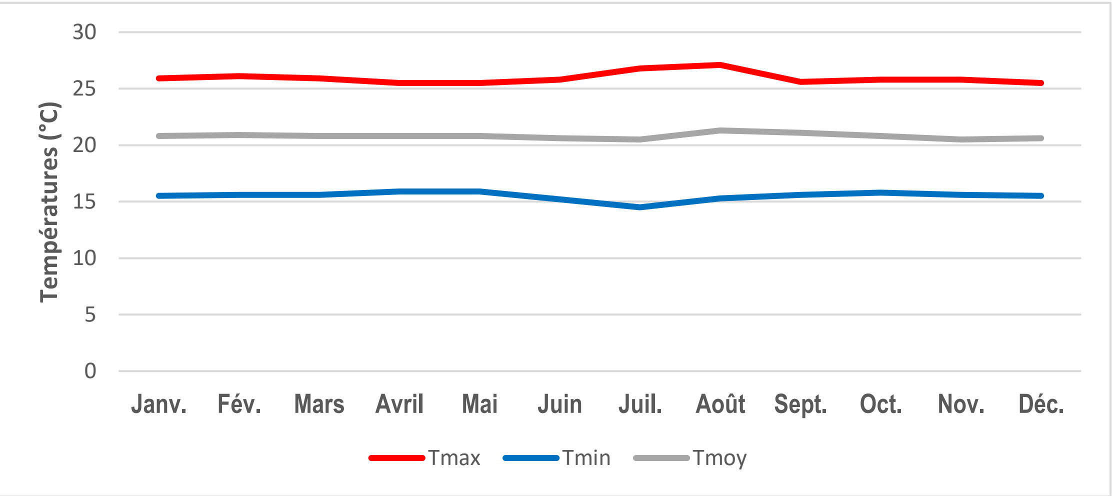
Source: Rwanda Meteorology Agency, 2019

Figure 7-2 Distribution of Average Monthly Rainfall at Kamembe Airport (1991-2019)



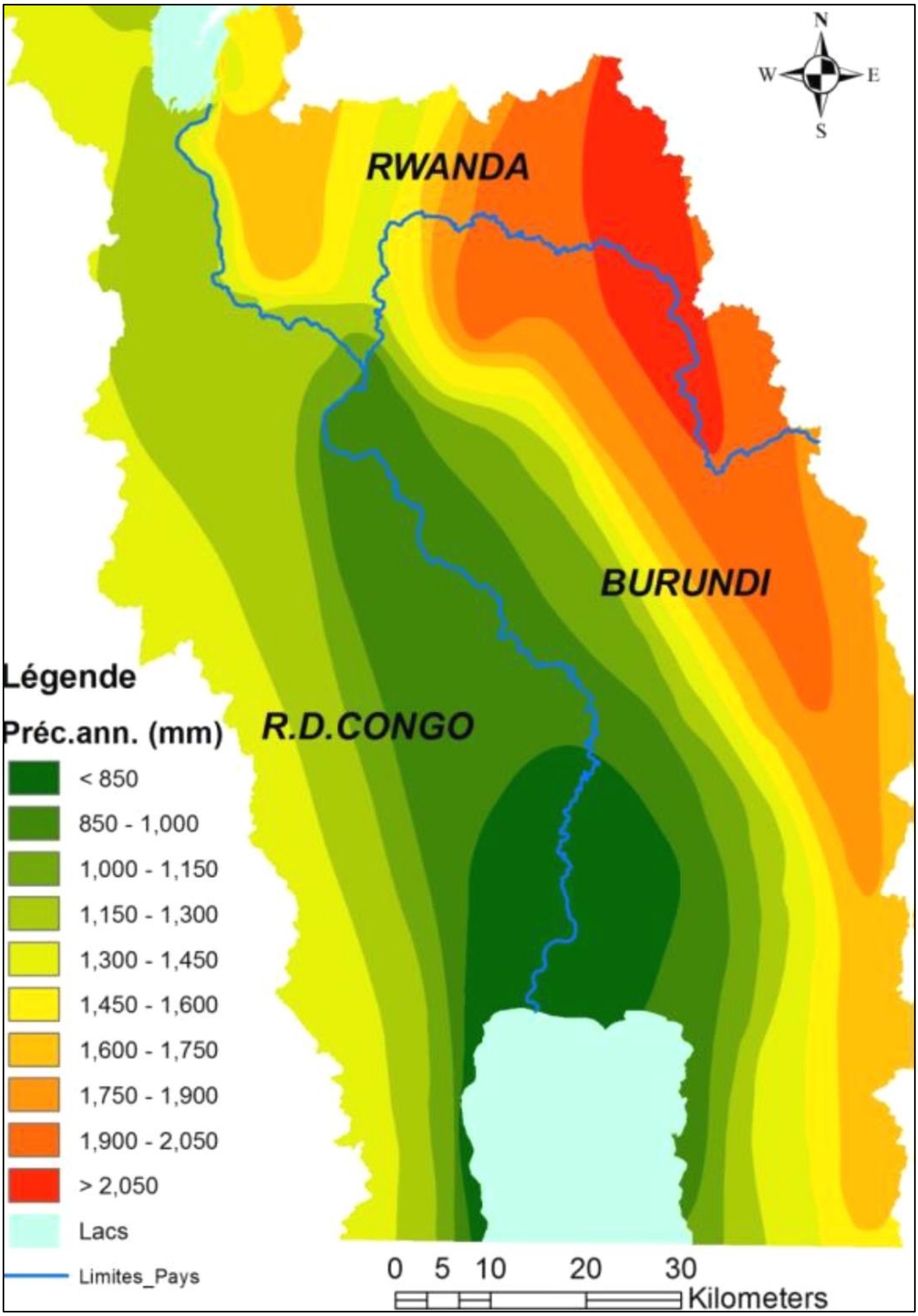
Source: Rwanda Meteorology Agency, 2019

Figure 7-3 Average Annual Rainfall at Kamembe Airport (1991-2019)



Source: Rwanda Meteorology Agency, 2019

Figure 7-4 Max., Min. and Average Monthly Temperatures at Kamembe Airport (1991-2019)



Source: Nibigira, 2017

Figure 7-5 Regional Distribution of Rainfall

According to the Government of the Netherlands, 2019 (as cited in Tractebel, 2020), DRC and Rwanda are estimated to be the most vulnerable to climate change in the Ruzizi Plain due to the high density in this region (2,000 people per km^2), a large dependency on natural resources and an agricultural productivity considered to be particularly low. Vulnerability indicators defined for the Great Lakes Region and Ruzizi Plain are presented in Figure 7-6 below.

Variable	Indicator	Year	Vulnerability level		
			Burundi	DRC	Rwanda
Environmental disasters	Drought	2010	high	high	high
		2030	high	high	high
	Floods and landslides	2010	moderate	moderate	moderate
		2030	high	moderate	moderate
	Storms	2010	low	low	low
		2030	low	low	low
	Wildfires	2010	low	moderate	low
		2030	low	moderate	low
Environmental disasters	Agriculture	2010	acute	high	acute
		2030	acute	severe	acute
	Fisheries	2010	high	severe	moderate
		2030	acute	acute	moderate
Health impact	Hunger	2010	severe	acute	high
		2030	severe	acute	high
Total climate (including the factors above + 15 others)		**2010**	**severe**	**severe**	**high**
		2030	**acute**	**acute**	**severe**

Source: Government of the Netherlands, 2019 (as cited in Tractebel, 2020)
Figure 7-6 Vulnerability Indicators Defined for the Great Lakes Region and Ruzizi Plain

7.2 Geology

7.2.1 General Geological Context

The Project area is part of the West African Great Rift and has undergone numerous folds, deformations and collapses. The geological substratum consists of highly metamorphosed sedimentary rocks of Precambrian age (metasediments), mainly schists and quartzites. During the Miocene epoch (Tertiary era), the region experienced intense volcanic activity which covered the Precambrian substratum with lava rocks such as trachytes, basalts and tuff. Figure 7-7 shows the geological context of the Kivu rift region.

The Ruzizi flows through a trough fault (Bugarama graben) which, before the volcanic period, must have veered northwards (Nile basin). More recently, in the Quaternary era (Pleistocene and Holocene epochs), the river's alluvium was deposited along its course to form islands and low terraces, and further downstream the vast plain of the Ruzizi.

The 2010 Fichtner Feasibility Study describes the succession of geological formations along the incised Ruzizi valley as follows:

- The upstream part, from Bukavu to about 2 km downstream of the Ruzizi II dam, is covered with basalt, tuff and to a lesser extent trachyte. Its geomorphology is characterised by gentle slopes and a relatively wide valley floor.

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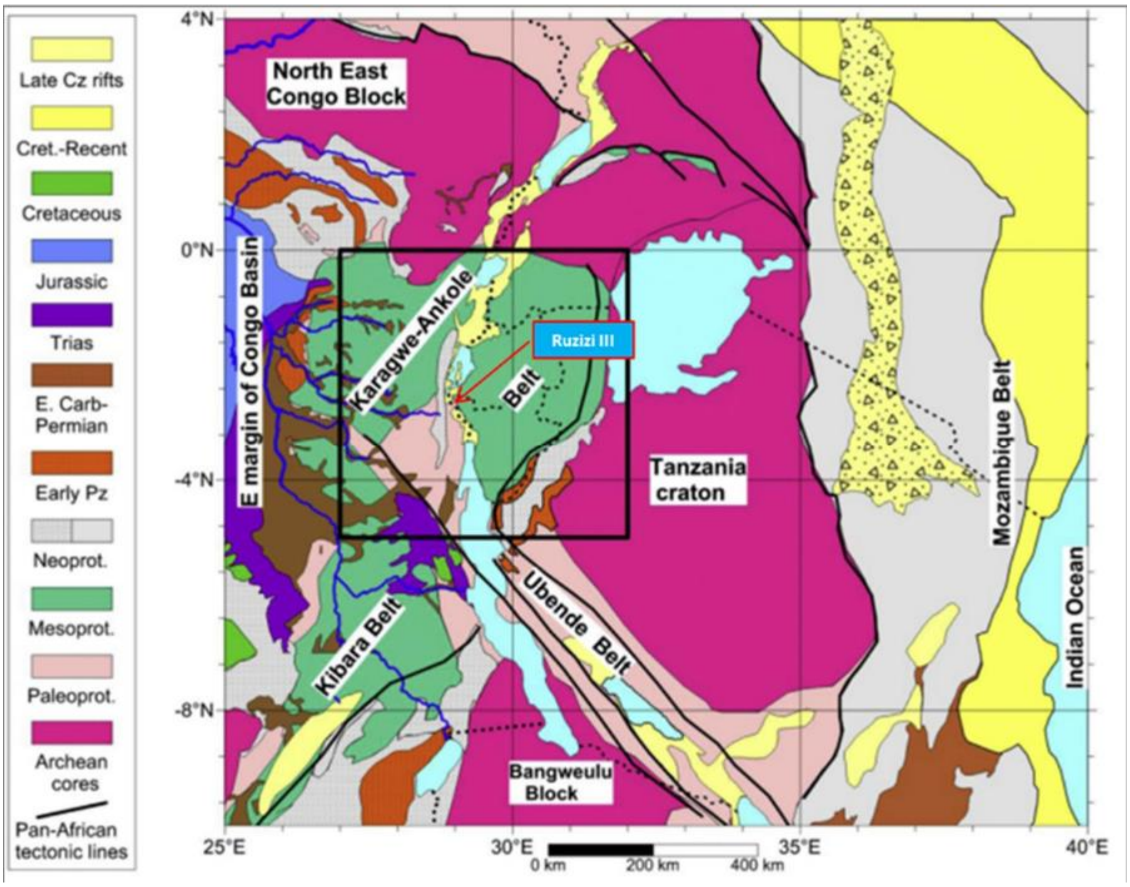
- The intermediate part starts from the previous site and extends to the site planned for the Original Project's power plant. The basaltic lava gives way to rocks of the Precambrian basement: quartzite, quartzo-schist and micaschist. The V-shaped valley has steep slopes with frequent rocky outcrops. This part is roughly equivalent to the direct impact area.
- The downstream part, beyond the power plant site of the Original Project, is composed of metamorphic rocks and basaltic lava. In this section the Ruzizi River has to bypass or encircle numerous rocky outcrops: its course becomes winding and turbulent. Many rock steps and waterfalls are visible at this level.

Given the border situation, it is not easy to find an accurate, good quality geological map covering both sides of the Ruzizi. Figure 7-8, presents a simplified geological map and shows the dominance of volcanic rocks upstream and of Precambrian metasedimentary rocks further downstream.

At the mouth of the incised valley towards Bugarama/Kamanyola, the substrate consists of boulders and large pebbles deposited by the river over 10,000 years ago (Ilunga, 2007) in the form of an alluvial fan.



Source: Delvaux et al.

Figure 7-7 Geological Context of the Kivu Rift Region

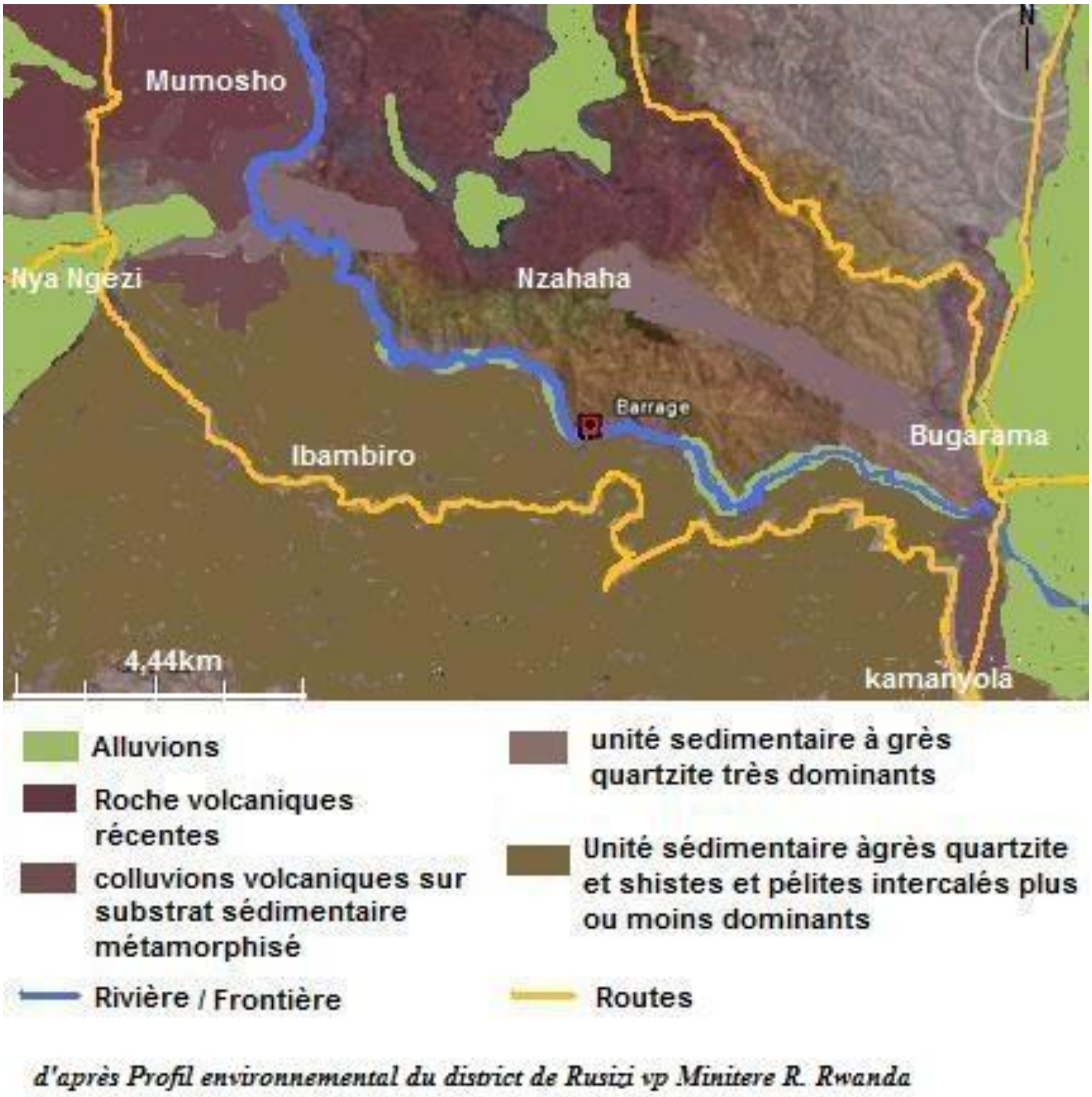


Figure 7-8 Simplified Geological Map of the Project's Area

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7.2.2 Seismicity

7.2.2.1 Geodynamic Context

The project area is located in the context of active rifting, at the junction between the Kivu rift segment and northern Tanganyika rift segment of the East Africa Rift System (EARS). The onshore EARS extends approximately 4000 km, from the Gulf of Aden in the north to the gulf of Mozambique in the south. The EARS is characterized by a series of aligned tectonic basins (rift valleys), separated from each other by relative shoals and generally bordered by uplifted shoulders (Figure 7-10). Each basin is controlled by normal faults and forms a subsiding graben (or trough) up to one hundred kilometres long and 40-60 km wide (Chorowicz, 2005).

The EARS is divided into two branches, an eastern and western rift branch (hereafter referred to ERB and WRB, respectively), surrounding the Tanzanian Archean craton and lying on Proterozoic mobile belts and following their pre-existing crustal-scale fabric trends (e.g. Chorowicz and Sorlien). Rifting along these two rift branches is the consequence of the divergence between the Nubian and the Victorian plate (western rift branch) and between the Victorian and the Somalian plates (eastern branch) (e.g., Calais et al., 2006; Saria et al. 2014).

7.2.2.2 Regional and Local Seismicity

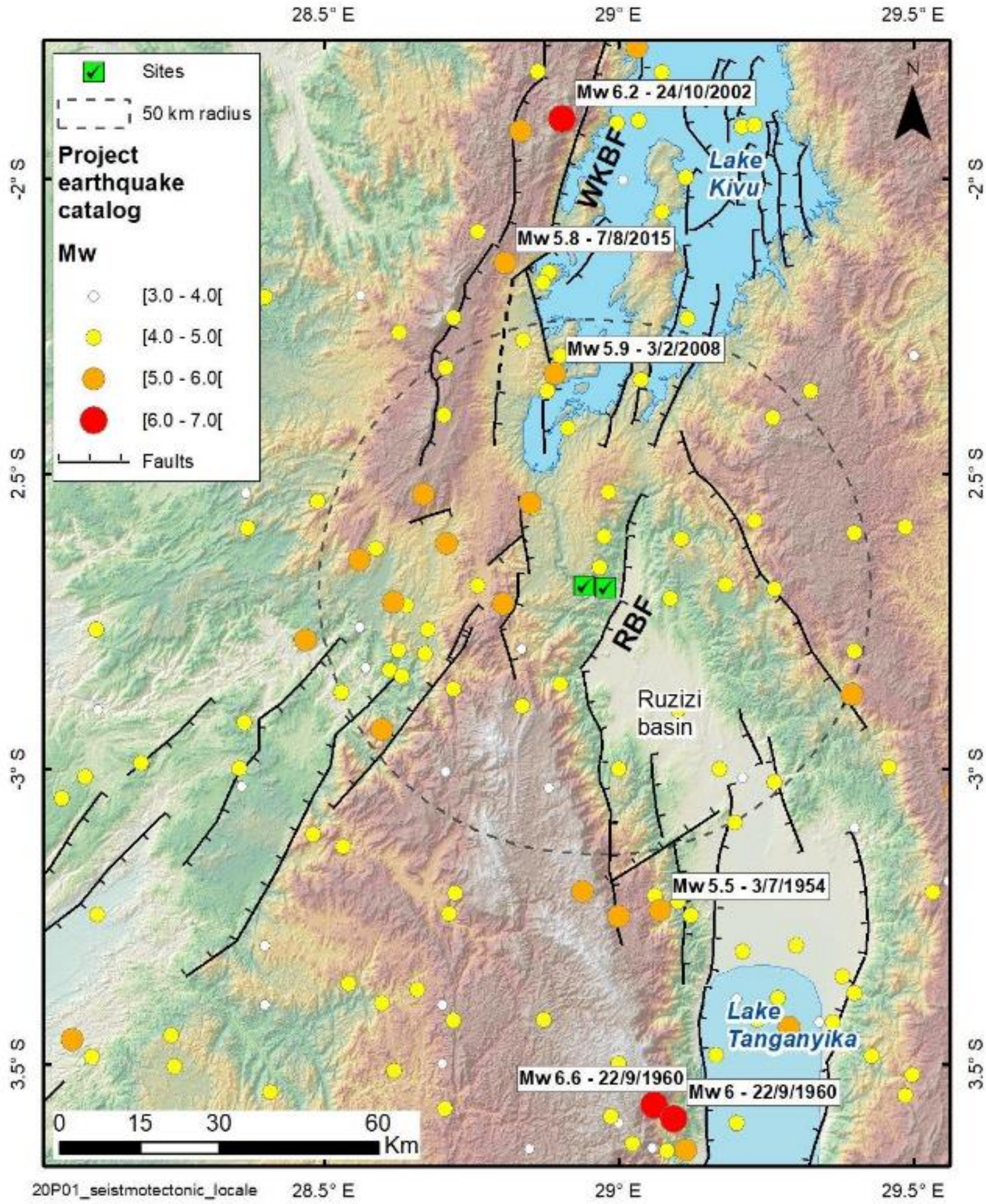
The project is located along the western branch of the EARS, which is the most seismically active zone of the Tanzania craton region. Figure 7-9 shows the local seismotectonic map compiled from the fault mapping of Wood et al. (2015) and Delvaux et al. (2017).

Nine earthquakes of magnitude Mw[1] equal or higher to 6.0 are recorded between approximately 100 and 300 km from the sites. These events are located both along the rift and within the rift margin, at the transition with the Tanzania and Congo craton.

The main events, shown on Figure 7-9, were the following:

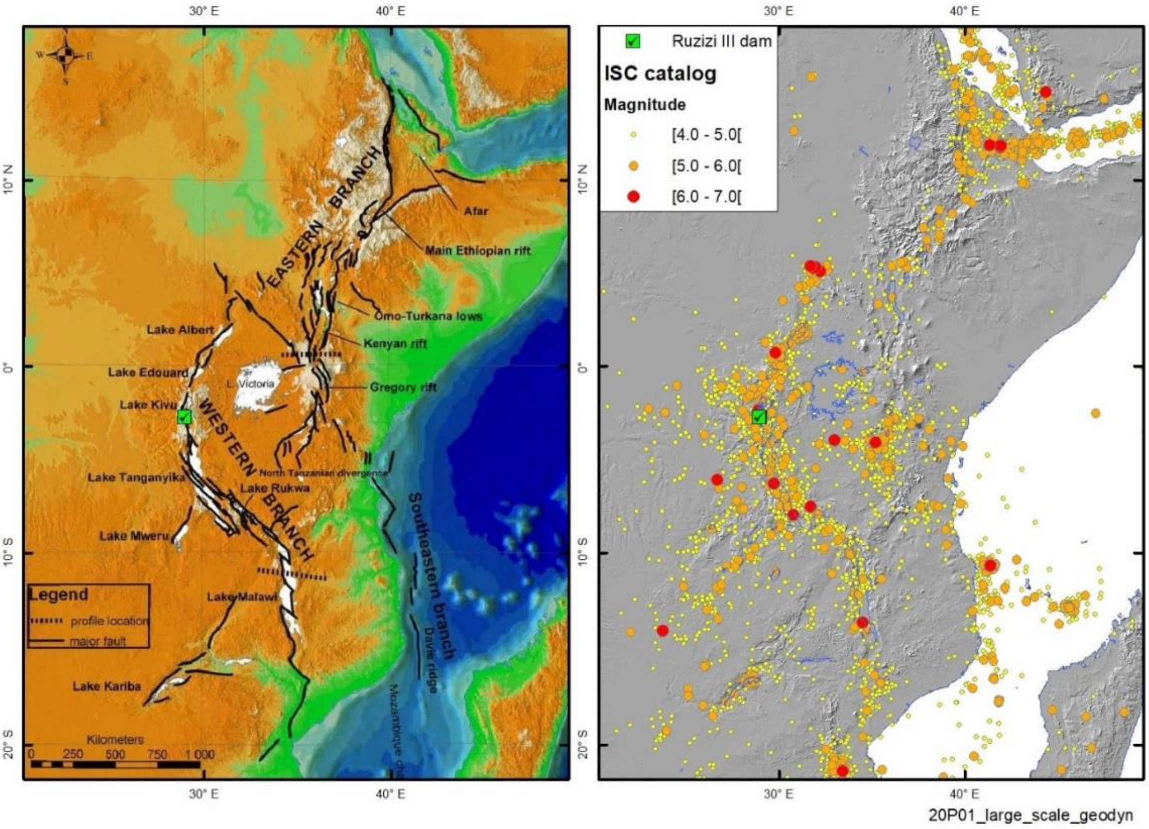
- The largest earthquake at a regional scale occurred along the western border of the Kivu rift were the Mw 6.2 (24 October 2002) event that may be related with an activity of the West Kivu Border Fault (WKBF).
- The largest event recorded within a radius of 300 km around Ruzizi dam occurred on the 22 September1960 with a magnitude Mw 6.6, at the north-western edge of the Tanganyika rift zone (Figure 7-9). Two main shocks are recorded for this event (Mw 6.6 and Mw 6.0). This sequence is located at approximately 100 km south of Ruzizi dam III.
- In the southern part of Kivu rift, an earthquake occurred on the 03 February 2008 with magnitude Mw 5.9
- Closer to Ruzizi dam site, six earthquakes of magnitude 5.0 to 5.3 that occurred in 1965, 1977, 1981, 2017 and 2019 are located between 15 and 45 km west from the site. There is only one recorded earthquake in the catalogue within a radius of 10 km around the sites. The closest recorded event is located at approximately 4 km north of both sites and occurred on 5 December 2017 with magnitude Mw 4.8.

[1] Mw is the moment magnitude scale is a measure of an earthquake's magnitude ("size" or strength) based on its seismic moment.



Source: Tractebel, 2021 using data from Wood et al. (2015) and Delvaux et al. (2017).

Figure 7-9 Seismotectonic Map of the Project's Region



Major Faults of the East African Rift System (Chorowics, 2005)

Seismicity distribution in the East African Rift System (ISC, Earthquake with Magnitude >4, from 1964 to 2020)

Figure 7-10 Major Faults and Seismicity Distribution in the EARS

7.2.3 Slope Stability

7.2.3.1 Potential Landslide Identification

The Project has undertaken slope stability studies to identify potentially unstable areas in the Project area and assess the risk of landslides that could affect the dam or the reservoir as well as other Project's components. The purpose is that the risks can then be addressed in the Project design and risk reduction measures defined. The information presented in the following sub-sections 7.2.3.2 - 7.2.3.5 is key information taken from the Ruzizi III HPP & Dam Final Project Design Report - Appendix E: Stability Assessment of Slopes and Appendix V: Sediment Management Study (Tractebel, 2022). Information on the April 2021 landslide event on the right bank above the dam site is included.

7.2.3.2 Previous Investigations (2008-2009)

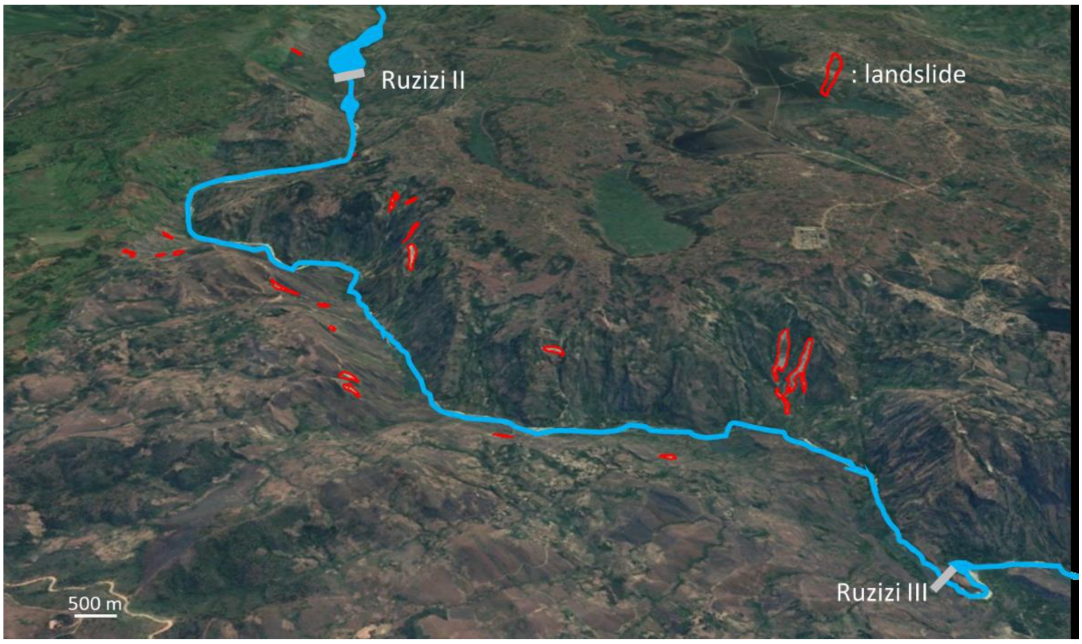
Investigations performed by Fichtner in 2008-2009 noted exposed bedrock on very steep slopes. Less steep slopes were noted to be covered by slope debris and colluvium accumulated by slow downslope movement.

An ancient landslide area was identified on the right hillside upstream from the pre-Feasibility Study dam site. A test pit dug in this area indicated that the landslide material consisted of a mixture of rock blocks and fragments, silt and fine-grained sand. The landslide would have been triggered by river undercutting. The presence of a clay-rich sliding surface has been considered unlikely.

7.2.3.3 2020-2021 Investigations

A Sediment Study

The technical sediment study noted that landslides have been observed in 22 areas between Ruzizi II and Ruzizi III (Figure 7-11). When comparing the two Ruzizi inter-basins, more landslides have been observed between Ruzizi II and Ruzizi III than upstream of Ruzizi II. The general characteristics of these landslides is presented in Table 7-1 below. These landslides have been identified to be the sources of some of the sedimentation materials that can be driven by the Ruzizi River. The slope of the river valley is noted to be a major factor of sedimentation risk within the Ruzizi III inter-basin (Figure 7-12).



Source: Tractebel, 2022

Figure 7-11 Landslides Observed Between Ruzizi II and Ruzizi III

Table 7-1 Landslide characteristics between Ruzizi II and Ruzizi III

Parameters	Data
Number	22
Minimum area (m²)	428
Maximum area (m²)	14,049
Average (m²)	5,350
Total (m²)	117,703
Source: Tractebel, 2022	

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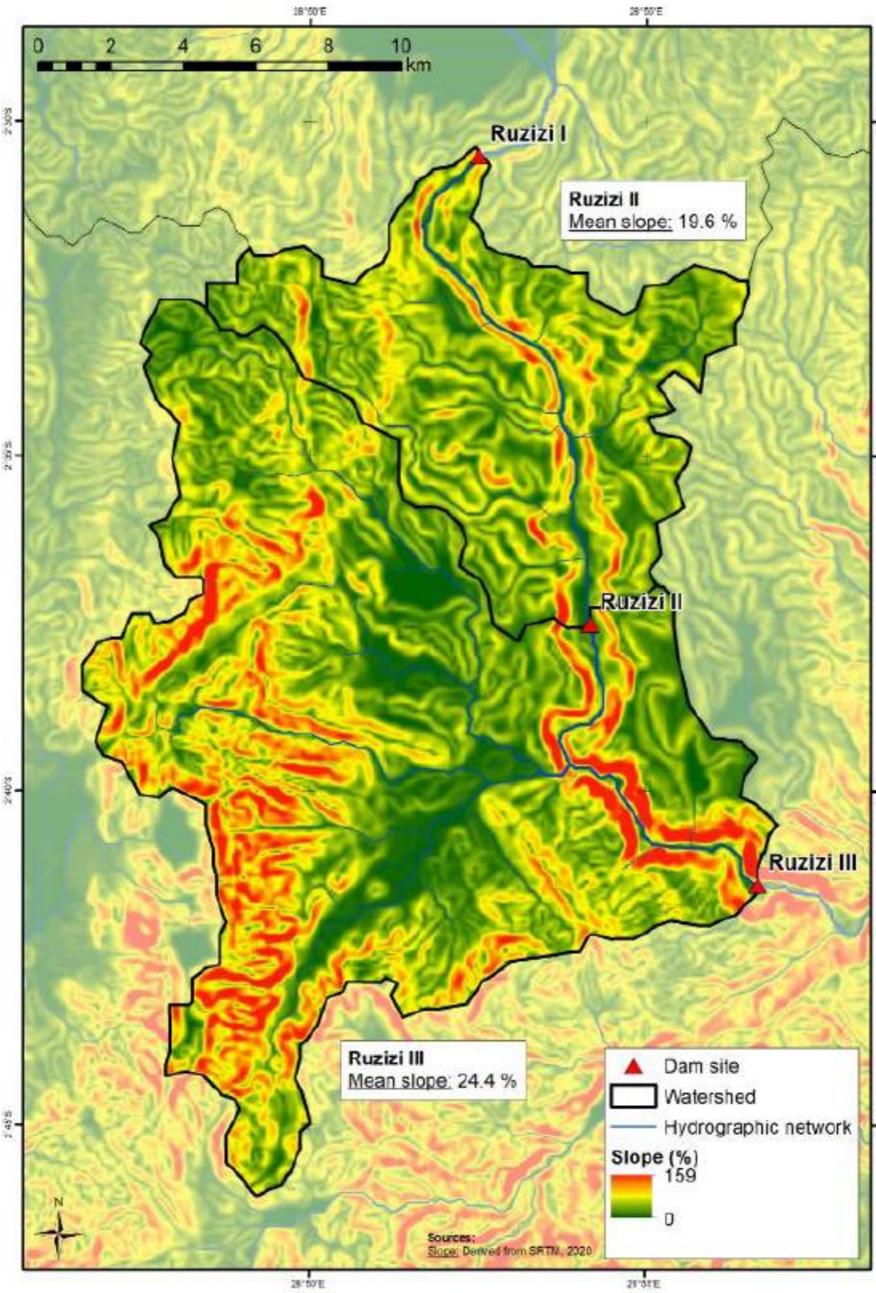

Source: Tractebel, 2022

Figure 7-12 Slope Risk in the Ruzizi III Inter-basin

7.2.3.4 Interferometry Data and SAR Analysis

In order to detect and characterize any possible slope instability affecting the Project's components, including both reservoirs, an analysis of historical satellite radar images of the area, acquired by the Sentinel-1 (SNT) satellite, from October 2016 to September 2021 was performed by TRE-Altamira. The analysis focused on general slope stability within the defined study area (outlined in red on Figure 7-13) and on areas already identified to be potentially unstable or known to be unstable (approximate areas outlined in navy blue on Figure 7-13).

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7.2.3.5 Risk Assessment

As a result, two main deformation areas (1 and 2 on Figure 7-13) have been identified on the South side of the Ruzizi River, downstream of the planned location of the dam. Two secondary deformations (3 and 4 on Figure 7-13) have also been identified. The technical report concludes: (i) Stable slopes at the proposed dam site, (ii) no significant ground displacement upstream the proposed dam site, (iii) unstable slope near the future bridge between Rwanda and DRC (ongoing ground displacement), and (iv) ground displacement in the east of Powerhouse area (likely due to land use).

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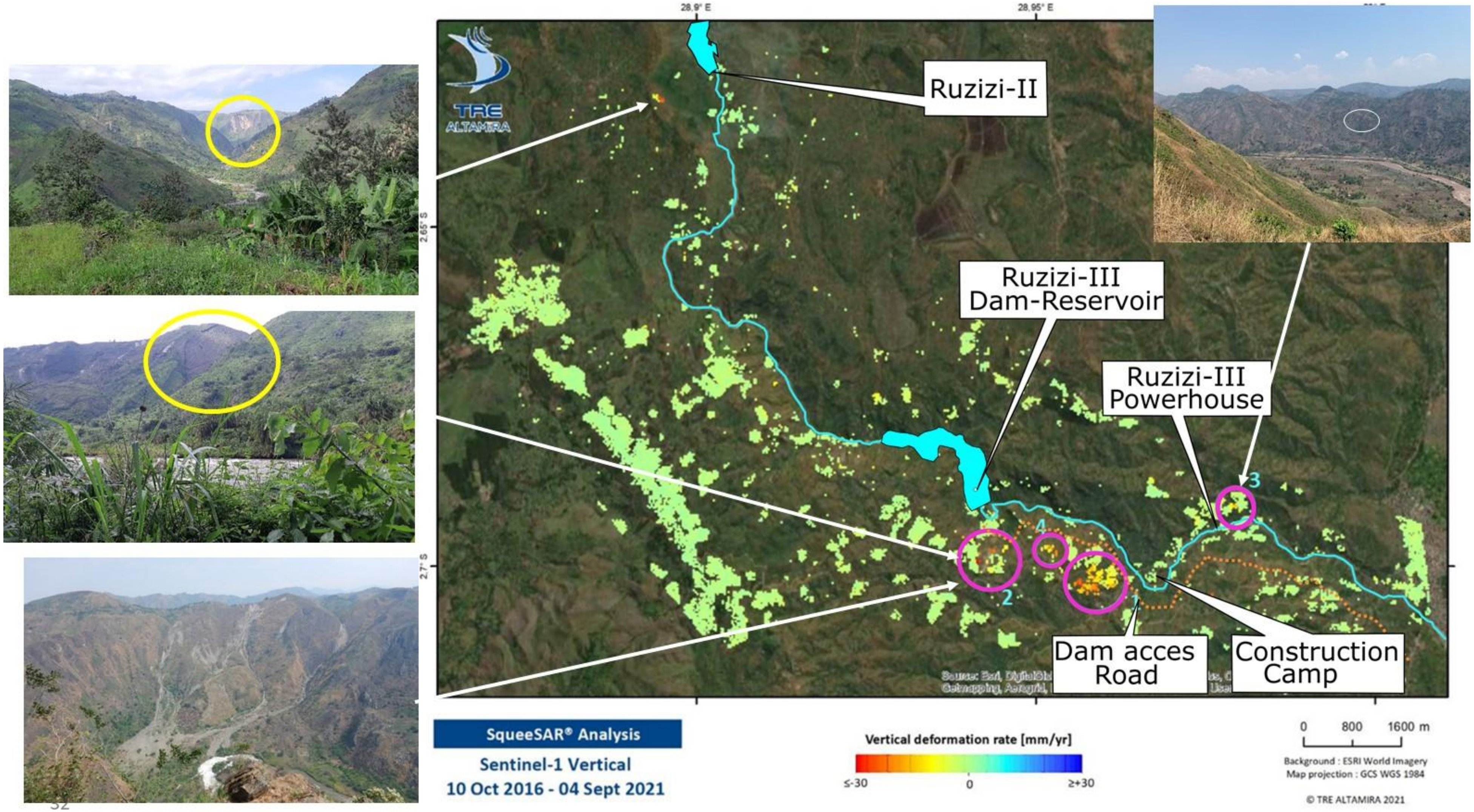


Source: TRE Altamira, 2021, modified by SLR

Figure 7-13 – Deformation areas identified on satellite imagery

View of landslide area n°1

View of landslide area n°2

View of landslide area n°3 (Powerhouse area)

Source: Tractebel, 2021

Figure 7-14 Photographs of Landslide Areas

7.3 Hydrogeology

7.3.1 Generalities

The information on hydrogeology provided in this subsection is taken from the *Baseline Study for the Basin of Lake Kivu and the Ruzizi River* prepared by SHER Consult for ABAKIR (SHER, 2020).

The basin is characterised by the presence of mostly Precambrian and Phanerozoic indurated terrains, composed of metamorphic rocks (schists, gneiss, quartzite), intrusive magmatic rocks (mainly granitic), and volcanic rocks (mainly basaltic). In addition to these formations constituting the weathered and fissured base present throughout the basin, there are also loose formations consisting of fluvio-lacustrine alluvial deposits from the Quaternary period. These alluvial deposits are mainly found in the Ruzizi plain (middle and lower Ruzizi), as well as in the lower valleys of the most important sub-basins of the study area.

7.3.2 Types of Aquifers

Within these geological formations, four main types of aquifers can be defined in the basin, based on their hydrodynamic properties and aquifer potential:

- Quaternary sedimentary aquifers corresponding to alluvial deposits (fluvio-lacustrine), mainly found in the alluvial plain of the middle and lower Ruzizi. The alluvial plains of secondary rivers can also constitute aquifers in the lower valleys, although their exploitation potential is more limited.
- Superficial aquifers located in the alteration zones of the metamorphic and crystalline Precambrian bedrock (granites, quartzites, gneiss, schists and psammites).
- Discontinuous and deeper aquifers located in fissured zones of metamorphic and crystalline Precambrian bedrock (granites, quartzites, gneisses, shales and psammites).
- Complex aquifers located in the volcanic terrains (basalt, pyroclastic deposits) of the Cenozoic. The Project dam and powerhouse are located in this area.

7.3.3 Aquifer Potential

The most important aquifer potentialities are found in the alluvial aquifer of the Ruzizi plain. This aquifer extends over the whole of the Ruzizi alluvial plain and at the level of the low valleys of its tributaries, over an area of approximately 1,700 km². The thickness of this aquifer can reach 50 to more than 150 m in the Ruzizi plain, and 10 to 30 m in the alluvial deposits of the lower inland valleys.

Groundwater can be mobilised from boreholes, with an expected productivity of more than 10 l/s. This water table is encountered at a shallow depth, often less than 10 m below the ground surface, making it easily accessible from shallow structures. However, it contains high levels of iron and manganese, often exceeding drinking standards.

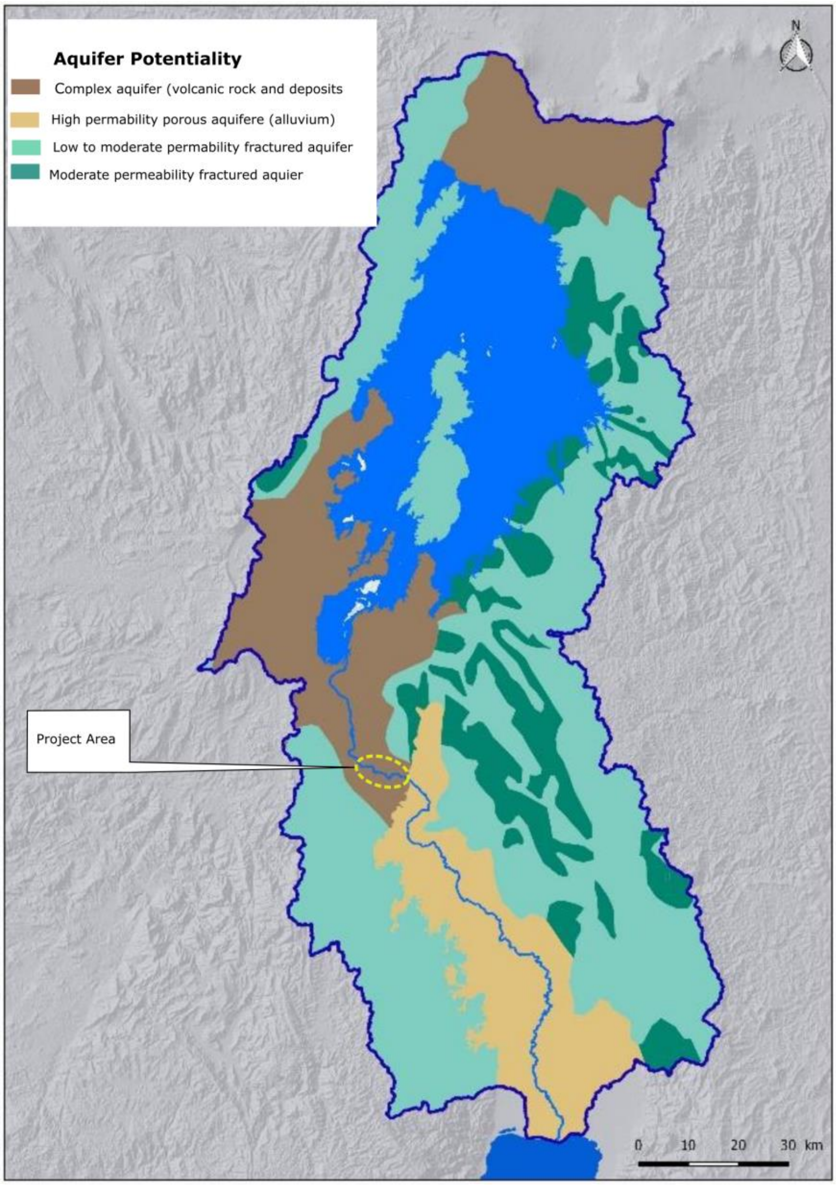
Interesting potential is also found in granite alteration, which can be particularly water-bearing and provide exploitation rates of up to 5 to 10 l/s from boreholes. Their thickness can reach 100 m. Metamorphic formations offer more limited potential for exploitation, depending on the degree of alteration and cracking encountered, and on the nature of the rock, particularly its clay fraction. The potential for exploitation by drilling is generally more limited, and may not exceed 1 l/sec.

The aquifer potential of volcanic soils (Cenozoic basalts) is extremely variable and difficult to quantify, as the heterogeneity of this environment is so varied.

7.3.4 Groundwater Exploitation

In the Burundian part of the Ruzizi alluvial plain, there are about fifteen boreholes used for rural hydraulics (IGEBU 2018 inventory). A few boreholes exploiting the aquifers of cracks in the crystalline basement are also identified in the basin, including boreholes in the urban area of Bubanza (granitic context) in Burundi.

Groundwater in the basin is mainly exploited from developed natural springs, mainly for drinking water supply in rural areas. In the Rwandan and Burundian parts of the basin, there are more than 550 springs for drinking water supply, as well as many natural springs (several thousand) that have not been developed but are nevertheless used by local populations without improved access to drinking water. In addition to these, there are also around 70 thermal springs in the basin. An overview of the hydrogeological context, illustrated based on the basin's aquifer potential, is presented in Figure 7-15.



Source: SHER, 2021

Figure 7-15 Hydrogeological Map of the Lake Kivu and Ruzizi River Basin

7.4 Geomorphology

The river geomorphology has been largely described from high-resolution land-based, satellite and aerial images. The land-based images were captured in 2021 and 2022. The satellite images were available for a range of dates (1985 to 2021) on the GoogleEarth platform which allowed a view of high and low flow conditions and various seasons for the entire length of the river. The aerial images were captured in 2020. This allowed insights into valley confinement, possible flooding extent, the reworking of bars and banks, lateral shifts of the channel, landslides, gully erosion and changes in watercolour which is a proxy for suspended sediment concentration along the main river, tributary streams and river mouth. The descriptions were supported by longitudinal gradient and the geomorphic zones that can be derived from the reach slope and its likely planform, reach type and sediment composition as described by Rowntree and Wadeson (1999). A river longitudinal profile was extracted using Google Earth's elevation model and a river centre line.

7.4.1 General Area Description

The Ruzizi River is located along an active rift zone at the junction between the Kivu and Northern Tanganyika Rift segments of the western branch of the East African Rift System (Seister, 2020; Tractebel, 2021a). The Ruzizi is a relatively young river (~10,000 years old) and formed when volcanic activity blocked the outflow of Lake Kivu northwards to the Nile River, diverting the flow southwards to the Congo River basin (Tractebel, 2021a).

The western branch of the East African Rift System is defined by steep mountains and deep rift valleys (formed by half grabens) with thick sediment fills along the valleys, such as along Lake Kivu (more than 500 m of sediment fill recorded) and the Ruzizi plain approaching Lake Tanganyika (sediment fill of 1,500 m thick) and Lake Tanganyika (sediment fill of up to 3,000 m thick) (Seister, 2020; Tractebel, 2021a).

The Ruzizi River is 168 km long and the first 40 km flows through a steep confined gorge (underlain by volcanic rocks along the upper part followed by schist, quartzites and volcanic intrusions along the lower reach where Ruzizi III will be located) surrounded by steep mountain slopes.

After 40 km the valley opens up, the gradient lowers and the river flows across the broad sedimentary Ruzizi Plain (the floor of the western Rift Valley) (Figure 7-16).

Over the last 50 km the Ruzizi flows along a low gradient floodplain and delta into Lake Tanganyika.

The first 40 km (from Lake Kivu) of the Ruzizi River valley is deeply incised into the surrounding landscape, resulting in steep slopes with no or narrow flood benches/plains lining the river's edge. The river is located along strike-slip faults, tension fractures and tectonic discontinuities with N-S, E-W and NW-SE orientations between the Lake Kivu and the Ruzizi extensional basins, giving the valley floor and river course its zig-zag pattern (Tractebel, 2021a).

The history of the Ruzizi River is characterised by deep excavation, followed by landslides causing temporary damming and sedimentation (Tractebel, 2021a). These events can be observed in the cores that were drilled for the Ruzizi III geotechnical survey. Landslides are a common occurrence, supplying large volumes of sand, silt, rock fragments and large angular rock debris to the lower slopes, floodbenches and river channel. The colluvium on the hillslopes ranges from several metres to more than 20 m thick (Tractebel, 2021a).

Large block accumulations can be up the 10 m thick on the lower hillslopes (Tractebel, 2021a). Along the river the bed consists of a thick (10 -50 m) layer of coarse alluvium covered by calcrete (Tractebel, 2021a). Bedrock, indurated alluvium (carbonate cementation forming calcrete) and larger blocks (several cubic meters in volume) form rapids along the river and act as a local base level control (Tractebel, 2021a). Along this steep reach the banks are mostly composed of large rocky material with discontinuous layers of sandy material (Tractebel, 2021a). Large pools are present along gentler longitudinal sections of the river, with sand and gravel bars forming in low energy environments where the channel widens.

Once the Ruzizi River exists the confined gorge, it flows straight across the plain/fan in a southeasterly direction towards the conluence with the Rubyiro and Ruhwa tributaries. The river is partly incised into the plain and has numerous bedrock/cemented steps along its course, with the largest being just upstream of the confluence with the Rubyiro River. From the confluence with the Ruhwa River, the Ruzizi River turns in a southerly direction and flows across the partly incised plain towards Lake Tanganyika via the unconfined active floodplain and delta. These plains are surrounded by steep mountains with a dense drainage network.

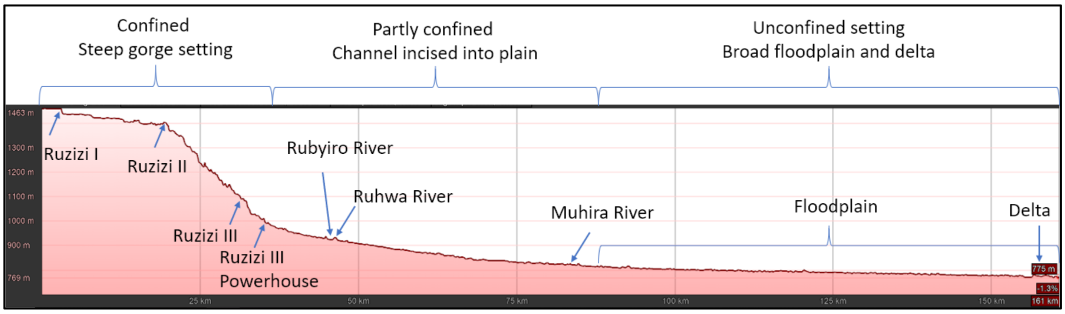


Figure 7-16 Longitudinal profile of the Ruzizi River

Showing the existing and planned hydropower plants and main tributaries (Profile created using Google Earth)

7.4.2 Lake Kivu Outflow to Ruzizi-II Dam

The river gradient is relatively gentle along this reach at 0.0038 m/m and can be classified as a Lower Foothills geomorphological zone (Rowntree and Wadeson, 1999). This zone can be described based on its river gradient as being a mixed bed river with sand and gravel dominating the bed, with localised bedrock controls, forming a pool-rapid sequence with small sections of floodplain (Rowntree and Wadeson, 1999). Based on satellite images this section has long deep pools along lower gradient sections, interspersed by steeper high energy rapids, possibly composed of boulders and bedrock (Figure 7-17). The channel is straight to wandering along the confined valley floor, with the valley floor bending to some degree as it follows geological lineaments. Multiple channels and vegetated bedrock-core islands form along or immediately downstream of the rapid sections. Sediment deposition in the form of bars is not evident from the satellite images, possibly due to the proximity to the outflow of clear water from Lake Kivu and limited lateral sediment input. Agriculture and residential development are widespread along the slopes with some evidence of landslides along steeper hillslopes. Landslides occur along the valley slopes, with 13 landslides mapped with a total area of 16,400 m^2 (Tractebel, 2021b). Debris or alluvial fans are visible along the channel margins.

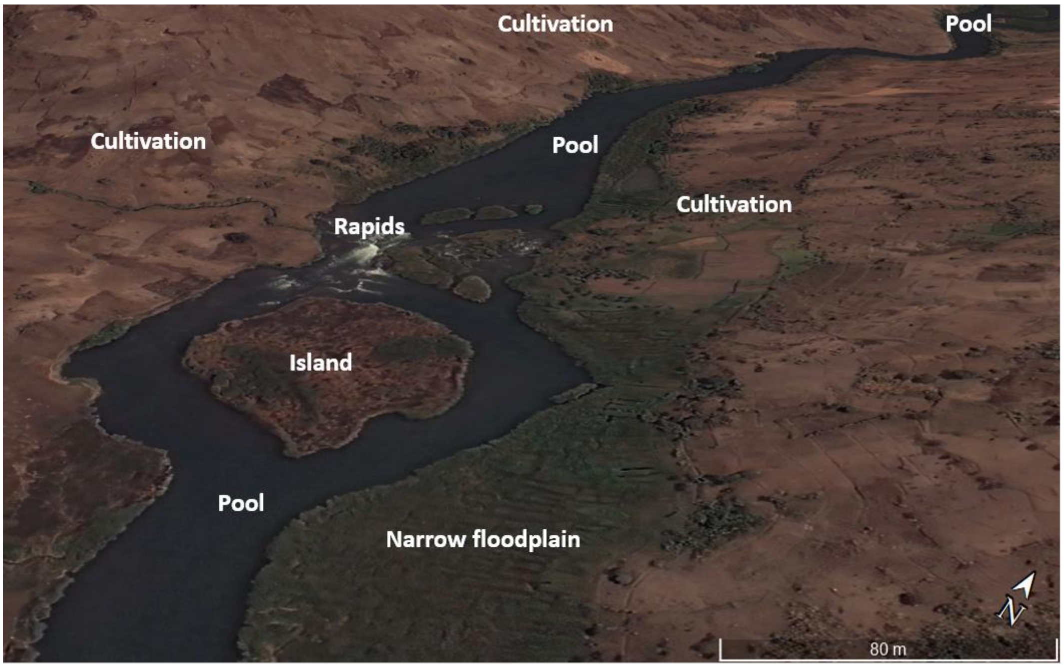


Figure 7-17 Geomorphological Features between Lake Kivu Outfall and Ruzizi-II Dam
Satellite imagery showing the confined valley floor, rapid and long pools with a narrow floodplain (Google Earth image date 7/08/2017).

7.4.3 Ruzizi-II to Ruzizi-III Dam Site

The Ruzizi gradient steepens along this reach with an average gradient of 0.0224 m/m and can be categorised as the Transitional geomorphic zone (Rowntree and Wadeson, 1999). Typical characteristics of the Transitional zone is a bedrock and boulder dominated bed with pool-rapid or pool-riffle reach types (Rowntree and Wadeson, 1999). The valley floor is confined with limited floodplain development (Rowntree and Wadeson, 1999). The zonal classification matches the features observed on the satellite images. This steep reach has short pools and long high energy rapids (Figure 7-18). Bedrock, calcrete and large blocky material form the rapids. The channel is relatively straight to wandering and follows the zigzag pattern of the valley floor.

Agriculture is common on the hillslopes and landslide scars suggest sediment contributions directly to the river or tributary channels. A total of 22 landslides with an area of 117,700 m^2 were mapped along the valley margins (Tractebel, 2021b). These features contribute to both fine suspended sediment and coarser bedload material directly to the river network. Sediment deposition is likely on protruding bedrock features forming anastomosing channels, supporting small, vegetated islands. Some small depositional features, such as gravel bars are only visible during very low flows in locations where the channel widens.

Ruzizi II traps most of the coarse bedload sediment from upstream, forming large bars along the top of the reservoir, starving the reach directly downstream of Ruzizi II of sediment. This reach is thus largely starved of bedload sediment from upstream. A larger right bank tributary 4.5 km downstream of Ruzizi II contributes significant volumes of sediment, possibly offsetting some of the sediment trapping by the Ruzizi II reservoir.

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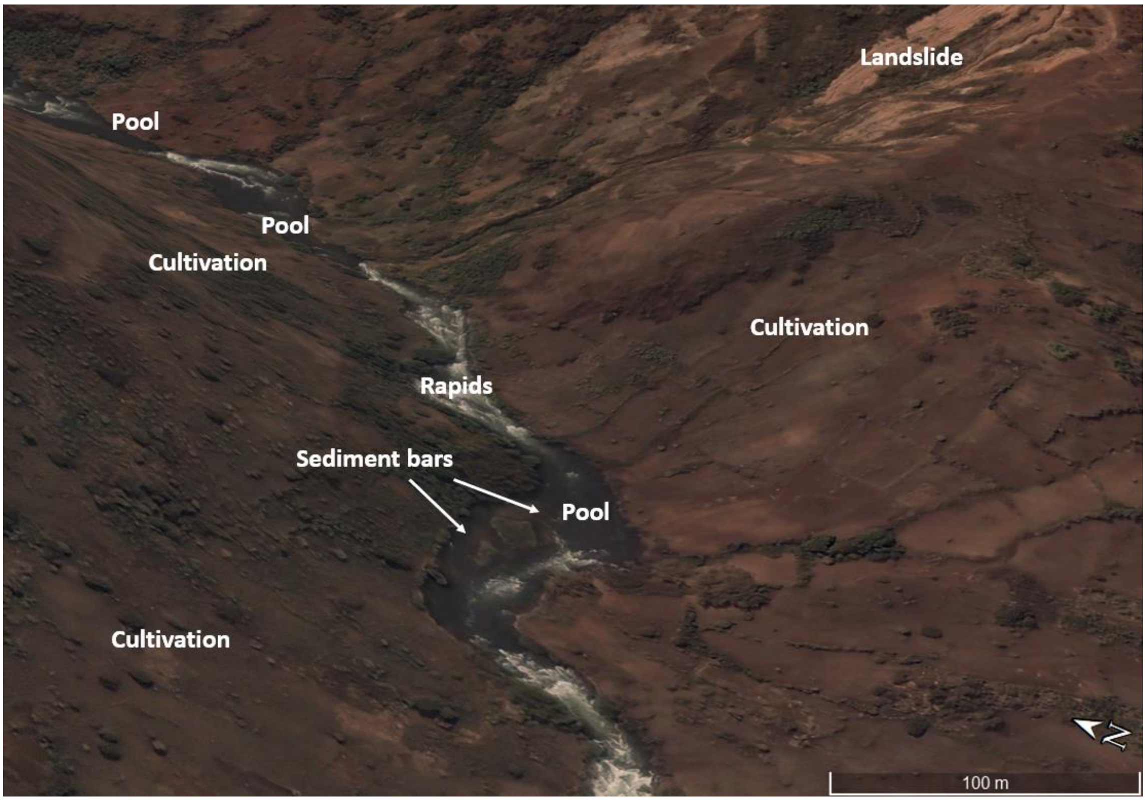

Figure 7-18 Geomorphological Features between Ruzizi-II and Ruzizi-III Dam Sites
Satellite imagery showing the narrow valley floor, steep rapid reach type with limited sediment storage (Google Earth image date 7/08/2017).

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7.4.4 Reach to be Occupied by the Proposed Ruzizi-III Dam and Reservoir

This steep reach can be classified as the Transitional geomorphic zone based on its gradient of 0.0242 m/m. Typical characteristics of the Transitional zone is a bedrock and boulder dominated bed with pool-rapid or pool-riffle reach types (Rowntree and Wadeson, 1999). The valley floor is confined with no or limited floodplain development (Rowntree and Wadeson, 1999). The zonal classification matches the features observed on satellite images. This steep reach has short pools and long rapids, with bedrock, calcrete and large blocky material forming rapids (Figure 7-19). The banks are composed of large blocky material filled with a finer matrix. The relatively straight to wandering channel follows the zigzag pattern of the valley floor.

Widespread agriculture on hillslopes and landslide scars contributes sediment directly to the river or tributary channels. These features contribute to both fine suspended sediment and coarser bedload material forming steep colluvial deposits. Protruding bedrock in the channel form anastomosing channels. Sediment deposition on these islands supports vegetation establishment.

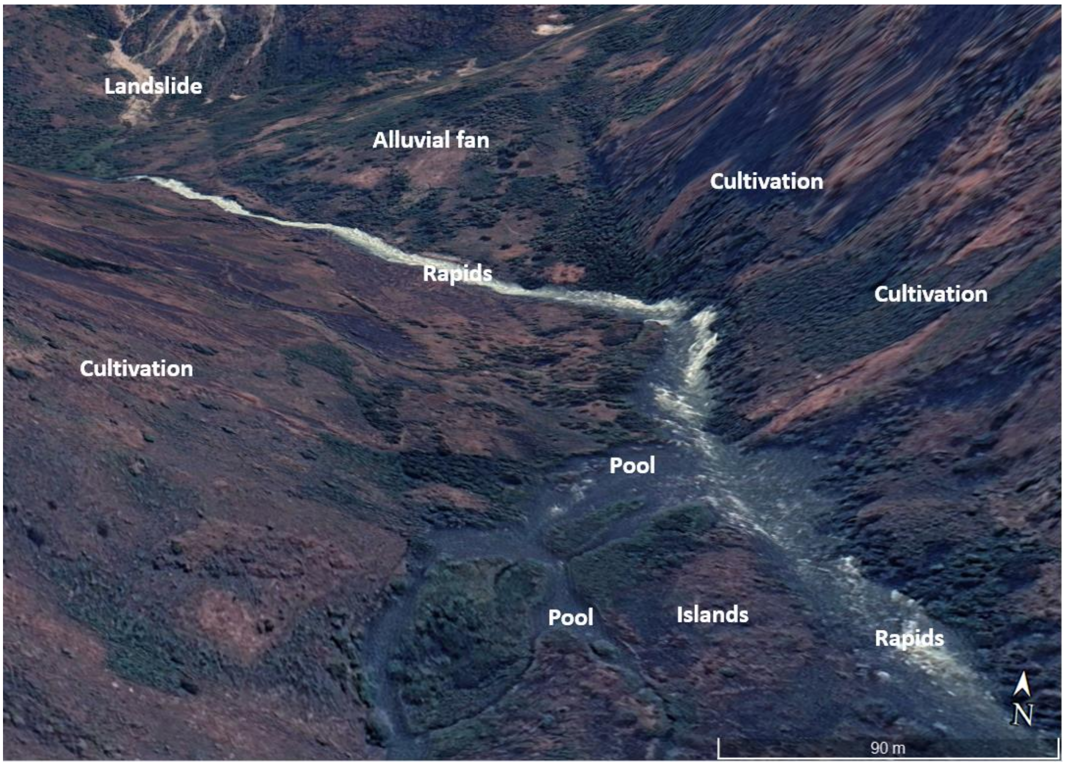

Figure 7-19 Geomorphological Features of the Ruzizi River that will be Inundated
Satellite imagery showing the narrow valley floor, rapids, islands and pool sections (Google Earth imagery date 7/08/2017)

The river bed is composed of a layer of calcrete overlying and binding the deeper coarse-grained alluvium. The alluvium fills a paleo channel to a depth of 40 to 50 m (Figure 7-20; Tractebel, 2021a). The alluvium consists of gravel, cobbles, boulders and sandy layers (Figure 7-21; Tractebel, 2021a). The sandy layers (inorganic silts and fine sands with low plasticity) are associated with periods of damming when landslides block the channel (Tractebel, 2021a). The vertical and lateral variation in alluvial material size can be explained by debris flows, producing layers of large blocky material interspersed by finer material (Tractebel, 2021a). The rapids are formed by bedrock, calcrete and large blocky material that originated from the hillslopes (Tractebel, 2021a).

Modelled flow velocities along this reach are very fast (for a flow of 150 m^3/s) ranging from 0.5 m/s along the deeper pools (~4 m deep) to 5 m/s along steeper shallow sections

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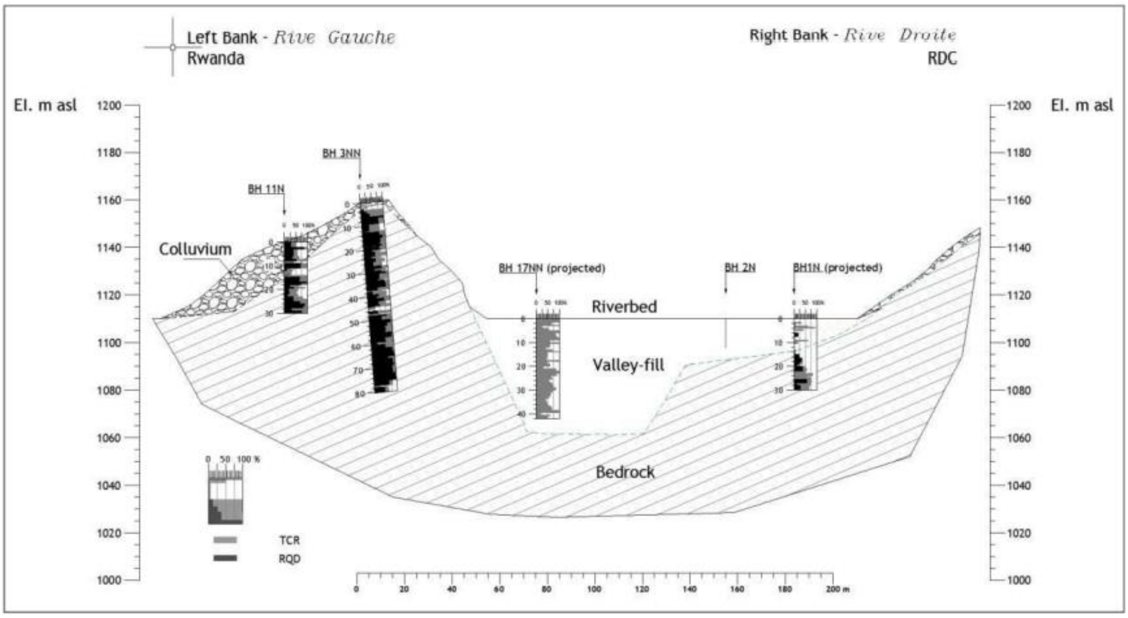
(2 m deep) (Tractebel, 2020a). Limited sediment deposition was observed along this reach due to the narrow valley floor and high energy flow conditions.



Source: Tractebel, 2021a

Figure 7-20 Interpreted Cross-Section Along the Axis of the Ruzizi III dam Wall
TRC = Total Core Recovery, RQO = Rock Quality Designation index.

Figure 7-21 River Bed Alluvium at the Project Dam Site
Cemented Alluvium Exposed on the Bed at the Dam Site (left) and a closeup of a portion of the calcrete layer (right) (Source: Tractebel, 2021a).

7.4.5 Reach Bypassed by the Ruzizi-III Headrace Tunnel

The Ruzizi River gradient along this reach is 0.0238 m/m and can be classified as falling in the Transitional geomorphological zone. Typical characteristics of the Transitional zone is bedrock and boulder dominated river bed with pool-rapid or pool-riffle reach types (Rowntree and Wadeson, 1999).

The valley floor is confined with limited floodplain development (Rowntree and Wadeson, 1999). The zonal classification matches the features observed on the satellite images (Figure 7-22). This steep reach has mostly short pools (except one long pool) and long rapids. The calcrete/bedrock and large blocky material form rapids Figure 7-22(). The banks are composed of large blocky material filled with a finer matrix. The channel is relatively straight to wandering and follows the abrupt bends of the valley floor.

Agriculture is widespread on the hillslopes and landslide scars suggest sediment input directly to the river or tributary channels.

There is a large right bank tributary (3.2 km downstream of the dam location; just upstream of the Manda monitoring site; Lat -2.700657°; Long 28.964259°) supplying significant sediment volumes to this reach (frequent blanket sediment deposits and channel avulsions on the tributary fan can be seen on satellite images). These features contribute both fine suspended sediment and coarser bedload material to the channel. Small bedrock islands form anastomosing channels. Sediment deposition on these islands supports vegetation establishment.

Figure 7-22 Geomorphological Features of the Ruzizi River in the Dewatered Reach
Satellite imagery showing the narrow valley setting, pool-rapid reach type and widespread agriculture (Google Earth image date 17/08/2020)

The modelled hydraulic output shows the flow velocities are very fast (for flow of 150 m^3/s) ranging from 0.5 m/s along deeper pools (4 – 5 m deep) to 5 m/s along steep shallow sections (2 m deep) (Tractebel, 2020a). Velocities and depths increase for higher discharges, but velocities are competent to mobilise a range of finer bedload sediment, resulting in limited sediment deposition along this reach.

7.4.6 Ruzizi-III Powerhouse to the confluence with the Ruhwa River

Along this reach, the gradient of the Ruzizi River becomes gentler (0.0059 m/m) and can be classified as the Upper Foothills geomorphological zone. Rowntree and Wadeson (1999) describe this zone as moderately steep with a mixed cobble bed channel supporting pool-rapid and pool-riffle reach types. A narrow floodplain of sand, gravel and cobble can be present.

This description is accurate for this reach despite the transition from the confined valley setting (first two kilometres) to a partly confined plain setting along the plain. The river morphology alternates between shorter pools, rapids and riffles, with fewer pools along the lower sections (Figure 7-23).

The bed elevation is controlled by bedrock/calcrete and larger immobile rocks (Figure 7-24). Islands form where calcrete protrude from the channel floor or larger immobile sediment is deposited. Sediment deposition on these features supports vegetation. The river course is relatively straight across the plain to the confluence with the Rubyiro and Ruhwa Rivers with a narrow floodplain (~100 m wide).

The river and narrow floodplain are incised into the surrounding plain (5 to 10 m based on the SRTM dataset). The banks are composed of coarser alluvial material filled with sandy and clayey material. The banks appear well-vegetated and relatively stable on satellite images despite the fluctuating water levels from Ruzizi II releases, but localised bank erosion has been observed along agricultural fields. It is not clear if the localised bank erosion is due to vegetation clearing (associated with floodplain agriculture) or fluctuating water levels, but possibly driven by both processes.

Agriculture is common on the steep hillslopes, floodplains and surrounding plains, contributing fine sediment to the channel. Most of the tributaries are small and drain the local slopes along the confined upper section. Two large tributaries (Rubyiro and Ruhwa) contribute significant flow and sediment from the northern parts of the drainage basin. The Ruhwa appears more laterally active and turbid on satellite images and shows evidence of transporting and storing large quantities of sand and gravel.

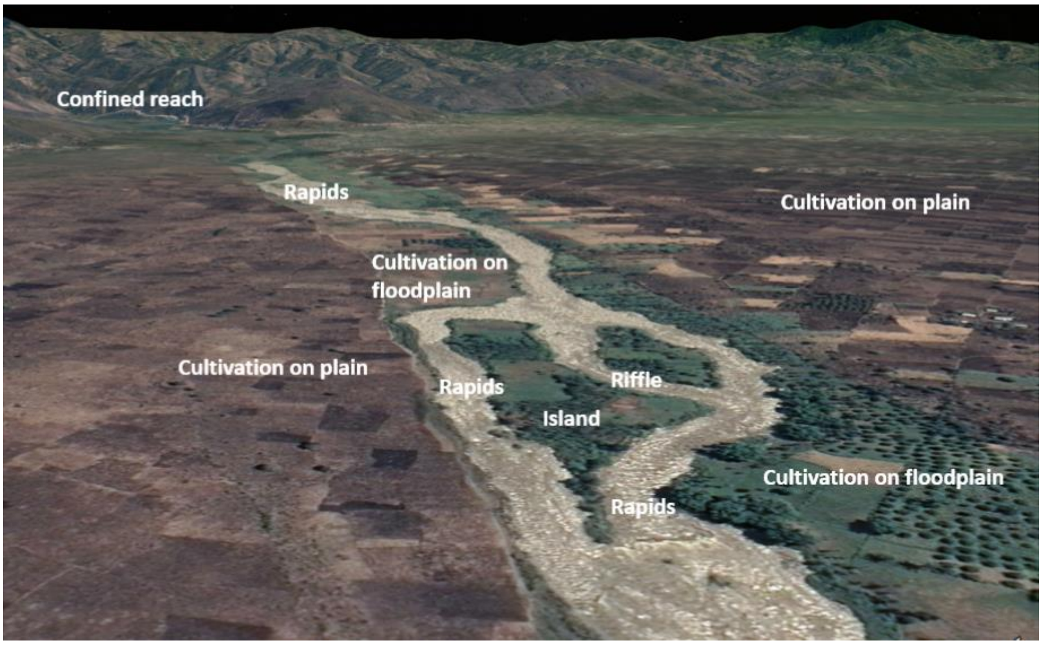


Figure 7-23 Geomorphological Features of the Ruzizi Plain
Satellite imagery showing the narrow floodplain and rapid riffle habitat types (Google Earth image date 27/08/2020)

Figure 7-24 Cemented Coarse Alluvium and Calcrete at the Kamanyola Incompleted Bridge
Source: Tractebel, 2021a).

The modelled hydraulic results for the confined section shows very fast flow velocities (for a flow of 150 m^3/s) ranging from 0.8 m/s along deeper pools (~3 m deep) to 2.5 m/s along steep shallow sections (~2 m deep) (Tractebel, 2020a).

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7.4.7 Tributaries & Sediment Input in the Ruzizi Downstream from the Project

The Ruzizi River downstream of the Ruhwa River confluence flows across the gently sloping Ruzizi Plain towards Lake Tanganyika (Figure 7-25). The plains are surrounded by steep mountains along both sides and drained by tributaries with well-developed drainage networks. The valley floor and steep hillslopes (sides of the Rift valley) are largely used for agriculture, unless within a protected area such as the Nyungwe Forest National Park or Kibira National Park. The land cover is poor on the cultivated lands, driving increased soil erosion (SHER Consult, 2020). Soil erosion is very high for large areas of the Ruzizi River basin (SHER Consult, 2020). A USLE based model predicts 91 t/ha/year on average, with significant inputs from tributaries, such as the Muhira and Nyamagana Rivers with rates of 108 t/ha/year for their respective catchments (SHER Consult, 2020). Predictions for the undisturbed forests, such as the Nyungwe-Kibira Forest, is very low due to the good vegetation cover (SHER Consult, 2020). The steep hillslopes are well connected to the drainage network, enhancing sediment delivery to the Ruzizi River.

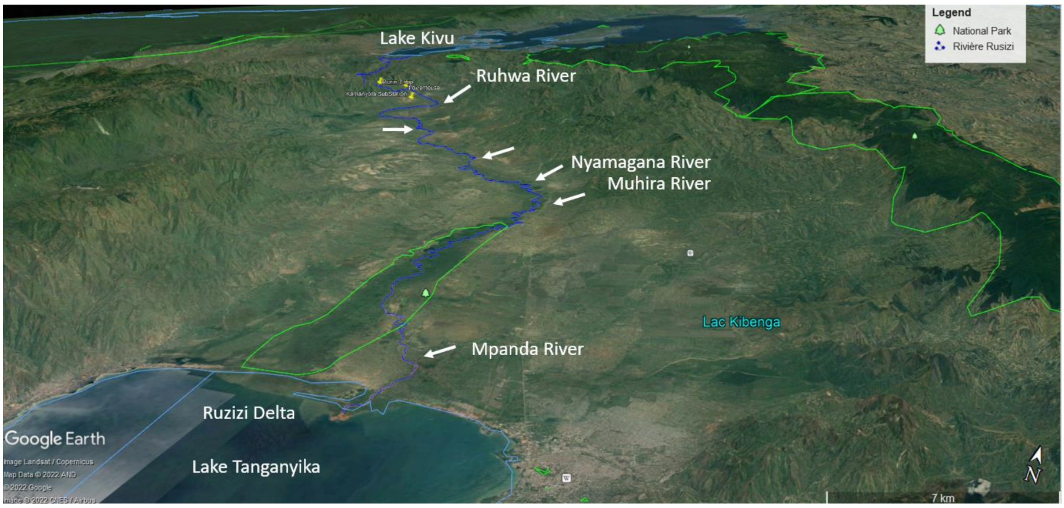

Figure 7-25 Geomorphological Features of the Ruzizi Plain
Flanked by steep mountains and the location of several large tributaries with significant sediment loads (indicated by the white arrows)

Satellite images for these tributaries suggest that sediment eroded from the various catchments are effectively transported to the Ruzizi River without significant sediment buffers, such as wetlands, floodplains or lakes along the river courses. Sediment input from these tributaries includes fine suspended sediment, as evident in the highly turbid Ruhwa River, and bedload as seen along the Muhira River (braided channel pattern with large sediment bars; Figure 7-26). Many of the tributaries appear to have higher turbidity compared to the Ruzizi mainstem, indicating that suspended sediment concentrations increase in a downstream direction. The bedload along these tributaries will be mobilised during higher flows and injected into the Ruzizi River.

Figure 7-26 Tributaries Bringing Sediment to the Ruzizi
Satellite imagery showing contributing significant volumes of sediment to the Ruzizi River (flow direction of the Ruzizi indicated with blue arrows)

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Other direct sources of sediment along the Ruzizi include landslides and gully erosion along the channel margin (Figure 7-27). In Figure 7-27 it can be seen that the landslides inject sediment directly into the Ruzizi River (suspended and bedload sediment), whereas the sediment eroded by the gully is deposited as a fan, storing most of the coarser bedload on the floodplain. Input from the gully will be largely in the form of finer suspended sediment. Limited bank erosion is taking place along the riverbanks of the Ruzizi, and is largely located along a single bank, suggesting that the channel is not actively expanding laterally (bank erosion along both banks).

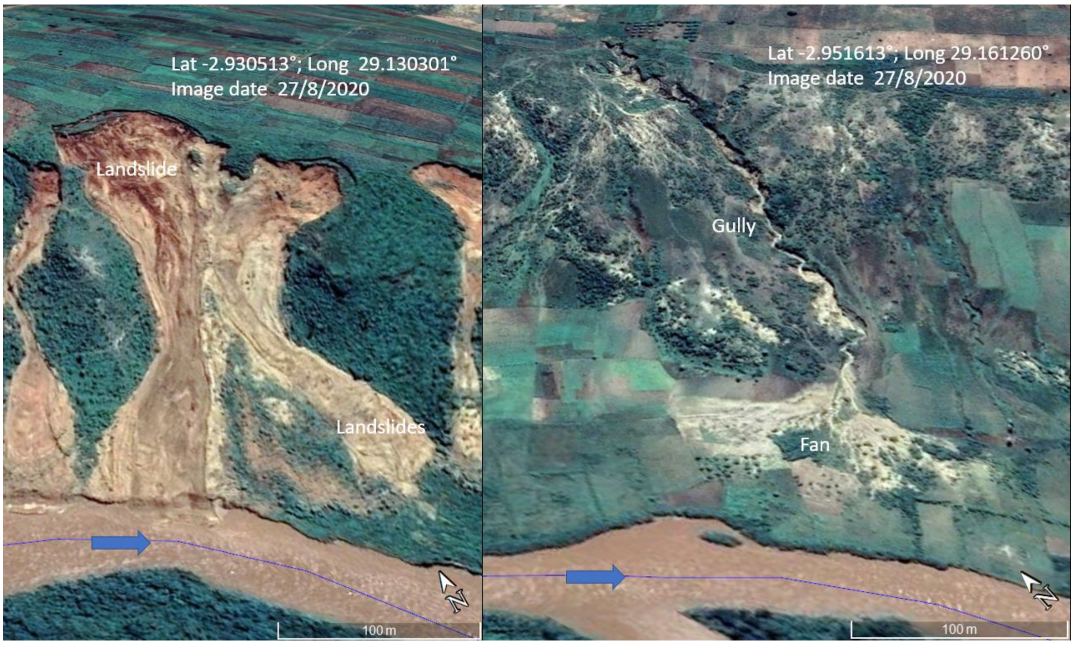

Figure 7-27 Landslides and Gully Erosion Along the Ruzizi River
(Google Earth images)

The Ruzizi River mouth shows high suspended sediment concentrations for the available satellite images from 1985 to 2021 (Figure 7-28). The delta has also expanded continuously over this period supporting the notion that sediment loads are high despite sediment trapping by Ruzizi I and Ruzizi II. These sediment contributions are largely from the Ruhwa River and downstream tributaries.

Figure 7-28 Ruzizi River Delta Development from 1985 to 2021
Satellite imagery, the blue line is the modern river centre line and is static for all images

7.4.8 Estimate of Sediment Loading in the Ruzizi River at the Ruzizi-III dam Site

The information provided in the following paragraphs is taken from the Project's Feasibility Study and specifically the Sediment Management Study (Tractebel, 2022). The Sediment Management Study has cited information from the Project's 2010 Feasibility Study (Fichtner, 2010), Sediment studies for Ruzizi-I and -II (Studio Petrangeli, 2013a and 2013b) and suspended sediment measurements by Tiger Engineering Company (2020).

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7.4.8.1 Sediment Inflow from Lake Kivu

Lake Kivu acts as a large sediment trap and the outflow has a very very low suspended sediment concentration. It has therefore been assessed that there is negligible inflow of sediment into the Ruzizi River from Lake Kivu.

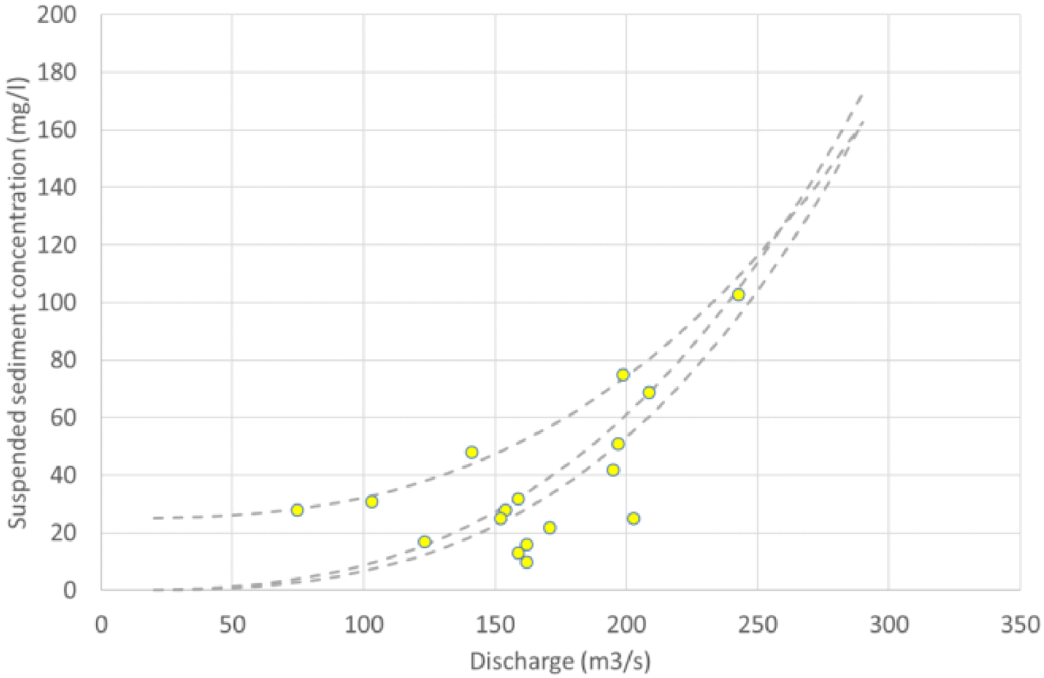
7.4.8.2 Measurement of Suspended Sediment Concentration in the Ruzizi River

Suspended sediment in the Ruzizi River at the Ruzizi-III dam site was measured in November 2020 (Tiger Engineering Company, 2020). A total of 21 samples were collected, each taken from 4 depths, and river flow rates were recorded using an Acoustic Doppler Control Profiler. The suspended solids concentrations are provided in Table 7-2.

Three regression laws were established to show the relationship between river flow rate and suspended solids concentration (see Figure 7-29).

Table 7-2 Suspended Sediment Concentrations at the Ruzizi III Dam Site

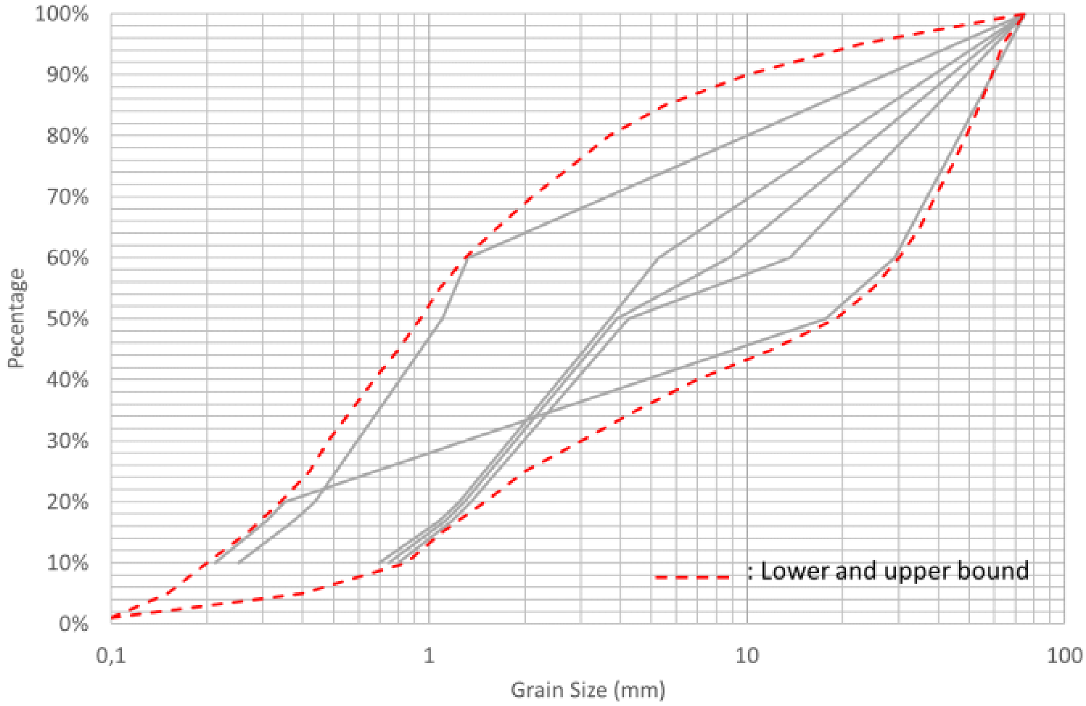
Date	Suspended Solids Concentration (mg/l)	River flow rate (m3/s)	Date	Suspended Solids Concentration (mg/l)	River flow rate (m3/s)
7 Nov. 2020	28	153.7	11 Nov.	32	158.7
7 Nov.	31	102.9	11 Nov.	28	74.5
7 Nov.	25	202.5	15 Nov.	48	140.9
8 Nov.	13	158.7	15 Nov.	74	76.6
8 Nov.	16	162.0	15 Nov.	103	242.5
8 Nov.	25	152.0	15 Nov.	75	198.6
10 Nov.	22	170.7	16 Nov.	42	194.7
10 Nov.	17	123.0	16 Nov.	69	208.5
11 Nov.	10	162.0	16 Nov.	51	196.7
Source: (Tiger Engineering Company, 2020)					



Source: (Tractebel, 2022)
Figure 7-29 Regression Laws between Suspended Sediment Concentrations and River Flow Rate

7.4.8.3 Measurement of Bedload Sediment Particle Size Distribution

Five bedload samples were taken, and particle size distribution determined. The distribution is representative of sands and gravels with some small cobbles. The particle size distribution is shown in Figure 7-30.



Source: (Tractebel, 2022)
Figure 7-30 Particle Size Distributions for Bedload at Ruzizi-III Dam Site

7.4.8.4 Assessment of Sediment Load

A Suspended Sediment

The long-term suspended sediment load was calculated using the hourly river flow time series for the period 1989-2008 (20 years) and the regression laws between suspended sediment concentration and river flow rate (see Figure 7-29).

It has been computed that the annual load varies in the range of 22,700 to 78,800 tonnes/year, with a mean annual value of 44,500 tonnes.

B Bedload

The bedload was assessed using the ratio between suspended load and bedload, using the empirical formula developed by P.Y. Julien (2010) and Van Rijn (1993). For the conditions at the Ruzizi III dam site, the empirical formula predicts that bedload and suspended load are equivalent, i.e. the annual load varies in the range of 22,700 to 78,800 tonnes/year, with a mean annual value of 44,500 tonnes.

C Overall Sediment Load

The overall sediment load is predicted to be between 45,400 to 157,600 tonnes per year with a mean annual value of 89,000 tonnes.

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7.4.8.5 Contribution from Landslides

The assessment of landslide contribution to the sediment load of the Ruzizi River was computed using the empirical relationship between the landslide area (A) and the volume of materials (V) developed by Guzetti et al (2009).

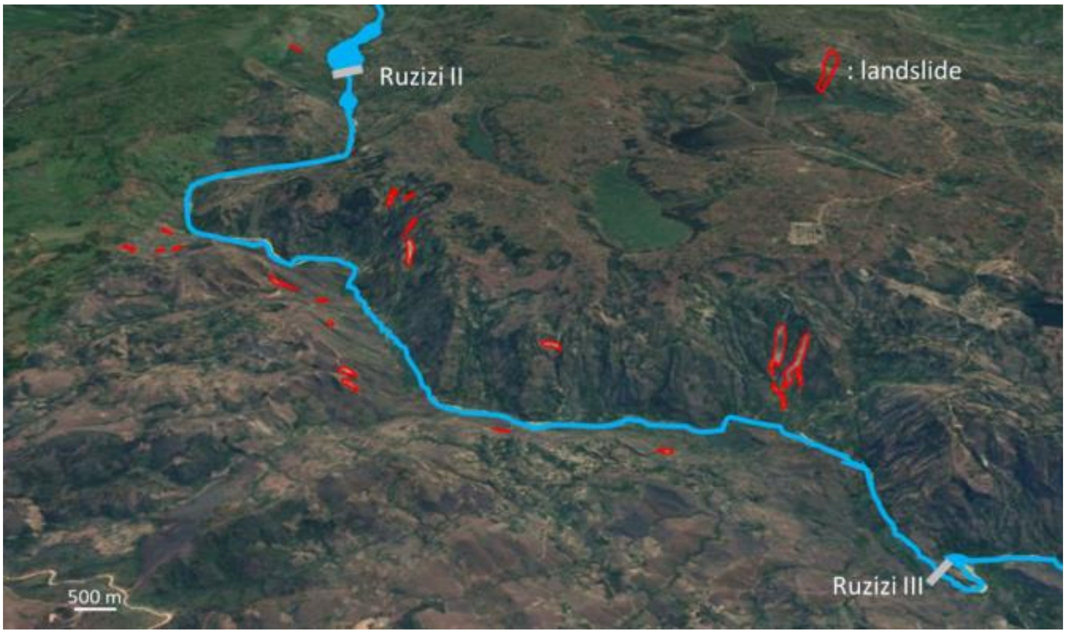
$$V\ (m^3) = k.A^{\alpha}$$

With k = 0.074 and α = 1.45

The potential contribution of landslides is presented in Table 7-3 and the location of the landslide areas shown in Figure 7-31.

Table 7-3 Potential Sediment Contribution of Landslides using Guzetti et al Empirical Formula

Landslide ID	Area (m^2)	Contribution Volume between 2010 and 2020 (m^3)	Landslide ID	Area (m^2)	Contribution Volume between 2010 and 2020 (m^3)
1	12,911	67,628	12	3,779	11,387
2	14,049	76,439	13	428	484
3	3,621	10,704	14	1,992	-
4	3,245	9,130	15	6,379	18,245
5	8,375	36,104	16	4,858	16,391
6	4,248	13,493	17	3,834	11,629
7	2,389	5,623	18	1,346	2,549
8	4,186	11,491	19	3,466	-
9	13,267	58,389	20	4,511	-
10	3,798	11,471	21	7,952	-
11	3,459	10,016	22	5,610	20,194
Note: Values show the results of a diachronic analysis to assess the contribution over a 10-year period between July 2010 and September 2020 by comparison of satellite images					
Source: Tractebel (2022)					



Source: (Tractebel, 2022)

Figure 7-31 Locations of Landslide Areas between Ruzizi-II and -III

7.5 Water Quality

The information provided in the following paragraphs is taken from the *Baseline Study for the Basin of Lake Kivu and the Ruzizi River* prepared by SHER Consult for ABAKIR (SHER, 2020).

7.5.1 Generalities

The major problem in relation to surface water quality is the massive erosion observed in the basin, with an average soil loss value of around 100 t/ha/year in the basin. This erosion generates extremely high and widespread turbidity in most of the basin's watercourses. The phenomena of sediment transport in the watercourses and sediment accumulation, which are associated with the extreme turbidity observed, constitute the major problem facing the basin.

In addition to the alteration of surface water quality due to erosion and the massive transport of sediment to the rivers and Lake Kivu, the water resources of the basin are also threatened by various forms of pollution linked to urbanisation and industrialisation, especially in large cities such as Bukavu or Goma. Other threats to the quality of the basin's water resources come mainly from mining and industrial discharges. On the agricultural level, although the use of chemical fertilisers and phytosanitary products is globally moderate in the basin, their use may be locally more significant (especially in large farms in the Ruzizi plain) and may lead to surface and groundwater pollution in this area.

7.5.2 Lake Kivu and its catchment area

The water in Lake Kivu is of the soda-magnesian carbonate type, low in calcium and rich in potassium. The pH of the water is very high at the surface, with values of the order of 9, and decreases at depth tending towards neutralisation.

The waters of Lake Kivu are influenced by the salt content of the volcanic lava in the region and show consistent concentrations of soluble cations and anions that increase with depth. Electrical conductivity and concentrations of major elements are relatively high at the surface of the lake, with electrical conductivity values of the order of 1,000 to 1,500 µS/cm and a salinity of the order of 1 g/l. Due to the permanent stratification of the lake and the existence of thermal springs at the bottom of the lake, these values increase with depth. Nitrates and nitrites become less abundant at depth, but phosphates are much more abundant than at the surface.

Very little data on the physicochemical quality of Lake Kivu is available, and the same is true for the rivers that form part of its catchment area: regular monitoring of the water quality (physico-chemical, bacteriological, biological) of the lake and its tributaries is very limited to date, with the exception of the data from Rwanda, which is included in the Rwanda Water Portal. Data from nine stations are thus available for Rwanda in the Lake Kivu watershed, six stations in rivers and three on the shore of the lake.

Table 7-4 overleaf shows the average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for the three Lake Kivu stations with data. A generally basic pH and a high electrical conductivity exceeding 1,000 µS/cm are observed.

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Table 7-4 Water Quality of Lake Kivu

Parameter	Unit	City of Rubavu	Bralirwa	City of Kibuye
pH	-	9.1	8.8	7.5
Conductivity	µS/cm	1,751	1,708	1,180
Dissolved Oxygen	mg/l	6.5	2.3	7.4
Turbidity	NTU	25	22	6
Source: SHER, 2020				

7.5.3 The Ruzizi River and its Tributaries

The hydrography of the Ruzizi plain is dominated by the Ruzizi River and its tributaries. The chemical composition of the water of the Ruzizi River is complex because it changes as a result of the contributions of its tributaries. The water quality of these rivers is controlled by the type of soil, geology and anthropological activities in the catchment area. The latter are a major source of environmental pollution and can cause a significant impact on public health.

In its upper course, in addition to the waters of the lake, the Ruzizi River collects the high salinity waters from the volcanic regions of South Kivu and the waters of the thermal springs. The Ruzizi River retains in its upper course many of the physicochemical characteristics of the water of Lake Kivu: pH close to 9, electrical conductivity of around 1000 µS/cm, high ionic concentrations (above 1 g/l), and low Ca/Mg ratio. Phosphates are observed in non-negligible quantities, while nitrate and nitrite concentrations are very low.

After crossing the volcanic areas and entering the plain, the salinity decreases from upstream to downstream, an effect due to the dilution by the tributaries of the low salinity Moyenne Ruzizi. The water of the Ruzizi is diluted along its course by the contribution of the waters of the tributaries, which are milder and much less mineralised. However, there is an increase in sulphates from upstream to downstream, which are thought to originate in the areas crossed by the Ruzizi and in the thermo-mineral springs located in the plain.

The water of the Ruzizi River shows strong seasonal variations in mineralisation, with the highest values being reached in the dry season. Indeed, in the rainy season, the inputs of low mineralised water from the tributaries of the Ruzizi River are more important and this results in a stronger dilution of the highly mineralised water coming from Lake Kivu.

The tributaries of the Ruzizi show, overall, pH values close to neutrality, and a very low electrical conductivity (rarely exceeding 200 µS/cm). The major ions are also present in low concentrations compared to the Ruzizi.

The primary source of the salinity of the Ruzizi River and the soils of the Ruzizi plain would therefore be linked to the volcanism of Kivu and the hydrothermalism of its watershed. Appreciable quantities of cations (Na, K, Mg and Ca) would come from the alteration of volcanic rocks. As for the anionic constituents, the primary source of the CO_3^{2-}/HCO_3^- would be the atmosphere while the ions $Cl^-$and SO_4^{2-} and part of the carbonates would be of hydrothermal and volcanic origin. Sulphates would also come from active hydrothermalism in the rift of Lake Tanganyika. Large quantities of ions are poured into the Ruzizi and eventually reach Lake Tanganyika.

As the waters of the Ruzizi are in equilibrium with the water table of the Ruzizi plain, salts diffuse into the soil profile and are brought back into the surface layers by capillary rise. In the event of overflow during the rainy season, the soil becomes impregnated with salts and, in the dry season, the salts are brought to the surface by evapo-concentration. Factors such as the topography, the proximity of the lake, the semi-arid climate and poorly managed irrigation would facilitate the concentration of salts in the soils in Lower Ruzizi.

Ultimately, the Ruzizi would have the role of transporting ions whose primary source would be the meteoric alteration of basic rocks, hydrothermalism and the recent volcanism of South Kivu. Their accumulation in the soils of the Ruzizi plain would be accentuated by the combined effect of climate, topography and the proximity of the lake. The soils of the Ruzizi delta, due to its proximity to Lake Tanganyika, would be under the direct influence of the lake's waters and would receive, in addition to salts from the volcanism of South Kivu, salts from the sub-lacustrine hydrothermalism of Tanganyika.

In order to estimate the impact of anthropogenic activities on the surface water environment, a study of the water quality (physicochemical and bacteriological parameters) of the Ruzizi River and its major tributaries was carried out in 2018 (SMEC, 2018). The results of this study highlight the following elements of surface water quality for the Ruzizi River and its tributaries:

- Very high turbidity, with measured values generally between 300 and 1,000 NTU, regularly exceeding this high value.
- Very locally high values of Phosphates, Chlorides and Ammonium, without this problem being significant on the scale of the basin and the main sub-basins.
- High concentrations of iron and manganese.
- Dissolved oxygen in freshwater quality standards, generally in the range 4-9 mg/l.
- Generalised and very high bacteriological contamination (total coliforms and E-Coli).

Apart from this one-off study, very little data is available on the physicochemical quality of the rivers in the Ruzizi catchment area: regular monitoring of water quality (physicochemical, bacteriological, biological) is very limited to date, with the exception of the data from Rwanda, which is included in the Rwanda Water Portal. Data from four stations are thus available for Rwanda in the Ruzizi catchment area. Table 7-5 below shows the average measured values of pH, electrical conductivity, dissolved oxygen and turbidity for the four river stations. A basic to neutral pH and high turbidity are observed in relation to the very significant erosion phenomena that characterise most of the sub-basins in the area.

Table 7-5 Water Quality in the Ruzizi Basin

Parameter	Unit	Ruzizi River upstream	Kamanyola River	Rubyiro River	Ruhwa River
pH	-	7.4	6.7	8.7	7.0
Conductivity	µS/cm	-	575	200	66
Dissolved Oxygen	mg/l	-	7	6.7	7.7
Turbidity	NTU	-	380	440	455
Source: SHER, 2020 (using data from Rwanda Water Portal)					

7.6 Hydrology

7.6.1 Introduction

The hydrological baseline assessment includes the following components:

- An assessment of the monthly inflows to Ruzizi III and study area inflows including: i) intervening catchment inflows between Ruzizi II and Ruzizi III; ii) Rubyiro River inflows; and iii) Ruhwa River inflows.
- An assessment of the study area hydrology including: i) observed water level variations at the Kamanyola (Bugarama Bridge) water level monitoring station; and ii) modelled hydrological / hydraulic characteristics for the "Ruzizi III Reach" between the proposed dam wall and powerhouse locations, and the "Ruzizi II – Burundi Border Reach". The "Ruzizi III Reach" represents the proposed future "dewatered reach" and as such an analysis of reach area, depths, velocities, shear stress, and hazard is presented for the current range of observed flows (i.e., from 10 m^3/s to 160 m^3/s). The "Ruzizi II – Burundi Border Reach" represents the current study area (upstream of Burundi) that is subject to hydropeaking effects, and as such an analysis of variation in flow and level, and ramp-up and ramp-down rates, for selected key locations along the reach is presented.
- A summary of flood risk at the proposed Ruzizi III dam wall location, with a primary focus on extreme flood events (the 10,000-year return period design flood and the 100,000-year return period check flood).

Table 7-6 provides a summary of the catchment areas in the Ruzizi III study area. It can be seen that a significant proportion of the catchment upstream of Ruzizi III (7,687 km^2) is controlled by the Lake Kivu outlet (7,329 km^2, or 95%). The total catchment area to the Burundi border – including the River Ruhwa catchment – is 8,687 km^2, which includes the River Rubyiro catchment (350 km^2, or 4% of the total catchment) and the River Ruhwa catchment itself (618 km^2, or 7% of the total catchment).

Table 7-6 Summary of Ruzizi III Catchment Areas

Description	Cumulative catchment area (km^2)	Intervening catchment area (km^2)
Lake Kivu outlet	7,329	
Ruzizi II (4.8 km upstream intervening catchment)	7,471	142
Ruzizi catchment upstream of right-bank 'intervening catchment'	7,480	9
Right-bank intervening catchment (between Ruzizi II and Ruzizi III)	177	
Ruzizi III (7.2 km downstream intervening catchment)	7,687	30
Ruzizi catchment to upstream River Rubyiro	7,718	31
River Rubyiro catchment	350	
Ruzizi catchment to upstream River Rubyiro	8,069	1
River Ruhwa	618	
Ruzizi catchment to Burundi border	8,687	

Figure 7-32 overleaf illustrates the location of Ruzizi III and the contributing catchment areas.

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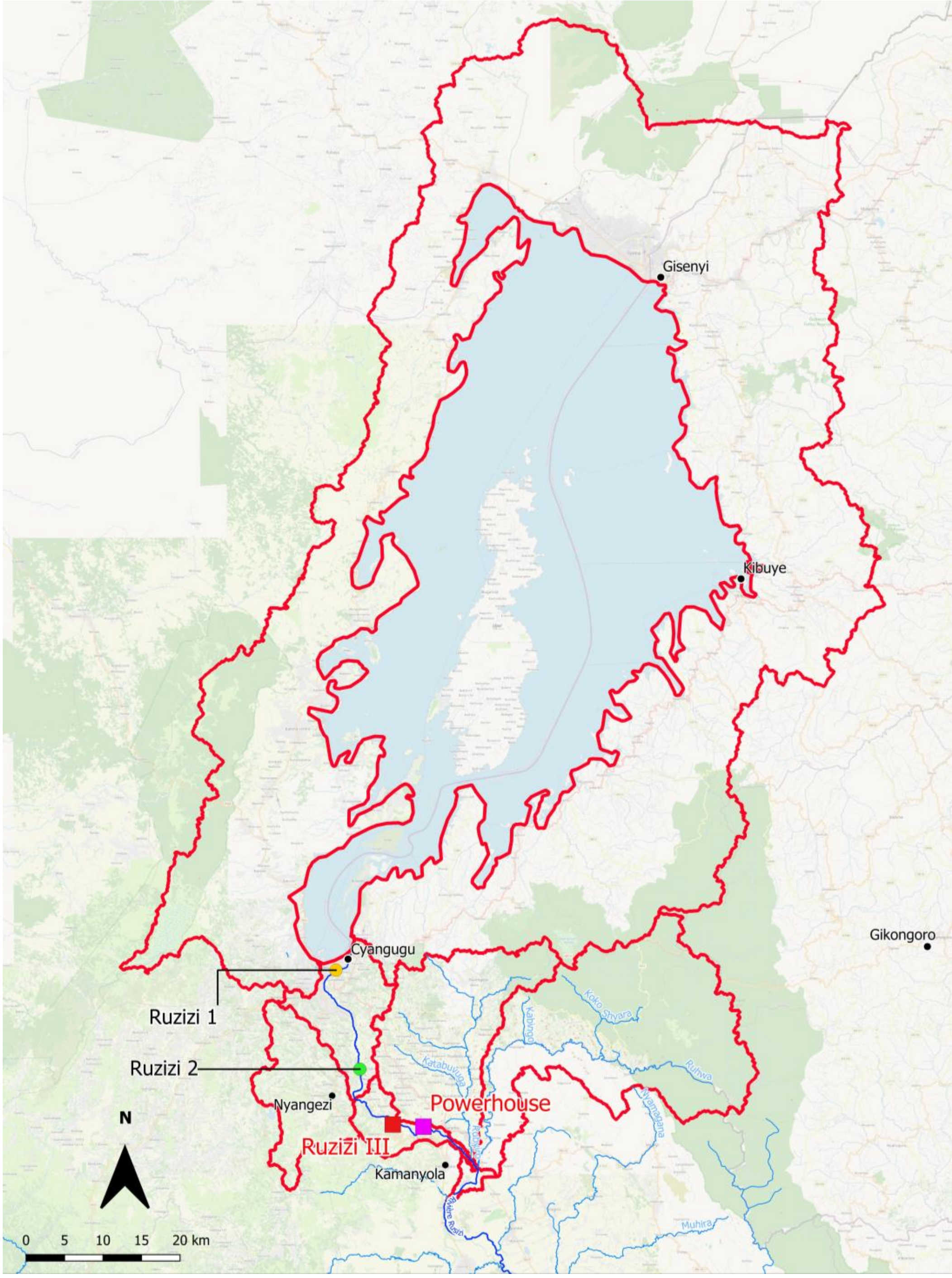

Figure 7-32 Ruzizi III and Contributing Catchments

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7.6.2 Monthly Inflows

7.6.2.1 Introduction

The monthly inflows to Ruzizi III are determined by both the outflow from Lake Kivu and inflows in the intervening catchment area between the Lake Kivu outlet and the Ruzizi III dam wall site. Outflows from Lake Kivu, and how such outflows vary with the long-term variation in lake water level, are by far the most significant contributor to Ruzizi II inflows.

Many studies have been undertaken to estimate outflows from Lake Kivu. Of particular interest is the 'Hydrology and Sedimentation Review' undertaken in 2020 as part of the Ruzizi III Feasibility Study, a 'Baseline Study for the Basin of Lake Kivu and the Ruzizi River' undertaken in 2020 for ABAKIR, and a study undertaken in 2014 modelling Lake Kivu water level variations over the period 1941 – 2011 (Muvungja et al, 2014).

These studies suggest that the long-term outflow from Lake Kivu is approximately 71 – 86 m^3/s, but that a more recent average outflow (for the period 2010 – 2018) may be as high as 106 m^3/s. It is suggested that this recent change may reflect land-use change in the Lake Kivu catchment. However, this difference may also be attributable to long-term cyclical behaviour observed in Lake Kivu (and East African lakes in general) and hydrological / hydro-meteorological dataset uncertainty associated with a sparse data network.

7.6.2.2 Feasibility Study Analysis (2020)

The 'Hydrology and Sedimentation Review' (Tractebel, February 2020) presents the analysis undertaken to derive estimates of long-term inflows to Ruzizi III. It includes a review of previous studies undertaken in 2010 (Fichtner Feasibility Study) and 2016 (Tractebel Due Diligence Review) and presentation of hydro-meteorological datasets including Lake Kivu and Lake Victoria water level variation (1950-2016). No analysis was undertaken to assess inflows for tributaries downstream of Ruzizi III.

A water balance modelling approach has been applied to estimate outflows from Lake Kivu, based on direct lake precipitation and evaporation, and precipitation over the catchment draining to Lake Kivu.

$$Q_{in}^{sim} = (P - E) \cdot A_{Lake} + \varphi \cdot P \cdot (A_{RB} - A_{Lake})$$

The model was calibrated against historical estimates of lake inflow for the periods 1950 – 1960 and 1989 - 2006, itself derived from observed lake water levels and outflows based on operation of Ruzizi I.

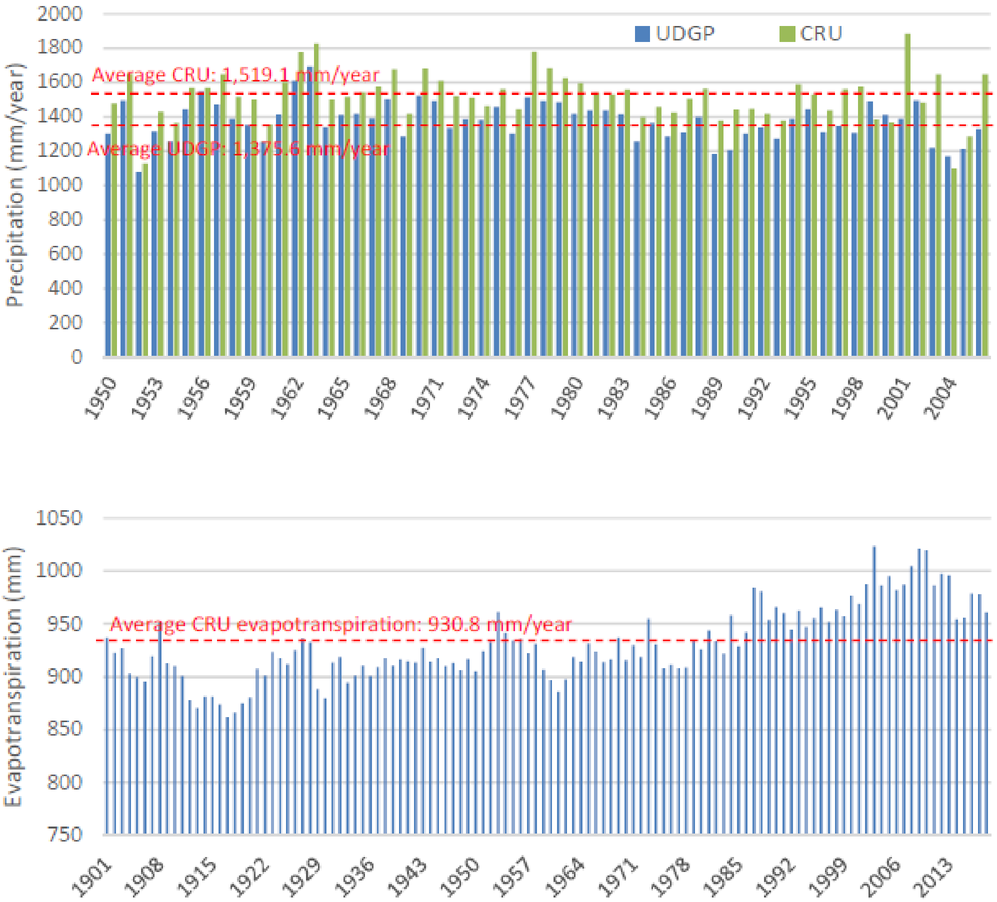
$$Q_{in}^{obs} = \Delta H_{Lake}^{obs} \cdot A_{Lake} + Q_{out}^{obs}$$

Precipitation and evaporation datasets (1901-2018) are from the University of East Anglia's Climate Research Unit (CRU)[2]. A mask of the Lake Kivu catchment area has been used to define the spatial extent of the precipitation dataset, evapotranspiration data is obtained from 0.5 ° raster cells located over Lake Kivu.

Annual precipitation (1950-2006) and evapotranspiration (1901-2018) are shown in Figure 7-33[3]. This shows a long-term average precipitation of 1519 mm/year and a long-term average evapotranspiration of 931 mm/year. The comparison of precipitation data shows that the CRU LTA is approximately 10% higher than the UDGP LTA, the evapotranspiration

[2] The CRU rainfall dataset contained a number of identified inconsistencies for the period 2009-2018. These values have been replaced with data from the CHIPS dataset.
[3] The annual average rainfall data is shown alongside UDGP rainfall that was used in the 2010 Feasibility Study.

data shows a clear upward trend dating from the mid-1970s through to approximately 2010.



Source: Tractebel, 2020

Figure 7-33 Annual Precipitation and Evapotranspiration Data

The water balance model was initially calibrated over the period 1989 – 2006 to predict a runoff coefficient of 0.17 (bias = 0.1%). Model performance in terms of lake net inflows and lake water levels is shown in Figure 7-34. The model was verified for the historical period 1950 – 1960 (bias = 17.7%).

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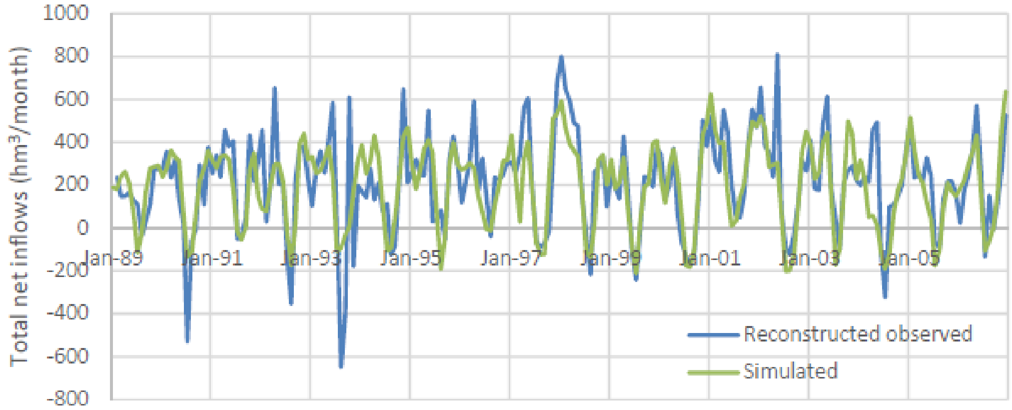
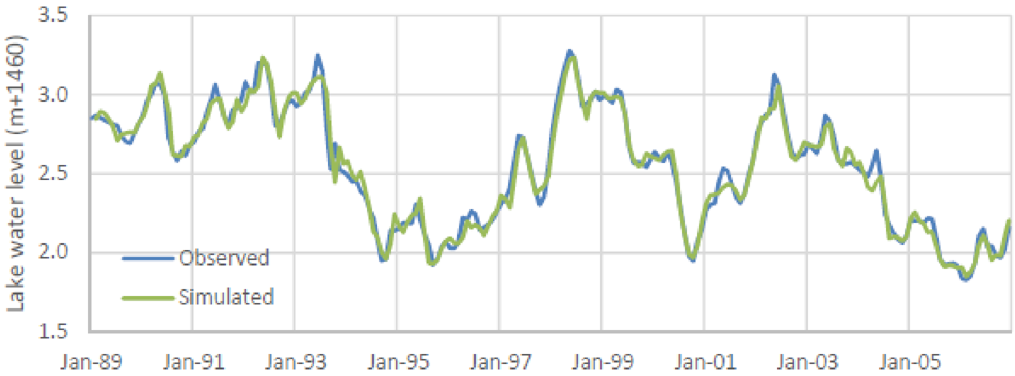


Variations of Lake Kivu's Total Net Inflow (1989-2006) (Tractebel, 2020)

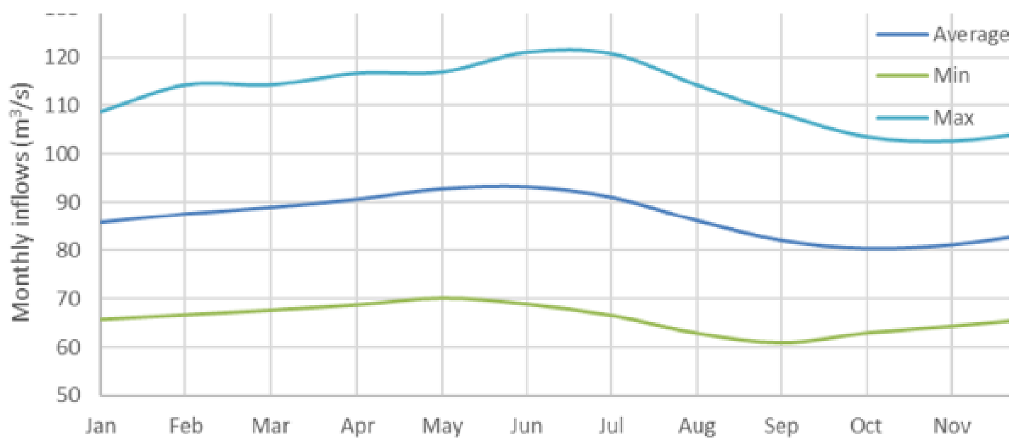


Variations of Lake Kivu's Water Level (1989-2006) (Tractebel, 2020)

Figure 7-34 Water Balance Model Performance: Calibration Period 1989 – 2006

Applying the calibrated water balance model to the period 1901 – 2018, the annual average lake net inflow is estimated as 83.9 m^3/s.

Based on Ruzizi I management rules and relationships established with Lake Kivu water levels, and the application of the runoff coefficient (0.17) applied to the intervening catchment between Ruzizi I and Ruzizi III, the **Ruzizi III annual average inflows have been estimated as 86.9 m^3/s**. Long-term monthly average flow estimates (1901-2018) are shown in Figure 7-35 and Table 7-7. The variation in annual inflow is shown in Figure 7-36. A strong cyclical pattern to estimated inflows is apparent. Inflows for the period 1980 onwards tend to be lower than the longer-term average.

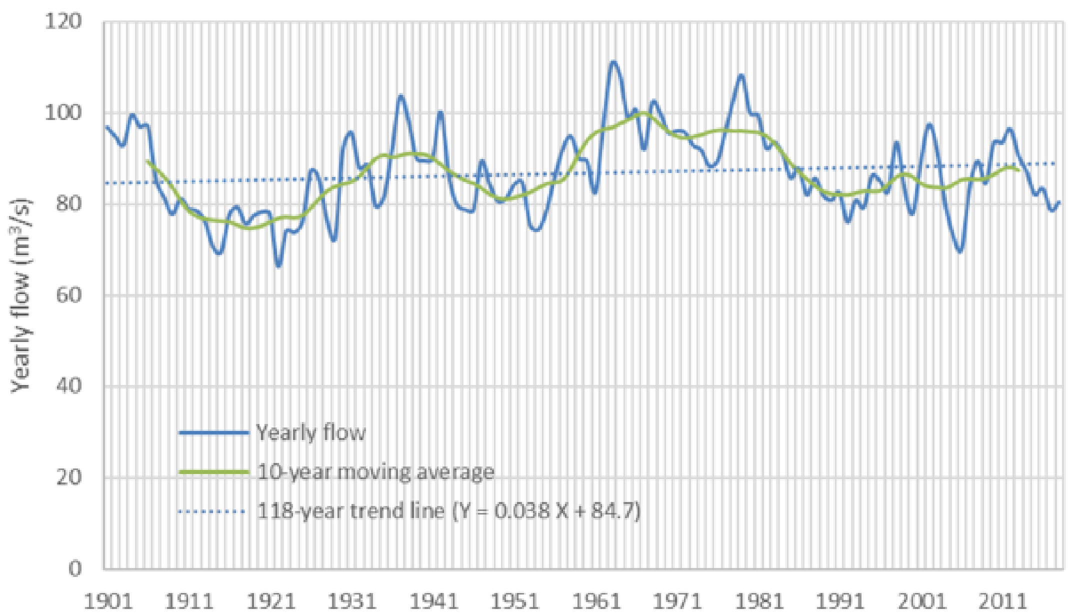


Monthly Distribution of Ruzizi III's Inter-Annual Inflows (1901-1918) (Tractebel, 2020)

Figure 7-35 Long-Term Monthly Inflows to Ruzizi III: Calibration Period 1989 – 2006

Table 7-7 Long-term monthly inflows to Ruzizi III: calibration period 1989 – 2006

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum (m^3/s)	109	114	114	117	117	121	121	114	108	104	103	105	111
Average (m^3/s)	86	88	89	91	93	93	91	86	82	80	81	83	87
Minimum (m^3/s)	66	67	68	69	70	69	66	63	61	63	64	66	66



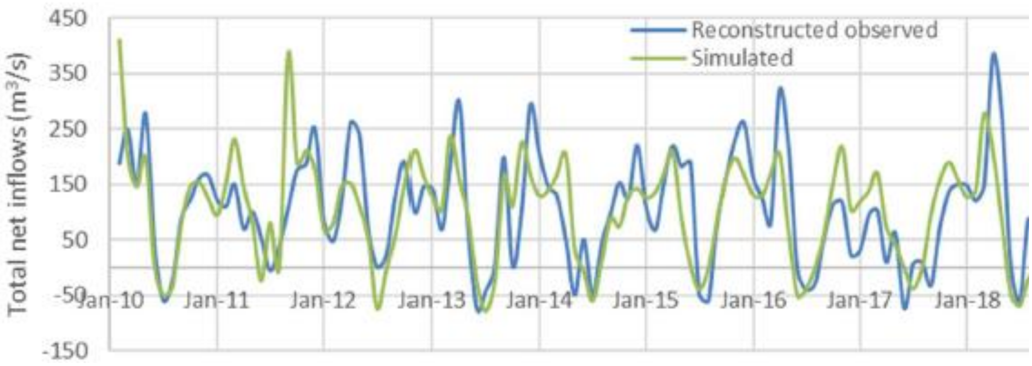
Source: Tractebel, 2020

Figure 7-36 Annual inflows to Ruzizi III: calibration period 1986/9 – 2006

Following receipt of energy production data for Ruzizi II for the period 2010 – 2019, a comparison of actual production and modelled production was undertaken. This concluded that average turbinated flows at Ruzizi II for the period 2010 – 2019 was 99 m^3/s, as opposed to a long-term inflow estimate of 85 m^3/s from the initial model calibration.

This higher estimate of recent annual average flow has not been attributed neither to a change in precipitation as the CRU monthly average precipitation is reported as 126.4 mm for 2010 – 2018 and 122.8 mm for 1989 – 2006, an increase of just 3%[4, 5], nor to a change in temperature. Rather it is proposed that the change in reported annual average flow could be attributable to a change in rainfall-runoff relationship due to land cover change.

Accordingly, the water balance model was recalibrated using data for the period 2010 – 2018 and a revised runoff coefficient of 0.26 was obtained (bias = 0.0%). The recalibrated model performance with respect to lake net inflows is shown in Figure 7-37.



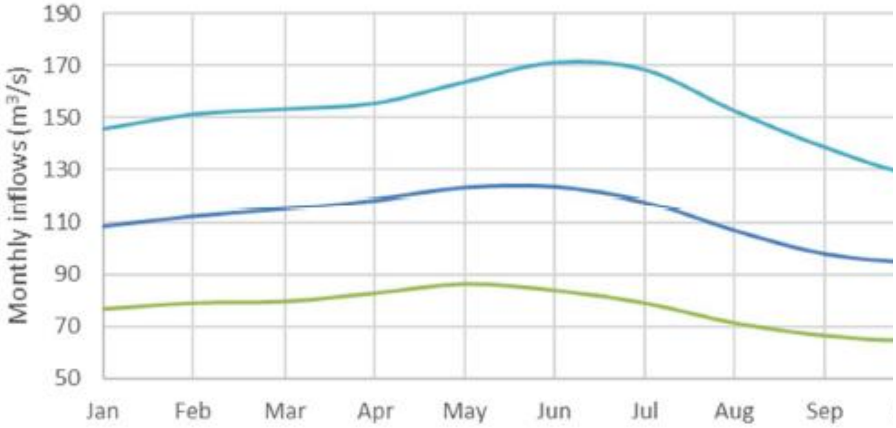
Variations of Lake Kivu's Total Net Infows (2010-2018) (Tractebel, 2020)

Figure 7-37 Water Balance Model Performance: Recalibration Period 2010 – 2018

Applying the recalibrated water balance model to the period 1901 – 2018, the annual average lake net inflow is estimated as 105.6 m^3/s (26% greater than the value obtained during initial calibration).

Applying the recalibrated runoff coefficient (0.26) to the intervening catchment between Ruzizi I and Ruzizi III, the recalibrated **Ruzizi III annual average inflows have been estimated as 109.9 m^3/s**. Long-term monthly average flow estimates (1901-2018) are shown in Figure 7-38 and Table 7-8. The variation in annual inflow is shown in Figure 7-39. A strong cyclical pattern to estimated inflows is apparent. Inflows for the period 1980 onwards tend to be lower than the longer-term average.

[4] Note however that no assessment has been made regarding possible differences in temperature / evapotranspiration during the two distinct periods 1989 – 2006 and 2010 – 2018. Data presented suggests that evapotranspiration may have been lower in this later period.
[5] Note also that a quality review of CRU data can be readily undertaken using the Google Earth interface CRU TS v. 4.04 Google Earth Interface (uea.ac.uk). This shows the location of the 0.5 ° grid cells, and associated time-series data for temperature, diurnal temperature range, precipitation, and vapour pressure, and the location, status, and data values of associated station data. See Annex for further information.

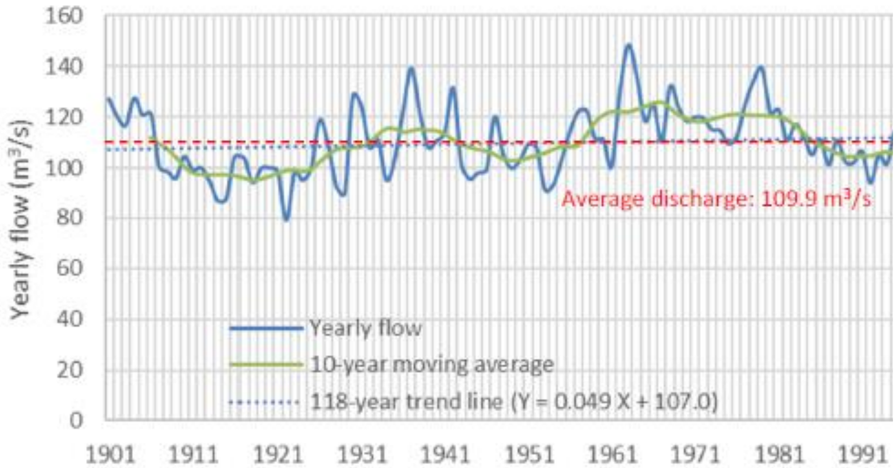


Monthly Distribution of Ruzizi III's Inter-Annual Inflows (Period 1901-1918) (Tractebel, 2020)

Figure 7-38 Long-Term Monthly Inflows to Ruzizi III: Recalibration Period 2010 – 2018

Table 7-8 Long-Term Monthly Inflows to Ruzizi III: Recalibration Period 2010 – 2018

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum (m^3/s)	146	151	153	155	164	171	168	152	139	129	134	140	148
Average (m^3/s)	108	112	115	119	123	123	118	107	98	95	97	103	110
Minimum (m^3/s)	77	79	80	83	86	84	79	71	67	65	68	74	79



Variations of the Yearly Inflows to Ruzizi III (1901-2018) with Upgraded Calibration (Tracebel, 2020)

Figure 7-39 Annual Inflows to Ruzizi III: Recalibration Period 2010 – 2018

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7.6.2.3 Other Analysis

A 'Baseline Study for the Basin of Lake Kivu and the Ruzizi River' was undertaken for ABAKIR in 2020 (Sher Consult, 2020). This study included: (i) presentation of river flow based on data available from the Rwanda Water Resources Board "Water Portal"; (ii) the development of a water balance model providing flow estimates at key locations in the basin including at the outlet of Lake Kivu and at Kamanyola (upstream of the confluence of the Ruzizi and Ruhwa rivers); (iii) the development of a Water Evaluation and Planning (WEAP) model; and iv) land use evolution. The report provides summarises of catchment characteristics including catchment area, precipitation, potential evapotranspiration, and runoff. Runoff coefficients of approximately 54% are given for the intervening catchment upstream of Kamanyola, based on average monthly runoff coefficients derived from catchment precipitation and gauged data for the Nyangama tributary in Burundi.

WEAP model results for average conditions (50% exceedance) and drought conditions (80% exceedence) for Lake Kivu outflows, inflow contributions from the right-bank and left-bank of the intervening catchment upstream of Kamanyola, and for the Ruhwa river[6] for "current" conditions are from the ABAKIR baseline study are summarised below in Table 7-9 and Table 7-10 which summarise the Lake Kivu outflows and total flow at Kamanyola under "climate change" conditions. Average lake outflows are given as 78 m^3/s and flows at Kamanyola are given as 94 m^3/s. Elsewhere in the report, average flows are reported as 71 m^3/s for the Lake Kivu outlet and 89 m^3/s at Kamanyola (in Section 11.2 of the baseline study report).

Change in land use is presented based on use of the European Space Agency Climate Change Initiative (ESA-CCI) global land cover datasets from 1992 and 2016 (in section 9 of the baseline study report). This suggests that for the study area as a whole over this period, agricultural land has increased from approximately 16% to 45%, prairie and shrub cover has decreased from approximately 46% to 23% and forest cover has decreased from approximately 35% to 30%.

Muvundja et al (2014) also present estimates of Lake Kivu outflows based on water balance modelling of lake water level variations over the period 1941 – 2011. Long-term estimates of lake outflow of 86 m^3/s are reported (for the period 1941 – 1991). The variation in lake levels and lake outflows are reported to be dependent on lake precipitation and evaporation, catchment runoff processes (both surface and subsurface runoff), and deep subaquatic groundwater discharge (SGD). Indeed, lake precipitation and evaporation rates for Lake Kivu (and for East-African lakes in general) are considered to be comparable, with catchment runoff processes contributing approximately 55% to the lake outflow and SGD processes contributing approximately 45%. More generally, a regional surface runoff coefficient of approximately 0.3 is reported.

The relationship between lake levels and precipitation and sea surface temperature in the Indian Ocean is also discussed. Average precipitation is reported as approximately 1,400 mm/year, and average lake evaporation is reported to be approximately 1,530 mm/year, although a range of 800 mm to 1,800 mm is also given. Similarly, a catchment average potential evapotranspiration of 1,100 mm/year and a range of average potential evapotranspiration of 900 mm to 1,500 mm is reported.

[6] Flows for the Ruhwa river have been derived from reported contributing catchment areas for the Ruhwa river and for the modelled group of sub-catchments 'RU-RG-HA', i.e., the left-bank group of catchments immediately downstream Kamanyola. The Ruhwa is assumed to contribute 32% of the 'RU-RG-HA' inflows based on a comparison of catchment area.

Table 7-9 WEAP Model Monthly Average and Drought Flows (Current Conditions)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average inflows (50% exceedance) (m^3/s)													
Lake Kivu outflow	82.0	80.0	83.0	89.0	94.0	85.0	71.0	67.0	66.0	68.0	75.0	78.0	78.2
Intervening catchment inflows – right-bank	7.7	7.2	8.4	7.8	8.0	3.1	1.7	4.6	5.6	4.6	6.5	7.0	6.0
Intervening catchment inflows – left-bank	11.3	10.7	12.9	13.4	13.6	4.7	1.8	7.0	8.5	7.8	9.6	10.2	9.3
Total at Kamanyola	101.0	97.9	104.3	110.2	115.6	92.8	74.5	78.6	80.1	80.4	91.1	95.2	93.5
Ruhwa inflows	18.2	18.6	20.7	25.3	24.8	5.3	1.8	9.8	12.2	13.3	16.0	16.5	15.2
Drought inflows (80% exceedance) (m^3/s)													
Lake Kivu outflow	45.0	45.0	47.0	53.0	55.0	47.0	34.0	30.0	30.0	34.0	42.0	44.0	42.2
Intervening catchment inflows – right-bank	6.4	6.4	7.1	7.1	6.0	2.1	1.2	3.2	4.2	3.7	5.3	6.2	4.9
Intervening catchment inflows – left-bank	8.9	9.3	10.8	11.7	10.5	2.8	1.4	4.3	6.1	6.2	7.9	8.9	7.4
Total at Kamanyola	60.3	60.7	64.9	71.8	71.5	51.9	36.6	37.5	40.3	43.9	55.2	59.1	54.5
Ruhwa inflows	14.9	15.2	16.1	21.1	19.6	3.1	0.9	5.5	9.6	11.0	13.8	14.0	12.1

Table 7-10 WEAP Model Monthly Average Flows (Climate Change Conditions)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average inflows (50% exceedance) (m^3/s)													
Lake Kivu outflow	82.0	80.0	83.0	89.0	94.0	85.0	71.0	67.0	66.0	68.0	75.0	78.0	78.2
Total	100.3	97.4	103.7	109.6	115.1	92.5	74.1	78.1	79.2	79.5	90.5	94.5	92.9
Drought inflows (80% exceedance) (m^3/s)													
Lake Kivu outflow	45.0	45.0	47.0	53.0	55.0	47.0	34.0	30.0	30.0	34.0	42.0	44.0	42.2
Total	90.9	78.1	87.2	92.0	92.8	60.0	41.1	49.8	54.9	56.2	72.0	77.9	71.1

7.6.2.4 Ruzizi I and II Production Data

Production data for Ruzizi I and Ruzizi II for the period 2009 to 2019 was obtained via Tractebel. Monthly hourly average production data (MW) and derived flows (m^3/s), and tables relating Lake Kivu water level (mAOD) to outflow (m^3/s) and production (MW) have been reviewed. Excluding any environmental flow releases, releases from Ruzizi I and Ruzizi II are estimated as 95.5 m^3/s and 101.1 m^3/s respectively.

Lake Kivu water levels for the period 2010 – 2019 are shown in Figure 7-40. Compared with levels experienced during the period 1989 – 2006 (as shown in Figure 7-34), it can be seen that lake levels tend to be higher in the period 2010 – 2019 than in the period 1989 – 2006.

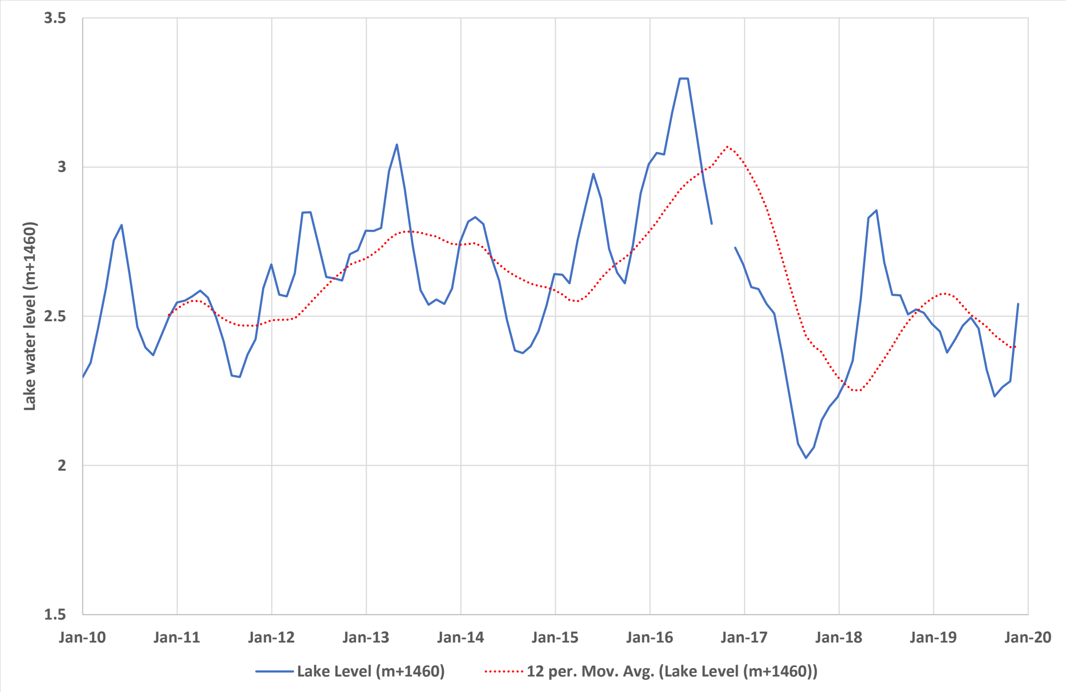

Figure 7-40 Lake Kivu Water Levels (2010-2019)

The recent Ruzizi I and Ruzizi II production data and derived inflows were used in the Feasibility Study analysis (2020) in the recalibration of the hydrological model (see previous section for further details).

7.6.2.5 Summary

The current best estimate of hydrological inflows upstream of Ruzizi III dam wall are as provided by the recalibrated hydrological model presented as part of the Feasibility Study (2020), suggesting an annual average inflow of 109.9 m^3/s, and an annual average lake outflow of 105.6 m^3/s.

This average lake outflow / Ruzizi III inflow is notably larger than other estimates as discussed herein (e.g., initial Feasibility Study hydrological model development, ABAKIR's 'Baseline Study of the Basin', and Muyundia et al.'s 2014 study into Lake Kivu outflows).

Table 7-11 and Figure 7-41 summarise the monthly inflows from the Feasibility Study initial hydrological model and the recalibrated model.

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Table 7-11 Summary of Feasibility Study monthly inflows

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Initial Model (m^3/s)													
Dry	68.0	70.0	71.9	73.9	76.0	76.0	74.9	69.0	65.0	63.0	64.9	66.0	70.9
Normal	83.0	85.0	85.5	87.0	89.0	89.5	87.0	83.0	79.0	76.5	77.0	79.5	83.0
Wet	98.3	100	101	104	107	107	105	99.3	95.0	92.2	94.0	97.0	98.2
Recalibrated Model (m^3/s)													
Dry	84.0	92.1	93.4	95.9	101	101	97.9	87.9	78.9	75.9	77.9	83.7	90.9
Normal	108	111	115	117	121	122	116	106	97.0	93.0	96.0	102	109
Wet	135	135	139	146	152	151	142	131	119	116	119	129	131

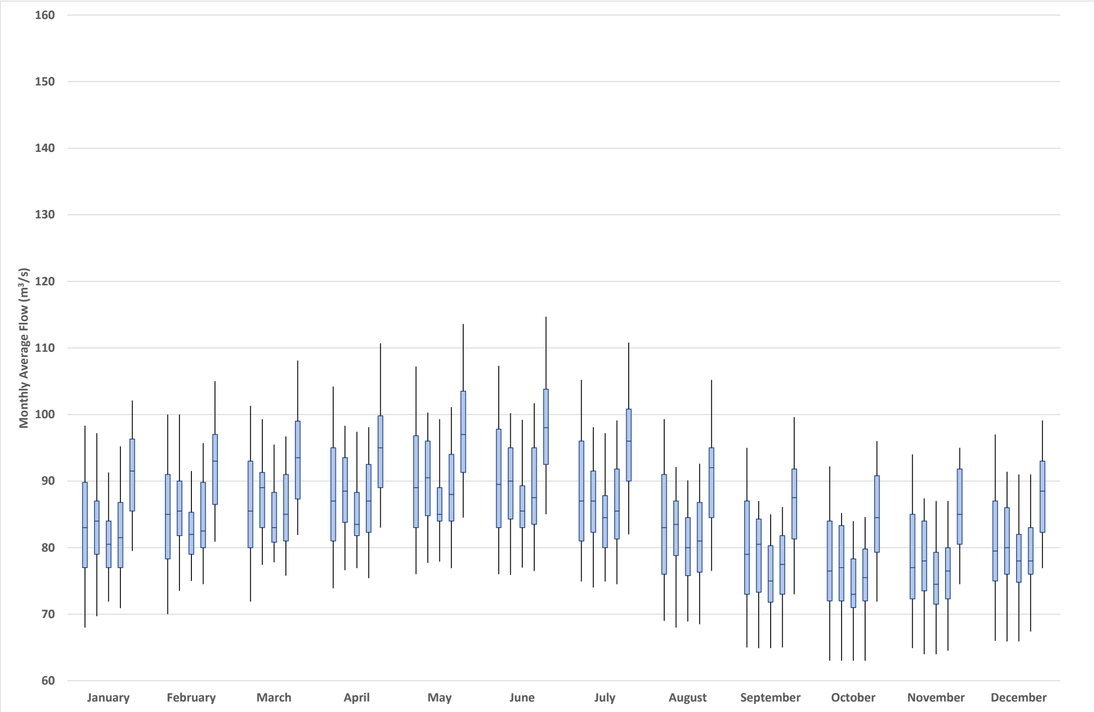
The reported difference has been attributed by the Feasibility Study to a change in land use in the upper Lake Kivu basin. However, it is noted that the calculated differences in inflows may also be attributed to hydrological and hydro-meteorological observational uncertainty in, for example, the Lake Kivu level-outflow relationship, and catchment average precipitation and evapotranspiration, and lake evaporation estimates.

The water balance model adopted in the Feasibility Study is relatively simplistic. It can be differentiated from Muyundia et al.'s water balance model by the absence of consideration of deep subaquatic groundwater discharge (SGD) and characterised by its adoption of the University of East Anglia's Climate Research Unit (CRU) time-series datasets. It is noted that the CRU time-series datasets are derived from both satellite data and local individual stations, and that the inclusion of local data is typically sparse in Rwanda and varies over time. The brief review of CRU data presented in the Annex shows that less local data is available for the period post-2000, and as such, estimates of precipitation and evapotranspiration for this period have a greater associated uncertainty.

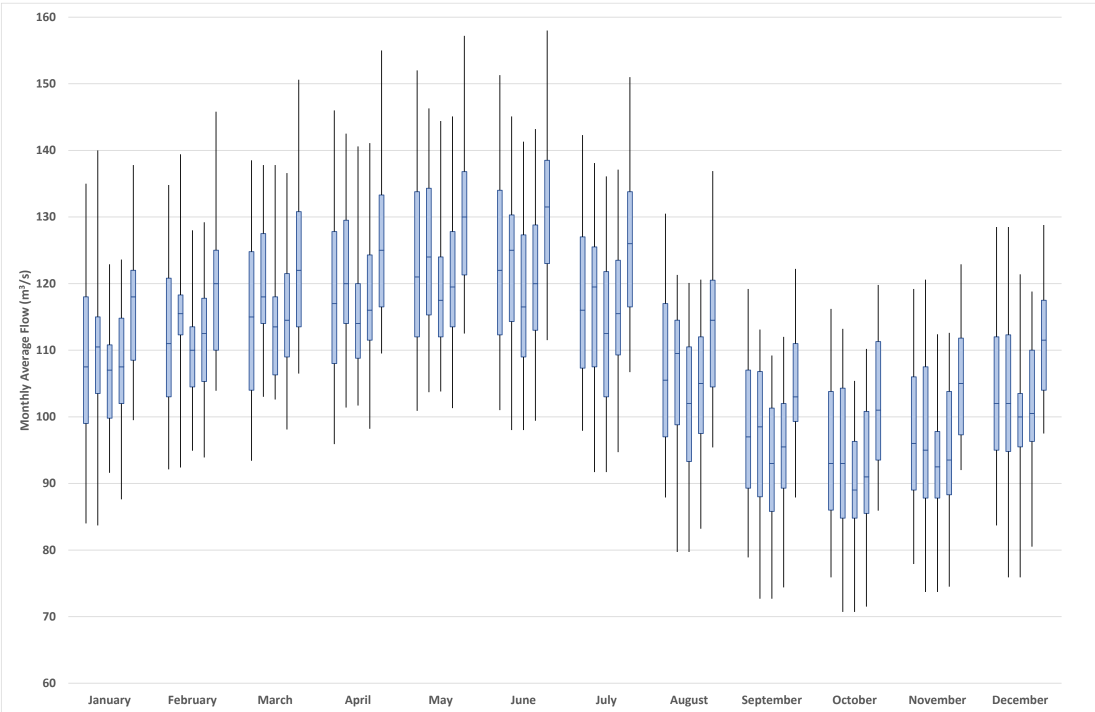
Furthermore, it is noted that long-term cyclical water level behaviour is observed in Lake Kivu (and East African lakes in general), and that differences in the estimated long-term average inflows to Ruzizi III may (in part) be attributed to this variation.

Accordingly, it is recommended that the current Feasibility Study Ruzizi III inflows (as reported in Table 7-8) are considered "current" estimates, and that previous Feasibility Study estimates of inflows are considered as "historic" estimates.

Less information is available to estimate the inflows into the study area downstream of Ruzizi III. However, the ABAKIR 'Baseline Study of the Basin' provides a useful source of information that can be adopted as current "best estimates", recognising that hydrological inflows from downstream tributaries are significantly lower than those from upstream Ruzizi III.



Initial Model Monthly Inflows (above)



Recalibrated Model Monthly Inflows (above)

Figure 7-41 Summary of Feasibility Study Monthly Inflows

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7.6.3 Study Area Hydrology

7.6.3.1 Introduction

The hydrology in the study area between Ruzizi III dam wall and the border with Burundi is determined both by the outflow from Lake Kivu and inflows from the intervening catchment but also at a sub-daily level by the operation of Ruzizi I and Ruzizi II.

The Feasibility Study (2020) presents an analysis of power production for the (future) Ruzizi cascade, i.e., for the operation of Ruzizi I, II, and III. A key component of this analysis is that the cascade shares the same demand curve for power production, and that the installed capacity for both Ruzizi II and Ruzizi III is 150 m^3/s. In the absence of comprehensive hydrological monitoring, the optimised outflows from Ruzizi II, whilst not matching current / historic operation, provide an appropriate reference for considering the baseline hydrology in the study area.

7.6.3.2 Water Level Monitoring

The Rwanda Water Resources Board (RWB) 'Water Portal' makes available surface water data and includes lake level data at the Lake Kivu outlet and river level data at Kamanyola (Bugarama Bridge).

View from Bugarama Bridge | View from left bank

Figure 7-42 Kamanyola (Bugarama Bridge) Water Level Monitoring Station

Lake level data is available for the Lake Kivu outlet for: i) manually-read data at 08:00, 12:00, and 17:00 for the period 01/03/2016 – 31/03/2017; and ii) telemetry-read data at irregular hourly intervals for the period 02/09/2021 – 08/01/2022. There is limited utility of these datasets due to their short duration and irregular recording. Kamanyola river level data availability includes 15-minute telemetry level data for the period 01/06/2018 onwards.

The Kamanyola river level data illustrates the impact of the existing operation of Ruzizi II and the associated hydropeaking effects. Table 7-12 summarises the frequency of river level change exceeding selected thresholds (1 m and 1.5 m) within selected short durations (2 hours; 1 hour; 45 minutes; 30 minutes) during the 3-year period June 2018 to May 2021. It can be seen that:

- A change of water level of more than 1 m in a 1-hour duration occurs on average approximately 1 day in 3.
- A change of water level of more than 1 m in a 30-minute duration occurs on average approximately 1 day in 5.
- A change of water level of more than 1.5 m in a 1-hour duration occurs on average approximately once per fortnight.

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- A change of water level of more than 1.5 m in a 30-minute duration occurs on average approximately once per 50 days.

Table 7-12 Summary of Kamanyola Water Level Monitoring Station Change in Water Level (Jun-2018 – May-2021)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
River level change exceeding 1 m													
In 2 hours	53	43	39	31	32	18	9	6	20	34	37	62	384
In 1 hour	47	39	32	29	28	17	8	5	16	29	34	59	343
In 45 mins	38	30	29	27	27	17	8	5	14	25	32	54	306
In 30 mins	21	21	21	19	22	14	6	5	12	22	22	38	223
River level change exceeding 1.5 m													
In 2 hours	15	11	12	12	14	7	1	0	5	11	10	19	117
In 1 hour	9	10	9	9	12	7	0	0	4	7	6	14	87
In 45 mins	6	7	9	8	8	6	0	0	4	5	4	9	66
In 30 mins	3	3	4	3	1	3	0	0	2	2	1	1	23

Figure 7-43 summarises the seasonality of "exceedance events".

It can be seen that the exceedance events tend to occur during the period October to May, with the maximum number of recorded exceedance events occur in December.

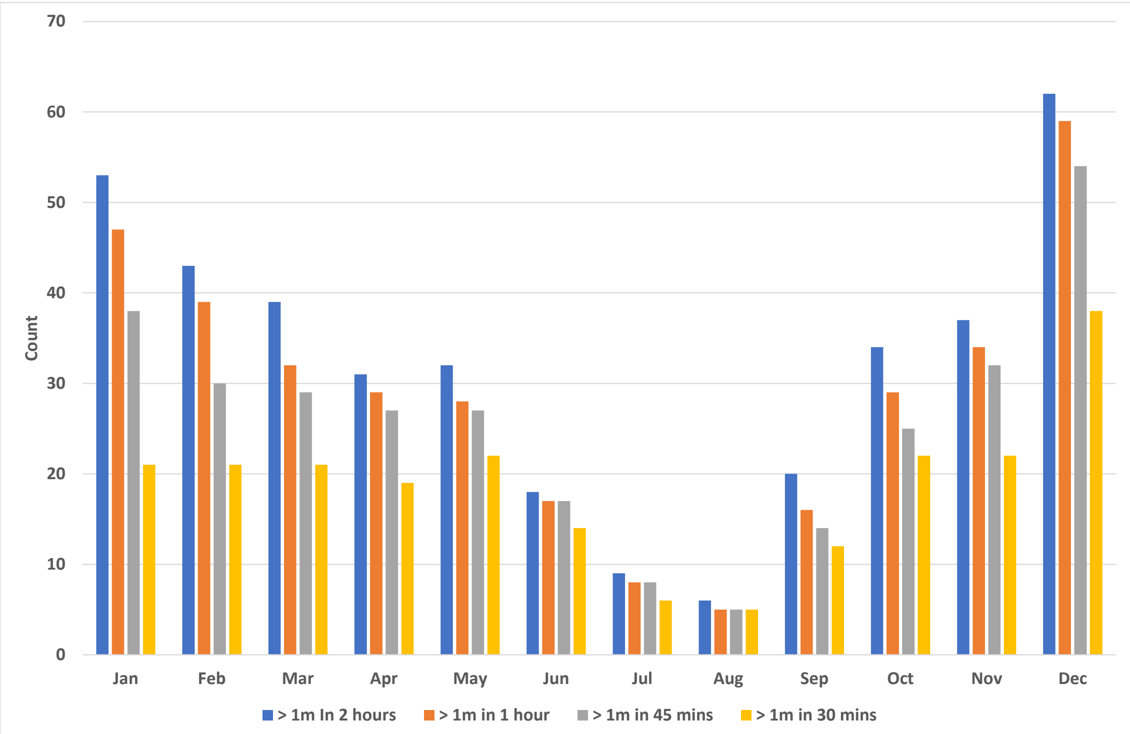

Figure 7-43 Kamanyola Water Level Monitoring Station Change in Water Level Seasonality (Jun-2018 – May-2021)

Figure 7-44 shows the variation in daily water levels at Kamanyola for selected days (the first day of each month) in 2019. This illustrates the variation in water levels in terms of the differences between daily maximum and daily minimum water levels, and the difference in timing of daily minimum water levels. The effects of Ruzizi II hydropeaking are not predictable and differ from optimised operational rules.

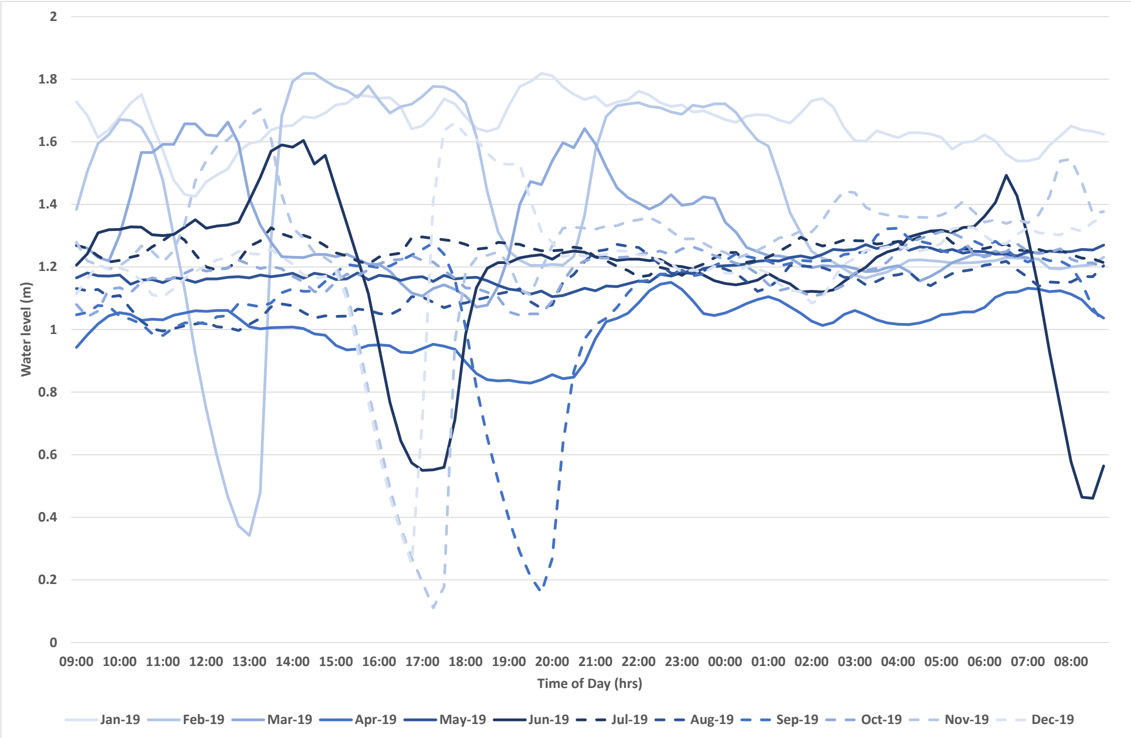

Figure 7-44 Selected Daily Water Levels at Kamanyola (2019)

The Rwanda Water Resources Board (RWB) 'Water Portal' also provides reports on river flow monitoring. Reports are available for the period 2018-2019 and for 2020. However, the data presented shows that flow monitoring on the Ruzizi (and Rubyiro and Ruhwa) is infrequent and as such the estimation of river flow is uncertain. The 2020 report flows at Kamanyola and on the Ruhwa and Ribyiro rivers were measured in November 2020 at 156 m^3/s, 13.5 m^3/s and 4.41 m^3/s respectively.

Additional water level monitoring has also been undertaken by the Project during the period 10/02/2023 – 11/03/2023 at both the Manda monitoring site (located approximately 2 km downstream of the proposed Ruzizi III dam wall location) and the Rusizi monitoring site in Burundi (located approximately 120 km downstream of Ruzizi III / 14 km upstream of Lake Tanganyika). At both locations, water level has been monitored daily during the period 7h00 to 18h00 at 15-minute intervals.

The water level monitoring data from 2023 clearly shows the significant attenuation in observed water levels along the length of the Ruzizi River:

- At Manda, the average daily range of observed water levels is 1.25 m, with a rate of change of 70 cm/hour. It is noteworthy that there is little intervening flow into the Ruzizi upstream of Manda - as Manda is upstream of main tributaries (Ribyiro and Ruhwa).
- At Rusizi upstream Lake Tanganyika, the average daily range of observed water levels is 0.07 m, with a rate of change of 0.3 cm/hour.

The impact of existing hydropeaking is unlikely to be observable at the lower end of the Ruzizi River in Burundi, including the Rusizi National Park which is confirmed by park authorities. Rather, due to the large distance downstream and large intervening catchment area, the small daily variation in water levels at this location are at least as likely to be associated with natural hydrological processes.

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7.6.3.3 Modelled Hydrological / Hydraulic Characteristics

A Introduction

The "River Channel Hydraulics" report (December 2020), produced as part of the Ruzizi II Feasibility Study, describes the analysis and modelling undertaken in order to develop high flow level-flow rating curves at selected sites of interest between the Ruzizi II dam wall and powerhouse. A HEC-RAS 1D hydraulic model was developed for the river reach between the dam wall and approximately 1.4 km downstream of the powerhouse based on cross-section survey data and local LiDAR data.[7] During model development, any discrepancies between cross-section survey data and LiDAR were removed by adjusting the survey data.

The hydrological and hydraulic characterisation is presented in this section of the baseline assessment in order to provide important contextual information that informs the subsequent environmental flow assessment (provided in Chapter 10)..

B The Ruzizi III Reach

The existing HEC-RAS model of the reach between the Ruzizi III dam wall and approximately 1.4 km downstream of the powerhouse includes the post-Ruzizi III dewatered reach. The model has been obtained and re-run for a range of steady state flows in order to provide a hydraulic characterisation of the reach representing the proposed Ruzizi III dewatered reach. Flows over a range of 10 m^3/s to 160 m^3/s have been modelled as, due to the hydropeaking operation of Ruzizi II, these correspond to the typical flow range currently observed in the reach.

The approximately 5.5 km dewatered reach has an average width of 63 m and a total wetted area of approximately 354,000 m^2. Table 7-13 and Figure 7-45 shows how the reach wetted area varies with flow. It can be seen that:

- At a flow of 10 m^3/s (minimum flow), the total wetted area is 157,000 m^2 (48% of wetted area for natural flow conditions and 44% of peak flow conditions).
- At a flow of 90 m^3/s (typical off-peak flow), the total wetted area is 307,000 m^2(over a wetted area of 87% and 94% of peak and natural flow conditions respectively);
- At a flow of 160 m^3/s (typical peak flow), the total wetted area is 354,000 m^2 (over a wetted area of 100% and 109% of peak and natural flow conditions, respectively).

Table 7-13 Summary of Variation of Reach Area

Flow (m^3/s)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
Area (000 m^2)	157	195	223	244	259	273	284	296	307	318	325	331	338	343	349	354
Area as % of Maximum at 160 m^3/s (peak flow rate)																
	44 %	55 %	63 %	69 %	73 %	77 %	80 %	84 %	87 %	90 %	92 %	94 %	95 %	97 %	99 %	100 %
Area as % of Maximum at 110 m^3/s (average annual flow for natura conditions																
	48 %	60 %	69 %	75 %	80 %	84 %	87 %	91%	94 %	98 %	100 %	102 %	104 %	106 %	107 %	109 %

[7] The cross-section survey data is more thoroughly described in the "Draft Report of Ruzizi Bathymetric Survey for Ruzizi III HEPP" report (Tiger Engineering Company Limited, January 2021). An ADCP was used to survey cross-sections at 68 out of 80 planned locations – 12 locations were not able to be surveyed due to the high level of turbulence. The ADCP surveyed data was extended onto the riverbanks using Total Station topographic survey.

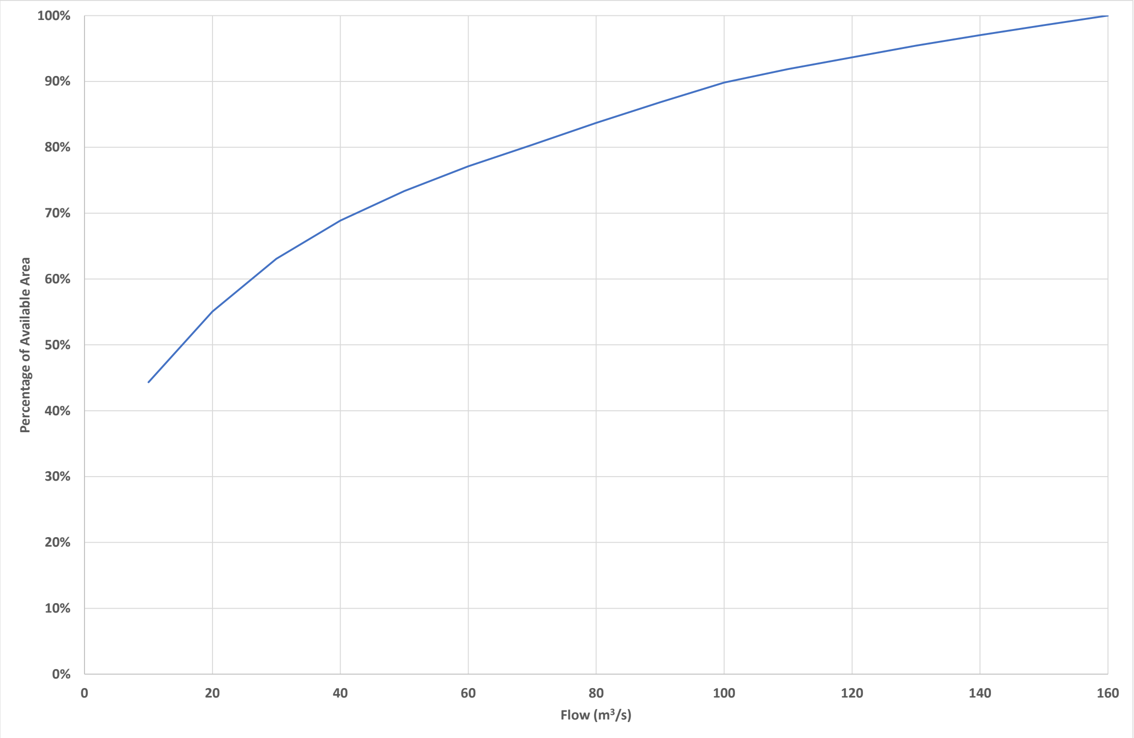

Figure 7-45 Variation of Reach Water Area

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The Tennant Method percentage width requirements are approximately 60%, 65%, and 85%, for 10% MAF, 30% MAF and 60% MAF. Equating width with area, a flow of 26 m^3/s, 33 m^3/s, and 83 m^3/s would be required in the reach to meet these requirements.

Figure 7-46 shows how the average depth in the reach varies with flow:

- At a flow of 10 m^3/s (minimum flow), the average depth is 0.55 m (over 44% and 48% of peak and natural flow conditions respectively);
- At a flow of 90 m^3/s (typical off-peak flow), the average depth is 1.15 m (over a wetted area of 87% and 94% of peak and natural flow conditions respectively); and
- At a flow of 160 m^3/s (typical peak flow), the average depth is 1.60 m (over a wetted area of 100% and 109% of peak and natural flow conditions respectively).

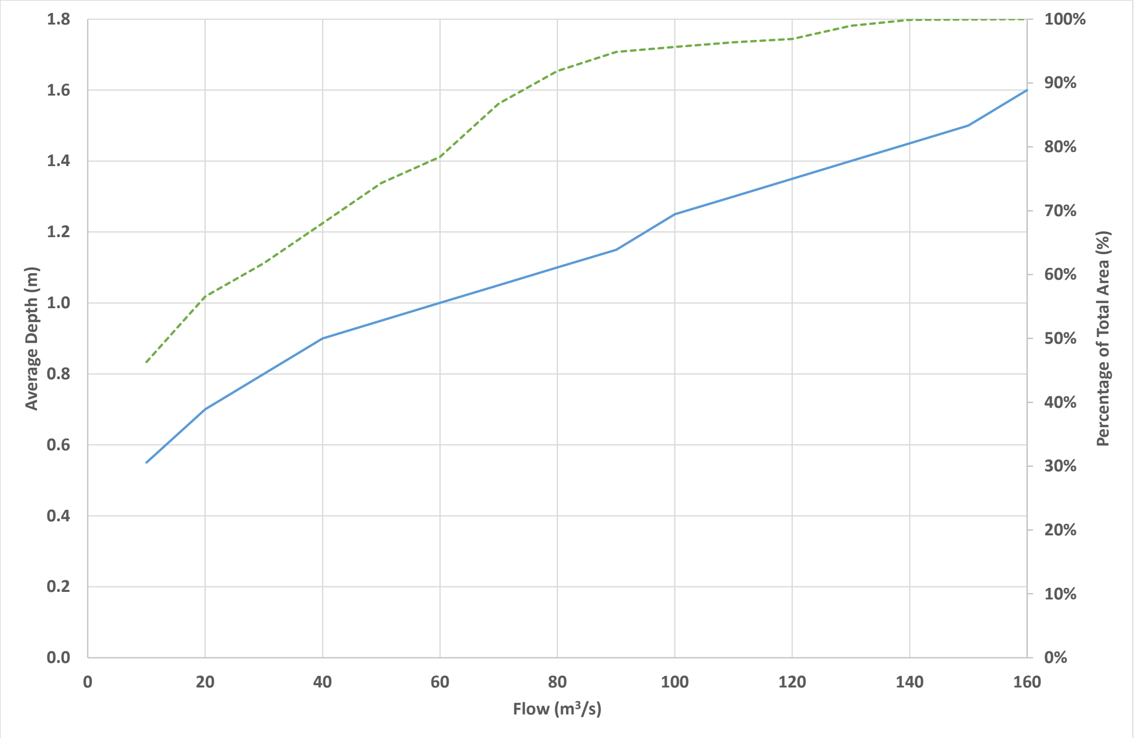

Figure 7-46 Variation of Reach Average Depth

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Table 7-14 and Figure 7-47 provide further insight into how the depth of water in the reach varies over a similar flow range[8]. For example:

- At a flow rate of 10 m^3/s (minimum flow), 91,000 m^2 (26%) is at least 0.5 m deep, 40,000 m^2 (11%) is at least 1 m deep, and 6,000 m^2 (2%) is at least 2 m deep.
- At a flow rate of 90 m^3/s (typical off-peak flow), 265,000 m^2 (75%) is at least 0.5 m deep, 192,000 m^2 (54%) is at least 1 m deep, and 69,000 m^2 (20%) is at least 2 m deep.
- At a flow rate of 160 m^3/s (typical peak flow), 335,000 m^2 (95%) is at least 0.5 m deep, 287,000 m^2 (81%) is at least 1 m deep, and 131,000 m^2 (37%) is at least 2 m deep.

Table 7-14 Summary of Variation of Reach Water Area at Selected Depth Exceedance Thresholds

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
D > Min	164	200	219	241	263	278	307	325	336	339	341	343	350	354	354	354
D > 0.25	130	174	197	216	233	253	271	286	310	328	332	337	339	341	344	347
D > 0.5	91	130	167	191	202	216	234	252	265	280	300	316	325	328	332	335
D > 1.0	40	71	92	108	127	147	167	182	192	203	216	233	248	256	268	287
D > 2.0	6	12	14	25	32	41	50	62	69	78	87	97	104	112	122	131
D > 3.0	-	1	2	3	3	5	9	11	13	15	21	22	26	30	33	35
D > 4.0	-	-	-	-	-	-	-	1	2	2	2	3	3	4	5	8
D > 5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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[8] % wetted area is expressed as a % of wetted area of peak flows at 160 m^3/s. Wetted area expressed as a % of natural flow conditions at 110 m3/s are not indicated but are 2-3% higher.

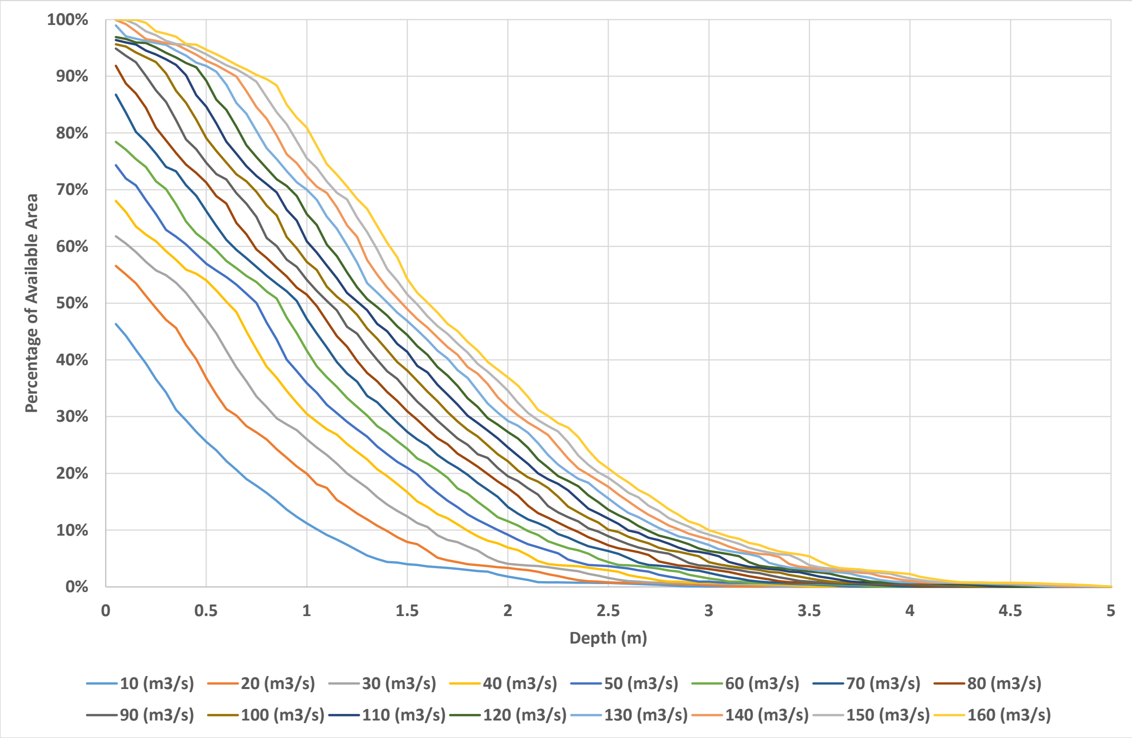

Figure 7-47 Variation of Reach Water Depth Exceedence as a Percentage of Total Wetted Area

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The Tennant Method percentage depth requirements are approximately 0.33 m, 0.5 m, and 0.67 m, for 10% MAF, 30% MAF and 60% MAF.

Figure 7-48 shows how the average velocity in the reach varies with flow:

- At a flow of 10 m³/s (minimum flow), the average velocity is 0.55 m/s (over 44% and 48% of peak and natural flow conditions respectively);
- At a flow of 90 m³/s (typical off-peak flow), the average velocity is 0.80 m/s (over a wetted area of 87% and 94% of peak and natural flow conditions respectively); and
- At a flow of 160 m³/s (typical peak flow), the average velocity is 1.15 m/s (over a wetted area of 100% and 109% of peak and natural flow conditions respectively).

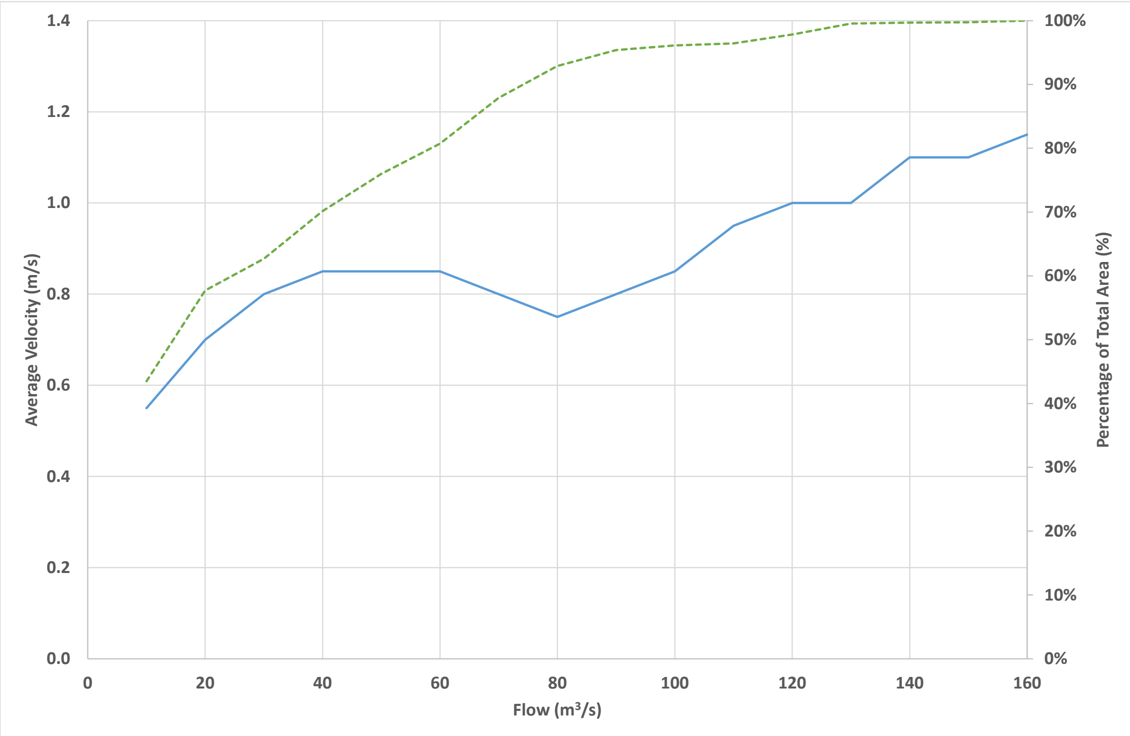

Figure 7-48 Variation of Reach Average Velocity

Table 7-15 and Figure 7-49 provide further insight into how the velocity of water in the reach varies over a similar flow range[8]. For example:

- At a flow rate of 10 m³/s (minimum flow), 82,000 m² (23%) is at least 0.5 m/s fast, 37,000 m² (10%) is at least 1 m/s fast, and 3,000 m² (1%) is at least 2 m/s fast.
- At a flow rate of 90 m³/s (typical off-peak flow), 323,000 m² (91%) is at least 0.5 m/s fast, 138,000 m² (39%) is at least 1 m/s fast, and 48,000 m² (14%) is at least 2 m/s fast.
- At a flow rate of 160 m³/s (typical peak flow), 339,000 m² (96%) is at least 0.5 m/s fast, 185,000 m² (52%) is at least 1 m/s fast, and 98,000 m² (28%) is at least 2 m/s fast.

The Tennant Method percentage velocity requirements are approximately 0.25 m/s, 0.5 m/s, and 0.6 m/s, for 10% MAF, 30% MAF and 60% MAF.

Table 7-15 Summary of Variation of Reach Water Area at Selected Velocity Exceedance Thresholds

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
V > Min	154	205	222	249	270	286	312	330	339	341	342	347	353	354	354	355
V > 0.5	82	121	137	205	225	250	281	298	323	325	327	332	338	338	339	339
V > 1.0	37	66	82	100	116	120	129	132	138	144	145	176	184	184	184	185
V > 2.0	3	10	13	34	36	36	39	40	48	50	51	52	69	75	96	98
V > 3.0	-	-	-	8	9	9	12	13	11	37	37	39	41	44	44	44
V > 4.0	-	-	-	-	-	-	-	-	-	10	10	11	11	12	12	12
V > 5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

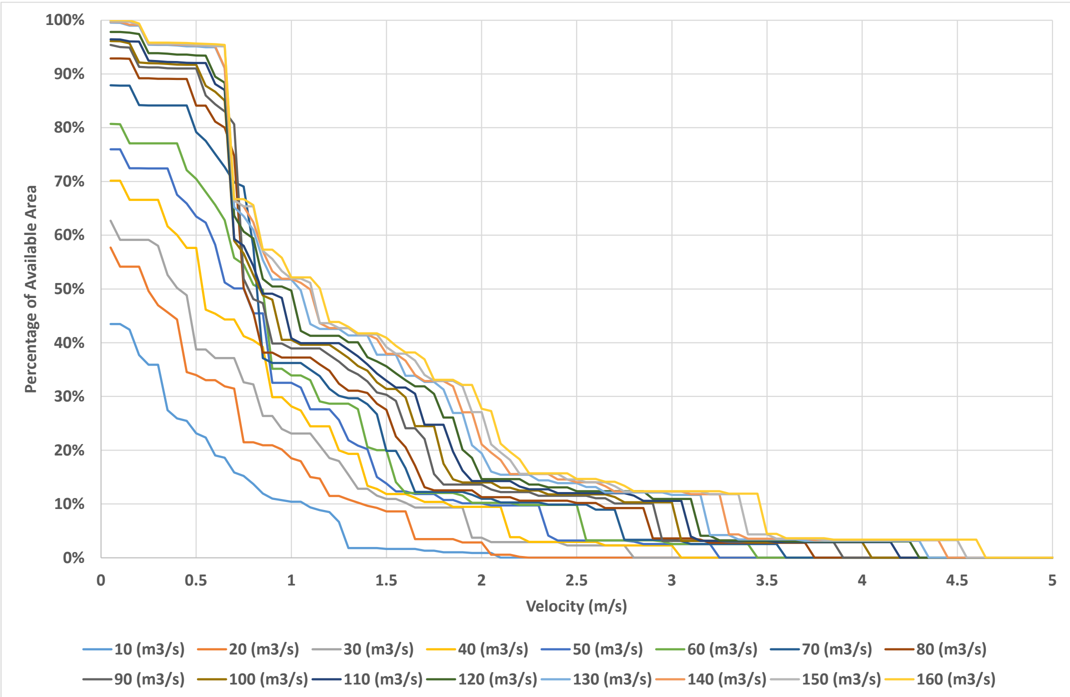

Figure 7-49 Variation of Reach Water Velocity Exceedence as a Percentage of Total Wetted Area

Figure 7-50 shows how the average shear stress in the reach varies with flow:

- At a flow of 10 m^3/s (minimum flow), the average shear stress is 15 N/m^2 ((over 44% and 48% of peak and natural flow conditions respectively);
- At a flow of 90 m^3/s (typical off-peak flow), the average shear stress is 30 N/m^2 (over a wetted area of 87% and 94% of peak and natural flow conditions respectively); and
- At a flow of 160 m^3/s (typical peak flow), the average shear stress is 55 N/m^2 (over a wetted area of 100% and 109% of peak and natural flow conditions respectively).

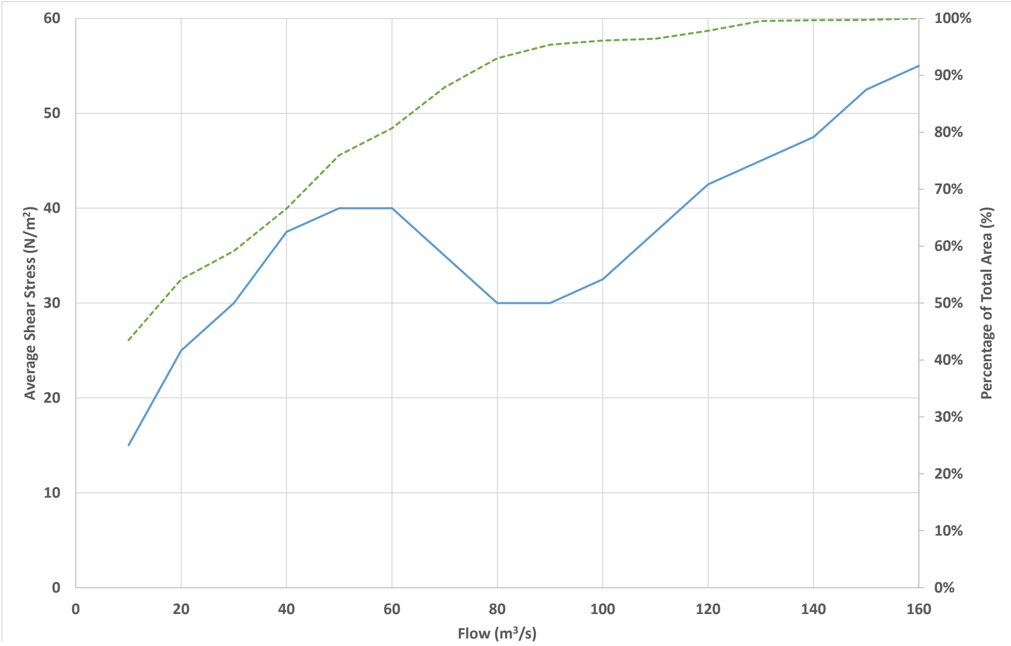

Figure 7-50 Variation of Reach Average Shear Stress

Table 7-16 and Figure 7-51 provide further insight into how the shear stress[9] in the reach varies over a similar flow range[8]. For example:

- At a flow rate of 10 m^3/s (minimum flow), 90,000 m^2 (25%) has a shear stress of at least 10 N/m^2, 39,000 m^2 (11%) of at least 50 N/m^2, and 24,000 m^2 (7%) of at least 100 N/m^2.
- At a flow rate of 90 m^3/s (typical off-peak flow), 324,000 m^2 (91%) has a shear stress of at least 10 N/m^2, 138,000 m^2 (39%) of at least 50 N/m^2, and 112,000 m^2 (32%) of at least 100 N/m^2.
- At a flow rate of 160 m^3/s (typical peak flow), 340,000 m^2 (96%) has a shear stress of at least 10 N/m^2, 185,000 m^2 (52%) of at least 50 N/m^2, and 145,000 m^2 (41%) of at least 100 N/m^2.

Table 7-16 Summary of Variation of Reach Area at Selected Shear Stress Exceedance Thresholds

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
τ > 0.5	154	192	210	236	270	286	312	330	339	341	342	347	353	354	354	355
τ > 2.5	130	188	210	236	257	274	299	317	325	328	330	335	339	341	341	342
τ > 10	90	123	173	205	229	250	281	299	324	327	328	333	339	339	339	340
τ > 25	66	106	132	157	178	198	245	265	272	187	197	212	222	223	228	234
τ > 50	39	74	85	104	112	120	129	132	138	141	142	150	154	159	182	185
τ > 100	24	38	46	63	72	84	94	109	112	114	122	126	135	135	145	145
τ > 200	4	12	33	34	35	36	42	43	47	48	51	52	55	55	55	56

[9] Reported shear stress thresholds are the approximate critical thresholds (higher range values) for sediment mobility for medium sand, very coarse gravel, and fine cobbles.

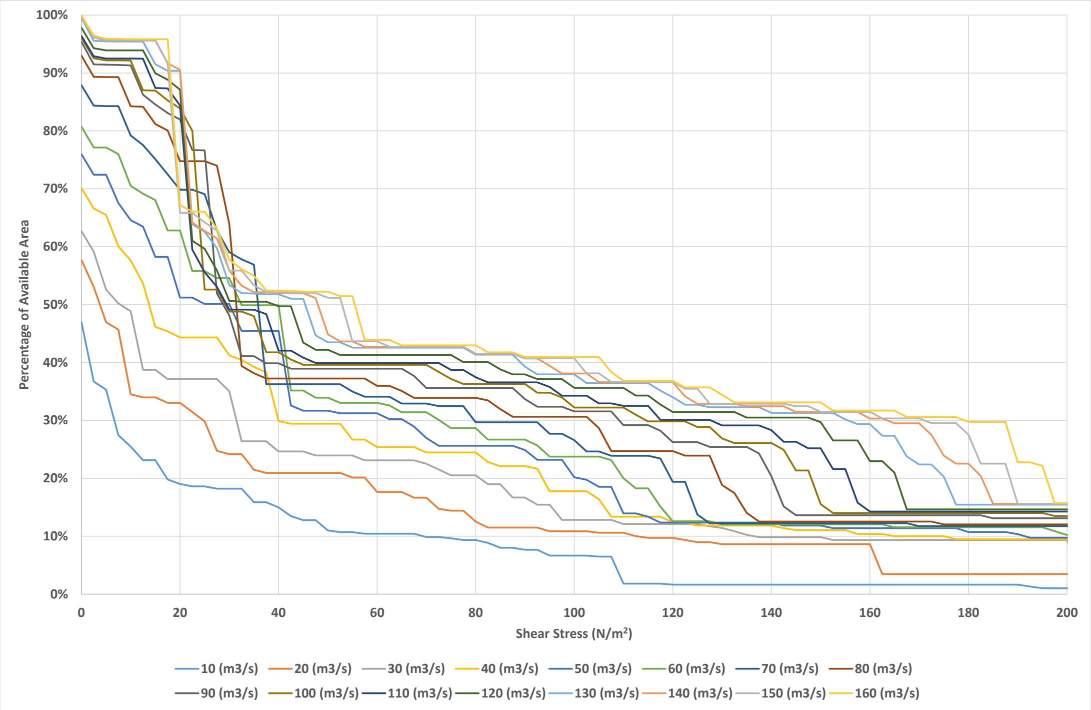

Figure 7-51 Variation of Reach Water Shear Stress Exceedence as a Percentage of Total Wetted Area

The reach water depth and velocity data has also been combined to provide an estimate of hazard (using the classification system developed by the Australian Water Research Laboratory).

Figure 7-52 summarises the hazard classification of the reach over the modelled range of flows (where class 1 is "very low" hazard and class 6 is "very high" hazard). It can be seen that, as expected, hazard generally increases with flow magnitude (as both depth and velocity increase):

- At a flow rate of 10 m^3/s (minimum), 34.4% of the reach is considered to be at a hazard rating of 3 or less, and 12.7% is of the reach is considered to be at a hazard rating of 4 or more.
- At a flow rate of 90 m^3/s (typical off-peak flow), 25.3% of the reach is considered to be at a hazard rating of 3 or less, and 70.1% is of the reach is considered to be at a hazard rating of 4 or more.
- At a flow rate of 160 m^3/s (typical peak flow), 3.4% of the reach is considered to be at a hazard rating of 3 or less, and 96.6% is of the reach is considered to be at a hazard rating of 4 or more.

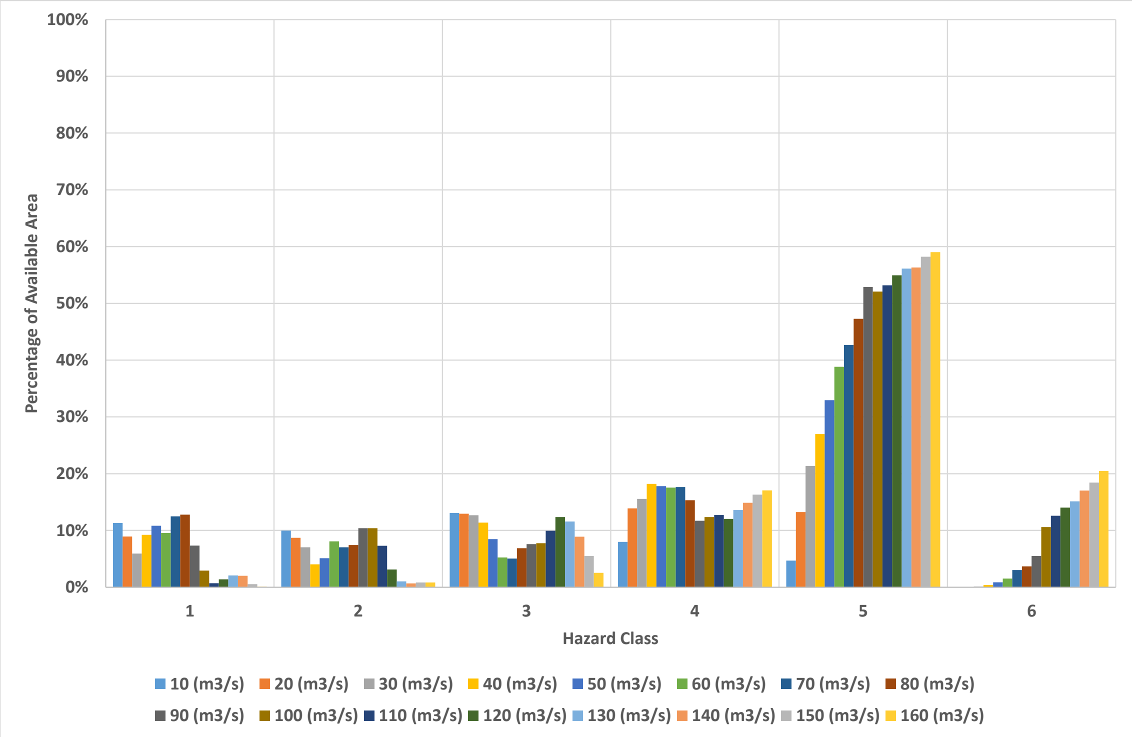

Figure 7-52 Hazard Classification of the Reach

The hydrological and hydraulic characteristics in the reach show a reach that is subject to a high level of sub-daily variation in river flow. The total wetted area typically varies between 157,000 m^2 and 354,000 m^2. Compared with average flow conditions, it both shrinks to half of its usual size and expands by approximately one-sixth of its usual size on a daily basis. Average depth changes on a typical day between 0.55 m and 1.60 m. Average velocity changes on a typical day between 0.55 m/s and 1.15 m/s. Within reach variations of depth and velocity are noticeably higher[10], with depths varying by between 0.15 m and 3 m, and velocities varying by between 0.15 m/s and 3.45 m/s.

C The Ruzizi II – Burundi Border Reach

The existing HEC-RAS model of the reach between the dam wall and approximately 1.4 km downstream of the powerhouse has been used as the basis for constructing a 1D hydraulic model of the full reach between the Ruzizi II dam wall and (just below) the confluence with the River Ruhwa.

Surveyed cross-section data has been reviewed and synthetic cross-sections generated for the non-surveyed reaches. The synthetic cross-sections explicitly take into account both the general pattern of in-bank river geomorphology and local variation. Figure 7-53 illustrates the variation in cross-section profile in the surveyed reach, illustrating the range of depths[11] (expressed as a percentage of maximum depth) surveyed across each cross-section profile.

[10] Reported variations are based on the 10% and 90% exceedance percentile range for modelled reach depths and velocities.
[11] The range of surveyed depths is expressed in terms of exceedance percentiles.

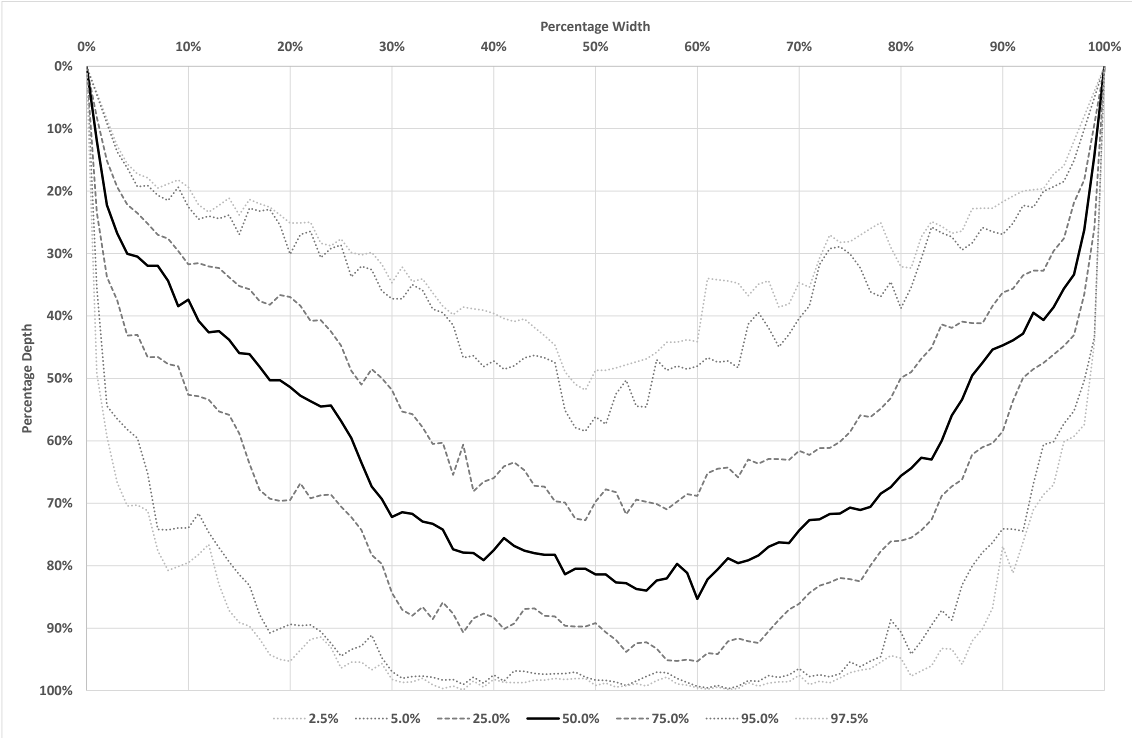

Figure 7-53 Variation in Cross-Section Profile in the Surveyed Reach

Cross-section width has been estimated from satellite imagery. Bank-full levels have been defined with reference to available DTM data, ALOS 30m data in the reach downstream of Bugarama Bridge and 2m photogrammetry data (Fichtner, 2009)[12] in the remainder of the (non-surveyed) reach upstream of Bugarama Bridge. The DTM data bank-full long profile was reviewed – and included use of field observations (January 2022) of the river profile– to smooth out local discrepancies. Field observations were also used in assigning roughness values to the synthetic cross-sections. As with the existing HEC-RAS model, the main channel was assigned a Manning's n value of 0.07, out-of-bank was assigned a value of 0.1.

Five baseline scenarios have been modelled, based on the optimised reservoir operation schedules presented in the Feasibility Report:

- "Very dry" conditions (95% exceedance probability);
- "Dry" conditions (90% exceedance probability);
- "Normal" conditions (50% exceedance probability);
- "Wet" conditions (10% exceedance probability); and
- "Very wet" conditions (5% exceedance probability).

Table 7-17 summarises the model inflows adopted for each of these scenarios. The model inflows include: i) Ruzizi II environmental flow; ii) Ruzizi II powerhouse release; iii) 'intervening catchment' inflows; iv) River Rubyiro inflows; and v) River Ruhwa inflows.

[12] Etude de Faisabilité pour l'Aménagement Hydroélectrique de Ruzizi III, VOLUME IV : TOPOGRAPHIE, Rapport final.

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Table 7-17 Summary of baseline hydrological inflows in the Ruzizi II – Burundi Border Reach

Conditions	Ruzizi II Environmental Flow (m^3/s)	Ruzizi II powerhouse release (m^3/s)	Intervening Catchment Flow (m^3/s)	Total Flow to Ruzizi III (m^3/s)	River Rubyiro Flow (m^3/s)	River Ruhwa Flow (m^3/s)
Very Dry	10.8	See Figure 7-54	1.3	78.3	3.7	8.2
Dry	10.8		1.6	84.3	4.6	10.1
Normal	10.8		2.4	108.4	6.9	15.2
Wet	10.8		3.7	131.1	10.6	23.4
Very Wet	10.8		4.9	139.2	14.1	31.0

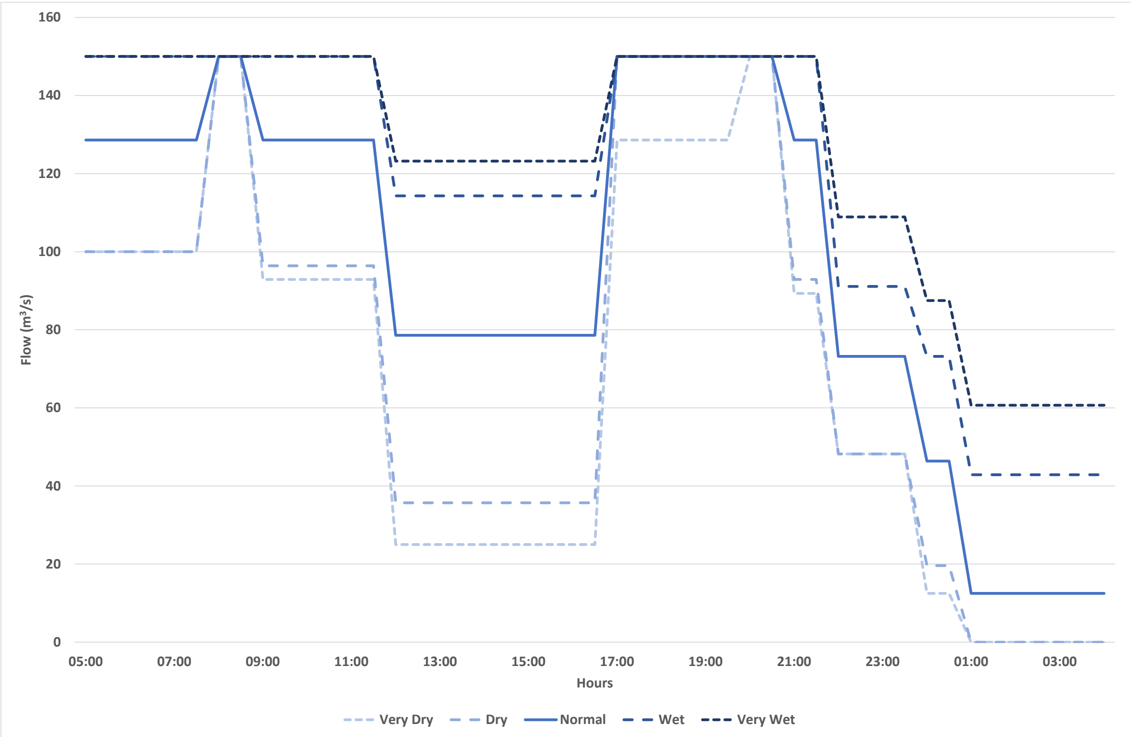


Figure 7-54 Ruzizi II Powerhouse Release Schedules

The model has been run for a 48-hour duration (repeated daily schedule). The operational schedule has been implemented such that changes between flow values are assumed to occur over a 30 minute-duration (based on current operational conditions at Ruzizi II). The 1D Finite Volume Solver has been used to improve model stability and performance for the observed flow conditions.

Modelled flow and water levels are reported for selected key locations:

- Downstream Ruzizi II dam wall / powerhouse release;
- Downstream intervening catchment;
- Downstream Ruzizi III powerhouse release location;
- Upstream Bugarama Bridge / Kamanyola Monitoring Station;
- Upstream Rubyiro tributary;
- Upstream Burundi border / Ruhwa tributary; and
- Downstream Burundi border / Ruhwa tributary.

Figure 7-55 and Figure 7-56 summarise the maximum flow (m^3/s), minimum flow (m^3/s), flow range (m^3/s), maximum water level elevation (mAOD), minimum water level elevation (mAOD), water level elevation range (m), and water level ramp-up and ramp-down rates (cm/min) for selected durations (15-minute, 30-minute, and 60-minute).

Location	Flow Range	Max Flow (m^3/s)	Min Flow (m^3/s)	Flow Range (m^3/s)	Max Elevation (mAOD)	Min Elevation (mAOD)	Elevation Range (m)
Ruzizi II dam wall / powerhouse release	"Very Dry" (95% exceedence)	161	11	150	1,368.43	1,366.86	1.57
Downstream intervening catchment		162	12	149	1,273.25	1,271.45	1.80
Ruzizi III powerhouse release		160	12	148	979.62	977.95	1.67
Upstream Bugarama Bridge		160	12	148	947.55	945.74	1.81
Upstream Rubyiro tributary		158	12	146	929.80	927.82	1.98
Upstream Burundi border		162	16	146	920.01	918.81	1.20
Downstream Burundi border		171	25	146	908.82	907.65	1.17
Ruzizi II dam wall / powerhouse release	"Dry" (90% exceedence)	161	11	150	1,368.44	1,366.86	1.58
Downstream intervening catchment		162	12	150	1,273.26	1,271.46	1.80
Ruzizi III powerhouse release		162	12	150	979.63	977.96	1.67
Upstream Bugarama Bridge		162	12	150	947.57	945.75	1.82
Upstream Rubyiro tributary		162	12	150	929.84	927.83	2.01
Upstream Burundi border		167	17	150	920.03	918.83	1.20
Downstream Burundi border		178	28	150	908.86	907.70	1.16
Ruzizi II dam wall / powerhouse release	"Normal" (50% exceedence)	161	23	138	1,368.44	1,367.05	1.39
Downstream intervening catchment		163	26	138	1,273.26	1,271.75	1.51
Ruzizi III powerhouse release		163	26	138	979.64	978.31	1.33
Upstream Bugarama Bridge		163	26	138	947.58	946.09	1.49
Upstream Rubyiro tributary		163	26	138	929.84	928.21	1.63
Upstream Burundi border		170	33	138	920.04	919.06	0.98
Downstream Burundi border		185	48	138	908.89	907.95	0.94
Ruzizi II dam wall / powerhouse release	"Wet" (10% exceedence)	161	54	107	1,368.44	1,367.41	1.03
Downstream intervening catchment		165	57	107	1,273.27	1,272.24	1.03
Ruzizi III powerhouse release		165	57	107	979.65	978.80	0.85
Upstream Bugarama Bridge		165	57	107	947.59	946.62	0.97
Upstream Rubyiro tributary		165	57	107	929.86	928.77	1.09
Upstream Burundi border		176	69	107	920.07	919.41	0.66
Downstream Burundi border		200	93	107	908.97	908.37	0.60
Ruzizi II dam wall / powerhouse release	"Very Wet" (5% exceedence)	161	72	89	1,368.44	1,367.58	0.86
Downstream intervening catchment		166	76	89	1,273.28	1,272.47	0.81
Ruzizi III powerhouse release		166	76	89	979.65	979.01	0.64
Upstream Bugarama Bridge		166	76	89	947.60	946.83	0.77
Upstream Rubyiro tributary		166	76	89	929.87	929.01	0.86
Upstream Burundi border		181	91	89	920.09	919.58	0.51
Downstream Burundi border		213	124	89	909.02	908.57	0.45

Figure 7-55 Summary of Baseline Flows and Water Levels at Selected Key Locations

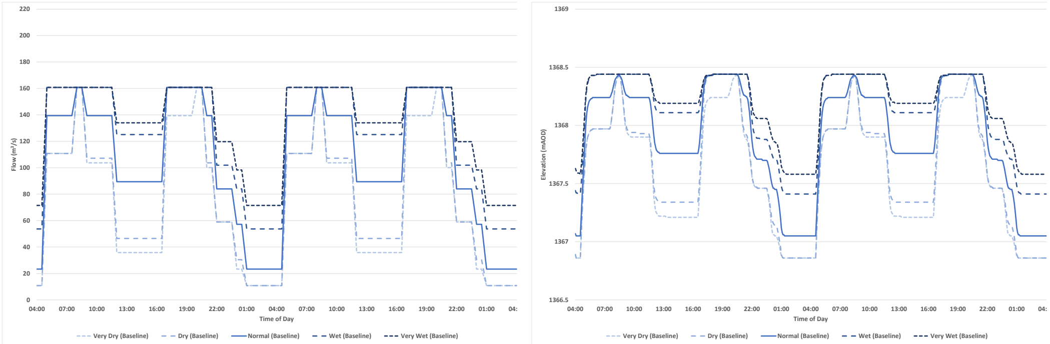
Location	Flow Range	15-min max. ramp-up rate (cm/min)	15-min max ramp-down rate (cm/min)	30-min max. ramp-up rate (cm/min)	30-min max ramp-down rate (cm/min)	60-min max. ramp-up rate (cm/min)	60-min max ramp-down rate (cm/min)
Ruzizi II dam wall / powerhouse release	"Very Dry" (95% exceedence)	3.3	-2.2	2.8	-1.8	1.8	-1.1
Downstream intervening catchment		6.5	-1.7	4.3	-1.6	2.3	-1.2
Ruzizi III powerhouse release		7.9	-0.9	4.4	-0.8	2.2	-0.8
Upstream Bugarama Bridge		8.7	-0.9	4.7	-0.8	2.4	-0.7
Upstream Rubyiro tributary		8.9	-0.8	5.1	-0.8	2.6	-0.7
Upstream Burundi border		5.7	-0.5	3.1	-0.5	1.6	-0.5
Downstream Burundi border		5.7	-0.5	3.1	-0.5	1.6	-0.5
Ruzizi II dam wall / powerhouse release	"Dry" (90% exceedence)	3.3	-1.9	2.8	-1.6	1.8	-1.0
Downstream intervening catchment		6.5	-1.5	4.3	-1.4	2.3	-1.0
Ruzizi III powerhouse release		7.8	-0.8	4.4	-0.8	2.2	-0.7
Upstream Bugarama Bridge		8.7	-0.8	4.7	-0.8	2.4	-0.7
Upstream Rubyiro tributary		9.0	-0.8	5.1	-0.8	2.6	-0.7
Upstream Burundi border		5.7	-0.5	3.1	-0.5	1.6	-0.4
Downstream Burundi border		5.5	-0.5	3.0	-0.4	1.5	-0.4
Ruzizi II dam wall / powerhouse release	"Normal" (50% exceedence)	3.0	-1.6	2.9	-1.4	2.0	-0.9
Downstream intervening catchment		5.7	-1.2	4.0	-1.1	2.2	-0.9
Ruzizi III powerhouse release		6.7	-0.7	3.8	-0.7	2.0	-0.6
Upstream Bugarama Bridge		7.9	-0.8	4.4	-0.7	2.2	-0.7
Upstream Rubyiro tributary		7.6	-0.8	4.7	-0.8	2.4	-0.7
Upstream Burundi border		5.0	-0.5	2.8	-0.4	1.4	-0.4
Downstream Burundi border		4.9	-0.5	2.8	-0.4	1.4	-0.4
Ruzizi II dam wall / powerhouse release	"Wet" (10% exceedence)	2.9	-1.7	2.5	-1.4	1.7	-0.9
Downstream intervening catchment		3.6	-1.2	2.8	-1.1	1.6	-0.8
Ruzizi III powerhouse release		3.7	-0.8	2.5	-0.7	1.4	-0.6
Upstream Bugarama Bridge		4.8	-0.9	3.0	-0.8	1.6	-0.7
Upstream Rubyiro tributary		4.6	-0.8	3.3	-0.8	1.8	-0.7
Upstream Burundi border		2.7	-0.5	1.9	-0.4	1.1	-0.4
Downstream Burundi border		2.7	-0.4	1.8	-0.4	1.0	-0.4
Ruzizi II dam wall / powerhouse release	"Very Wet" (5% exceedence)	2.5	-1.1	2.1	-1.0	1.4	-0.6
Downstream intervening catchment		2.6	-0.9	2.1	-0.8	1.3	-0.5
Ruzizi III powerhouse release		2.5	-0.6	1.8	-0.5	1.1	-0.4
Upstream Bugarama Bridge		3.1	-0.7	2.2	-0.6	1.3	-0.5
Upstream Rubyiro tributary		3.1	-0.6	2.4	-0.6	1.4	-0.5
Upstream Burundi border		1.7	-0.3	1.3	-0.3	0.8	-0.3
Downstream Burundi border		1.6	-0.3	1.2	-0.3	0.8	-0.3

Figure 7-56 Summary of Ramp-Up and Ramp-Down Rates at Selected Key Locations

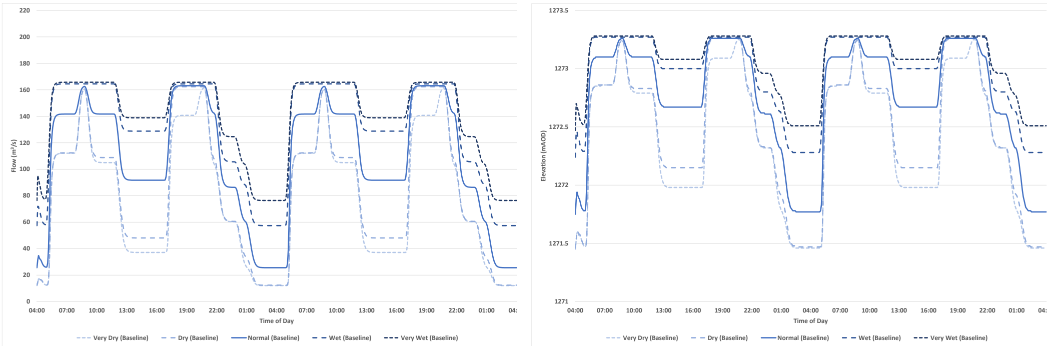
Figure 7-57 and Figure 7-58 provide a graphical summary of how flows and water levels vary over a 48-hour period at the selected key locations, for a variety of different inflow conditions ("very dry", "dry", "normal", "wet", and "very wet").

This complements the summary previously provided in tabular format and clearly shows the variation on daily flows and levels throughout the day, associated with the morning and afternoon peak power productions periods, and also provides a clear illustration of how daily water level variation is lower towards the downstream part of the reach, due in large part to the influence of tributary inflows.

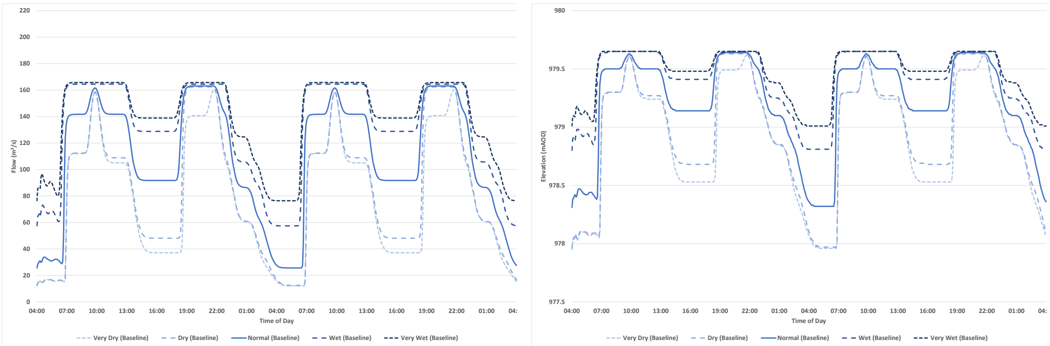
48-hour hydrographs (left) and limnigraphs (right) for different flow conditions



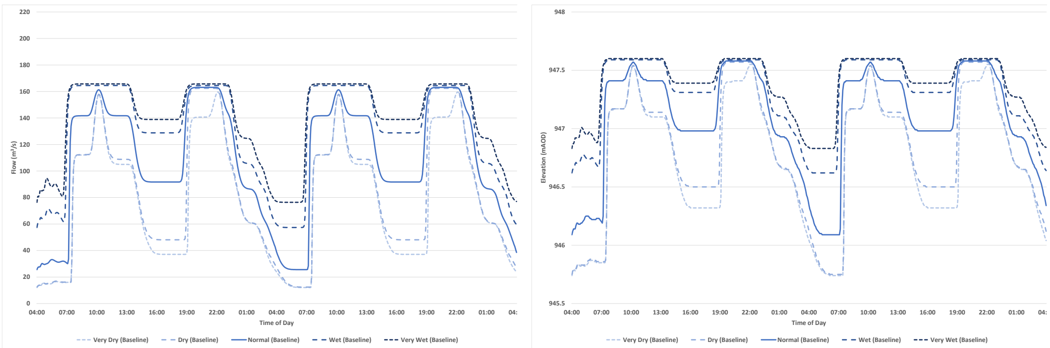
Downstream Ruzizi II dam wall / powerhouse release



Downstream intervening catchment



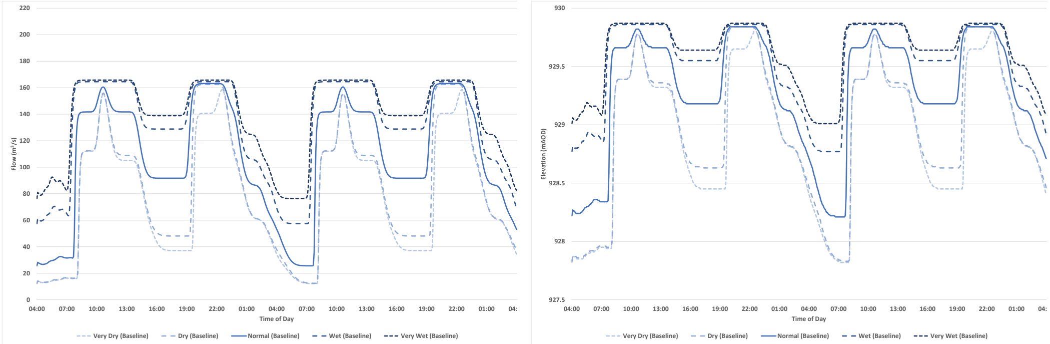
Downstream Ruzizi III powerhouse release location



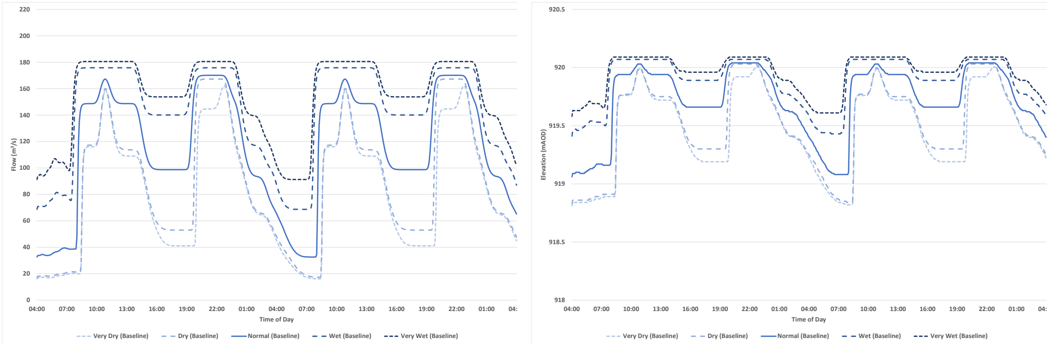
Upstream Bugarama Bridge / Kamanyola Monitoring Station

Figure 7-57 Modelled Flows and Elevations at Key Locations in the Ruzizi II – Burundi Border Reach (1/2)

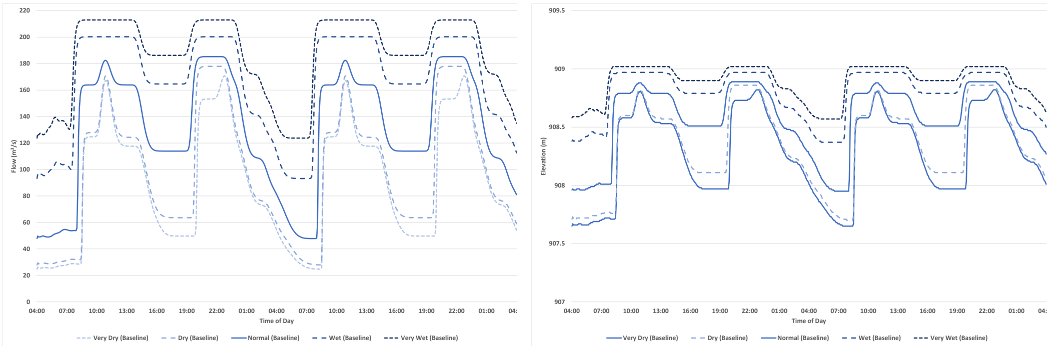
48-hour hydrographs (left) and limnigraphs (right) for different flow conditions



Upstream Rubyiro tributary



Upstream Burundi border / Ruhwa tributary



Downstream Burundi border / Ruhwa tributary

Figure 7-58 Modelled Flows and Elevations at Key Locations in the Ruzizi II – Burundi Border Reach (2/2)

7.6.4 Flood Risk

The 'Hydrology and Sedimentation Review' undertaken in 2020 as part of the Ruzizi III Feasibility Study summarises the key issues related to the current flood risk at the proposed Ruzizi III dam wall location, and hence its associated flood security. The Natural Resources Conservation Service (NRCS) Unit Hydrograph method and the Rational Method have been applied to estimate the flood hydrograph of the reservoir spillway design flood and check flood.

It is reported that the Unit Hydrograph Method has adopted use of CN=81 such that a runoff coefficient of 30% is defined. This has been applied to the intervening contributing catchments between Ruzizi I and II (26.7 km^2) and between Ruzizi II and III (173.6 km^2).

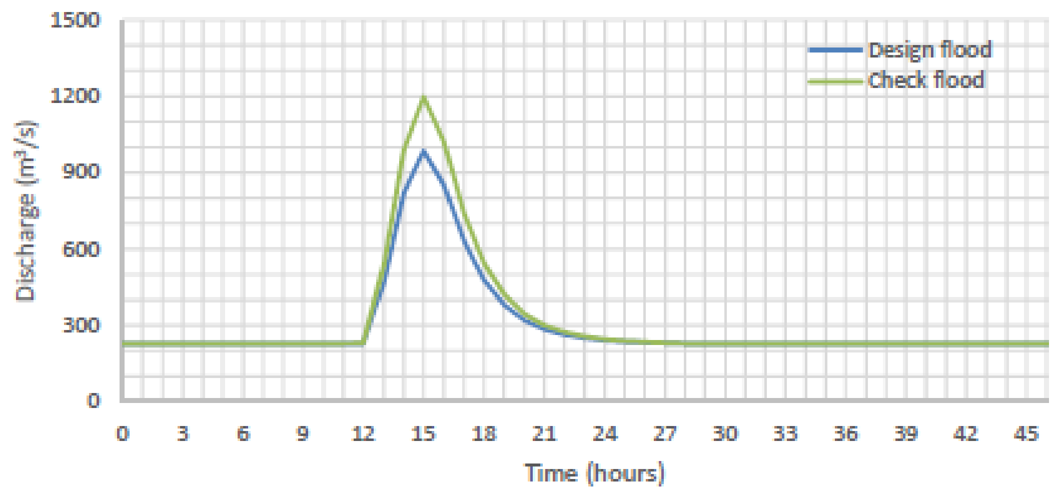
Rainfall Intensity-Duration-Frequency (IDF) curves based on data at Bugarama and Kamembe have been used, for a return period range of 2-years to 100-years. Rainfall depths for the 3-hour "critical storm" for the 10,000-year and 100,000-year return period events have been extrapolated from the IDF curves using a Gumbel distribution.

The intervening catchment floods are combined with the spill capacity of Ruzizi I (227 m^3/s) to provide an estimate of the "whole catchment" flood inflow hydrographs. Results summaries are presented for a range of return periods, the estimates for the design flood and check flood are as given in

Figure 7-59. It should be noted that flood peaks are largely dependent on flood estimates for the intervening catchments but flood volumes are more closely associated with the contribution from Ruzizi I.

Table 7-18 Discharge and Volume Characteristics of the Design and Check Floods

Flood	Q_{24h} (m^3/s)	Q_{3h} (m^3/s)	Q_p (m^3/s)	V_{24h} (hm^3)	V_{48h} (hm^3)	V72h (hm^3)	$V_{storage}$ (hm^3)
Design flood	362.9	884.8	985.7	31.4	51.0	70.6	2.0
Check flood	400.9	1,069.1	1,197.9	34.6	54.3	73.9	4.1
Source: Tractebel, 2020							



Global Hourly Hydrographs for the Design and Check Floods at Ruzizi III (Tractebel, 2020)

Figure 7-59 Summary of Ruzizi III Design Flood and Check Flood Estimates

It is reported that given a Ruzizi III design full release capacity of 700 m^3/s, flood storage of 2.0 hm^3 and 4.1 hm^3 is required to store the design and check floods.

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The 'Feasibility Study' itself reports that the Ruzizi III spillway has been designed based on a Design Flood of 986 m^3/s and a Safety Evaluation Flood of 1,420 m^3/s. That is, the Design Flood is based on the calculations presented above whereas the Safety Evaluation Flood also incorporates a "climate change" contribution, i.e., an 18% increase in peak flow (see 'Application of the Hydropower Sector Climate Resilience Guide' (Tractebel, August 2020)). An ungated labyrinth weir spillway has been designed to be located on the dam wall left abutment rock spur.

The flood estimates have been compared with preceding studies and have been considered comparable. However, it is noted that no attempt has seemingly been made to locally validate the estimates of design floods. There is both a large discrepancy in peak flow estimates between the Unit Hydrograph method and the Rational Method at a wide range of return periods (10-yr to 1,000-year) and a high degree of extrapolation uncertainty in the estimates of design flood and check flood rainfall totals.

It can also be noted that the Ruzizi III flood security estimates can be related to both the current baseline and future post-Ruzizi III downstream flood risk and impacts.

During the field mission undertaken in January 2022, it was also reported by local communities that flooding of riparian agricultural land occurs on a regular basis at various locations along the reach between Ruzizi III and the downstream tri-point border. For example, one report suggested annual short duration flooding a short distance upstream of the confluence with the River Rubyiro to a depth of approximately 0.7 m every April / May, resulting in extensive crop damage.

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7.7 Aquatic Ecology

The Aquatic Ecology Assessment was based on a desktop and field assessment approach. The methods used and the respective assumptions and limitations are provided in Annex D.

7.7.1 Regional Context

The Ruzizi River falls within two freshwater ecoregions: 1) Lake Victoria Basin; and 2) Lake Tanganyika Freshwater Ecoregion (FEOW 2020). The proposed HPP is located within the former, and includes the upper portion of the Ruzizi River, from Lake Kivu to ~90 river-km downstream, near the confluence of the Kagunizi River in Burundi. The lower ~40 km of the Ruzizi River falls within the Lake Tanganyika Freshwater Ecoregion (FEOW 2020).

The Lake Victoria Basin Freshwater Ecoregion supports a high diversity of freshwater fish, of which 79% are endemic to this ecoregion. The biological distinctiveness of this ecoregion is classified as "Globally Outstanding"; the global conservation status is classified as "Critical"; and conservation priority is classified as "Very High" (Table 7-19).

Table 7-19 Conservation Classification of the Lake Victoria Basin Freshwater Ecoregion

Biological Distinctiveness	Conservation Status	Priority Class
Globally Outstanding	**Critical**	**I – Very High**
Continentally Outstanding	Endangered	II – High
Bioregionally Outstanding	Vulnerable	III – Moderate
Nationally Important	Relatively Stable	IV – Low
	Relatively Intact	V – Very Low

Source: Oyugi and Chapman (2008)

Lake Victoria is the centre of fish diversity and endemism for this ecoregion, with the total number of fish species found here being estimated at over 600. All but four of these are haplochromine cichlids and several hundred have yet to be undescribed (Sayer, Máiz-Tomé, *et al*. 2018). Predation by Nile perch (*Lates niloticus*) following their introduction in the 1980s, compounded by habitat degradation in the wider basin, are believed to have driven around 200 of these species to extinction. The rivers draining into Lake Victoria, the largest being the Kagera, support a lower diversity of river-adapted fauna.

The Ruzizi River flows from Lake Kivu into Lake Tanganyika, and the fish composition is characterised by species from these two lakes rather than species from Lake Victoria. Lake Tanganyika is the oldest (9-12 million years (MY)) of the two, and because of its depth, one of the most stable lakes in Africa (Cohen, Soreghan, *et al.* 1993). As a result, its cichlid fauna has undergone explosive adaptive radiation and speciation, supporting a genetically, morphologically, ecologically and behaviourally more complex and diverse cichlid flock than elsewhere in Africa (Salzburger, Meyer, *et al*. 2002). Indeed, the haplochromine cichlids are believed to have originated in Lake Tanganyika and seeded other water bodies in Africa, including Lakes Malawi and Victoria (Pauquet, Salzburger, *et al*. 2018). Of the 287 fish species found in the lake, 57 are cichlids, of which 49 are endemic (Abell, Thieme, *et al*. 2008). Because of its linkage via the Lukuga River to the Congo Basin, the fish fauna of the Ruzizi Basin bears many affinities with the Congo basin.

Lake Kivu has a lower fish diversity (29 species, including five introduced species) compared with either of the Lakes Tanganyika or Victoria (Snoeks, Kaningini, *et al.* 2012). The paleolimnology of the Lake Kivu shows that it was much less stable than Lake Tanganyika and that it initially drained north towards Lake Edward and the Nile River basin during the Pleistocene. However, uplift resulting from the Virunga volcanoes likely caused it to become endorheic until the link via the Ruzizi River to Lake Tanganyika became established (Haberyan and Hecky 1987, Snoeks, Kaningini, *et al*. 2012). As a result, and

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because of Lake Tanganyika's links to the Congo Basin, it is now part of the latter's drainage. The earlier link to the Victoria Basin explains why the lake's fish species community more closely resembles the latter basin's fauna more so than it does the Tanganyikan or Congo faunas (Snoeks, Kaningini, *et al*. 2012). This explains the presence of species such as *Enteromius kerstenii,* which is found in Lake Kivu, the Ruzizi River as well as the middle Kagera River in the Lake Victoria Basin. Like the other lakes in the region, Lake Kivu was affected by a period of aridity 10,000-15,000 years ago, and while not completely drying out, high salinity levels may have contributed to the lower diversity of fish currently found (Snoeks, Kaningini, *et al*. 2012).

The river fish fauna differs from either of the two lake's fish fauna in composition and structure, with a higher proportion of rheophilic (flowing water) species, such as the Amphiliid and Mochokid catfish, together with the larger rheophilic cyprinids (*Labeobarbus* species). The cichlids which occur in the river are either likely to be incidental, or those species better adapted to rheophilic conditions. Historically, the Ruzizi has been an important dispersal corridor between Lakes Kivu and Tanganyika for species like the Lake Rukwa minnow (*Raiamas moorii*), which is thought to have colonised Lake Kivu from Lake Tanganyika, and the Ripon barbel (*Labeobarbus altianalis*), which is thought to have colonised in the opposite direction (Snoeks, Kaningini, *et al*. 2012). This latter species is also found in the Victoria Basin, suggesting the common drainage this basin once shared with Lake Kivu.

7.7.2 Hydrogeomorphological Types

Three hydrogeomorphic aquatic ecosystem types were identified within the Project AoI: two in the Ruzizi River, and one in a tributary, as follows:

Type:	**1) Transitional Zone (Ruzizi River)**
Description:	Mostly a single, confined channel, but anastomosed in places (Figure 7-60)
Width:	20 to 60 m wide, but anastomosed areas up to 300 m wide
Gradient:	0.0238 to 0.0244 (moderate)
Sites:	R01 to R10 (i.e. the Full Supply Level, proposed dam and tailrace outlet)
Substrates:	see below
Soils:	Umbric Acrisols (left bank), which are characterised by acidic conditions, low nutrients; and with clay-rich subsoil; and Umbric Ferrasols (right bank), which are leached soils characterized by low nutrients (Jones *et al.* 2013).

Substrate	Rating
Gravel - F (2-8)	0
Gravel - M (8-16)	2
Gravel - C (16-64)	3
Cobble - Small (64-128)	3
Cobble - Large (128-250)	4
Boulder - Small (250-500)	5
Boulder - Medium (500-1000)	2
Boulder - Large (1000-4000)	1
Bedrock	2
Waterfall	0

Rating categories

0 = not present
1 = rare (>0–5%)
2 = sparse (>5–25%,)
3 = common (>25–50%)
4 = abundant (>50–75%)
5 = predominant (>75–95%)
6 = near-entire (>95–100%)

Figure 7-60 Hydrogeomorphological Types - Transitional Zone

Type:	**2) Upper Foothill (Ruzizi River)**
Description:	Mostly a single, unconfined channel, but with multiple channels in places (Figure 7-61)
Width:	Mostly 30 to 60 m wide, but up to 200 m wide in areas with islands
Gradient:	0.0059 (gentle)
Sites:	R12 to R14 (downstream of the proposed HPP)
Substrates:	(see table below)
Soils:	Undifferentiated Nitisols, which are deep red soils with well-developed structure and derived from iron-rich rocks, such as basalt (Jones *et al.* 2013).

Substrates:

Substrate	Rating
Sand - Fine (0.125-0.5)	2
Sand - Coarse (0.5-2.0)	0
Gravel - F (2-8)	1
Gravel - M (8-16)	1
Gravel - C (16-64)	2
Cobble - Small (64-128)	2
Cobble - Large (128-250)	4
Boulder - Small (250-500)	4
Boulder - Medium (500-1000)	0
Boulder - Large (1000-4000)	0
Bedrock	0
Waterfall	0

Rating categories

0 = not present
1 = rare (>0–5%)
2 = sparse (>5–25%,)
3 = common (>25–50%)
4 = abundant (>50–75%)
5 = predominant (>75–95%)
6 = near-entire (>95–100%)

Figure 7-61 Hydrogeomorphological Types - Upper Foothill Zone

Type:	**3) Mountain Headwater (Tributary)**
Description:	Small tributary of the Ruzizi River on the left bank (Rwanda), comprising a single, confined channel (Figure 7-62). These tributaries were mapped but they were too narrow to map instream habitats.
Width:	Mostly 2 m wide
Gradient:	0.283 (steep)
Sites:	T1, within the proposed Full Supply Level
Substrates:	(see below)
Soils:	Umbric Acrisols (left bank), which are characterised by acidic conditions, low nutrients and with clay-rich subsoil (Jones *et al.* 2013)

Substrates:

Sand - Fine (0.125-0.5)	3
Sand - Coarse (0.5-2.0)	2
Gravel - F (2-8)	1
Gravel - M (8-16)	2
Gravel - C (16-64)	3
Cobble - Small (64-128)	3
Cobble - Large (128-250)	4
Boulder - Small (250-500)	4
Boulder - Medium (500-1000)	2
Boulder - Large (1000-4000)	2
Bedrock	2
Waterfall	0

Rating categories

0 = not present
1 = rare (>0–5%)
2 = sparse (>5–25%,)
3 = common (>25–50%)
4 = abundant (>50–75%)
5 = predominant (>75–95%)
6 = near-entire (>95–100%)

Figure 7-62. Hydrogeomorphological Types - Mountain Headwater

A further three hydrogeomorphic types were recorded in tributaries, as listed in Annex D, but these were not detailed further for the purposes of this report as they were outside the Project AoI.

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7.7.3 Aquatic Biotopes

Aquatic biotopes within the three hydrogeomorphic zones were dominated by following depth-flow categories (Figure 7-63):

Transitional Zones (R01 to R10)	Upper Foothill (R12 to R14)	Mountain Headwater (T1)
• Deep – Very Fast (cascades) • Deep – Fast (rapids) • Deep – Slow (pools)	• Deep – Fast (rapids) • Shallow – Slow (runs)	• Shallow – Fast (Note: these were too narrow to map)

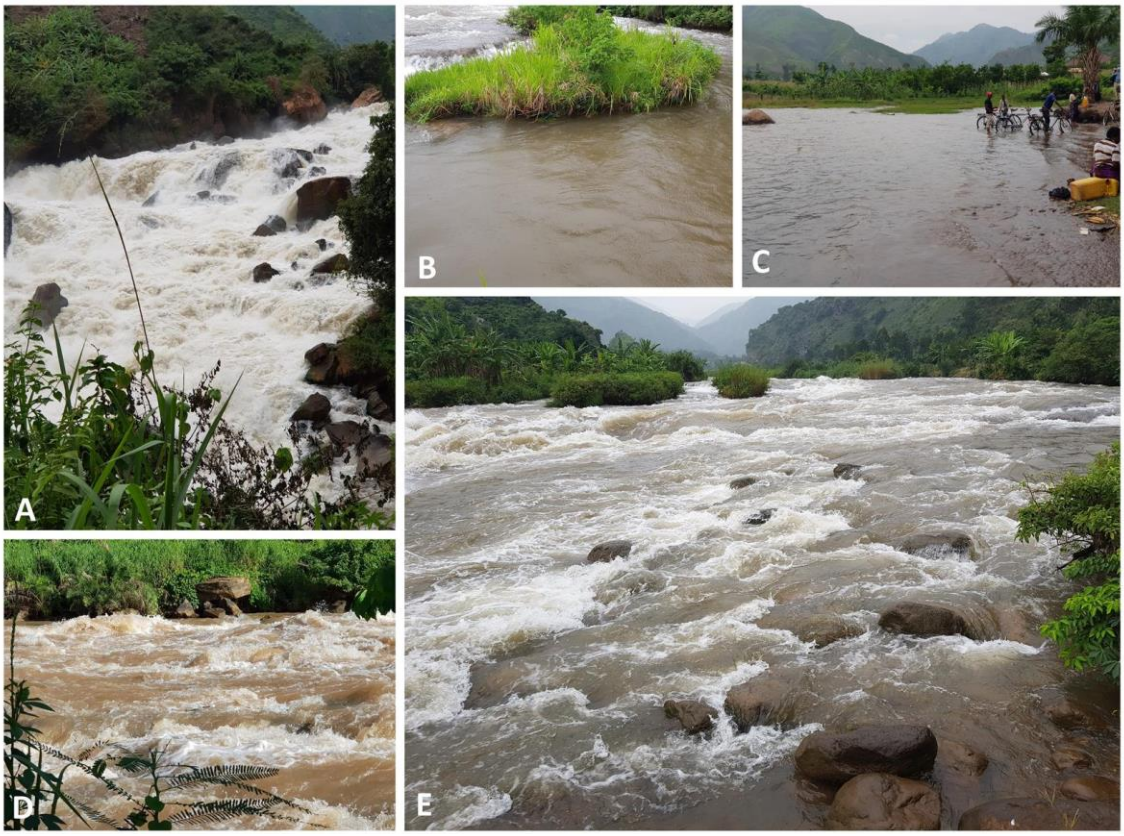

Figure 7-63 Aquatic Biotope Depth-Flow Categories in the Ruzizi River

[A) Deep-Very Fast; B) Deep-Slow; C: Shallow-Slow; D) Deep-Fast; E) Shallow-Fast]

7.7.3.1 Distribution of Aquatic Biotopes

Aquatic biotopes within the Full Supply Level of the proposed HPP reservoir comprised the following (Figure 7-64):

- One stretch of Deep-Very Fast Cascade, extending for ~650 m, and sufficient to present a potential natural barrier to upstream migration of some species of fish.
- Two areas of Shallow-Fast Riffle, which are likely to be important spawning areas for *Labeobarbus* species.
- Two stretches of Deep-Fast Rapids, with a total length of ~1,600 m.

Aquatic biotopes within the dewatered area of the proposed HPP comprised the following (Figure 7-65):

- Five stretches of Deep-Very Fast Cascade, with a total length of ~1,600 m.
- Seven stretches of Deep-Fast Rapids, with a total length of ~2,700 m.

- One area of Shallow-Fast Riffle, ~600 m downstream of the proposed HPP, which is likely to be important spawning areas for *Labeobarbus* species.
- Two stretches of Deep-Slow Pools, with a total length of ~1,200 m.

Aquatic biotopes downstream of the proposed tailrace outlet comprised the following (Figure 7-66):

- Mostly Deep-Fast Rapids.
- One area of Deep-Flow Pool.
- One area of Shallow-Fast Riffle, ~4,300 m downstream of the proposed tailrace outlet.

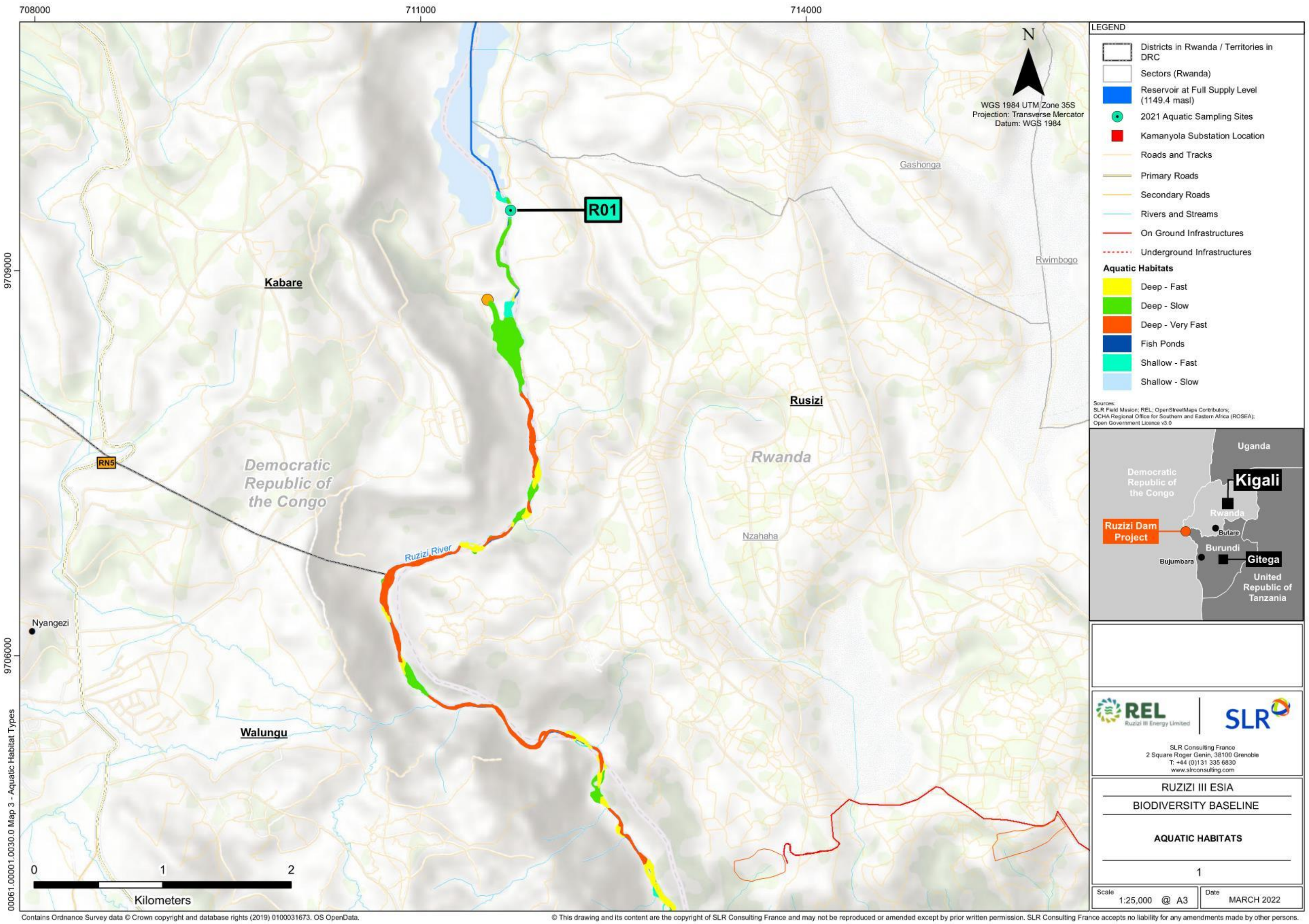

Figure 7-64 Aquatic Biotopes Within the Ruzizi River Upstream of the Ruzizi III Reservoir

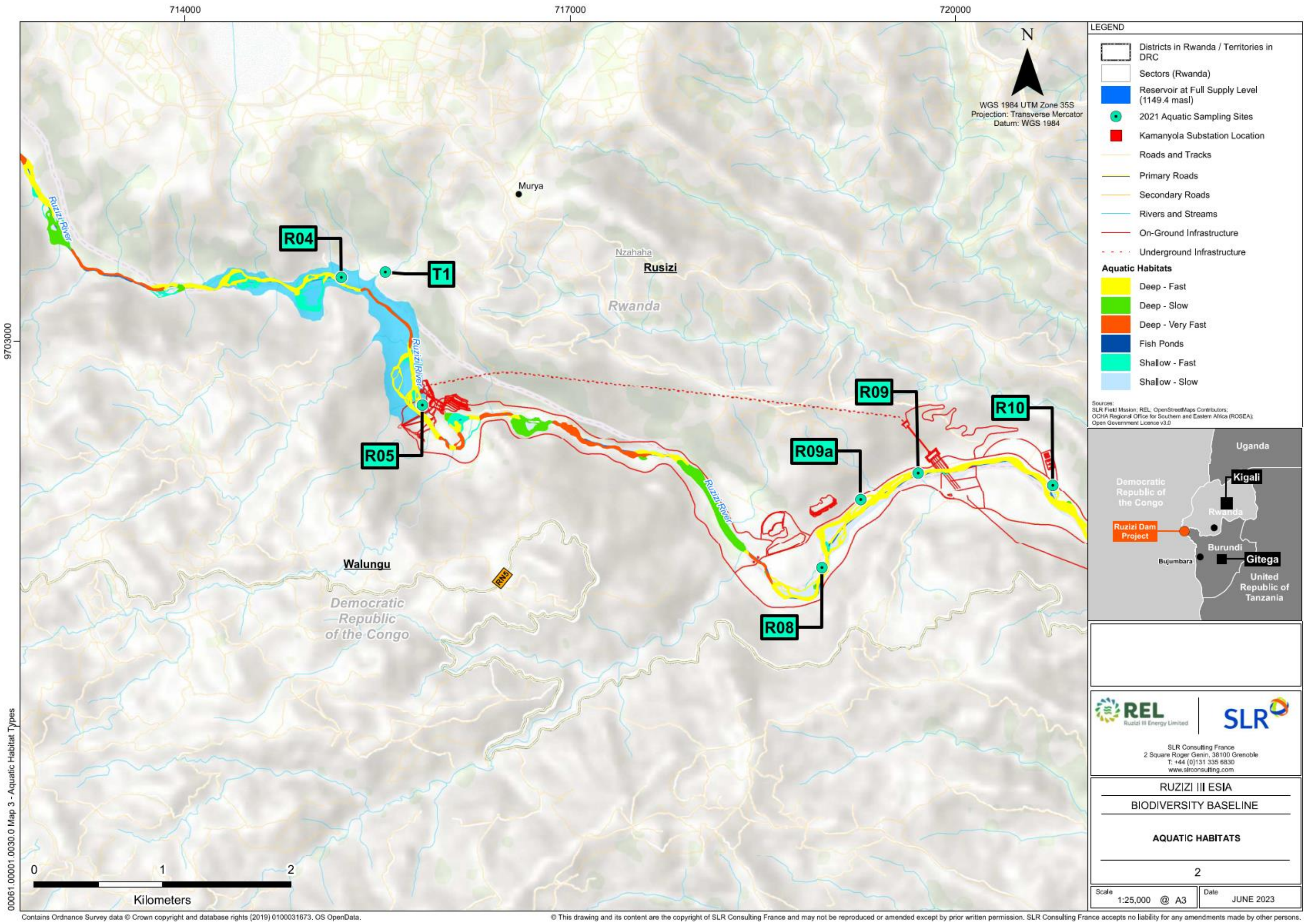

Figure 7-65 Aquatic Biotopes Within the Ruzizi III Reservoir and Dewatered Reach
Note: Proposed Ruzizi III Dam is at survey site R05, while tailrace outlet lies between R09 and R10

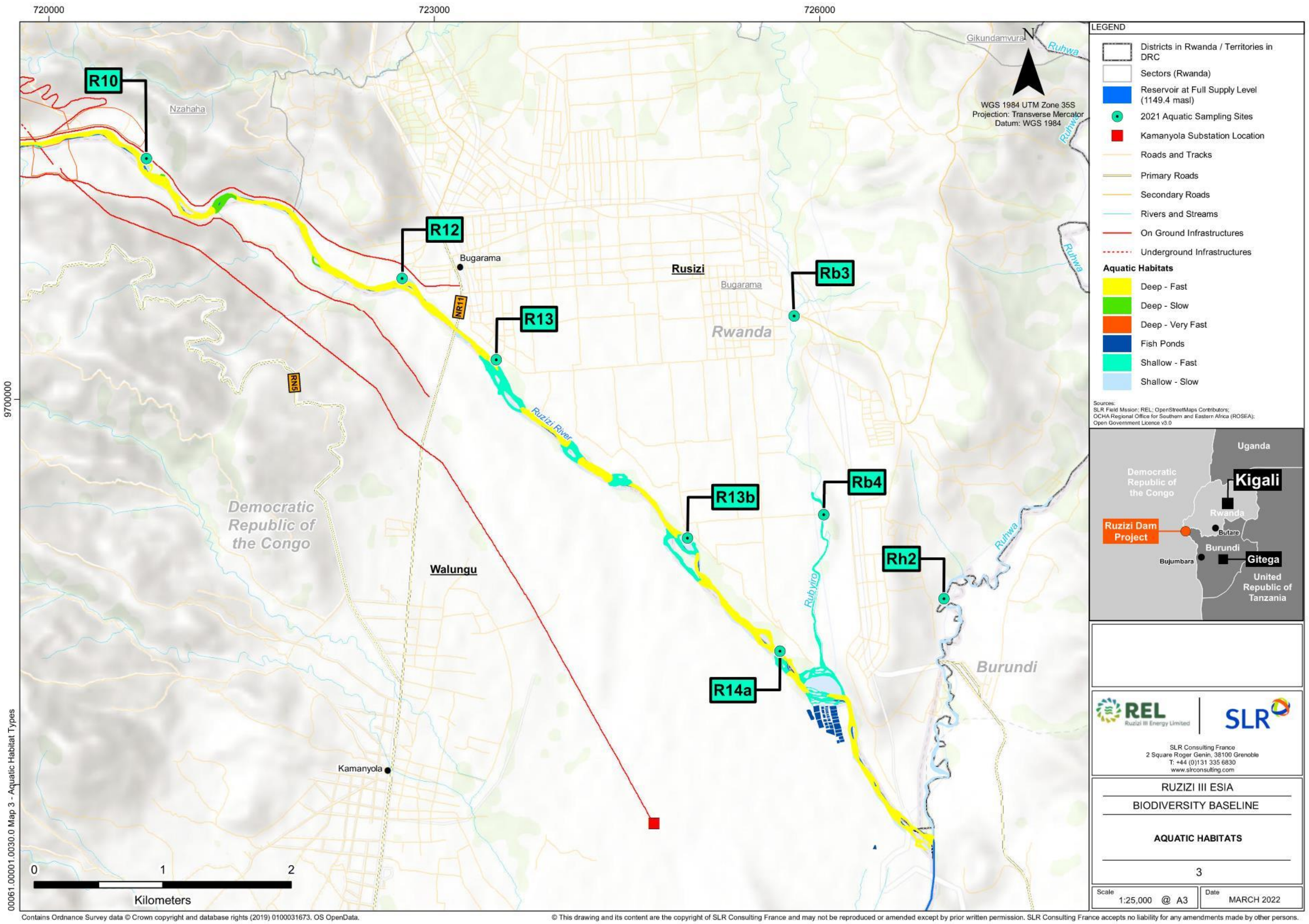

Figure 7-66 Aquatic Biotopes Downstream of the Powerhouse and the Burundi Border

7.7.3.2 Water Levels

Water levels in the Ruzizi River during the field survey in January 2022 were high for most of the survey period, but there were short periods of lower water level, when turbines at Ruzizi II were closed. A sudden short-term drop in water level was noted at the permanent stage at S2.696590, E28.962200, on 21 January 2022. The water level at this site dropped from 2.65 to 2.53 m (12 cm) in about 40 minutes between ~15h20 and 16h00 (Figure 7-67).

Figure 7-67 Water Level in the Ruzizi River at 16h00 on 21 January 2022

7.7.3.3 Water Quality

Water in the Ruzizi River in January 2022 was light brown and had low to moderate turbidity that ranged between 5 and 39 NTU (Table 7-20). The pH was alkaline and ranged between 8.8 and 8.9 (Table 7-20). Conductivity was elevated and ranged between 105 and 108 mS/m (Table 7-20). Similar results were reported previously (Sher 2020, Mulungula 2020).

Table 7-20 Field Water Quality Results

Code	Colour	Turbidity (NT)	pH	Conductivity (mS/m)	Date
Ruzizi River					
R04 [#]	Light Brown	5	8.8	105	2022/01/20
R09	Light Brown	15	8.8	108	2022/01/21
R12	Light Brown	39	8.8	108	2022/01/12
R13	Light Brown	8	8.8	110	2022/01/22
R14a	Light Brown	7	8.9	108	2022/01/22
Tributaries					
Rb4	Reddish-Brown	107	7.5	27	2022/01/22
Rh2	Reddish-Brown	757	7.6	8	2022/01/23

Water in the lower Rubyiro River at Rb4 on 22 January 2022 was reddish-brown and had elevated turbidity of 107 NTU (Table 7-20). The pH was circum-neutral at 7.5, and conductivity was moderate at 27 mS/m (Table 7-20).

Water in the lower Ruhwa River at Rh2 on 23 January 2022 was reddish-brown and had extreme elevated turbidity of 757 NTU (Table 7-20). The pH was circum-neutral at 7.6, and conductivity was low at 8 mS/m (Table 7-20).

7.7.4 Benthic Diatoms

Diatom analysis results are summarised in Table 7-21. Detailed results are presented in Annex D.

Table 7-21 Summary of Diatom Results

Code	No of Species	SPI Score	PTV (%)	Deformities (%)	Class	Category
R01	31	6.8	5.5	0	Poor	D/E
R04	10	7.4	0.3	0	Poor	D/E
R09	17	5.5	7.8	0	Bad	E

SPI = Specific Pollution Index; BDI=Biological Diatom Index; PTV=Pollution Tolerant Valves

Site R01

The SPI Score at Site R01 in January 2022 was 6.8 (D/E Ecological Category). Biological water quality prevailing at the time of sampling was *Poor.* While organic load was low, nutrient levels and salinity concentration was elevated. Nutrient levels had the biggest influence on diatoms at this site. Further analysis of the various indices within OMNIDIA suggested that pollution levels were moderate. Species diversity was the highest of the three sites sampled. *Luticola* species occurred at highest abundance and suggested that sedimentation rates were high. *Luticola* species are mostly found in terrestrial and sub-aerial habitats and washed into streams when flow increases. The dominance of motile species within the diatom community, suggested that nutrients were elevated and most probably increasing, as motile species are superior competitors for nutrients in nutrient-rich environments and can physically avoid stress within the benthic mat by moving to resource-rich microhabitats (Passy *et al*. 2007). The dominance of *Nitzschia* species and *Amphora pediculus* reflected the nutrient-rich conditions. According to Cholnoky (1968), *Nitzschia* species are abundant in waters with readily available nutrients. *Amphora pediculus* has an optimum for total nitrogen, total phosphorus and dissolved oxygen concentrations (DOC) of 1.99 mg/L, 0.05 mg/L, and 1.46 mg/L, respectively (Tan *et al*. 2014). Valve deformities were absent, suggesting that metal toxicity was below detection limits.

Site R04

The SPI Score at Site R04 in January 2022 was 7.4 (D/E Ecological Category). Biological water quality prevailing at the time of sampling was *Poor.* While organic load was low, nutrient levels and salinity concentrations were high. Nutrient levels had the biggest impact on the site and increased from Site R01. Further analysis of the various indices within OMNIDIA suggested that pollution levels were large and increased from Site R01. Species diversity was the lowest of the three sites sampled. *Luticola* species dominated the diatom community by 67%, suggesting sudden flow fluctuation and high sedimentation rates. As observed at Site R01, motile species were prolific, with *Nitzschia* species dominating. This reflected high nutrient levels that increased between Site R01 and R04. Valve deformities were absent, suggesting that metal toxicity was below detection limits.

Site R09

The SPI Score at Site R09 in January 2022 was 5.5 (E Ecological Category). The water quality prevailing at the time of sampling was *Bad* and ecologically unacceptable. Organic load was the highest at this site compared to the other two sites sampled. The data suggested that salinity concentration and nutrient levels increased to levels that were concerning. Further analysis of the various indices within OMNIDIA suggested that pollution levels were serious, increasing from Site R04. Species composition was similar to Sites R01 and R04, with *Luticola* and *Nitzschia* species dominating. The abundance of *Luticola* species decreased between Site R04 and R09, suggesting that sediment loading decreased between the sites. However, nutrient levels increased notably and were reflected by the increased abundance of *Nitzschia* species at Site R09. *Nitzschia palea* was sub-dominant and is typical of phosphate enriched or organically polluted waters (Teply and Bahls, 2006). According to Davey *et al.* (2008) this species has an optimum filterable phosphorus between 0.35 and 1 mg/L and can tolerate a broad range of phosphorus concentrations. Valve deformities were absent, suggesting that metal toxicity was below detection limits.

7.7.5 Aquatic Flora

Submerged vegetation in the main channel of the Ruzizi River comprised extensive mats of the filamentous alga *Cladophora glomerata* (Figure 7-68 A). This species is the most abundant alga in alkaline streams and rivers throughout the world, and is typically associated with polluted conditions, especially elevated concentrations of phosphate (Burkholder 2009). This plant was evident on the stream bed when flows were dropped on the 27 February 2022, and this indicated that the riverbed was not light-limited. This plant appears to be the most important primary producer in the Ruzizi River, and as such, constitutes the base of the aquatic food chain. The food chain in the Ruzizi River therefore is founded mainly on a monoculture of this species, which is typically associated with ecological disturbance, such as pollution.

The filamentous cyanobacterium *Phormidium* sp. was also noted at most sites in the Ruzizi River, but in lower abundance than *C. glomerata* (Figure 7-68 B). This genus is typically associated with polluted water with elevated concentrations of nutrients (Soltani *et al*. 2012). The river margins and bed were also colonised by patches of the aquatic moss *Barbula* sp. (Figure 7-68 C). There was a notable absence of floating weeds, such as water hyacinth, *Pontederia crassipes.*

There was no evidence of any Podomastaceae aquatic plants on rocks at any of the surveyed sites. Only one species of this family – *Tristicha trifaria* – which is IUCN listed as Least Concern and based on GBIF records is recorded in the Ruzizi River basin with no specific records from the Ruzizi River itself.

Figure 7-68 Aquatic Vegetation in the Main Channel and Margins of the Ruzizi River
[A) *Cladophora glomerata* (Cladophoraceae); B) *Phormidium sp.* (Phormidiaceae); C) *Barbula sp.* (Pottiaceae)]

Emergent vegetation was dominated by the reed *Phragmites mauritianus.* Slow-Shallow margins of the Ruzizi River supported growth of various submerged or emergent herbs and grasses, and included Sago weed *Stuckenia pectinata*, *Ludwigia* cf. *palustris*, *Setaria geminata*, and the alien grass *Paspalum notatum* (Figure 7-68). There were also small patches of the alien sedge *Cladium mariscus* (Cyperaceae).

The wetland habitats within the river and along the river margins were typically small with several used for agriculture (where accessible during low flow) or for fish farming. These wetlands are subject to regular daily hydropeaking from upstream hydropower plants, and none were considered ecologically significant. Riparian wetland vegetation is discussed in Section 7.8.3.2.

Figure 7-69 Aquatic Vegetation in Shallow-Slow Margins of the Ruzizi River
[A) *Stuckenia pectinata* (Potamogetonaceae); B) *Ludwigia cf. palustris* (Onagraceae); C) *Setaria geminata* (Poaceae); D) *Paspalum notatum* (Poaceae).]

7.7.6 Aquatic Macroinvertebrates

Aquatic macroinvertebrates recorded during the field surveys in January and February 2022 are listed in Annex D. The following section presents and discusses the results.

7.7.6.1 Diversity

The diversity of aquatic macroinvertebrates recorded in the Project AoI during the field surveys in 2022 was very low. The composition of taxa was dominated by true flies (Diptera), which comprised eight families; dragonflies and damselflies (Odonata), which comprised five families; and mayflies (Ephemeroptera), which comprised four families. The diversity of hydraulic habitats was high, and although the stream bed was largely embedded, there was sufficient instream habitat available to support a high diversity of macroinvertebrates. The low diversity of aquatic macroinvertebrates is attributed mainly to the impacts of short-term variations in water level associated with the operation of Ruzizi II. The lower diversity may also be attributed, in part, to the abundance of the filamentous alga *Cladophora glomerata,* which is likely to be unpalatable to many grazing macroinvertebrates. Furthermore, naturally elevated concentrations of salts may have contributed to the low diversity of macroinvertebrates by eliminating some of the more sensitive taxa, such as mayflies (Oligoneuridae).

7.7.6.2 Abundance

The abundance of aquatic macroinvertebrates recorded in the Project AoI during the field surveys in 2022 was very low, even when water levels were dropped on the 27 February 2022 to enable sampling on this day. The most common taxa were non-biting midges (Chironomidae), and the Stonefly *Neoperla spio* complex (Perlidae). The low abundance of aquatic macroinvertebrates is attributed to the impacts of short-term variations in water level associated with the operation of Ruzizi II. The fauna was characterised by taxa with moderate lifecycles (3-6 months). This suggests that ecological conditions were stable, and that the low abundance constituted typical conditions rather than a response to recent change. An implication of the low abundance of macroinvertebrates is that there was very little for insectivorous fish to feed on.

7.7.6.3 Present Ecological State

A Ruzizi River

The balance of evidence collected in January and February 2022 indicated that the Present Ecological State (PES) of aquatic macroinvertebrates in the Project AoI was *Seriously Modified* (Category E). This conclusion was based on the following lines of evidence: 1) SASS5 Data; 2) Indicator Species; 3) Drifting Stages; 4) Adult Odonata (RDBI); and 5) Malaise (Insect) Trap Data.

The findings of this assessment were compared with the study undertaken by Dusabe *et al.* (2022) to evaluate the influence of the existing Ruzizi I and Ruzizi II HEPP. The study sampled the macroinvertebrate community at eight stations from December 2015 to August 2017 every three months to cover both wet and dry seasons. Samples were collected at sites upstream and downstream of Ruzizi I and Ruzizi II. Additional samples were collected further downstream of Dam II at Manda/Ngomo and Kamanyola. The findings of the study were in alignment with this assessment, wherein the Ruzizi supports a low diversity of macroinvertebrates. The study confirmed the presence of more pollution tolerant species and scarcity of sensitive species upstream and downstream of Ruzizi I and II dams. It attributed the low macroinvertebrate diversity to a combination of naturally saline water from Lake Kivu, the effect of hydropeaking dams and riverbank disturbance and domestic pollution. Lake Kivu is a species-poor lake because of its geological history and catastrophic volcanic events that affect also its current limnology, and consequently the lake's environmental condition affects the Ruzizi River

The paper argues that there is no significant difference in macroinvertebrates between impounded and riverine habitats. However, the data is not directly comparable between the upstream Ruzizi River with its two impoundments and the downstream river partly due to the effect of more saline water from Lake Kivu but also because sampling methods used in the reservoir are not appropriate for standing water. The results actually appear to suggest that the low diversity in both dams and rivers in the upper Ruzizi may reflect the impact of dams on the downstream reach. The paper does not change the findings of this report that assess the Middle Ruzizi River as Modified Habitat as the data on fish and inverts indicate that the primary ecological functions and species composition are fundamentally modified by human activity.

A.1 *SASS5 Data Field Survey 1*

Sampling macroinvertebrates in January 2022 was limited by high water levels such that it was not possible to apply the South African Scoring System (SASS5) to each site that was sampled. However, an approximate SASS5 Score for the Project AoI was derived by pooling the data from all the sites that were sampled. Detailed results of this analysis are presented in Annex D. The results indicated seriously modified conditions for aquatic invertebrates. A total of 22 SASS5 taxa was recorded, and these gave an approximate SASS5 Total Score of 124, and an approximate Average Score per Taxon (ASPT) of 5.6. Sixteen (16) of the 22 SASS5 taxa recorded (i.e. 73%) are classified as tolerant or highly tolerant of water quality deterioration (sensitivity value <7). The most sensitive taxon recorded was the Stonefly *Neoperla spio* (Plecoptera), which has a sensitivity rating of 12/15. The most common taxa recorded were non-biting midges (Chironomidae), which have a low SASS5 sensitivity rating of 2/15. The Proportion of Sediment-Sensitive taxa (PSI) was low (0.3), indicative of elevated suspended sediments. The proportion of air-breathing taxa was moderate (18%), and this is higher than expected for a river that appears to be well-oxygenated. Functional feeding groups comprised a dominance of predators (43%), and this is typically associated with disturbance and an ecosystem that is in poor health. The ecological system therefore appeared to be functionally compromised. However, no alien macroinvertebrate taxon was recorded.

A.2 *SASS5 Data Field Survey 2*

SASS5 was applied to data on macroinvertebrates collected at Bugarama (Site R12) when water levels were dropped on the 27 February 2022. Detailed results of this analysis are presented in Annex D. The results indicated seriously modified conditions, and this confirmed the results from the previous survey. A total of 11 SASS5 taxa was recorded, and these gave a Total Score of 58, and an approximate Average Score per Taxon (ASPT) of 5.3. Eight of the eleven SASS5 taxa recorded (i.e. 73%) are classified as tolerant or highly tolerant of water quality deterioration (sensitivity value <7). The most sensitive taxon recorded was the Stonefly *Neoperla spio* (Plecoptera), which has a sensitivity rating of 12/15. Abundances of all taxa were very low, except for Stonefly, which was common. The Proportion of Sediment-Sensitive taxa (PSI) was low (0.5), and this suggests suspended sediments were moderately elevated. The proportion of air-breathing taxa was moderate (18%), and the same as the pooled data from the previous survey. Functional feeding groups were dominated by predators (58%), and this is typically associated with an ecosystem that is disturbed and in poor health. The ecological system therefore appeared to be functionally compromised. However, no alien macroinvertebrate taxon was recorded.

1) <u>Indicator Species</u>

Four species of macroinvertebrates that are typically associated with modified habitats were recorded as follows:

- Baetis harrisoni, a mayfly (Ephemeroptera) species that is highly tolerant of water quality deterioration and typically associated with polluted urban streams;
- Simulium hargreavesi, a blackfly (Simuliidae) that is typically associated with impoundment outlets and seasonal streams;
- Simulium adersi, a blackfly (Simuliidae) that is typically associated with slow-flowing polluted streams; and
- *Palpopleura lucia*, a dragonfly (Libellulidae), that is typically associated with open, standing or temporary wetlands.

2) <u>Drifting Stages</u>

No drifting macroinvertebrates were recorded in the water column, indicating that macroinvertebrate populations were low, and the aquatic ecosystem was in poor health.

3) Adult Odonata

The Rwandan Dragonfly Biotic Index (RDBI) was applied to the combined data on Odonata species collected from the Ruzizi River in January 2022 to derive an approximate RDBI Score. A total of 11 species of Odonata was recorded, and these gave a Total Score of 23, and an approximate RDBI Score of 2.1. The result indicated that the Ruzizi River ecosystem was in poor health.

4) Malaise Trap

A baited malaise trap set ~200 m from the Ruzizi River for five days caught large numbers of terrestrial flies, flying ants and wasps, but aquatic insects were largely absent. Aquatic insects trapped included mostly non-biting midges (Chironomidae), biting midges (Ceratopogonidae), micro-caddis (Hydroptilidae), Hydropsychid caddis (*Hydropsyche* sp.), and blackflies (Simuliidae). The result provided further evidence that the Ruzizi River ecosystem was in poor health.

B Mountain Headwaters

The Present Ecological State of the Mountain Headwater site at T1 in the Ruzizi III reservoir area in January 2022 was considered *Largely Modified*. The stream supported a low diversity of macroinvertebrates (four taxa only). The low diversity of macroinvertebrates is attributed to elevated concentrations of suspended material associated with subsistence agriculture in the catchment.

7.7.6.4 Ecological Sensitivity

Data collected in January and February 2022 indicated that the Ecological Sensitivity of aquatic macroinvertebrates in the Ruzizi River was *Low*. This conclusion was based on composition of taxa that were recorded during the field surveys (listed in Annex D).

A Segmented Worms (Annelida)

Five species of segmented worms were recorded, four in the Ruzizi River and one attached to a catfish (*Clarias gariepinus*) in the Rubyiro River (Figure 7-70).

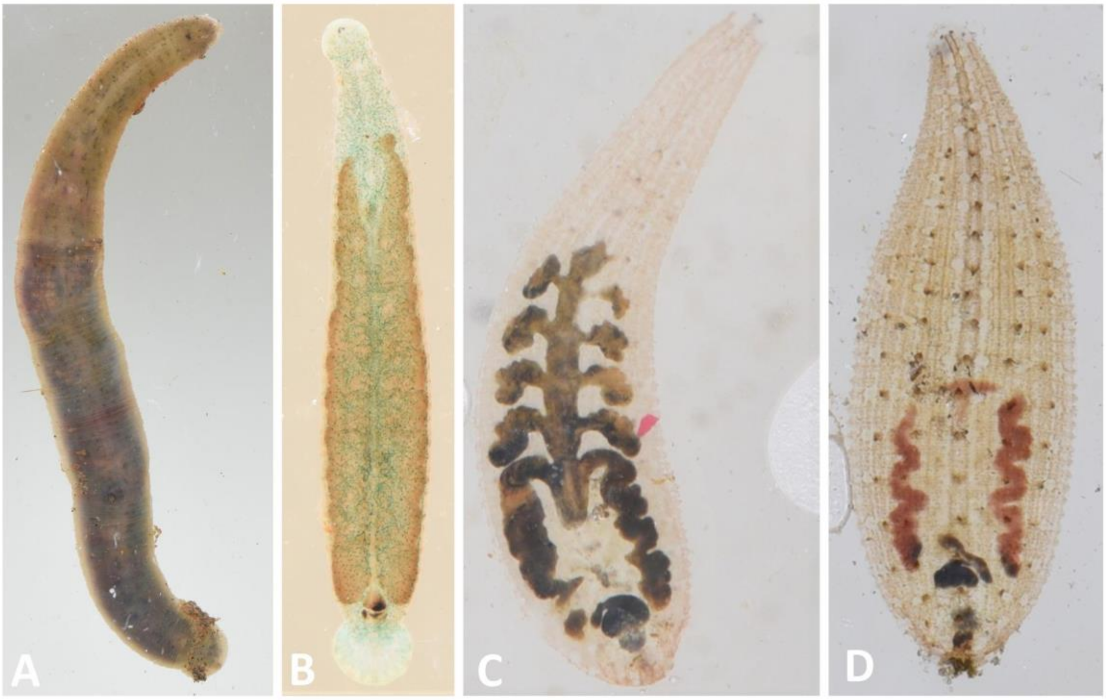

Figure 7-70 Photographs of Annelida
[A) *Salifa perspicax* (Salifidae) at R01; B) Glossiphonidae, attached to the catfish *Clarias gariepinus* at Rb3; C) *Alboglossiphonia sp.* (Glossiphonidae); D) *Aliolimnatis sp.* (Hirudinidae).]

B **Freshwater Crab (Brachyura)**

One species of freshwater crab, namely *Potamonautes lirrangensis* was recorded (Figure 7-71). Five specimens of this species were recorded in and around the funnel trap that was set at Site R09a, so this species appears to be common in the Project AoI. This species is common and widespread in East Africa and is listed by the IUCN as Least Concern (LC).

Figure 7-71 Photograph of Freshwater Crab *Potamonautes lirrangensis* (Potamonautidae) from Site R09a

C **Stoneflies (Plecoptera)**

One species of Stonefly, *Neoperla spio* complex, was recorded (Figure 7-72). This species was recorded at Sites R01 and R13 in January 2022, both as larvae and exuviae, and appeared to be common in the Project AoI. This was confirmed at Site R12 on 27 February 2022, when water levels were lowered to allow the stream bed to be sampled. This species was the most common macroinvertebrate in the Ruzizi River at R12 at the time of the second survey. This was the most sensitive macroinvertebrate recorded in the Project AoI and is therefore a potential useful indicator species for long-term monitoring.

Figure 7-72 Photographs of Stoneflies (Plecoptera)
[A) *Neoperla spio* (Perlidae); B) *Neoperla spio* exuviae (case)

D **Mayflies (Ephemeroptera)**

Seven species of mayflies were recorded, which is low for a river the size of the Ruzizi River. The species recorded included the highly tolerant *Baetis harrisoni* (Figure 7-73).

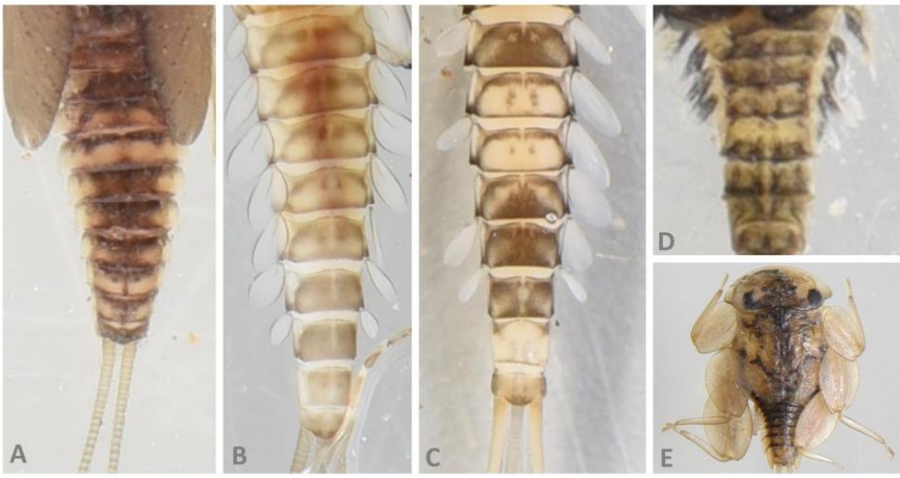

Figure 7-73 Photographs of Mayflies (Ephemeroptera)
[A) *Afroptiloides sp.* (Baetidae); B) *Baetis harrisoni* (Baetidae); C) *Baetis sp.* (Baetidae); D) *Tricorythus sp.* (Tricorythidae); E) *Dicercomyzon sp*. (Dicercomyzidae)]

E Dragonfly Adults

Six species of Dragonfly (Anisoptera) were recorded, including four species of Libellulidae, all of which are widespread and highly tolerant species (Figure 7-74).

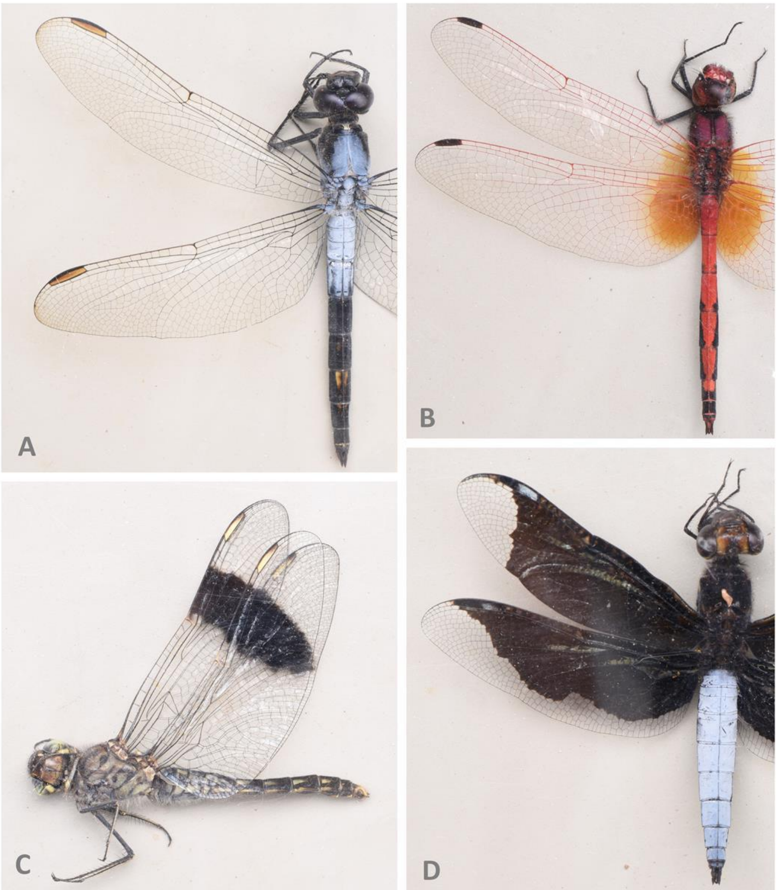

Figure 7-74 Photographs of Anisoptera Adults
[A) Nesciothemis farinosa (Libellilidae); B) Trithemis arteriosa (Libellulidae); C) Brachythemis leucosticta (Libellulidae); D) Palpoleura lucia (Libellulidae)]

F Damselfly Adults

Five species of damselflies (Zygoptera) were recorded, including the flow dependent *Platycypha caligata* (Figure 7-75).

Figure 7-75 Photographs of Zygoptera Adults
[A) *Pseudagrion massaicum* (Coenagrionidae); B) *Phaon irridipennis* (Calopterygidae); C) *Platycypha caligata* (Chlorocyphidae); D) *Pseudagrion kersteni* (Coenagrionidae); E) *Pseudagrion hamoni* (Coenagrionidae)]

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G Odonata Nymphs

Four species of Odonata nymphs were recorded, including the flow dependent *Zygonyx natalensis* (Figure 7-76).

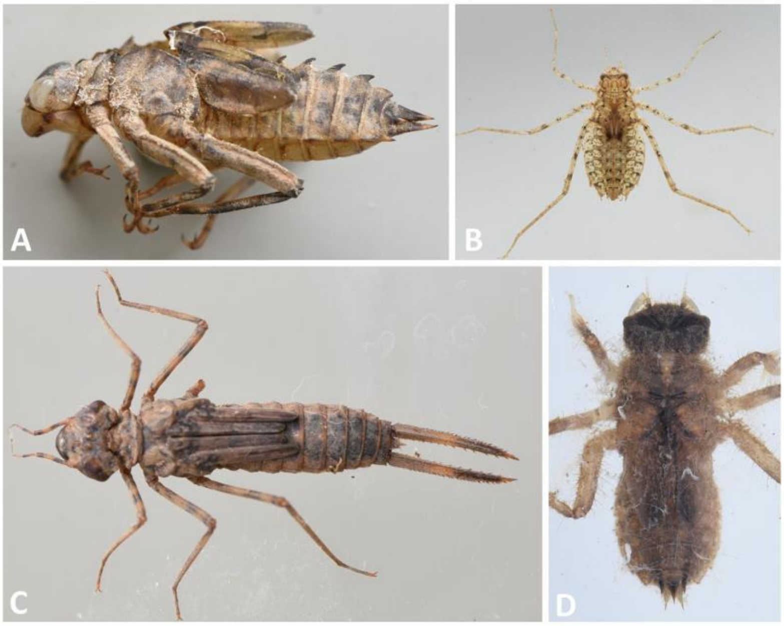

Figure 7-76 Photographs of Odonata Nymphs
[A) *Zygonyx natalensis* (Libellulidae); B) *Phyllomacromia contumax* (Macromiidae); C) *Platycypha caligata* (Chlorocyphidae); D) *Nesciothemis farinosa* (Libellulidae)]

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H Caddisflies (Trichoptera)

Three caddisfly taxa were recorded, of which one (Hydroptilidae), was recorded during the first survey only in the malaise trap set near Site R12 (Figure 7-77). Larvae were confirmed at Site R12 when water levels were dropped on the 27 February 2022. The diversity of caddisflies was low for a river the size of the Ruzizi River.

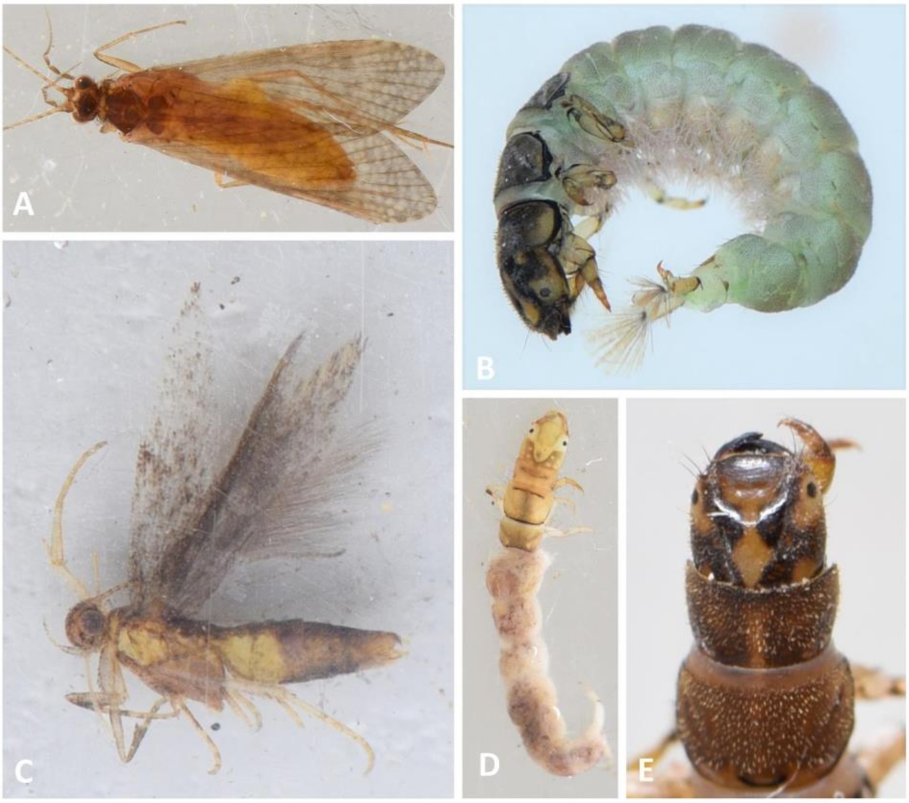

Figure 7-77 Photographs of Caddisflies (Trichoptera)
[A, B&E) *Hydropsyche* sp. (Hydropsychidae); C) Hydroptilidae; D) *Ecnomus* sp. (Ecnomidae)]

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I Beetles (Coleoptera)

Three aquatic beetle taxa were recorded, of which one (Gyrinidae), was recorded only in the Mountain Headwater at T1 (Figure 7-78). The diversity of aquatic beetles was low for a river the size of the Ruzizi River.

Figure 7-78 Photographs of Aquatic Beetles (Coleoptera)
[A) *Potamodytes sp.* (Elmidae); B) Gyrinidae; C) *Stenelmis sp.* (Elmidae)]

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J Blackflies (Simuliidae)

Four species of blackflies (Simuliidae) taxa were recorded: two in the Ruzizi River and two in the Mountain Headwater at T1 (Figure 7-79). The diversity of blackflies was low for a river the size of the Ruzizi River. The two species recorded in the Ruzizi River are common and widespread throughout sub-Saharan Africa. The most abundant blackfly species in the Ruzizi River was *Simulium hargreavesi*, which is typically associated with seasonal rivers and impoundment outlets. Onchocerciasis is transmitted to humans through exposure to repeated bites of infected blackflies of the genus *Simulium*. The two most abundant species recorded are not vectors of Onchocerciasis (Vatandoost, 2022). *Simulium damnosum* is the primary vector of Onchocerciasis within the region, but this species was not recorded within the sub-catchment, and therefore, an increase in Onchocerciasis is not expected.

Figure 7-79 Photographs of Blackflies (Simuliidae) pupal stage.
[A) *Simulium dentulosum*, at T1; B) *S. perforatum*, at T1; C) *S. hargreavesi*, at R01; D) S. adersi, at R01)]

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K Other Aquatic Flies (Diptera)

Five other aquatic fly taxa were recorded, including *Sepedon* sp. (Sciomyzidae) at Site R08 (Figure 7-80). Members of the family Sciomyzidae are cosmopolitan and feed exclusively on snails, including bilharzia snails. The diversity of aquatic flies for a river the size of the Ruzizi River was low.

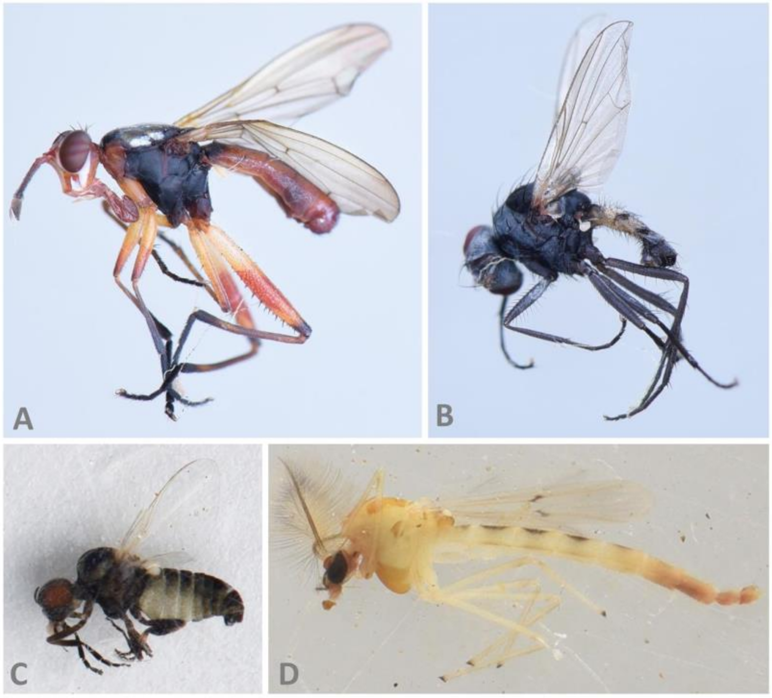

Figure 7-80 Photographs of Other Flies (Diptera)
[A) *Sepodon sp.* (Sciomyzidae); B) *Pelina sp.* (Ephydridae); C) *Simulium cf. hargreavesi* (Simulidae); D) Chironomidae]

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L **Freshwater Snails**

Two species of freshwater snail were recorded in the Project AoI but it is uncertain if they were carrying cercariae for the transmission of bilharzia. These were:

- *Bulinus truncatus,* recorded in a fish-pond adjacent to the Ruzizi River at Site R12 in February 2022 (Figure 4-22A). This species is a host for urinary bilharzia among humans.

- *Biomphalaria pfeifferi*, recorded in the Ruzizi River at Sites R01, R08 and R10 in January 2022 (Figure 7-81B). This species is an intermediate host of rectal bilharzia among humans.

Figure 7-81 Photographs of Snails
[A) Bulinus *truncatus* (Planorbidae); B) *Bioamphalaria pfeifferi* (Planorbidae)

PUBLIC DISCLOSURE AUTHORIZED

7.7.7 Fish

A 2022 Fish Survey Results

Fish species recorded at sites surveyed for this report in January and February 2022 using electrofishing are listed in Table 7-22. Detailed data are presented in Annex D. Supplementary data from previous studies are reported on later in the report.

A total of 22 species in seven families were recorded in the Ruzizi (17), Rubyiro (4) and Ruhwa (2) Rivers. A total of 629 fish were enumerated in electrofishing (453) and from local fish catches (176). The Nile tilapia (*Oreochromis niloticus*) was the most common fish in local fisher catches, followed by Grauer's Kivu haplo (*Haplochromis* cf. *graueri*) – a Lake Kivu endemic – at Site R01, the most upstream site on the Ruzizi River and immediately downstream of Ruzizi II. Electrofishing catches at Site R01 were dominated by the Lake Rukwa minnow (*Raiamas moorii*) (Danionidae) (68). Also found here was the redspot barb (*Enteromius kerstenii*), Ripon's barb (*Labeobarbus altianalis*) and the alien Tanganyika killifish (*Lamprichthys tanganicus*).

Burton's haplo (*Haplochromis burtoni*) was most abundant in electrofishing catches at sites R04, R04a, R05, R08, R09 and R10. Also caught at these sites were guppies (*Poecilia reticulata*) (an introduced species) the Sudan catfish (*Bagrus docmak*), *Enteromius taeniopleura*, Ripon's barb (*Labeo altianalis*) and the redeye labeo *Labeo cylindricus* (the latter species also being recorded from Site 14a).

Hore's haplo (*Ctenocrhomis horei*) was abundant in electrofishing catches at site R12 and R13 on the Ruzizi River (72 and 80, respectively). The highest abundances (5 and 4, respectively, at each of the aforementioned sites) of *L. altianalis* were also recorded, as were East African redfin barbs (*Enteromius apleurogramma*).

Eight specimens of *Amphilius* cf. *kivuensis* (8 individuals) were collected at Rb1 on the Rubyiro River by electrofishing and 6 and 9 *C. asymetricaudalis* (EN) were collected from Sites Rb2a and Rb2b, respectively. Only one species – *E. taeniopleura* – was collected from the Ruhwa River. A brief description of the key species caught follows.

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Table 7-22 Fish Recorded During the 2022 SLR Surveys

		IUCN		Ruzizi River												Rubyiro River				Ruhwa
Fish Family	Fish Species	IUCN Red List	R01	R04a	R04	R05	R08	R09	R09a#	R10	R12	R12#	R13	R13b	R14a	Rb1	Rb2a	Rb2b	Rb3	Rh2
Cypriniformes																				
Cyprinidae	*Enteromius apleurogramma*	LC	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
	Enteromius cf *taeniopluera*	LC	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	X
	Enteromius kerstenii	LC	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Enteromius cf *pellegrini*	LC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
	Labeo cf *cylindricus*	LC	-	-	-	-	-	-	X	(X)	-	X	X	-	(X)	-	-	-	-	-
	Labeobarbus altianalis	LC	X	-	-	-	-	-	-	-	X	(X)	X	-	-	-	-	-	X	-
	Labeobarbus sp. A	?	-	-	-	-	-	-	-	(X)	-	-	-	-	-	-	-	-	-	-
Danionidae	*Raiamas moorii*	LC	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Cyprinodontiformes																				
Poeciliidae	*Poecilia reticulata**	LC	-	-	-	-	X	-	-	X	X	X	X	-	-	-	-	-	-	-
	*Lamprichthys tanganicanus **	LC	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cichliformes																				
Cichlidae	*Haplochromis* cf *graueri*	LC	(X)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Haplochromis sp.		-	-	-	-	-	-	-	-	(X)	-	-	-	-	-	-	-	-	-
	Haplochromis cf *astatodon*		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	*Haplochromis burtoni**	LC	-	X	X	X	X	X	-	-	X	X	-	-	-	-	-	-	-	-
	Haplochromis sp. *nov.*		-	(X)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ctenochromis horei	LC	-	-	-	-	-	-	X	X	X	X	X	-	-	-	-	-	-	-
	Oreochromis niloticus	LC	(X)	-	-	-	-	-	-	-	X	(X)	(X)	-	-	-	-	-	-	-
Siluriformes																				
Amphiliidae	*Amphilius* cf *kivuensis*	?	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
Bagridae	*Bagrus docmak*	LC	-	-	-	-	-	-	-	X	(X)	-	-	(X)	(X)	-	-	-	-	-
Clariidae	*Clarias gariepinus*	LC	(X)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
	Clarias liocephalus	LC	-	X	-	X	-	-	-	-	-	X	X	-	-	-	-	-	-	-
Mochokidae	*Chiloglanis asymetricaudalis*	EN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-
	Total Number of Species (Species Richness)		**8**	**2**	**2**	**2**	**2**	**1**	**2**	**6**	**8**	**7**	**6**	**1**	**2**	**1**	**1**	**1**	**2**	**2**

*# = Recorded on 27th February 2022 *Species awaiting confirmation * = introduced species X = presence (X) = fisher catches*

A.1 Enteromius Barbs

Of the small-bodied *Enteromius* barbs, *E. kerstenii* (Figure 7-82 D) is the most common barb in Lake Kivu as well as being present in the Ruzizi River. The species is widespread through east, central and southern Africa and can be found in the Lake Victoria Basin, Okavango, Cunene and Zambezi systems. *E. pellegrini* (Figure 7-82 A) is widespread through the Lakes Kivu, Tanganyika and Albert basins. This species is closely related and therefore morphometrically similar to *Enteromius neumayeri* which has a slightly wider distribution including the Lake Victoria Basin and coastal streams of Kenya and Tanzania (Mlewa 2013). However, the latter's current distribution is uncertain and its presence in the Ruzizi River is considered unlikely (Banyankimbona, Emmanuel, *et al.* 2012). *E. apleurogramma* (Figure 7-82 B) is widespread through the Lake Victoria, Edward, Rukwa and Kivu basins and known to occur in the Ruzizi and Malagarasi Rivers – thus occurring in both river and lake environments. It is common in channelled valley-bottom wetlands and papyrus swamps. Unlike the aforementioned species *E. taeniopleura* (Figure 7-82 D) is associated more strongly with the Tanganyikan-Congo basin and with rivers draining into Lake Tanganyika – not the lake itself – as well as the Lukuga River linking the lake to the Congo system. Migration by *Enteromius* barbs is known to occur, but they are likely to take place over short distances than the larger-bodied cyprinids discussed below.

A.2 Large-Bodied Cyprinids

The *Labeobarbus* genus is one of the most speciose genera in Africa and includes a group of 127 large-bodied hexaploid cyprinids from Africa and the Arabian Peninsula (Vreven, Musschoot, *et al*. 2018). This species is widely distributed through the lake and inflowing rivers of the Lake Victoria Basin, the Nzoia and Nyando Rivers in Kenya (Mugo and Tweddle, 1999) and Lake Kyoga in Uganda. Whitehead (1959 cited in Welcomme, 2003) classed *L. altianalis* as long-distance migrators (over 80 km). The Ruzizi River is the southern limit of its range (FishBase team RMCA and Geelhand, 2018c).

The *Labeobarbu*s genus was represented in the SLR 2022 catches by the ripon barbel *L. altianalis* (Figure 7-83 B), where it was recorded in the Ruzizi River at Ruzizi I, downstream of Ruzizi III and lower Rubyiro River. The CRBEC/CRSNE survey recorded it as frequent near Bugarama bridge and at sites further downstream. Results indicate migration up the Middle Ruzizi River.

A further two *Labeobarbus* species were caught in the 2022 surveys (Figure 7-83 C & E), with slight morphological differences and possibly representing morphotypes from hybridisation (Kisekelwa CRBEC, *pers. comm.*). Investigations by CRSNE and CRBEC are ongoing into the taxonomy of the *Labeobarbus* genus.

Labeobarbus somereni was recorded in the SOFRECO 2011 surveys above and downstream of the proposed Ruzizi III dam site in the Lower Ruzizi River. CRSNE/CRBEC surveys recorded it frequently near the Bugarama bridge (downstream of Ruzizi III) and at several downstream sites. Results also suggests an ability to migrate up the rapids in the Middle Ruzizi.

Another large-bodied cyprinid identified in the SLR 2022 surveys was *Labeo cylindricus*, widespread throughout southern, central and eastern Africa. It is considered part of the *Labeo forskalii* group of species which are closely related and difficult to distinguish morphologically (Reid 1985, D. Tweddle SAIAB, *pers. comm.*). As for *L. somereni*, it was also recorded by CRSNE/CRBEC at sites downstream of Bugurama Bridge and in the lower Ruzizi.

The vulnerable *Labeobarbus leleupanus* was not recorded in the SLR 2022 survey and was only recorded at the lower reaches of three tributary sites (Nyakagunda, Nyamangana and Kaburantwa) by CRSNE/CRBEC (at least 34 km downstream of Ruzizi III project site).

A.3 Haplochromine Cichlids

Six cichlid species were caught in the Ruzizi during the the January 2022 survey. Both Grauer's Kivu haplo (*Haplochromis graueri*) (Figure 7-84D) and Regan's Kivu haplo (*Haplochromis* cf *astatodon*) (Figure 7-84 B) are Lake Kivu endemics. *Haplochromis* sp. (Figure 7-84 C) has not been identified and *Haplochromis* sp. nov. (Figure 7-84 F) has been previously collected by Jos Snoeks in the Kagenga tributary of the Ruzizi and is an undescribed species (Snoeks, Royal Museum for Central Africa, *pers. comm.*). *Haplochromis burtoni* (not shown) is common in Lake

Tanganyika lagoons associated with inflowing rivers. It is also known to inhabit the rivers of the upper Congo, as well as the Ruzizi, Malagarasi and Kagera Rivers (the latter where it may have been introduced) (De Vos, Snoeks, *et al.* 2001). Like other lake and river dwelling, it is very likely primarily a lacustrine (lake) species in the early phases of adaptive divergence between river and lake populations (Rajkov, Weber, *et al*. 2018). Haplochromine cichlids are a diverse group of fish that many of which have not been identified to species level.

Hore's haplo *Ctenochromis horei* (Figure 7-84 E) is a Lake Tanganyika endemic but is common in rivers including the Lukuga River draining into the Congo Basin and the Ruzizi (Kullander and Roberts 2012). It is piscivorous occurring on sand bottoms in the lake (Brichard 1989, IUCN 2021, Kullander and Roberts 2012), but like *H. burtoni* is likely in the early phases of adaptive divergence between river and lake populations.

Astatoreochromis vanderhosti is considered a junior synonym of *Astatoreochromis straelini* (Banyankimbona, Vreven, *et al.* 2013).

A.4 Tilapiine Cichlids

The Nile tilapia (*Oreochromis niloticus*) (Figure 4-25 A) is native to Lake Kivu, and is also present in Lake Albert, Edward-George and Tanganyika (Snoeks, Kaningini, *et al*. 2012). *Oreochromis tanganicae* is not usually associated with rivers but occurs in Lake Tanganyika.

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PUBLIC DISCLOSURE AUTHORIZED

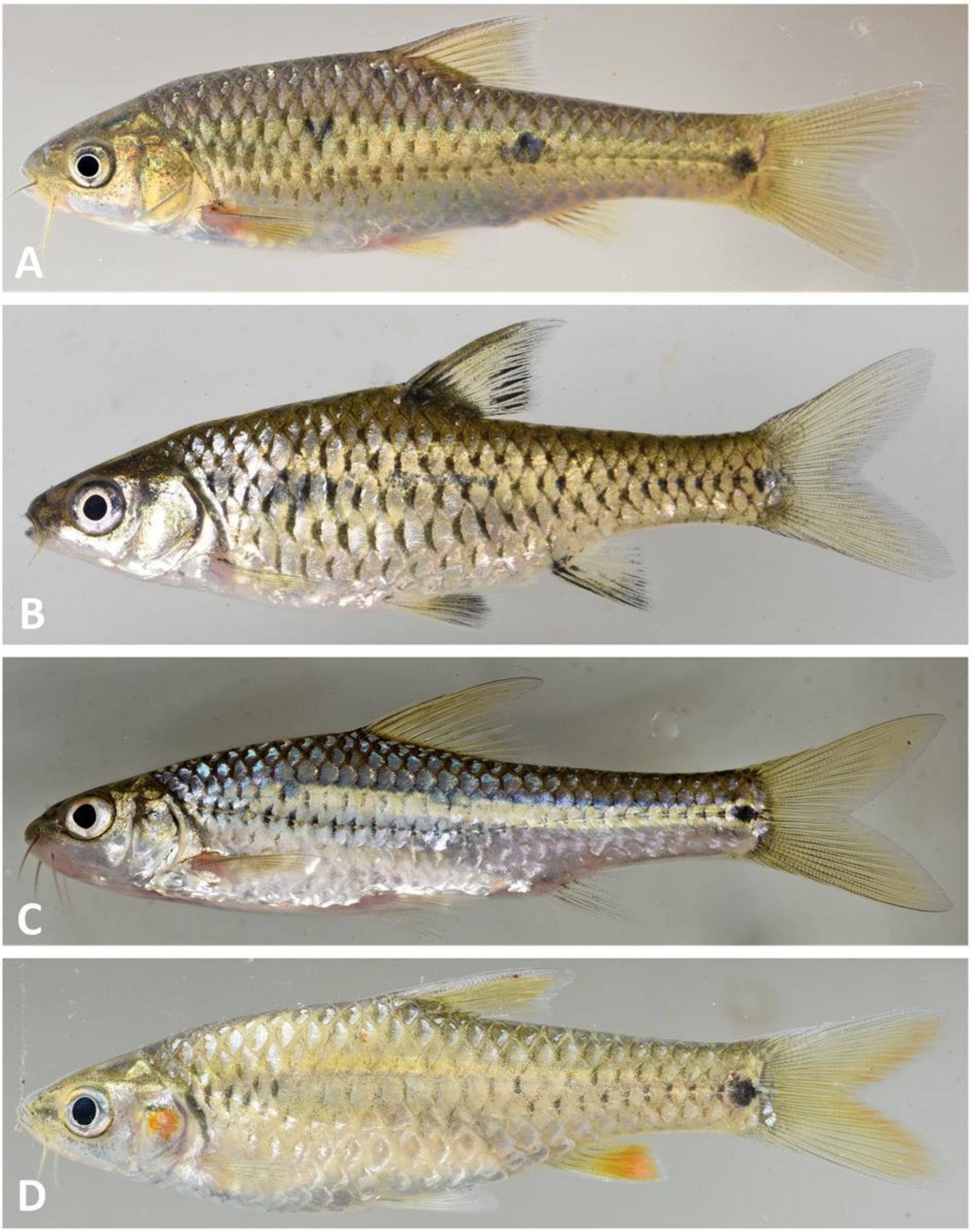

Figure 7-82 Photographs of *Enteromius* Species

[A) *Enteromius cf. pellegrini;* B) *E. apleuogramma;* C) *E.* c.f. *arcislongae*; D) *E. kerstenii*]

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Figure 7-83 Photographs of Other Cyprinid Species

[A) *Labeo* cf. *cylindricus;* B) *Labeobarbus* cf. *altianalis;* C) *Labeobarbus* sp.*;* D) *Raiamas moorii;* E) *Labeobarbus* sp.]

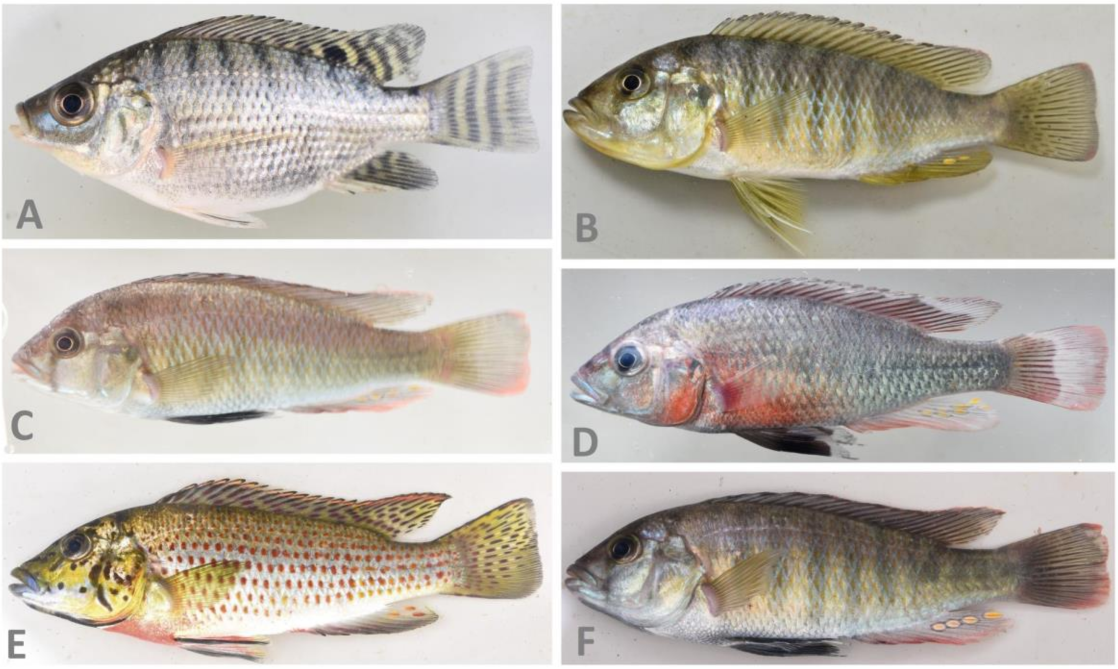

Figure 7-84 Photographs of Cichlids

[A) *Oreochromis niloticus;* B) *Haplochromis asatodon;* C) *Haplochromis* sp *nov.;* D) *Haplocrhomis graueri;* E) *Ctenochromis horei;* F) *Haplochromis* sp. *nov.*]

A.5 Siluriform Catfishes

Five species of Siluriform catfishes were caught in the Ruzizi River in January 2022, including Bagrid – the Sudan catfish (*Bagrus docmak*) (Figure 7-85 A), and two species of Clariid catfish: the sharptooth catfish (*Clarias gariepinus*) (Figure 7-85 C), and the smooth-head catfish (*Clarias liocephalus*) (Figure 7-85 E).

Figure 7-85 Photographs of Siluriformes
[A) *Bagrus docmak*; B&D) *Chiloglanis asymetricaudalis*; C&G) *Clarias liocephalus*; E&H) *Clarias gariepinus*; F) *Amphilius* cf. *kivuensis*.]

All three of these species are widely distributed – *C. gariepinus* being cosmopolitan throughout Africa, *C. liocephalus* occurring throughout central Africa, while the *B. docmak* is known from the Ruzizi northwards to the Lake Victoria Basin and the Nile system.

A single Amphiliid catfish – morphologically consistent with *Amphilius* cf. *kivuensis* (Figure 7-85 F) – was caught in the upper reaches of the Rubyiro River. This species is known from the Congo Basin, Ruzizi and Lake Tanganyika and the Kagera River (Marlier 1953).

The Ruzizi *Chiloglanis ruziziensis* is Critically Endangered and is a restricted range species to the Ruzizi Basin where it has been recorded

The longtail suckermouth (*Chiloglanis asymetricaudalis*) (EN) (Figure 7-85 B) is known from the Ruzizi Basin but is also more widely distributed in the south to the Luiche River, an affluent river flowing into the east of Lake Tanganyika (Friel and Vigliotta 2011). Several were caught in the Rubyiro tributary in the January 2022 survey but it is expected to occur in low numbers in the mainstem Ruzizi River in rapids (where it is difficult to sample).

A.6 Introduced Species

Lamprichthys tanganicanus (Figure 7-86 A), a native of Lake Tanganyika has appeared in Lake Kivu fishery catches since 2006. It is believed that the species was accidently introduced from Lake Tanganyika into Lake Kivu with the deliberate introduction of *Limnothrissa miodon* since it is unlikely to have been able to negotiate the natural rapid barriers on the Ruzizi River (Nshombo and Matabaro 2010). Although not reported from the Ruzizi River, the guppy (*Poecilia reticulata*), a native of South America (Figure 7-86 B) and a common aquarium species was found by both the SLR and SOFRECO survey teams. *Oreochromis leucostictus* (not shown) is thought to have been introduced into swamps on the Ruzizi plains (Banyankimbona, Emmanuel, *et al*. 2012)

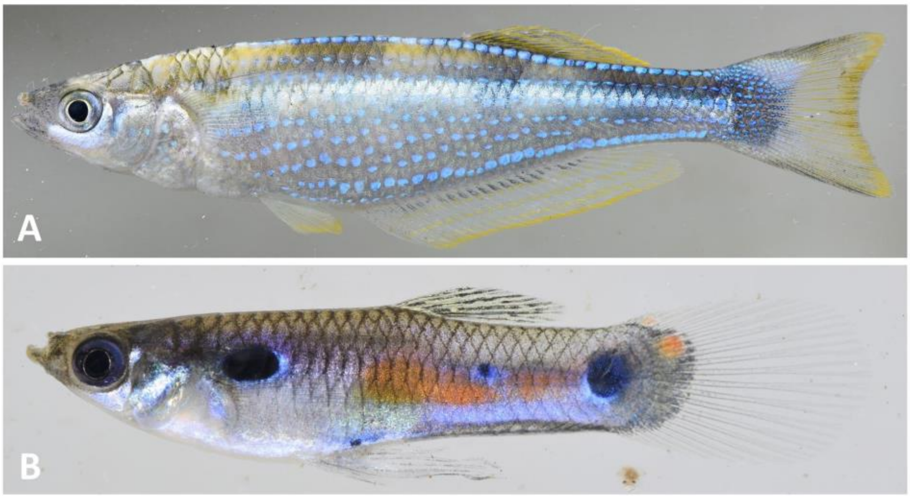

Figure 7-86 Photographs of Introduced Fish Species
[A) *Lamprichthys tanganicanus;* B) *Poecilia reticulata.*]

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B Comparison with Previous Studies

(CR) in the Ruhwa and Muhira Rivers near the confluence with the Ruzizi River. It appears that these two highly threatened rock catlets prefer the tributaries to the mainstem river. However, based on an informal interview with a local fisherman during the May 2024 supplementary field survey, *Chiloglanis* spp. occur within the Ruzizi River mainstem. No information of catch rates and size classes were obtained.

Table 7-23 summarises the fish species recorded for the Ruzizi River from various inventories including Banyankimbona, Emmanuel, *et al*. 2012, IUCN 2021, SOFRECO 2021; the SOFRECO (2010, 2011, 2021) and SLR (2022) field studies. It also includes occurrence data provided by the Centre of Research in Biodiversity, Ecology, Evolution and Conservation (CRBEC) in Bukavu and Research Centre in Natural Sciences and Environment (CRSNE) at the University of Burundi from surveys conducted in the mainstem Ruzizi River and tributaries between Ruzizi I HPP and the Ruzizi River mouth at Lake Tanganyika between 2017 and 2022 (CRBEC/CRSNE 2023, unpublished report).

For the cichlids, the main difference between the inventoried lists and field studies is the predominance of Haplochromines which were caught mainly in the upper reaches of the Ruzizi River. This suggests a sampling bias toward lentic waters (Ruzizi I & II reservoirs) in the SOFRECO surveys, but also the colonisation of the Ruzizi River by lake species promoted by the increased availability of lentic habitat afforded by these waterbodies. Ten species of haplochromine were recorded in the upper Ruzizi by CRBEC/CRSNE while the SLR survey recorded four species.

Among the Cypriniformes, *Labeo cylindricus*, *Labeobarbus altianalis* and the Lake Rukwa minnow *Raiamas moori* are the most commonly reported in field studies. The other *Labeobarbus species* (*L. caudovittatus*, *L. leleupanus* (VU), *L. somereni* and *L. tropidolepis*) were absent from recent catches in the Ruzizi III project area by SOFRECO and SLR, but all except *L. tropidolepis* were confirmed in CRBEC/CRSNE surveys downstream of Bugurama Bridge, with *L. somereni* more prevalent in the lower Ruzizi River near Lake Tanganyika.

The SLR and CRBEC/CRSNE surveys detected a greater diversity of *Enteromius* barbs (5/6 species) than the SOFRECO surveys (2 species) including: *E. apleurogramma*, *E*. cf. *taeniopleura*, *E*. *kerstenii*, and *E* cf. *pellegrini*. Of the mormyrids only individuals of*Cyphomyrus dischorhynchus* were reported in the lower Ruzizi River during the CRBEC/CRSNE surveys. While *C. gariepinus* and *C. liocephalus* are common Siluriform catfishes in catches, only the 2022 SLR survey found *A. kivuensis*. Both the 2022 SLR survey and CRBEC/CRSNE surveys recorded *C. asymetricaudalis* (EN) in tributaries of the Ruzizi River: Rubyiro River (SLR 2022) and Nyakagunda and Nyamagana Rivers (CRBEC/CRSNE surveys). CRBEC/CRSNE also recorded *Chiloglanis ruziziensis* (CR) in the Ruhwa and Muhira Rivers near the confluence with the Ruzizi River. It appears that these two highly threatened rock catlets prefer the tributaries to the mainstem river. However, based on an informal interview with a local fisherman during the May 2024 supplementary field survey, *Chiloglanis* spp. occur within the Ruzizi River mainstem. No information of catch rates and size classes were obtained.

Table 7-23 Combined Inventory of Fish Species Reported in the Ruzizi River

Order	Family/Scientific Name	Common Name	IUCN Status	Restricted Range /Alien	INVENTORIES				FIELD STUDIES			
					Banayankimbona *et al.* (2012)*	IUCN (2021)	SOFRECO (2021) Annex 5	SOFRECO (2010)	SOFRECO (2011)	SOFRECO (2021) Photos	SLR (2022)	CRBEC/CRSNE (2017-2022)*
	Protopterus aethiopicus	Marbled lungfish	LC		+		+					+
CERATODONTIFORMES	**Protopteridae**											
	Protopterus aethiopicus	Marbled lungfish	LC		+		+					+
CHARACIFORMES	**Alestidae**											
	Alestes macrophthalmus	Torpedo Robber	LC		+	+	+					
	Brycinus imberi	Spot-tail	LC		+	+	+					
	Micralestes stormsi		LC		+	+	+					+
CICHLIFORMES	**Cichlidae**											
	Astatoreochromis straeleni	Bluelip haplo	LC	RR	+	+	+					
	Astatoreochromis vanderhorsti		LC	RR		+						
	Astatotilapia burtoni	Burton's haplo	LC	RR	+	+	+	+	+		+	+
	Astatotilapia stappersii		LC	RR	+	+	+					+
	Aulonocranus dewindti		LC			+						
	Coptodon rendalli	Redbreast tilapia	LC			+						+
	Ctenochromis horei	Hore's haplo	LC	RR	+	+	+	+	+		+	+
	Gnathochromis pfefferi		LC	RR		+						
	Haplochromis adolphifrederici	Frederich's Kivu haplo	NE	Ke						+		+
	Haplochromis astatodon	Regan's Kivu haplo	NE	Ke				+	+		+	+
	Haplochromis crebridens		LC									+
	Haplochromis graueri	Grauer's Kivu haplo	LC	Ke		+	+	+	+		+	+
	Haplochromis insidae	Snoek's Kivo haplo	LC	Ke						+		+
	Haplochromis kamiranzovu	Kamiranzovu haplo	LC	Ke				+	+	+		
	Haplochromis microchrysomelas	Orangetail Kivu haplo	LC	Ke						+		+
	Haplochromis olivaceus	Olive Kivu haplo	LC	Ke						+		+
	Haplochromis paucidens	Trimorphic Kivu haplo	LC	Ke				+	+	+		+
	Haplochromis rubescens	Red Kivu haplo	LC	Ke						+		
	Haplochromis scheffersi	Scheffers' Kivu haplo	LC	Ke				+	+			
	Haplochromis vittatus	Striped Kivu haplo	LC	Ke						+		+
	Oreochromis leucostictus	Blue spotted tilapia	LC	Alien	+	+	+					+
	Oreochromis macrochir	Longfin tilapia	VU	Alien	+		+					+
	Oreochromis mweruensis	Mweru tilapia	LC				+					
	Oreochromis niloticus	Nile tilapia	LC	Alien		+	+	+	+	+	+	+
	Oreochromis tanganicae	Tanganyika tilapia	LC	RR	+							
	Tylochromis polylepis		LC			+						

Order	Family/Scientific Name	Common Name	IUCN Status	Restricted Range /Alien	INVENTORIES				FIELD STUDIES			
					Banayankimbona *et al.* (2012)*	IUCN (2021)	SOFRECO (2021) Annex 5	SOFRECO (2010)	SOFRECO (2011)	SOFRECO (2021) Photos	SLR (2022)	CRBEC/CRSNE (2017-2022)*
CLUPEIFORMES	**Clupeidae**											
	Limnothrissa miodon	Lake Tanganyika sardine	LC	Alien			+	+	+	+		+
CYPRINIFORMES	**Cyprinidae**											
	Acapoeta tanganicae	Mbaraga	LC	RR	+	+	+					
	Chelaethiops congicus		LC			+						
	Clypeobarbus congicus	Congo barb	LC		+	+	+					
	Enteromius apleurogramma	East African redfinned barb	LC		+	+	+	+	+		+	+
	Enteromius arcislongae		LC								+	
	Enteromius cf. *lineomaculatus*											+
	Enteromius innocens	Inconspicious barb	LC									+
	Enteromius kerstenii	Redspot barb	LC			+					+	+
	Enteromius lineomaculatus	Line-spotted barb	LC		+	+	+					
	Enteromius lufukiensis		NT	RR	+	+	+					
	Enteromius neumayeri	Neumayer's barb	LC		+	+	+					
	Enteromius oligogrammus		LC		+	+	+					
	Enteromius pellegrini	Pellegrin's barb	LC		+	+	+		+		+	+
	Enteromius taeniopleura		LC	RR	+	+	+				+	
	Enteromius urostigma		LC			+						
	Labeo cylindricus	Redeye labeo	LC		+	+	+	+	+	??	+	+
	Labeobarbus altianalis	Ripon barbel	LC		+	+	+	+	+	+	+	+
	Labeobarbus caudovittatus		LC		+	+	+					
	Labeobarbus cf. *caudovitattus*											+
	Labeobarbus leleupanus	Leleup's carp	VU	RR	+	+	+					+
	Labeobarbus somereni	Someren's barb	LC		+	+	+			+		+
	Labeobarbus tropidolepis		LC	RR	+	+						
	Danionidae											
	Raiamas marqueti		NE									+
	Raiamas moorii	Lake Rukwa minnow	LC	RR	+	+	+	+	+	+	+	+
	Raiamas salmolucius		LC			+						
CYPRINODONTIFORMES	**Poeciliidae**											
	Lacustricola pumilus	Tanganyika lampeye	LC		+	+	+					
	Lamprichthys tanganicanus	Tanganyika killifish	LC	RR			+			+	+	+
	Poecilia reticulata	Guppy	LC	Alien			+				+	

Order	Family/Scientific Name	Common Name	IUCN Status	Restricted Range /Alien	INVENTORIES				FIELD STUDIES			
					Banayankimbona *et al.* (2012)*	IUCN (2021)	SOFRECO (2021) Annex 5	SOFRECO (2010)	SOFRECO (2011)	SOFRECO (2021) Photos	SLR (2022)	CRBEC/CRSNE (2017-2022)*
OSTEOGLOSSIFORMES	**Mormyridae**											
	Cyphomyrus discorhynchus	Zambesi parrotfish	LC		+		+					+
	Mormyrus longirostris	Eastern bottlenose mormyrid	LC		+		+					
	Petrocephalus catostoma	Churchill	LC			+						
	Pollimyrus nigricans	Dark stonebasher	LC		+	+	+					
PERCIFORMES	**Anabantidae**											
	Ctenopoma muriei	Ocellated labyrinth fish	LC		+	+	+					
	Latidae											
	Lates mariae	Bigeye lates	VU			+						
SILURIFORMES	**Amphiliidae**											
	Amphilius kivuensis		NE		+		+				+	
	Amphilius platychir	Mountain barbel	LC		+		+					
	Amphilius ruziziensis		NE	RR			+					
	Amphilius uranoscopus	Stargazer mountain catlet	LC		+	+						
	Zaireichthys brevis		LC				+					
	Bagridae											
	Bagrus docmak	Sudan catfish	LC		+	+	+				+	+
	Claridae											
	Clarias alluaudi	Alluaud's catfish	LC		+	+						
	Clarias gariepinus	Sharptooth catfish	LC		+	+	+		+	+	+	+
	Clarias liocephalus	Smoothhead catfish	LC		+	+	+		+	+	+	
	Clarias sp.											+
	Clarias theodorae	Snake catfish	LC				+					
	Clarias werneri	Werner's catfish	LC		+	+	+					+
	Claroteidae											
	Auchenoglanis occidentalis	Bubu	LC			+						
	Chrysichthys brachynema	Kibonde	LC					+	+			
	Chrysichthys sianenna	Kanimba	LC	RR		+						
	Malapteruridae											
	Malapterurus electricus	Electric catfish	LC			+						
	Mochokidae											
	Chiloglanis asymetricaudalis	Longtail suckermouth	EN	RR	+	+	+				+ Ruby iro	+ Nyakagunda & Nyamagana
	Chiloglanis lukugae		LC			+	+					

Order	Family/Scientific Name	Common Name	IUCN Status	Restricted Range /Alien	INVENTORIES				FIELD STUDIES			
					Banayankimbona *et al.* (2012)*	IUCN (2021)	SOFRECO (2021) Annex 5	SOFRECO (2010)	SOFRECO (2011)	SOFRECO (2021) Photos	SLR (2022)	CRBEC/CRSNE (2017-2022)*
	Chiloglanis ruziziensis	Ruzizi suckermouth	CR	RR	+	+	+					+ Ruhwa & Muhira
	Synodontis melanostictus		NE		+							
SYNBRANCHIFORMES	**Mastacembelidae**											
	Mastacembelus frenatus	Longtail spiny eel	LC		+	+	+					

Ke = endemic to Lake Kivu RR = Restricted-Range A = Alien; * Survey data (unpublished) cover Upper to Lower Ruzizi from Ruzizi I HPP to Ruzizi River mouth at Lake Tanganyika.
(*Note: Banayankimbona *et al* (2012) data relate to Ruzizi Basin including tributaries)

C Fish Habitat Associations and Ecological Guilds

Ecological guilds group species according to similar morphological, physiological, behavioural and life history adaptations rather than by taxonomic relatedness. This assumes that species with similar adaptations will respond to environmental change and variability in similar ways. The guild concept is therefore useful for evaluating the effects of change on diverse river fish communities (Aadland 1993, Baumgartner, Conallin, *et al*. 2014, Leonard and Orth 1988, Welcomme, Winemiller, *et al*. 2006). It should be noted that these are broad guilds and fish species listed in each may not be restricted to a specific guild. The extreme phenotypic plasticity of fish also means that many species may fall in more than one guild (Rajkov, Weber, *et al*. 2018).

Fish guilds can be classed according to preferences for flowing-water (lotic), standing-water (lentic) and those that are tolerant of a wide range of conditions (eurytopic). Many of those in the lentic and eurytopic guilds will adapt to lake or reservoir environments. The lotic guild includes main channel residents that select moderate to high water current speeds and rocky, or gravel substrates. Other criteria applied to the classification of fish guilds include reproductive strategy after Balon (1975) and resistance to anoxia which may require specialised adaptations like ancillary breathing apparatuses (Welcomme, Winemiller, *et al*. 2006). While the guilds assigned here are adapted from Welcomme, Winemiller, *et al*. (2006), the number of guilds has been reduced and the terminology simplified for the sake of expedience.

The **lotic riffle-rapid guild** includes species that occur in the main channel in river segments with a steep relief (e.g., the Ruzizi River), high current speeds and large coarse bed elements (i.e. riffles or rapids). They may have suckers or spines that enable them to grip rocks and an elongated body shape to enable them to live in interstitial spaces. They require fast-flowing well-oxygenated water to complete their life cycles. Examples in the Ruzizi Basin include the *Chiloglanis* and Amphiliid catfishes (Table 7-24). This guild is particularly sensitive to sedimentation of riffle areas, dewatering and variable flow velocities (e.g. under hydropeaking flow regimes.

The **lotic lithophilic guild** includes species that are seasonal longitudinal migrants, breeding and often feeding in rocky riffles or rapids. The large-bodied cyprinids (*Labeobarbus*) fall into this guild and these fishes will often undertake medium to long distance migrations for reproductive purposes (Table 7-24). This guild is particularly sensitive to loss of river connectivity due to damming or insufficient flow to aerate eggs over the breeding season. Lotic floodplain species will use floodplains for breeding and undertake lateral (but also longitudinal) medium distance migrations onto spawning grounds. The abundance and biomass of these species are often closely correlated with the size of the flood and degree of inundation (Welcomme, Halls, *et al.* 2004). In the Ruzizi River this guild is represented by the Alestidae, *Labeos* and tilapias (*Oreochromis*).

The **lotic pool guild** inhabits deeper pools or slackwaters along river margins, they tend to feed on invertebrate drift from riffles or rapids and may be sensitive to long periods of no flow, particularly if this is accompanied by anoxic conditions. They may breed either in the rocky substrata of riffles or among plants. Many of the *Enteromius* barbs fall into this guild.

Semi-lotic guilds (riparian, pool and benthic) will occupy the interface between flowing and standing water, using often vegetated bays and inlets with slackwaters along the channel margins. Some of the haplochromine cichlids and *Enteromius* barbs in the Ruzizi River will fall into this guild. The semi-lotic pool guilds may be found in higher gradient river segments with typical pool-riffle-pool sequences. While they may spend most of their time in pools, they use faster-flowing riffles for drift feeding and possibly breeding. This guild will be sensitive to long periods of no-flow. Again, some of the *Enteromius* barbs and haplochromine cichlids may be found in this guild.

The **Semi-lotic benthic guild** feed on macroinvertebrate prey deeper in the water column along vegetated river margins of river channels and may migrate onto floodplains. The mormyrids which are included in this guild have the ability to generate a weak electric field for detecting prey. These fish are particularly sensitive to the adverse effects of dams on their invertebrate prey communities (Blake 1977). Fishes in this guild may populate floodplains for breeding and feeding.

Table 7-24 Ecological Fish Guilds, Predominant Habitats and Associated Fish Species in the Ruzizi River

Ecological Guild		Predominant Habitat	Description	Migration	Species
Lotic (flowing-water)	Riffle-rapid	Rapids and rocky areas, high gradient river segments with alternating pool-riffle-pool sequences	Rheophilic small-sized, elongated, or flattened body form. Equipped with suckers or spines.	Mostly non-migratory	*Chiloglanis asymetricaudalis, C. lukugae, C. ruziziensis, Amphilius kivuensis, A. platychir, A. ruziziensis. A. uranoscopus, Zaireichthys brevis*
	Lithophilic	Main channel	Main channel residents. Moderate to high water current speeds. Rock and sand substratum spawners.	Longitudinal medium distance seasonal migrations between downstream and upstream spawning habitats	*Labeobarbus altianalis, L. caudovittatus, L. leleupanus, L. somereni, L. tropidolepis*
	Floodplain	Floodplain	River fish that use floodplains for breeding and nursery habitats. River reaches adjoined by seasonally inundated floodplain. Sometimes semi-pelagic eggs and larvae.	Medium distance seasonal longitudinal and lateral migrations onto floodplains for spawning. Intolerant of anoxia.	*Alestes macrophthalmus, Brycinus imberi, Micralestes stormsi*, some *Labeo* species
Semi-lotic (Intermediate between flowing and non-flowing water)	Riparian	Slackwaters and backwaters, along channel margins and riparian areas	Intermediate between flowing- and standing-water guilds. Inlets, bays, side channels and swamps, with shallower water, slower current speeds and emergent vegetation.	Short distance migrations in the main channel or up tributaries and side-channels	Some *Haplochromis*, *Oreochromis* and *Astatoreochomis* sp. (e.g. *Astatoreochromis straeleni*) Some *Enteromius* barbs
	Pool	Pools in high gradient river segments with alternating pool-riffle-pool sequences	Sensitive to long periods without flow. Lithophilic phytophilic breeding habits.	Short-distance migrations	Some *Enteromius* barbs
Eurytopic (generalist)	Benthic	Main channel and slackwaters benthic (bottom-dwelling)	Channel margins and fringes of the marginal vegetation in the main channel. Moderate to low water current speeds. Intolerant of anoxia.	Short distance lateral migrations onto floodplains	*Cyphomyrus discorhynchus, Mormyrus longirostris, Petrocephalus catostoma, Pollimyrus nigricans, Synodontis melanostictus*
Lentic (standing-water)	Plesiopotamonic/ Paleopotamonic	Floodplains & wetlands seasonally or permanently disconnected to main channel	Tolerance for hypoxia/anoxia. Heavily vegetated river margins and floodplains with reedbeds and papyrus.	Variety of migration strategies. Protopterid movements only associated with foraging	*Protopterus aethiopicus* *Ctenopoma muriei, Clarias gariepinus, Clarias liocephalus,* some Tilapias
	Lacustrine	Lakes and open waterbodies	Predominantly lake-dwelling species that may incidentally occupy river habitats.	Little or no migration	*Haplochromine* cichlids
No preference	Eurytopic	Able to colonise a wide variety of aquatic habitats	These species are widely tolerant of a range of water quality and flow and non-flow conditions. They generally increase in numbers when rivers are degraded.	Variety of migration strategies	*Clarias gariepinus*, *Oreochromis mossambicus*
Terminology *Lotic*: affinity standing water *Lentic*: affinity for flowing water *Eurytopic*: generalist across several habitats *Slackwater*: slow flow on channel margins		*Lithophilic*: requiring gravels or cobbles in the main channel *Phytophilic*: requiring vegetation in the main channel or foodplain *Eupotamonic*: main channel consisting of the centre of the channel and the riparian zone with upper (rhithronic), middle and lower (potamonic) zones.		*Parapotamonic*: backwaters and slackwaters of the main channel, floodplain habitat sometimes disconnected from the main channel during low flow. *Plesiopotamonic*: connected lagoons and channels and floodplain lakes. *Paleopotamonic*: floodplains and wetlands occurring in the floodplain margins that may be groundwater fed only connected to the main channel by very high floods	

Lentic species include those adapted to lakes or floodplain pans and lagoons which may be seasonally (plesiopotamonic) or permanently (paleopotamonic) disconnected from the main channel during the dry season. These fishes are able to persist in these areas until the next flood. This group will include species with a high tolerance for anoxia include the Protopteridae and Clariid catfish (Table 7-24). Although the clariids are a metropolitan species and will occur throughout the Ruzizi, many of the other fishes in this guild will be restricted to the wetlands of the lower Ruzizi where it flows into Lake Tanganyika.

Lacustrine species include the endemic haplochromine cichlids in Lakes Kivu and Tanganyika which may colonise slow or no-flow conditions along river margins or in artificial reservoirs in the mainstem Ruzizi.

Eurytopic fishes tolerate a wide range of water quality, aquatic habitat and flow conditions. They will generally increase in numbers to pest proportions in degraded river systems. Examples include the *Oreochromis mossambicus* and clariid catfishes.

D Distribution and Biology of Priority Species

Priority species in the Ruzizi River are listed in (Table 7-25). These have been selected either on the basis that they are (1) an indicator species – i.e., (2) representative of one of the guilds listed in Section C which is expected to undergo change in distribution or abundance as a result of hydropower development, or (3) populations that are likely to be significantly impacted as a result of any one or combination of the following criteria: specialised habitat or migratory requirements, restricted-range (or Ruzizi endemic) and conservation importance. Apart from *A. straeleni*, which is regarded as primarily fluviatile (river-dwelling) haplochromid, range-restricted endemic haplochromids (*Ctenochromis horei, Gnathochromis pfefferi*) have been excluded since the river environment is considered marginal for this group. *A. vanderhorsti* is excluded because it is considered a junior synonym of *A. straeleni.*

Table 7-25 Priority Fish Species Identified for the Ruzizi River and their Known Distribution, Ecology and Threats.
(Note* - indicates that it was caught in the 2022 SLR fish surveys)

Species	Importance	Description
CICHLIFORMES		
Cichlidae		
Astatoreochromis straeleni	Range-restricted, semi-lotic riparian guild	The bluelip haplo is a range-restricted species with its global extant distribution including lake Kivu and the northern shores of Lake Tanganyika including the Ruzizi and Malagarasi Rivers. The taxonomic status of populations found in the Lukuga River (DRC) have yet to be determined. It is considered a fluviatile haplochromid, inhabiting clear tributaries and moving into associated swamps during the flood season. In the Ruzizi it occurs in swampy pools associated with the river and is especially common in the Gatumba swamps, seldom in the main channel (Banyankimbona, Emmanuel, *et al.* 2012; 2013, IUCN 2021). It is an invertivorous mouthbrooder likely breeding during the dry season (Dec-Jan) (Banyankimbona, Vreven, *et al.* 2013).
CYPRINIFORMES		
Cyprinidae		
Acapoeta tanganicae	Range-restricted, migratory, evolutionarily distinctive	Once considered endemic to Lake Tanganyika, *A. tanganicae* has subsequently been found in a tributary of the Songwe River draining into Lake Rukwa western Tanzania (Genner, Turner, *et al.* 2015). Although it has been recorded from inshore rocky areas of the lake, the species is considered migratory and common in rivers where it frequents rapids (Eccles 1992). Although *A. tanganicae* is listed as Least Concern by the IUCN, Adeoba, Tesfamichael, *et al.* (2019), have suggested this species has a high conservation priority due its Evolutionary Distinctiveness (ED), a measure of the evolutionary uniqueness of a species – *A. tanganicae* ranking top out of 539 African cyprinids evaluated (*Acapoeta* being a monospecific genus). No individuals of *A. tanganicae* have been caught in recent surveys.
Enteromius lufukiensis	Range-restricted, Near Threatened,	This species is known from rivers draining the western shores of Lake Tanganyika and the Ruzizi It is also reported from the Luama River, Congo River Basin, DRC (Poll 1953). It is classified by the IUCN as NT as

Species	Importance	Description
	semi-lotic pool/riparian guild	its extent of occurrence is less than 20,000 km² and area of occupancy less than 2,000 km². Populations are threatened by agricultural expansion, deforestation leading to erosion and increased sedimentation and turbidity in the catchment (Ntakimazi 2018). No specimens of this species have been caught in recent surveys.
*Labeobarbus altianalis**	Migratory, lotic-lithophilic guild	The ripon barbel is widely distributed through the lake and inflowing rivers of the Lake Victoria Basin, the Nzoia and Nyando Rivers in Kenya (Mugo and Tweddle, 1999) and Lake Kyoga in Uganda. Populations in the Ruzizi River are regarded as the southernmost distribution of the species which was first described from specimens collected from the latter river and Lake Kivu (Banister 1973). Mugo and Tweddle (1999) suggest that there may be distinct river and lake-dwelling populations, with those from lakes moving upriver to spawn. *L. altianalis* are reported as rheophilic gravel-bed spawners like many other species in the African *Labeobarbus* genus and migrate upstream to spawn during the wet season (Witte and De Winter, 1995 cited in Sunda Kemunto, 2018). Whitehead (1959 cited in Welcomme, 2003) classed *L. altianalis* as long-distance migrators (over 80 km), potentially indicating that this species could migrate from as far downstream as the Ruzizi River mouth at Lake Tanganyika. This species is believed to have been impacted by overfishing and the introduction of more efficient gillnets into Lake Victoria in the 1980s and 1990s (Sunda Kemunto, 2018), and it is possible the same might apply to Lakes Tanganyika and Kivu.
Labeobarbus leleupanus	Vulnerable, Migratory, lotic-lithophilic guild	*L. leleupanus* is restricted to the Lake Tanganyika Basin. IUCN EOO shows the species occurring throughout Lake Tanganyika, but museum records suggest it is mostly known from the Ruzizi River Basin (MRAC 1997). Low abundances of this species have been inferred from rare fisheries catches in the lake, suggesting low abundances here which may possibly be the result of under-sampling of the Ruzizi River. Like many other African large-bodied *Labeobarbus,* this species is likely to belong to the lotic lithophilic guild and likely migratory over medium to long distances. Populations are threatened by agricultural expansion, deforestation leading to erosion and increased sedimentation and turbidity in the catchment (Ntakimazi 2006b). Although not caught in the SLR 2022 survey, L. *leleupanus* was confirmed by CRBEC/CRSNE in lower tributaries of the Ruzizi River between 2016 and 2018 (unpublished data). The species ecology is poorly known but is assumed to migrate during the increase in flows during the onset of the long-wet season in October as other large African cyprinid species. The SLR 2022 surveys were undertaken during January and February suggesting that while peak migration may have been completed, the species is likely to use the mainstem reach, at least the lower reaches.
Labeobarbus somerini	Migratory, lotic-lithophilic guild	*L. somerini* occurs in the Ruzizi, Malagarasi and the middle and upper Kagera Rivers. It is also known from fast-flowing rivers in the Ruwenzoris flowing into Lake Edward (Banister 1973). It is believed to prefer the headwaters of rivers at high altitudes to a limit of 1600 m (Eccles 1992, Greenwood 1966). Like the other African large-bodied *Labeobarbus* species described here, it is likely to belong to the lotic lithophilic guild and be migratory over medium to long distances. The population status is unknown, but it is considered rare (FishBase team RMCA and Geelhand 2018). This species was caught by SOFRECO in 2021 upstream and downstream of Ruzizi III HPP and by CRBEC/CRSNE mainly in the lower tributaries of the Ruzizi River but also at the Bugurama Bridge.
Labeobarbus tropidolepis	Migratory, lotic-lithophilic guild	*L. tropidolepis* is endemic to the Lake Tanganyika Basin where it is common in inshore catches. It also occurs in affluent rivers including the Malagarasi (Natakimazi and Hanssens 2018) and like *L. altianalis* migrates up rivers to reproduce. It is likely to belong to the lotic lithophilic guild and be migratory over medium to long distances. Threats to the species include fishing pressure as well as agricultural expansion, deforestation leading to erosion and increased sedimentation and turbidity in the catchment (Natakimazi and Hanssens 2018). This species has not been caught in recent surveys by SOFRECO, SLR or CRBEC/CRSNE.
Labeobarbus caudovittatus		*Labeobarbus caudovittatus* is a migratory species, widely distributed with records from several Central and West African countries, including the Democratic Republic of the Congo, Gabon, Burundi, Angola and Zambia, and Rwanda including the Ruzizi River (De Vos and Thys van den Audenaerde 1990). It is considered to occur in several other river systems affluent to Lake Tanganyika including the Malagarisi and Lukuga Rivers. The global status of its populations is largely unknown, but it is not

Species	Importance	Description
		considered threatened at global level (Moelants 2010) but is assessed as Near Threatened in East Africa where it is threatened by fishing pressures and regression of habitat due to farming (Ntakimazi; IUCN redlist). It was collected in the Middle Ruzizi by SOFRECO 2021 and by the CRBEC/CRSNE in unpublished surveys downstream of Ruzizi III.
SILURIFORMES		
Mochokidae		
*Chiloglanis asymetricaudalis**	Endangered (EN), range-restricted, lotic riffle-rapid guild	The longtail suckermouth (EN) is known from Ruzizi Basin but is also more widely distributed in the south to the Luiche River, an affluent river into Lake Tanganyika (Friel and Vigliotta 2011). The species is well adapted for inhabiting fast-flowing riffle-rapid habitats in rivers. It is especially adapted for living and feeding in these types of habitats by having a flattened, elongated body form with a sucker mouth that enables it to feed on algae and invertebrates in fast currents. Its Area of Occupancy (AOO) is deemed less than 500 km^2 (Hanssens and Ntakimazi 2006). The species is especially susceptible to sedimentation of riffles and rapids which in the Ruzizi catchment results from agricultural expansion and deforestation. Note: several individuals were confirmed in the upper Rubyiro River by SLR in 2022 but were not confirmed in the Ruzizi River mainstem during that survey. They have also been caught by CRBEC/CRSNE in other tributaries of the Ruzizi River but not the mainstem. However, the presence of *Chiloglanis* species in the Ruzizi River mainstem was reported by local fishermen in May 2024, although likely to be rarely caught. This is likely due to fishing methods and difficulty of accessing river bottom habitats preferred by rock catlets but also because of water depth and velocity. It is predicted that numbers are also likely reduced due to upstream hydropeaking. Whether the fishermen referred to *C asymetricaudalis* or *C ruziziensis* is unclear.
Chiloglanis ruziziensis	Critically Endangered (CR), range-restricted, lotic riffle-rapid guild	*C. ruziziensis* is endemic to the Ruzizi River Catchment and has an Extent of Occurrence (EOO) <100 km^2 and an AOO <10 km^2 (Ntakimazi 2006a). Like *C. asymetricaudalis, C. ruziziensis* (CR) is well adapted to fast-flowing riffle-rapid habitats in rivers. It is especially adapted for living and feeding in these types of habitats by having a flattened, elongated body form with a sucker mouth that enables it to feed on algae and invertebrates in fast currents. Like the former species, *C. ruziziensis* is especially susceptible to sedimentation of riffles and rapids which in the Ruzizi catchment is results from agricultural expansion and deforestation. Note: It was not confirmed during surveys by SOFRECO in 2021 or SLR in 2022 and was not confirmed in the Ruzizi mainstem in surveys by CRBEC/CRNS between 2017-2022. However, the presence of *Chiloglanis* species in the Ruzizi River mainstem was reported by local fishermen in May 2024, although likely to be rarely caught. This is likely due to fishing methods and difficulty of accessing river bottom habitats preferred by rock catlets but also because of water depth and velocity. It is predicted that numbers are also likely reduced due to upstream hydropeaking. Whether the fishermen referred to *C asymetricaudalis* or *C ruziziensis* is unclear.
Amphiliidae		
Amphilius ruziziensis	Range-restricted, lotic riffle-rapid guild	A recent taxonomic study of a species described as *Amphilius jacksonii* revealed higher morphological differences than expected and the Ruzizi *Amphilius* was determined to be a different species. Originally thought to be *Amphilius platychir*, Thomson, Page, *et al*. (2015) described *Amphilius ruziziensis* from the river itself and the northeastern tributaries of Lake Tanganyika. Its conservation status is unknown since it has not been assessed. *Amphilius* species are adapted to fast-flowing rocky streams at high elevation, feeding off the substratum on benthic aquatic macroinvertebrates including chironomids, ephemeropterans and trichopterans. It has a thickened first ray on its pectoral and pelvic fins which enable it to cling to rocks (Thomson and Page 2022). Reproduction coincides with rainy season likely in response to increased flow (Marriott, Booth, *et al.* 1997). This species was not detected in any surveys by SOFRECO in 2021; SLR in 2022, or CRBEC/CRNS between 2017-2022.

E Fish Migration & Seasonal Changes in Fish Distribution

Migratory behaviour in African fish species, including those of the Ruzizi River, are poorly understood. There is insufficient seasonal data to reliably infer the importance of fish migration on their life cycles, either in terms of seasonality, migration distance or reliance on tributaries or rapids for spawning.

Prior surveys on the Ruzizi River have not reliably detected seasonal shifts in distributions that confirm migratory behaviour. However, fish migration is inferred from the SOFRECO fish surveys in August and October 2021 by the presence of larger numbers of *Labeo* species distributed further upstream in October than in August. In addition, the SLR team observed aggregations of fish at the base of the spillway of Ruzizi II in January 2022. Discussion with security guards posted at Ruzizi II revealed that migrating fish were sometimes stranded by down-ramping of the hydropower facility, during which time they were easily targeted by local fishers.

SOFRECO's 2010 and 2011 fish surveys found evidence of reduced relative abundances of *L altianalis* downstream of the existing hydropower facilities and attributed this to the barrier these structures represent to upstream fish migration, as well as the fact that the fish passes on Ruzizi I and Ruzizi II dams, have not functioned for over twenty years as a result of poor maintenance, the accumulation of debris and insufficient flows (SOFRECO 2021). Similarly, SHER Consult Ltd (2020) highlighted the barrier these dams pose to fish migration – particularly *L. altianalis* – and the fact the fish passage facilities are poorly maintained. They suggest that migratory fish such as *Labeobarbus* could be using the tributaries to breed. Aside from *L. altianalis*, *L. cylindricus*, *Acapoeta tanganicae* and all the other *Labeobarbus* cyprinids will likely be migratory over medium to long distances (>30 km). It is considered likely that fishes belonging to the lotic lithophilic guild (comprising *L. altianalis, L. caudovittatus, L. leleupanus, L. somereni,* and *L. tropidolepis*) migrate up the Ruzizi River from the Ruzizi floodplains at Lake Tanganyika for spawning purposes, and that young-of-the-year will disperse downstream following spawning. However, only *L. altianalis, L. cylindricus* and *L. somereni* have been caught in recent surveys (2010-2021).

F Fish Barriers

There are two existing and one potential barrier to fish migration on the Ruzizi River:

- *Ruzizi I HPP*. Ruzizi I HPP (28 MW) located on the Ruzizi River ~4 km downstream of the outflow from Lake Kivu. This facility was constructed in 1959, and controls the levels in the lake;
- *Ruzizi II HPP*. Ruzizi II HPP (45 MW) is located another 16 km downstream of Ruzizi I and ~20 km from the Lake Kivu outlet. This facility has been in operation since 1989. The Ruzizi II HPP possesses a fish ladder in an attempt to mitigate against the barrier effect, but it is currently not functioning and due to be rehabilitated; and
- *Natural barriers*. There is at least one cascade on the Ruzizi River, ~12 km downstream of Ruzizi II (see Figure 7-63 A), that may present an obstacle to some non-migratory fish species under certain flow conditions. However, it is evident that several migratory fish such as *L. altianalis, L. cylindricus* and *L. somerini* navigate these rapids as they have been recorded upstream of the proposed Ruzizi III HPP location.

Below Ruzizi II HPP the river is unobstructed by other dams for 140 km to Lake Tanganyika. Ruzizi III HPP would reduce the navigable river for migratory fish by an additional 13 km of the Middle and Lower Ruzizi without barriers for 130 km.

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7.7.7.2 Current Threats to Ruzizi River

Threats to the aquatic ecology of the Ruzizi River observed during the field survey in January 2022 are summarised in Table 7-26.

Table 7-26 Current Threats to Aquatic Ecology

Type of Threat	Description of Threat
Water Level Fluctuations	The main cause of ecological deterioration observed in the Project AoI during the field survey in January 2022 was attributed to short-term fluctuations in water level associated with the operation of Ruzizi I and II.
Solid Waste	Solid waste constituted a serious threat to aquatic ecosystems in the Project AoI. The waste appeared to be generated mostly from the city of Bukavu, the capital of South Kivu Province, DRC. Some of the waste was removed from the turbine intakes at Ruzizi II and burnt on site, leading to localised air pollution. However, most of the waste was carried downstream, and some accumulated in quieter backwaters within the Project AoI (Figure 7-87 A).
Suspended Solids	Elevated concentrations of suspended solids constituted a serious threat to aquatic ecosystems in the Project AoI. A plankton net left in the Ruzizi River for 30 minutes to collect drifting macro-invertebrates caught nothing but fine sand and plastic waste. The main cause of elevated sediments is attributed to subsistence agriculture, particularly on steep slopes and within riparian zones. Many of the tributaries sampled, including the lower Rubyiro River, had no or few aquatic macroinvertebrates or fish, and their absence was attributed to the abrasive action of suspended sediments. No fish were recorded at Rb2 in the Rubyiro River, the type locality of *Chiloglanis ruziziensis*.
Climate Change	The effects of climate change on aquatic ecosystems within the Project AoI are unknown, but it is likely that climate change has already increased the frequency and intensity of flash floods, and this is likely to have aggravated the problems associated with soil degradation (Sher 2020). Increased soil degradation and the consequent landslides will result in increased sediment loads in the Ruzizi River and aggravate the issue of sediment accumulation in Ruzizi-I and -II reservoirs. Increased sediment load leads to habitat degradation due to the abrasive of suspended sediment, and consolidated substrate and gravel habitat loss at deposition sites.
Migration Barriers	As described above, Ruzizi I and Ruzizi II H pose barriers to fish migration. During periods of suitable flow, *Labeobarbus* species migrate upstream until they reach the Ruzizi II impoundment. Fish accumulate below the impoundment and between hydropeaking periods the water level within the Ruzizi River drops causing some fish to become stranded, allowing people to easily collect the fish (as observed in January 2022). This confirms that the dam constitutes a complete barrier to upstream migration of fish (although its non-functional fish ladder is due to be rehabilitated). The cascade of rapids downstream of Ruzizi III may constitute a partial barrier for some species although it appears that *Labeobarbus* species are able to navigate them upstream.
Alien Fish	Several alien fish have been recorded in the Ruzizi River which predate on or displace indigenous fish. These include Nile tilapia *Oreochromis niloticus*, Longfin tilapia *O. macrochir*, blue-spotted tilapia *O. leucostictus*, Lake Tanganyika sardine *Limnothrissa miodon*, Tanganyika killifish *Lamprichthys tanganicanus*, and the guppy *Poecilia reticulata*. *Lamprichthys tanganicanus*, a native of Lake Tanganyika has appeared in Lake Kivu fishery catches since 2006. It is believed that the species was accidently introduced from Lake Tanganyika into Lake Kivu with the deliberate introduction of *Limnothrissa miodon* since it is unlikely to have been able to negotiate the natural barriers on the Ruzizi River (Nshombo and Matabaro 2010). *Poecilia reticulata*, a native of South America and a common aquarium species was found by both the SLR and SOFRECO survey teams. *Oreochromis leucostictus* and *O. niloticus* is thought to have been introduced into swamps on the Ruzizi plains (Banyankimbona, Emmanuel, *et al*. 2012). Both were prevalent in the lower Ruzizi River (CRBEC/CRSNE 2015-2022, unpublished)
Aquaculture	The farming of monosex Nile tilapia (*O. niloticus*) in floating cages takes places on Lake Kivu at several locations from Rwanda and the DRC and it is seen as an important component of food security and livelihoods in the region. Some of these sites are on the Ruzizi River, downstream of Ruzizi III. The environmental risks of aquaculture include organic pollution, introduction of pathogens, invasive species introductions and the use of chemicals and pharmaceuticals (SOFRECO 2010).
Overfishing	Before the introduction of *L. miodon* for fisheries purposes, the artisanal fishery on Lake Kivu was poorly developed and based on the endemic haplochromine species with an annual production of not more than 1500 t (Snoeks, Kaningini, *et al.* 2012). Catches of *L. miodon* represented 75% of the total catch and the stock was estimated at 4000 tonnes in 2018 with stocks in Lake Kivu considered stable and sustainable (Tessier, Richard, *et al.* 2020). However, illegal fishing in the lake is threatening fish stocks, with 404 cases reported in 2018 (RNP 2018).

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Type of Threat	Description of Threat
	The extent of fisheries within the Project AoI has not been quantified but is primarily performed by subsistence fishers largely for household consumption although some are reportedly sold in Bugarama. During the May 2024 survey, several fishermen were observed to use the Ruzizi River around the town of Bugurama (Rwanda) during periods of low flow. A local fisherman provided the local names of the groups that comprise the dominance of their catch. These names were searched on fishbase and the following species or groups were identified: Ishonzi – *Clarias* spp. Intama - *Mormyrus kannume;* Ikijagari – *Chiloglanis* spp.; Umukenya – *Raiamas moori;* Iningu – *Labeo* spp. and Imbaraga – *Petrocephalus catastoma.*

Figure 7-87 Photographs of Current Threats to Aquatic Ecosystems

[A) Solid Waste; B) Ruzizi II spillway – River Regulation; C) Riparian Cultivation; D) Fishing; E) Aquaculture; F) Washing and Ablutions; G) Alien Fish Species.]

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7.7.7.3 Aquatic Habitat Status

Aquatic habitats in the Project AoI were classified as "modified" in accordance with definitions provided in ESS6 and IFC PS6. It's modified status is specifically linked to erratic hydropeaking flow fluctuation in the catchment caused by upstream hydropeaking from Ruzizi I and II, as well as water pollution from Bukavu and other settlements. Although the majority of aquatic biota recorded were indigenous besides a few alien fish species, the diversity and abundance are significantly lower than expected and ecological functions of the Ruzizi River within the Project AoI were assessed as '*seriously modified*'.

Indicators of its modified status include marginal riverine habitats and all instream habitats above the lowest water level being largely devoid of aquatic life because of frequent exposure associated with short-term (sub-daily) fluctuations in water level. Other drivers of ecological deterioration were elevated nutrients and solid waste associated with the upstream City of Bukavu, and elevated sediments associated with the cultivation of most of the catchment areas that drain into the Project AoI. Aquatic flora was dominated by a monoculture of the filamentous alga *Cladophora glomerata*, a typical indicator of polluted water. The presence of this alga on the stream bed at about 0.5 m depth indicated that light was not limited, although deeper areas are likely to be light limited because of elevated turbidity. The composition of benthic diatoms also indicated elevated concentrations of nutrients and suspended sediments. The diversity and abundance of aquatic macroinvertebrates was very low, so there was little food to support insectivorous fish species. Low abundance of macroinvertebrates is attributed mainly to short-term fluctuations in water level but is also likely to be associated with the abrasive nature of suspended sediments and bedload. Furthermore, the composition of fish species showed measurable changes from historical records, indicating a change in fish community structure. Given the lack of macroinvertebrates in the Ruzizi River, it is suspected that migratory *Labeobarbus* species feed in the lower floodplain reaches in Burundi and swim up only to spawn in rapids, and are unlikely to feed upstream.

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7.8 Terrestrial Ecology

The Terrestrial Ecology Assessment was based on a desktop and field assessment approach, with two field surveys undertaken. The methods used in the assessment and the respective assumptions and limitations are provided in Annex C.

7.8.1 Protected and Internationally Recognised Areas

7.8.1.1 Protected Areas

The World Database on Protected Areas (WDPA)[13] indicates that the Project is not situated within any Protected Areas (PAs), although five PAs are located in the vicinity of the Ruzizi River catchment, and one is located in the lower reaches of the Ruzizi River. Two of the PAs in the catchment are in the DRC (Kahuzi-Biega National Park, Itombwe Mountains), two in Rwanda (Nyungwe National Park, Cyamudongo Forest) and one in Burundi (Kibira National Park). The only PA along the Ruzizi River is the Rusizi National Park in Burundi, which is located approximately 80 km downstream of the Ruzizi III HPP at the point where the river enters Lake Tanganyika. A more detailed description of the PAs is given in Table 7-27 and the locations of these in relation to the Project are shown in Figure 7-88. The Project is not predicted to impact on the integrity of any PAs.

7.8.1.2 Key Biodiversity Areas

The World Key Biodiversity Areas database[14] was searched for Key Biodiversity Areas (KBAs) in the vicinity of the Ruzizi River and its catchment area. All of the PAs described in Section 7.8.1.1 are also designated as KBAs as well as Important Bird Areas (IBAs) and are thus indicated on the map in Figure 7-88. One KBA that is not a PA is the Lake Kivu Catchment KBA, located in the DRC and Rwanda. Although the KBA title implies that the catchments of the rivers feeding the lake are included, the KBA only comprises the lake and its islands, an area of 243,227 ha. This is because the KBA has been designated entirely on aquatic features, including one endangered (EN) fish (*Lates microlepis*) and two EN freshwater crabs (*Potamonautes gonocristatus* and *Potamonautes idjiwiensis*). Even though the above PAs and KBAs are located in the Ruzizi catchment or along its lower reaches, they represent a wide range of habitats, altitudes and landscapes that are not represented in the Project Area. The Project is not predicted to impact on any KBAs.

7.8.1.3 Ramsar Sites

The Convention on Wetlands is a 1971 treaty between governments that provides a framework for the conservation and wise use of the world's most important wetlands and their resources. Over 90% of the UN member states are signatories and have provided lists of wetlands that are considered to be of global importance, which are referred to as Ramsar Wetlands. Only one Ramsar Wetland is located along the Ruzizi River, namely the Rusizi National Park ('Parc National de la Rusizi (Site No. 1180)) in Burundi[15]. The site covers approximately 10,600 ha and comprises the Ruzizi River delta at the junction of the river and Lake Tanganyika, as well as a portion of the lower Ruzizi River floodplain above the delta. Habitats include the permanent inland delta, freshwater lakes, rivers and associated wetlands. The site has been recognised as an important wintering site or stopover point for migratory waterbirds and a breeding site for resident waterbirds. It also supports populations of threatened species such as hippopotamus (VU) and Nile crocodile (VU). The wetland supports important processes that provide ecosystem services

[13] https://www.protectedplanet.net/country/COD
[14] https://www.keybiodiversityareas.org/kba-data
[15] https://rsis.ramsar.org/ris/1180

such as sediment trapping, carbon sequestration and nutrient cycling, and provides resources for human livelihoods such as fishing, livestock grazing and cultivation (rice, sugar cane, cotton). Major threats to the wetland include erosion, unsustainable utilisation of natural resources, and the use of pesticides and fertilizers for agriculture[16]. The project is not predicted to impact on the integrity of this Ramsar site as there only a small alteration to water level variations, which are already altered by Ruzizi I and Ruzizi II. Ruzizi National Park starts 88 km downstream of Ruzizi III and extends into the outflow of the river into Lake Tanganyika at 131 km (i.e. approximately 43 km of the lower Ruzizi River).

Table 7-27 Protected Areas and Key Biodiversity Areas in the Ruzizi Basin and Catchment Area

Protected Area	Description
Kahuzi-Biega National Park (DRC) – 6,689 km²	Kahuzi-Biega National Park is located along the western edge of the Albertine Rift in eastern DRC, west of Lake Kivu. The Kahuzi-Biega National Park is located outside of the Ruzizi Basin approximately 14 km and 36 km to the northwest of the basin and PAOI at its nearest point, respectively. In addition, none of the river systems traversing the park drain into the Ruzizi. It comprises two large sections that are connected by a forested corridor. Two large mountains are prominent in the park, namely Mt Kahuzi (3,300 m) and Mt Biega (2,900 m). The park comprises dense primary montane forest with some bamboo, as well as areas of woodland, swamp and peatbog. The western extension of the park comprises a vast undulating tract of transition and lowland forest (~600 to 1,500 masl). The park was originally established to protect a population of Grauer's gorilla (Critically Endangered (CR) and it is still one of the strongholds for this species. Other highly threatened species include African forest elephant (CR), chimpanzee (EN), Mt. Kahuzi climbing mouse (CR) and red-collared mountain babbler (EN). Habitats in this PA are not represented by remaining portions of habitat in the Ruzizi III PAOI.
Itombwe Mountains (DRC) – 6,009 km²	The Itombwe Mountains are a range of mountains south-west of Lake Kivu in South Kivu province (DRC). The mountain range partially overlaps with the eastern portion of the Ruzizi basin, located approximately 25 from the PAOI at its nearest point. It was declared a national reserve by the Institut Congolais pour la Conservation de la Nature (ICCN) in 2006. Itombwe is known to support at least 1035 plant species and 772 terrestrial vertebrates (of which at least five are endemic), including highly threatened species such as Grauer's gorilla (CR), Chimpanzee (EN), Congo Bay owl (EN) and Prigogine's nightjar (EN), and restricted-range species such as Itombwe Massif clawed frog (EN), Luvubu reed frog (EN) and white-striped reed frog (EN). The reserve comprises over 5,000 km² of montane forest and grassland (Kujirakwinja & Plumptre, 2016). The headwaters of the Ulindi River that are located within the Itombe Mountains partially overlap the Ruzizi Basin, but these drain west. There is no river connectivity between Itombwe and the Ruzizi River, and habitats are not represented by remaining portions of habitat in the Ruzizi III PAOI.
Nyungwe National Park (Rwanda) - 1019 km²	Nyungwe forest is situated in south-west Rwanda between Lake Kivu and the international border with Burundi, where it is contiguous with Kibira National Park. The Congo-Nile watershed is situated within the park and comprises a range of mountains that reach 2,600–2,900 masl, dividing the park into two distinct sections. The western section comprises dense forest between 1,700 and 2,000 masl on soils derived from schists. The eastern part supports mostly secondary forest with many clearings and is on granite-derived soils. Summits and rocky areas have low Erica-dominated scrub forest, while bamboo stands are extensive in the south-east. These parks overlap with the western portion of the Ruzizi Basin covering an area of approximately 100,000 ha and located approximately 20 km to the east and north-east of the PAOI. Montane bogs are a feature of the western part of Nyungwe, with Kamiranzovu being the largest alpine peat bog in Africa. The forest supports populations of threatened mammals such as chimpanzee (EN), L'Hoest's monkey (VU), Angolan colobus (VU) and owl-faced monkey (VU), and birds such as Shelley's crimsonwing (EN), red-collared mountain-babbler (EN) and Congo Bay owl (EN). These parks are the source of several major tributaries of the Ruzizi River, including the Rubyiro and Ruhwa Rivers.
Cyamudongo Forest Reserve (Rwanda) – 415 ha	Cyamudongo forest is a small relict forest that is an outlier of the much larger Nyungwe Forest with its entirety located within the Ruzizi Basin. It is located close to the town of Nyakabuye near the border with the DRC, approximately 14 km from the PAOI. The forest has been a designated forest reserve since 1933. Vegetation differs from Nyungwe in being denser and having fewer clearings. A number of plant and vertebrate species are only known in Rwanda from this forest. A small population of chimpanzee (EN) is reportedly present in the forest.

[16] https://rsis.ramsar.org/ris/1180

Protected Area	Description
	Numerous Albertine Rift bird endemics are present, although none of the highly threatened species occurring in Nyungwe are present due to the lower altitude.
Kibira National Park (Burundi) – 37 km^2	This national park is located in north-western Burundi and is contiguous with Nyungwe Forest in Rwanda, with which it forms a continuous montane forest block of 130 ,000 ha. Only about 16% of the remaining forest is considered to be primary forest, most of which is found on the wetter, western mountain slopes. Montane bogs and bamboo thickets are also supported in the park, The forest supports populations of threatened mammals such as chimpanzee (EN), L'Hoest's monkey (VU), Angolan colobus (VU), and birds such as Shelley's crimsonwing (EN), red-collared mountain-babbler (EN) and Grauer's swamp warbler (VU). This park is the source of several tributaries that drain into the lower Ruzizi River.
Rusizi National Park (Burundi) – 6.2 km^2	Rusizi National Park is located north-west of Bujumbura along the border with the DRC at the southern end of the Ruzizi Basin. It comprises a floodplain of about 2 km wide and 35 km long along the east bank of the Ruzizi River and a smaller area of delta where the Ruzizi enters Lake Tanganyika, with the main Bujumbura – Uwinka road separating these two areas. The delta is a mixture of islands and channels covered with *Phragmites* and papyrus swamps, while the northern floodplain comprises *Hyphaene* palm savannah. The delta section of the park is an important area for migratory waterbirds, such as Madagascar pond heron (EN), great snipe (NT), lesser flamingo (NT) and Eurasian curlew (NT) as well as other threatened species such as hippopotamus (VU) and Nile crocodile (VU). It is threatened by uncontrolled settlement, agriculture and fishing. *The park is situated approximately 80 km downstream of the Ruzizi HPP outfall.*

[Source: https://www.protectedplanet.net/country/COD; https://www.keybiodiversityareas.org/]

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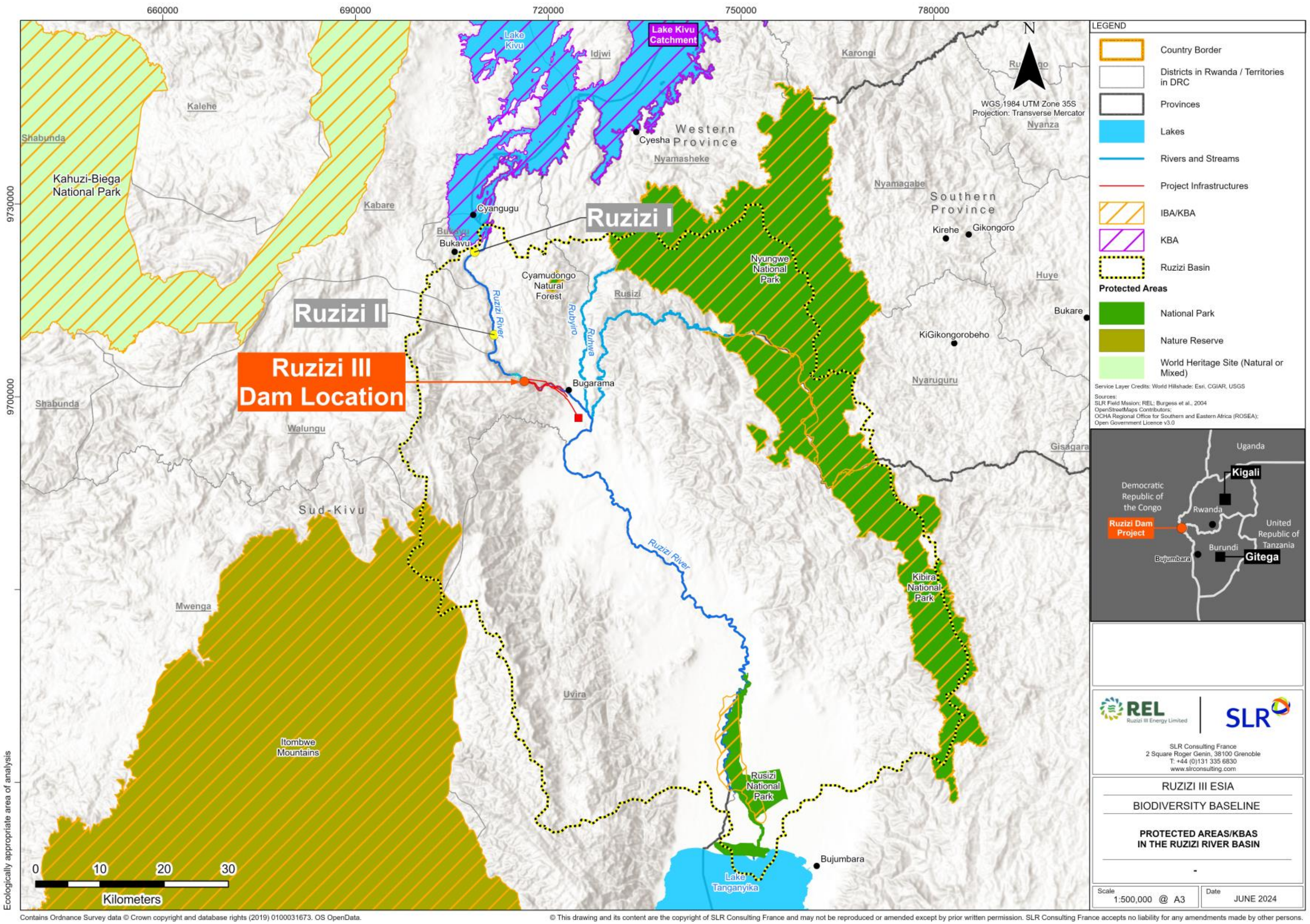

Figure 7-88 Protected Areas/KBAs in the Ruzizi River Basin [Source WDPA/Birdlife]

7.8.2 Regional Context

7.8.2.1 Terrestrial Ecoregions

The Ruzizi III Project is situated within the Albertine Rift Montane Forests terrestrial ecoregion (AT0101) (Figure 7-89). This is one of the top ten species richness hotspots in Africa, supporting more vertebrates than any ecoregion in Africa with an estimated 1149 species, including 732 avifauna species and 221 mammal species (Burgess *et al*. 2004). The Albertine Rift Montane Forests also have the highest number of endemic avifauna and mammal species for any ecoregion on mainland Africa. The ecoregion has been classified as Endangered by Burgess *et al.* (2004) and listed as a Class 1 Ecoregion (Globally Important and Highly Threatened Ecoregions), one of only 32 ecoregions in Africa that have been classified as such. It also has the second highest extinction risk score for any ecoregion in Africa.

Although the Ruzizi III Project is situated in a critically threatened and globally significant ecoregion, the Project is located in a severely degraded part of the ecoregion that is characterised by mostly modified habitat and a high proportion of agricultural lands and nearby settlement. None of these habitats are likely to support the high species diversity and endemism typical of the ecoregion and few of the many threatened species of this ecoregion are likely to be present in the project area.

7.8.2.2 National Conservation Priorities for Rwanda

The latest National Biodiversity Strategy and Action Plan (NBSAP) for Rwanda (2016) contains specific conservation priorities to enhance protection of the following: i) Nyungwe Forest National Park and to link it with Cyamudongo Natural Forest; ii) the Volcanoes National Park; iii) Akagera National Park, and iv) Lake Kivu Islands. No mention is made of the Ruzizi River as a priority river system connecting to Burundi's Rusizi National Park and Ramsar Site. Burundi does not appear to have compiled an NBSAP that outlines its conservation priorities.

No national species red lists have been compiled for Rwanda or Burundi.

7.8.2.3 Regional Vegetation Types

A Overview

The Vegetation and Climate change in East Africa project (VECEA) has produced a map of the Potential Natural Vegetation of East Africa, covering seven countries (Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia) (Lillesø *et al.* 2011). According to the Potential Natural Vegetation Map (https://vegetationmap4africa.org), the potential natural vegetation of the Ruzizi Valley between Kamembe and the Burundi border comprises three distinct vegetation mosaics:

- Evergreen and Semi-evergreen Bushland and Thicket and Riverine Wooded Vegetation Mosaic - between Kamembe and the approximate position of the proposed dam wall.
- Lake Victoria *Euphorbia dawei* Scrub Forest and Lake Victoria *Strychnos potatorum* Scrub Forest Mosaic – from the dam wall to Bugarama.
- Freshwater Swamp - between Bugarama and the Burundi border (including the lower Rubyiro River).

The potential natural vegetation of the plateau above the Ruzizi River is classified by VECEA as Lake Victoria transitional rain forest. The location of the project area within these vegetation types is indicated in Figure 7-90.

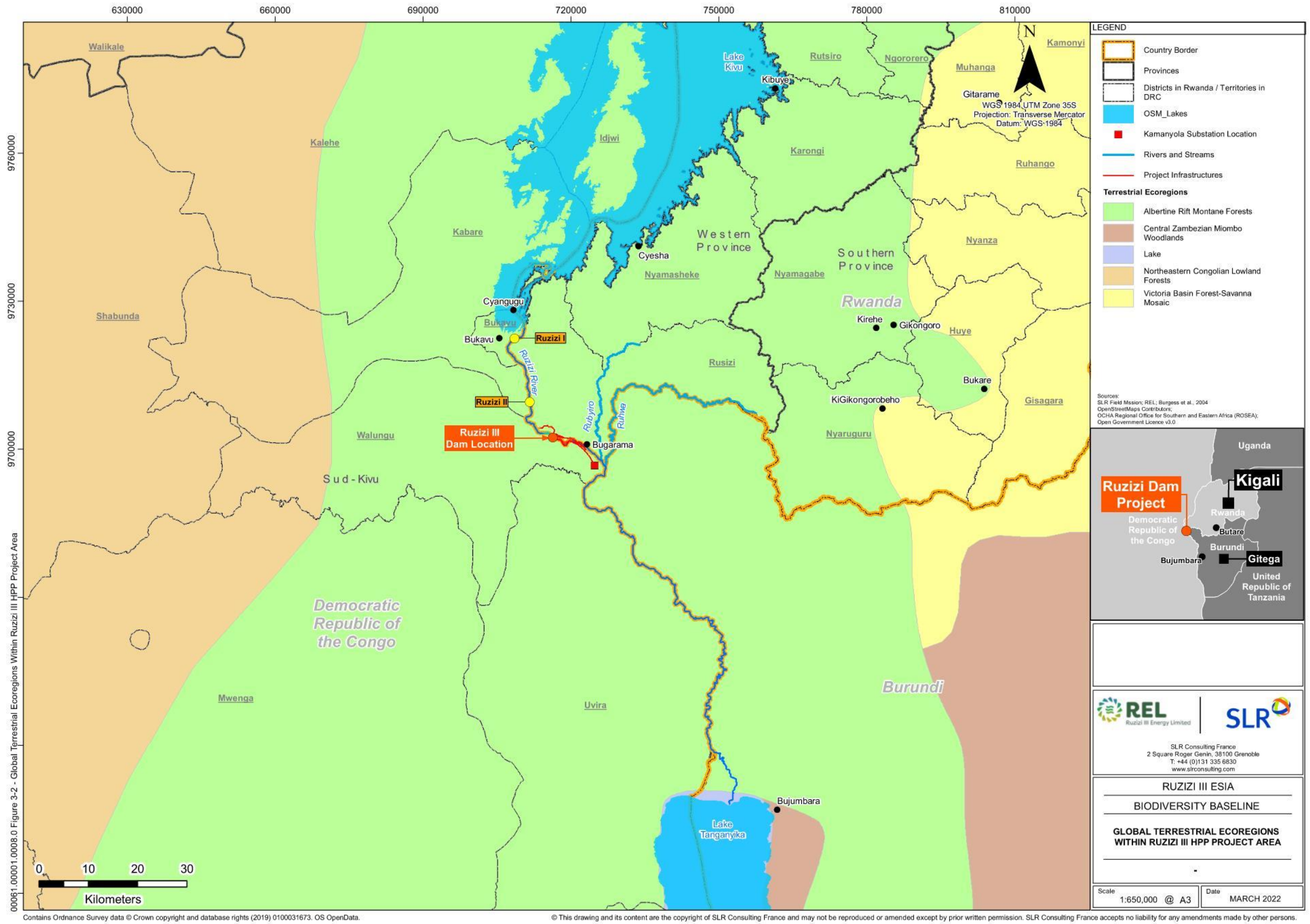

Figure 7-89 Global Terrestrial Ecoregions within Ruzizi III HPP Project Area
Source: Burgess *et al.*, 2004

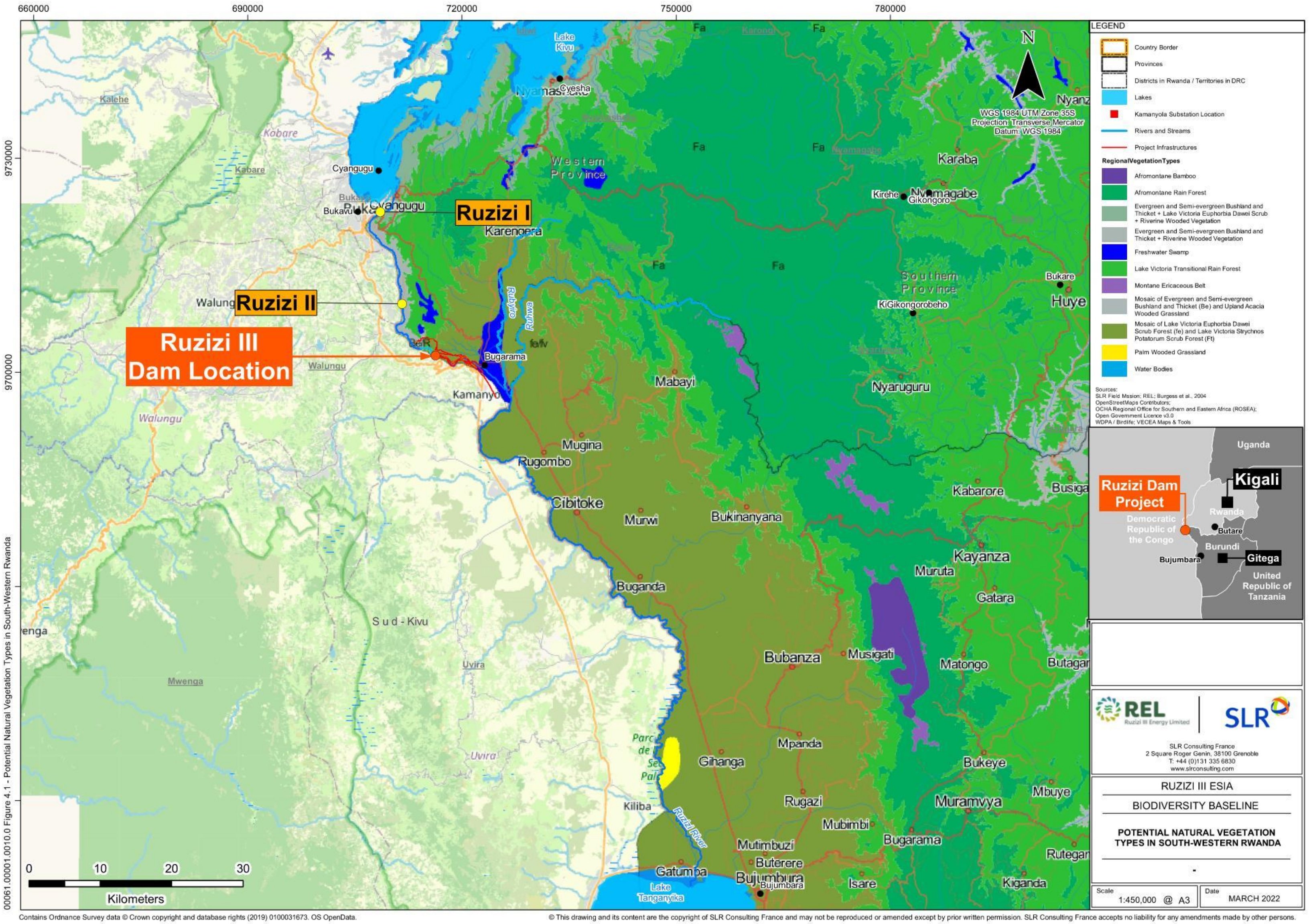

Figure 7-90 Map of the Potential Natural Vegetation Types in South-western Rwanda
[Source: VECEA]

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No natural vegetation representing the Lake Victoria *Euphorbia dawei* Scrub Forest and Lake Victoria *Strychnos potatorum* Scrub Forest Mosaic was located downstream of the dam wall and little of this remains in the vicinity of Bugarama town. No extensive areas of Freshwater Swamp vegetation remain along the Ruzizi Valley between Bugarama and the Burundi border, as well as in the lower reaches of the Rubyiro River, with only narrow, fragmented strips being located along the riverbanks of the Ruzizi.

The main vegetation mosaic that is still represented by natural vegetation in the Ruzizi Valley is the Evergreen and Semi-evergreen Bushland and Thicket and Riverine Wooded Vegetation Mosaic. The two vegetation types which make up this mosaic are described in more detail below.

B Evergreen and Semi-evergreen Bushland and Thicket

Evergreen and Semi-Evergreen Bushland and Thicket occurs is characteristic of drier slopes of mountains in East Africa and often forms the ecotone between Afromontane Forest and Deciduous Bushland. It has always been a localised vegetation type in western Rwanda where it is mostly confined to river valleys and the shores of Lake Kivu. Much of the vegetation type has been lost through extensive agriculture and today it is mostly confined to steep, rocky slopes that are difficult to cultivate. Characteristic trees and woody shrubs include *Senegalia brevispica, Vachellia hockii, Allophylus africanus, Cussonia holstii, Dodonaea viscosa, Dombeya burgessiae, Grewia similis, Olea europaea, Searsia natalensis* and *Carissa edulis*. *Euphorbia candelabrum* is a diagnostic emergent succulent tree. Characteristic lianes include *Capparis tomentosa, Pterolobium stellatum* and *Cissus* species.

C Riverine Wooded Vegetation

The main structural form of Riverine Wooded Vegetation occurring along the Ruzizi River is Riverine Forest or Thicket. Within western Rwanda the vegetation type is confined to the banks of perennial rivers such as the Ruzizi or as scattered fragments along the shore of Lake Kivu. Typical Riverine Forest / Thicket tree species include *Diospyros mespiliformis, Ficus sycomorus, F. vallis-choudae, Syzygium guineense, Senegalia polyacantha, Albizia grandibracteata, Antidesma venosum* and *Bersama abyssinica*, whereas typical shrub or liane species include *Allophylus africanus, Annona senegalensis, Capparis tomentosa, Dovyalis macrocalyx* and *Maesa lanceolata*.

7.8.3 Vegetation Communities

Two hundred and twenty-five (225) plant species were recorded in the project area during fieldwork (Annex C), of which a relatively high proportion (47 species, or 21%) are alien invasive species. Plant families that are well represented are Fabaceae (25 species), Asteraceae (22 species), Poaceae (20 species), Moraceae (10 species) and Malvaceae (9 species).

Five distinct vegetation communities were identified in the Ruzizi III project area during the desktop phase and ground-truthed during fieldwork. These were classified on the basis of floristic composition (dominant and diagnostic species), physical structure (canopy cover, presence of sub-canopy strata) and position in the landscape (e.g. hillslopes, cliffs, riverbanks). Each of these vegetation types is indicated on the maps of the project area (Figure 7-91a, b, c, d). Detailed descriptions of each community are given below, while a summary of each vegetation community and representative photographs are presented in Table 7-28.

7.8.3.1 Riparian Thicket

Riparian Thicket is located along the banks of the Ruzizi River between the upper end of the reservoir and the powerhouse area, as well as along a few of the larger seasonal tributaries of the river (Figure 7-91). This would have been a more extensive vegetation community in the past, but now is a highly fragmented community, comprising mostly small, disconnected strips of thicket along the riverbanks. In most places the riverbanks have been cleared for cultivation

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of crops such as maize, cassava or sorghum. No Riparian Thicket was encountered along the floodplain between Bugarama and the Burundi border. An estimated 3 ha are likely to be lost through dam construction and inundation, while 5.9 ha could be negatively impacted through extraction along the dewatered stretch and an additional 1 ha could be impacted through vegetation clearance along access roads and other infrastructure (Table 7-29).

Vegetation structure is Low to Tall Thicket (sensu Edwards, 1983), with a closed woody canopy and sparse herbaceous understory. The canopy is dominated by tree species such as *Sterculia tragacantha, Ficus vallis-choudae, F. sycomorus, Trema orientalis, Albizia gummifera, A. grandibracteata* and *Bridelia micrantha*. Lianes or scrambling shrubs are quite prominent in certain patches, including species such as *Grewia forbesii, Cardiospermum grandiflorum* and *Cissampelos mucronata*. Where an herbaceous understory is present, soft shrubs such as *Acalypha* cf. *bipartita, A. ornata* and *Hoslundia opposita* are dominant. Grasses are sparse in the understory but do include a few shade-loving species such as *Setaria lindenbergiana* and *Oplismenus* species. Invasive alien plants such as *Lantana camara, Tithonia diversifolia* and *Parthenium hysterophorus* are prominent in some patches of Riparian Thicket. Seventy-six (76) species were recorded in Riparian Thicket during fieldwork, representing 34% of the project area species list (Annex C). Floristic composition is most similar to Hillslope Thicket / Forest, with which it shares 40 species.

No threatened, near threatened or restricted-range species were confirmed to occur in Riparian Thicket. Even though the vegetation community has some functional importance (e.g. riverbank stabilisation, flood attenuation) it only has Moderate Ecological Importance due to being highly fragmented (impacting functional integrity) and densely invaded by alien plants in some thicket patches.

Riparian thicket occurs as narrow strips along riverine and stream courses. Several portions of Riparian Thicket in the project area have been heavily invaded by alien plants (e.g. *Lantana camara, Tithonia diversifolia*), particularly along seasonal tributaries. Portions of riparian thicket with indigenous species are highly fragmented and its ecological functionality is compromised and therefore this habitat is assessed as Modified.

7.8.3.2 Riparian Wetland

The Riparian Wetland vegetation community is confined to relatively narrow strips of recently deposited alluvium (sand, gravel) in discrete places along the banks of the Ruzizi River as well as most of the islands in the river (Figure 7-91). This would have had a more extensive distribution in the project area historically, but many areas have been cultivated with crops such as tree tomato (*Solanum betaceum*), cassava (*Manihot esculenta*) and maize (*Zea mays*). Riparian Wetland covers approximately 3 ha of the reservoir basin and 3.5 ha of the downstream reaches between the reservoir and the powerhouse (i.e. dewatered reach) (Table 7-29). Given that the Riparian Wetlands occur as small discrete habitats along the banks of the lower reaches of the Ruzizi between Bugarama and the Burundi border, they have not been mapped.

Vegetation structure is Tall Grassland (sensu Edwards 1983) on more recently colonised alluvium, where reeds (*Phragmites mauritianus*) and tall grasses (*Hyparrhenia* species) are dominant, but this changes to Low Shrubland when Riparian Wetlands become colonised over time by shrubs such as *Pluchea ovalis, Mimosa pigra, Tithonia diversifolia* and *Lipotriche scandens*. Grasses and sedges are prominent life forms in Riparian Wetlands, including species such as *Leersia hexandra, Sporobolus africanus, Cyperus cyperoides, Cyperus* cf. *dives, Cyperus* cf. *dubius* and *Cynodon dactylon*. Frequent flooding of these wetlands results in frequent deposition of seeds, particularly of herbaceous invasive alien species, which easily become established on the alluvium substrate, e.g. *Ageratum conyzoides* and *Parthenium hysterophorus*.

Thirty-three (33) species were recorded in Riparian Wetlands during fieldwork, representing 15% of the project area species list (Annex C). Floristic composition is most similar to areas of cultivation, with which it shares 17 species (many of which are invasive alien species).

Riparian Wetlands can play an important role in water quality amelioration, by trapping sediment and enhancing nutrient uptake; removal of water quality impurities (such as phosphorous), and

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flood attenuation. However, the riparian wetlands along the Middle Ruzizi in the project area of influence play a relatively minor role in regulating and supporting ecosystem services due to their small and fragmented occurrence and fast flow of the Ruzizi River where the volume of water has insufficient time to be attenuated by the wetlands. The riparian wetlands in the lower Ruzizi River are, however, of greater importance for regulating services.

No threatened, near threatened or restricted-range species were confirmed to occur in Riparian Wetlands. The wetlands have some functional importance (particularly flood attenuation) but functional integrity has been compromised by habitat fragmentation, modification (through cultivation) and invasion by alien plants, and it has relatively low conservation importance because of a low number of potentially occurring SCC. As a result, it only has a Moderate Ecological Importance.

Riparian Wetlands within the PAOI are highly fragmented and of small size as the majority of the alluvium has been converted into agricultural fields, with only interspersed patches of indigenous vegetation. Given the degraded status of riparian wetlands along the Middle Ruzizi River, and their reduced ecological status and functioning, these wetlands were classified as Modified.

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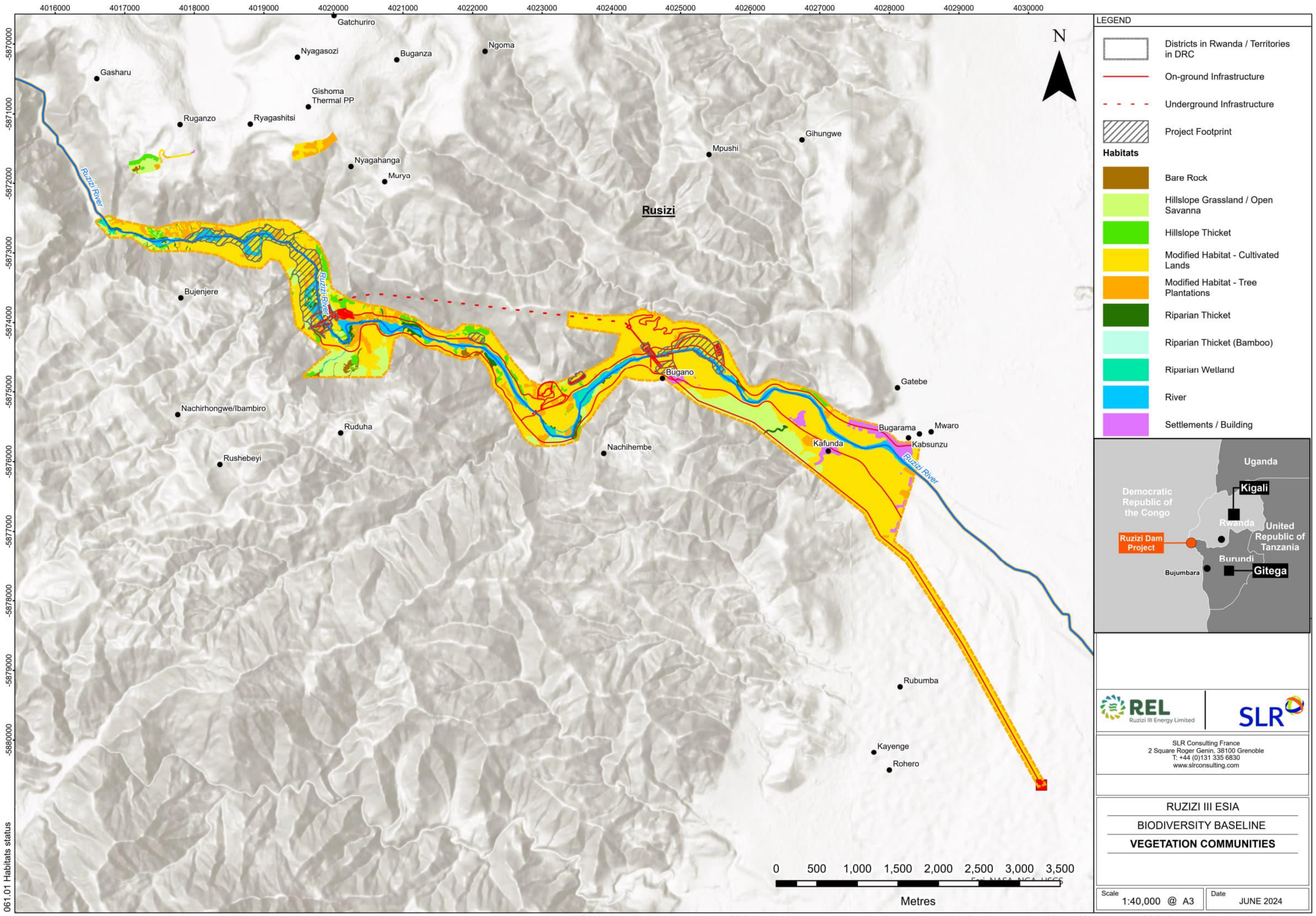

Figure 7-91a Map of Vegetation and Land Cover Types in the Project Area: Overview Map

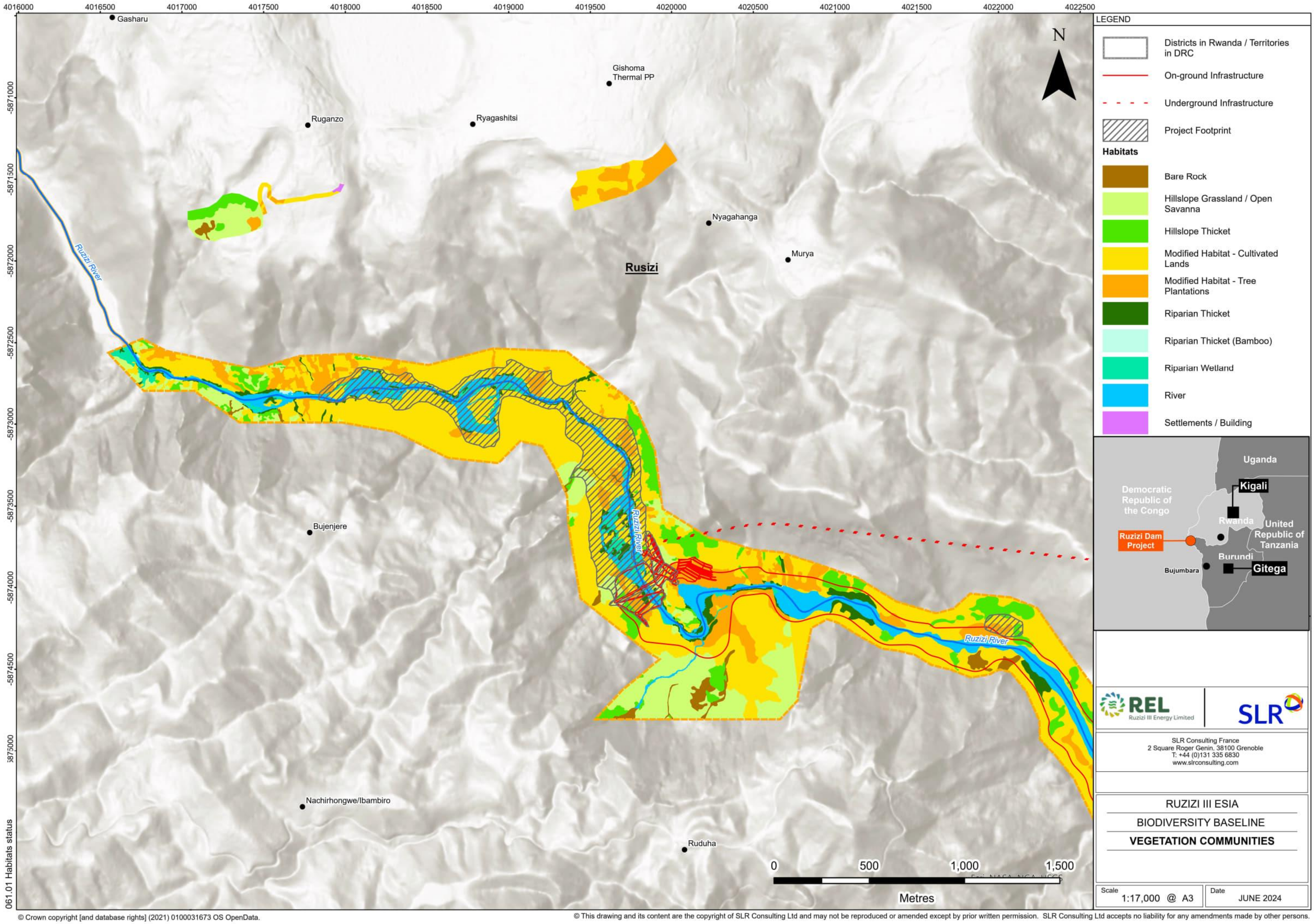

Figure 7-91b Map of Vegetation and Land Cover Types in the Project Area: Reservoir

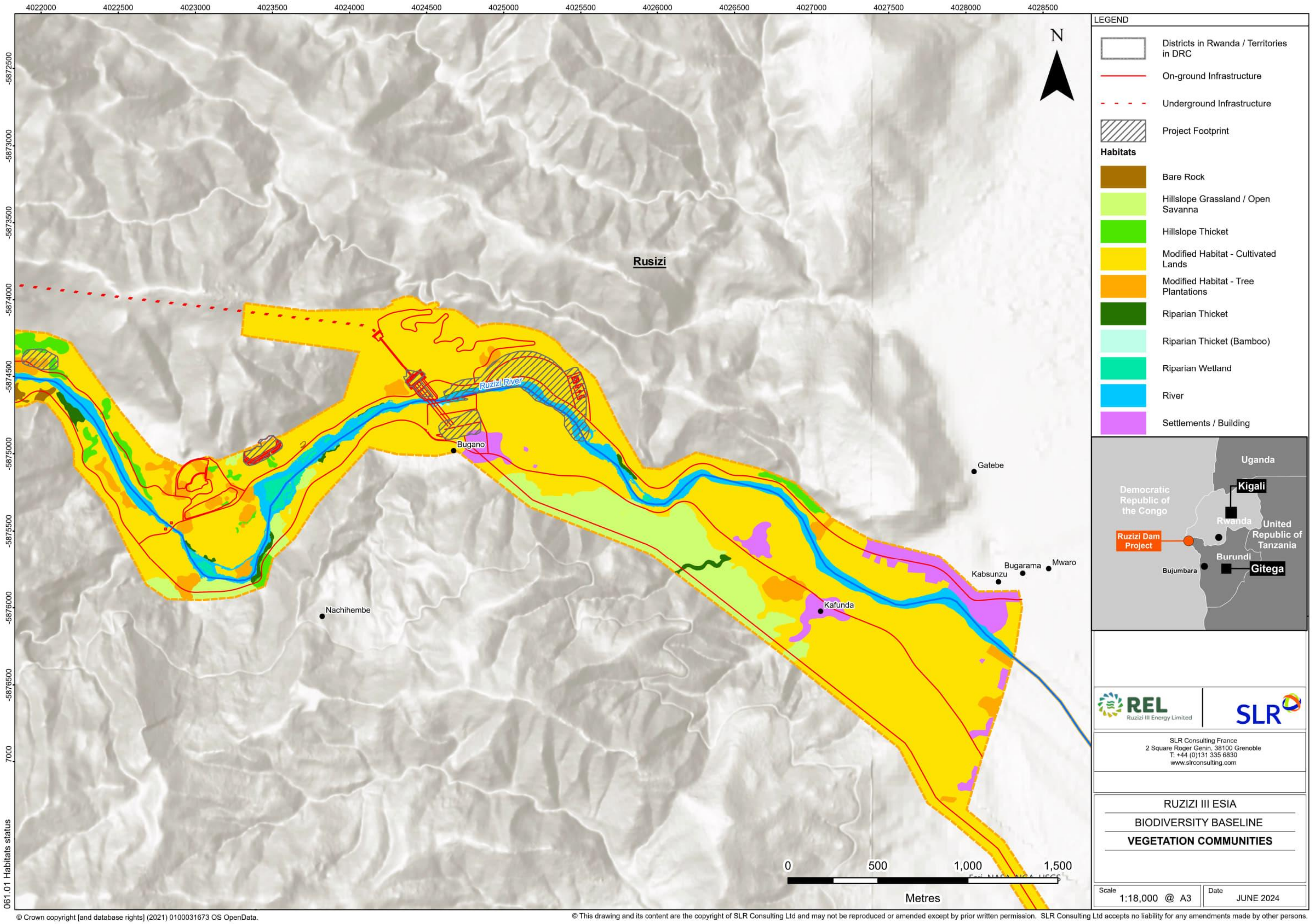

Figure 7-91c Map of Vegetation and Land Cover Types in the Project Area: Ruzizi HPP Downstream Reach

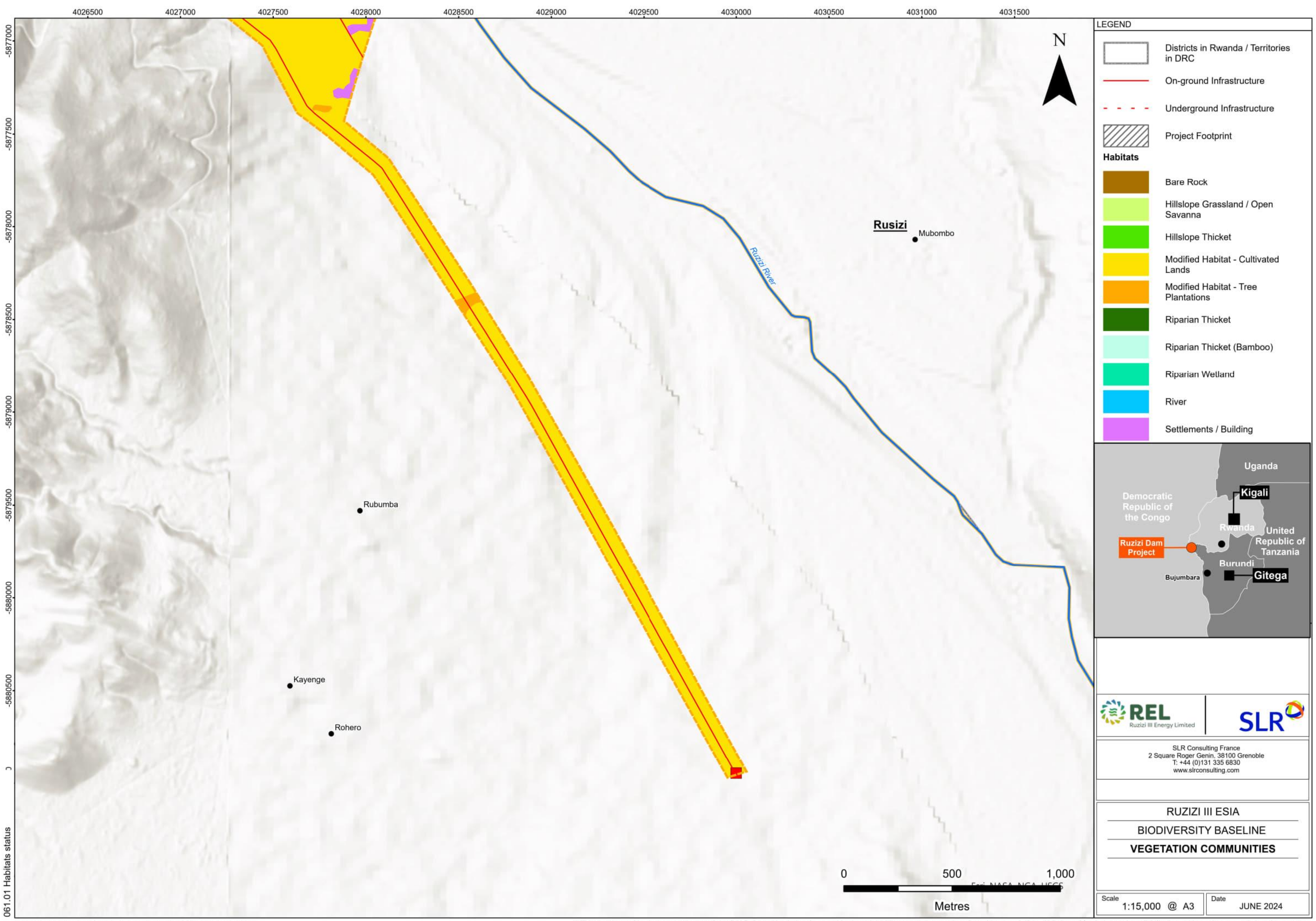

Figure 7-91d Map of Vegetation and Land Cover Types in the Project Area: Transmission Line and Access Road Corridor

7.8.3.3 Cultivation / Secondary Shrubland Mosaic

This vegetation mosaic is the most widespread community in the project area, occurring on the hillslopes above the Ruzizi River, the riverbanks and associated floodplain, and on the plateau above the valley (Figure 7-91). The pattern of the vegetation mosaic results from some of the cultivated fields being abandoned and lying fallow, allowing varying stages of regeneration of woody shrubs and herbaceous plants. Vegetation structure varies from Tall Grassland or Low Shrubland to Tall Woodland (tree plantations).

The vegetation mosaic covers 32.1 ha of the reservoir basin and upper slopes, 15 ha along the transmission line route; 34 ha along access roads and 63 ha in other project infrastructure footprints (Table 7-29). Most of the habitat along the floodplain of the lower reaches of the Ruzizi between Bugarama and the Burundi border has been converted to agriculture and is actively cultivated. The rich floodplain soils and ease of access to water for irrigation means that these cultivated areas are not rotated as they are in the dryland cultivation system upstream of Bugarama, resulting in less fallow land with regenerating shrubland. An estimated 32.1 ha of the Cultivation / Secondary Shrubland Mosaic are likely to be lost through dam construction and inundation.

The dominant crops in the Ruzizi Valley and hillslopes are maize (*Zea mays*), cassava (*Manihot esculenta*), tree tomato (*Solanum betaceum*), sweet potato (*Ipomoea batatas*) and millet (*Sorghum* species), while tree plantations comprise mostly banana (*Musa acuminata*), avocado (*Persea americana*), mango (*Mangifera indica*) and silky oak (*Grevillea robusta*). Prominent crops on the plateau above the Ruzizi Valley include coffee (*Coffea arabica*) and tea (*Camellia senensis*), while the tree plantations are mostly *Eucalyptus* species and banana. Crops that are cultivated mostly on the floodplain downstream of Bugarama and along the Rubyiro River are sugar cane (*Saccharum officinarum*) and rice (*Oryza sativa*). Typical woody shrubs that invade fallow fields are *Lantana camara, Markhamia lutea, Tithonia diversifolia, Solanum chrysotrichum, Urena lobata, Hoslundia opposita* and *Trema orientalis*, while common herbaceous species include *Parthenium hysterophorus, Bidens pilosa, Desmodium tortuosum, Sida acuta* and *Tridax procumbens* (most of which are invasive aliens).

Species richness is relatively high, with 80 species, or 36% of the project area species list, being recorded during the January 2022 survey (Annex C). However, a high number of these (43 species) are alien species, many of which are highly invasive.

No threatened, near threatened or restricted-range species were confirmed to occur in the Cultivation / Secondary Shrubland Mosaic and none are likely to be present.

This vegetation community has Low Ecological Importance as a result of integration of Low Functional Importance (low functional diversity) and Low Biodiversity Importance (high proportion of alien species). This entire vegetation community is classified as Modified Habitat as a result of the high proportion of alien plant species and due to the extent that the primary ecological functions and species composition of the original habitats have been altered.

Regulating ecosystem services are limited within this habitat type due to its modified characteristics. Clearance of indigenous vegetation for agriculture and settlement has resulted in higher velocity rainfall impacted onto the soil surface, leading to more rapid water runoff and reduced percolation into the soil. Consequently, this effect has caused gully and sheet erosion, and in certain places have become so severe as to cause landslides.

7.8.3.4 Hillslope Thicket / Forest

Hillslope Thicket / Forest is a fragmented vegetation community mostly comprising small patches of less than 100 m^2 that are confined to areas of exposed rock or cliffs on the hillslopes, or along seasonal drainage lines high up on the slopes (Figure 7-91); thicket size is mostly dependent on level of fire protection (e.g. areas of exposed rock), with more protected areas having larger thickets.

Vegetation structure varies from Low to Tall Thicket (sensu Edwards 1983), occasionally becoming more structurally complex on the moist upper slopes where it can be classified as Low Forest.

Hillslope Thicket / Forest covers approximately 0.5 ha of the reservoir basin and upper slopes, as well as 2.1 ha along the lower access road and 3.6 ha in other infrastructure (Table 7-29). None of this vegetation community is present on the level plains downstream of Bugarama. An estimated 0.5 ha of Hillslope Thicket / Forest are likely to be lost through dam construction and inundation, with 6.1 ha lost during construction of project infrastructure. None of the vegetation community downstream of the powerhouse is likely to be impacted by dewatering since none of the plant species are flow dependent.

The canopy is dominated by tree species such as *Sterculia tragacantha*, several *Ficus* species such as *Ficus vallis-choudae, F. sycomorus, F. oreodryadum* and *F. thonningii, Trema orientalis, Antidesma venosum*, *Sterculia quinqueloba* and *Bridelia micrantha*. Common woody shrubs include *Grewia forbesii, Hoslundia opposita, Gymnanthemum amygdalinum* and *Searsia longipes*. The herbaceous understory is usually more developed than in Riparian Thicket, with prominent species including soft shrubs such as *Acalypha* cf. *bipartita* and *A. ornata*. Geophytes are also quite common and include *Scadoxus multiflorus, Eulophia guineensis* and *Bonatea steudneri*. Grasses are sparse in the understory but do include a few shade-loving species such as *Setaria lindenbergiana* and *Oplismenus* species. Thickets on the lower hillslopes and along rocky sections above the Ruzizi River are often invaded by the alien shrubs *Lantana camara* and *Tithonia diversifolia.*

Ninety-four (94) species were recorded in Hillslope Thicket / Forest during fieldwork, which is the highest species richness for any vegetation community in the project area, representing 42% of the species list (Annex C). This is remarkably high species richness considering the small spatial coverage of the community in the project area. Floristic composition is most similar to Riparian Thicket, with which it shares 40 species.

No threatened or restricted-range species were confirmed to occur in Hillslope Thicket / Forest. One Near Threatened (NT) species (*Milicia excelsa*) was recorded at the base of a steep slope downstream of the powerhouse site and is unlikely to be directly impacted by the project. This vegetation community has relatively high functional importance (e.g. stabilisation of steep slopes and banks of seasonal drainage lines on upper slopes) and moderate Biodiversity Importance (proportion of habitat specialists, one NT species), resulting in an integrated Ecological Importance value of Moderate.

Regulating services associated with this habitat type are dependent on the density of alien plant encroachment. Soil stability is relatively high where a diversity of indigenous vegetation is present, attributed to the different root lengths and structure of the different functional growth forms. However, where monostands of alien plants are present, soil stability is weakened, with a concomitant increase in erosion. Although the habitat does support pollinators, the diversity was observed to be lower than Riparian Thicket.

This habitat is highly fragmented, comprises small discrete patches, and ecological functioning has been seriously compromised and there this habitat is assessed as Modified.

7.8.3.5 Hillslope Grassland / Savannah

Hillslope Grassland / Savannah is characteristic of the steepest hillslopes above the Ruzizi River between the upper reaches of the reservoir and the towns of Bugarama and Kamanyola (DRC), usually occurring on the highest slopes and only rarely reaching the river (Figure 7-91). Most of the accessible hillslopes have been cultivated and this vegetation community occurs in a patchwork of cultivation and regenerating low shrubland.

Hillslope Grassland / Savannah covers approximately 20 ha of the hillslopes above the Ruzizi Valley between the upper reaches of the reservoir and the towns of Bugarama and Kamanyola (Table 7-29); this includes approximately 48% of the transmission line route between the powerhouse and the Kamanyola distribution site. An estimated 1.66 ha of Hillslope Grassland / Savannah are likely to be lost through dam construction and inundation. None of the vegetation community downstream of the powerhouse is likely to be impacted by dewatering since none of the plant species are flow dependent. The only parts of this habitat that are likely to be impacted by erection of the transmission lines is at the location of each tower on the hillslopes.

Vegetation structure varies from Low Open to Closed Grassland (sensu Edwards 1983), becoming Open Woodland where trees and shrubs are more prominent. Very few grass species were in flower during fieldwork (making identification of non-flowering species problematic) but those that were identified included a *Cymbopogon* species, *Hyparrhenia* cf. *filipendula, Setaria sphacelata, Sporobolus* cf. *pyramidalis* and *S. africanus*. Forbs, dwarf shrubs and geophytes observed in this community included *Ocimum obovatum, Tinnea apiculatum, Bothriocline* cf. *longipes, Leonotis nepetifolia, Pentas zanzibarica* and *Habenaria* cf. *adolphii*. Low trees and woody shrubs that are characteristic of Hillslope Grassland / Savannah are *Ozoroa insignis, Vachellia hockii, Lannea* cf. *antiscorbutica, Cussonia arborea, Gymnosporia senegalensis* and *Sterculia quinqueloba*. Areas of exposed rock have a unique sub-community that is dominated by ferns such as *Adiantum incisum, Actiniopteris semiflabellata* and *Aleuritopteris farinosa*, as well as the succulent forb, *Peperomia* cf. *leptostachya*.

Fifty-nine (59) species were recorded in Hillslope Grassland / Savannah during fieldwork, which represents 26% of the project area species list (Annex C). Floristic composition is most similar to Hillslope Thicket / Forest, with which it shares 21 species, mostly woody shrubs or trees that occur in both vegetation communities.

No threatened, near-threatened or restricted-range species were confirmed to occur in Hillslope Grassland / Savannah. This vegetation community has relatively high functional importance (e.g. stabilisation of steep slopes) and moderate Biodiversity Importance (proportion of habitat specialists), resulting in an integrated Ecological Importance value of Moderate.

Hillslope Grassland / Savannah can be classified as largely Natural Habitat on the basis of the high proportion of indigenous species and relatively intact ecological functionality. This vegetation community has been least impacted by alien plant invasion in the project area.

Accordingly, this habitat type supports and provides important regulating services, especially soil stabilisation. This habitat type also plays a role in maintaining the hydrological characteristics of the sub-catchment. The dense graminoid growth reduces the physical impact of rainfall on the soil surface, while also reducing water velocity run-off. Notably, solitary bees were observed to be important pollinators within this habitat type.

Table 7-28 Summary of Vegetation Communities in the Ruzizi III Project Area

Vegetation Communities	Dominant and Diagnostic Species	Photographs		Habitat Status	Ecological Importance
Riparian Thicket	*Sterculia tragacantha, Ficus vallis-choudae, F. sycomorus, Trema orientalis, Albizia gummifera, A. grandibracteata, Bridelia micrantha, Grewia forbesii*			Modified	Moderate
Riparian Wetland	*Phragmites mauritianus, Hyparrhenia sp., Pluchea ovalis, Mimosa pigra, Lipotriche scandens, Leersia hexandra, Cyperus cyperoides, Cyperus dives, Cyperus dubius, Cynodon dactylon*			Modified	Moderate
Cultivation	*Zea mays, Manihot esculenta, Solanum betaceum, Ipomoea batatas, Musa acuminata, Persea americana, Mangifera indica, Coffea arabica, Eucalyptus species, Lantana camara, Tithonia diversifolia, Parthenium hysterophorus*			Modified	Low
Hillslope Thicket / Forest	*Sterculia tragacantha, Ficus vallis-choudae, F. sycomorus, F. oreodryadum, F. thonningii, Trema orientalis, Sterculia quinqueloba, Grewia forbesii, Searsia longipes, Scadoxus multiflorus, Eulophia guineensis, Bonatea steudneri*			Modified	Moderate
Hillslope Grassland / Savanna	*Cymbopogon sp., Hyparrhenia cf. filipendula, Setaria sphacelata, Ocimum obovatum, Tinnea apiculata, Bothriocline cf. longipes, Leonotis nepetifolia, Habenaria cf. adolphii, Ozoroa insignis, Vachellia hockii, Lannea cf. antiscorbutica*			Natural	Moderate

Table 7-29 Summary of Spatial Cover of Vegetation Communities in the Ruzizi III Project Area

Vegetation Community/ Habitat	Terrestrial Ecological Importance	Habitat Status	Reservoir (to Full Supply Level: 1150 masl)*		Dewatered Reach (only riparian wetlands, thicket) & open water)		Substation & Transmission Line RoW (30 m wide)		Access Road Corridor (20 m wide)		Access Road To Powerhouse**		Dam Site, Laydown Area, Spillway***		Other project infrastructure (powerhouse, disposal areas, laydown, camps)***		Total Footprint
			Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	ha	%	ha
Riparian Thicket	M	Modified	2.97	5.6%	5.9	15.4%	0.05	0.2%	0.45	1.%			0.35	4.8%	0.05	0.1%	**9.77**
Riparian Wetlands	M	Modified	3.04	5.7%	3.54	9.2%							0.10	1.4%			**6.68**
Hillslope Thicket / Forest	M	Largely Natural	0.45	0.8%					2.11	4.9%			0.46	6.3%	3.60	5.0%	**6.62**
Hillslope Grassland / Savannah	H	Largely Natural	1.66	3.1%			5.52	26.2%	2.84	6.6%	3.45	42.8%	0.90	12.3%	3.90	5.4%	**18.3**
Open Water	M	Modified	13.29	24.8%	28.93	75.4%			0.1	0.2%			0.95	13.0%	0..03	0.0%	**43.3**
Cultivation / Secondary Shrubland Mosaic	L	Modified	32.12	60%			15.0	71.2%	34.16	79.1%	4.52	56.0%	4.46	60.9%	63.5	87.8%	**153.8**
Towns & Villages	VL	Modified / Largely Modified					0.495	2.3%	3.24	7.5%	0.10	1.2%	0.10	1.4%	1.0	1.4%	**4.97**
Bare Rock	M	Largely Natural							0.27	0.6%					0.22	0.3%	**0.49**
Total			**53.53**	**100%**	**38.37**	**100%**	**21.06**	**100%**	**43.17**	**100%**	**8.07**	**100%**	**7.32**	**100%**	**72.34**	**100%**	**243.86**

* Note: 1150 masl was used although FSL is 1149.5masl
**Potential widening of the existing road is not included
*** These areas were based on the land acquisition areas which may be larger than the actual project footprint areas as the actual infrastructure footprint areas were not available. Therefore, these quantified areas likely represent a worst-case land loss However, note that total footprint excludes any potential quarry areas.

7.8.3.6 Flora of Conservation Concern

Eighty-two (82) threatened plant species have distribution ranges that overlap with the project area, of which fifty are classified by the IUCN as Vulnerable (VU) and 32 as Endangered (EN) (Annex C). An additional 23 species are classified as Near Threatened (NT). However, the vast majority of these are confined to undisturbed montane habitats at much higher altitudes than that of the project area and are unlikely to occur in the project area. Six (6) species that are threatened (3 EN and 3 VU species) and one species that is classified as NT but is also a restricted-range species (i.e. has an EOO of less than 50,000 km^2) are considered to be priority Species of Conservation Concern (SCC) in this project. These species occur at altitudes represented in the project area and in habitats that would have been more widespread in the area historically and thus have a moderate likelihood of being present, even if they were not located during fieldwork (Table 7-30).

Three EN species are apparently endemic or mostly confined to the Ruzizi River Valley, either in the vicinity of the project area or on the floodplain downstream of the project area, namely *Emilia subscaposa* (Asteraceae), *Chlorophytum hirsutum* (Anthericaceae) and *Blepharis burundiensis* (Acanthaceae). Each of these species is also classified as a Restricted-range species as a result of having an EOO of less than 50,000 km^2. However, *Blepharis burundiensis* is unlikely to be present since it occurs in habitats and at altitudes not represented in the project area[17]. *Emilia subscaposa* and *Chlorophytum hirsutum* potentially occur in the fragments of natural grassland or thicket habitat that remain on the slopes above the reservoir basin although they were not located in any of the habitats surveyed. The May 2024 survey confirmed the absence of these species from the transmission line route, and they are unlikely to occur within habitats accessible to people and livestock. However, if present within very steep inaccessible slopes, neither species will be impacted by the direct loss of habitat through reservoir inundation and transmission line construction.

An additional more widespread EN species, *Bulbostylis longiradiata* (Cyperaceae), potentially occurs in the Hillslope Grassland / Savannah vegetation community in the project area. This small, easily overlooked species potentially occurs on the hillslopes above the reservoir and is thus unlikely to be impacted by the direct loss of habitat through reservoir inundation. The species was initially thought to occur on the slopes along which the transmission lines are routed and would then be impacted by construction of pylons if present. However, none of the grassland fragments that were surveyed in proximity to the transmission line, including during the May 2024 survey, contained this species and it is considered unlikely to occur within the project area.

The potentially occurring three VU species and one NT species are described in more detail in Table 7-30. An additional NT species, *Milicia excelsa* (Moraceae), was confirmed to occur at one site during fieldwork. A single mature tree was located at the edge of Hillslope Thicket at the base of a slope downstream of the powerhouse (Figure 7-92. . Since this tree is not situated within any project infrastructure it is unlikely to be impacted by the development of the project. It is also likely to be present elsewhere in the project area at sites not surveyed during fieldwork. It is a widespread species occurring throughout tropical Africa and is heavily harvested for commercial timber but is unlikely to occur in sufficient density in the project area to be harvested.

[17] This is not one of the three EN species mentioned above

Figure 7-92. Near-Threatened *Milicia excelsa* in Hillslope Thicket near Powerhouse

Table 7-30 Priority Plant Species that could Potentially Occur in the Ruzizi III Project Area

Scientific Name	IUCN Status	Extent of Occurrence (km²)	Habitat	Likelihood	Rationale
Emilia subscaposa	EN	706	Prefers swamps, but has also been reported from sandy fallows, cassava fields, and dry grassland, at 775–1,030 m altitude.	Low	While much suitable present downstream of the project, this poorly known species has not been collected since 1971 and is only known from 6 specimens from the southern reaches of the Rusizi.
Chlorophytum hirsutum	EN	12,155	Grows in open forest, *Loudetia* grassland, forest margins among boulders, gallery forest, ravine with Euphorbia; at 675-1,200 m altitude.	Low	While there is suitable habitat in the project area the species is unlikely to occur within the project area due to anthropogenic influences.
Bulbostylis longiradiata	EN	111,949	Grows in grassland and open woodland at 800-1,250 m asl.	Low	While there is suitable habitat in the project area the species is unlikely to occur within the project area due to anthropogenic influences.
Vernonia melanocoma	NT	40,813	An annual herb of roadsides in wooded grassland and grassland.	Moderate	Some suitable present in the project area
Buchnera keilii	VU	578,853	Grows in grassland, light woodland at 1,300-2,000 masl.	Moderate	Some suitable present in the project area.
Ochna hackarsii	VU	83,791	Occurs in riparian forest at 750-1,470 masl.	Moderate	Some suitable present in the project area
Pauridiantha bequaertii	VU	206,231	Occurs in lowland to mid-altitude forests at 700–1,350 m elevation.	Moderate	Some suitable present in the project area

7.8.3.7 Threats to Vegetation and Flora

The greatest current threat to vegetation in the project area is the conversion of natural habitat through to agriculture. Cultivated lands and tree plantations comprise 66% of the project area, indicating the significant habitat losses that have already taken place. This loss of natural habitat has been most severe downstream of Bugarama, where the entire floodplain and adjacent terrestrial plains have been converted to high intensity small-scaler agriculture or urban residential developments. No natural habitat was located in this part of the project area, apart from narrow strips of Riparian Wetland vegetation along the banks of the Ruzizi River. A careful scan from a high vantage point above the confluence of the Rubyiro and Ruzizi Rivers confirmed that no extensive wetland habitat remains along this stretch of the Ruzizi in either Rwanda or the DRC.

Another significant threat to vegetation is invasion of habitats by invasive alien plants. Forty-seven (47) alien plant species were recorded during fieldwork, representing 21% of the total plant list, which is a high proportion. Three species are particularly invasive and are already present in significant numbers, namely *Tithonia diversifolia*, *Lantana camara* and *Parthenium hysterophorus*. Each of these species has the potential to transform landscapes by growing in such dense infestations that few other plants can compete, resulting in transformation of habitat structure and species composition. Photos of a selection of invasive alien plant species found in the project area is presented in Figure 7-93.

Another impact on natural habitat was visible on steep slopes, namely extensive soil erosion or landslides, most of which have resulted in loss of Hillslope Grassland / Savannah vegetation. Paths along some of the steep slopes on the DRC side of the river have resulted in accelerated soil erosion in places Exacerbated and additional landslides were observed during the May 2024 survey. The hillslopes adjacent to the RN5 in the DRC are particularly susceptible to erosion as the road traverses very steep slopes with no erosion control measures.

A single active charcoal kiln and a few old kilns were located within the reservoir area, but charcoal production does not seem to be widespread, possibly because of the lack of large trees in the area (apart from tree plantations Photographs of some of these threats to vegetation are shown in Figure 7-94.


Photo 1. *Lantana camara* (lantana)


Photo 2. Tithonia diversifolia


Photo 3. Parthenium hysterophorus


Photo 4. Desmodium tortuosum

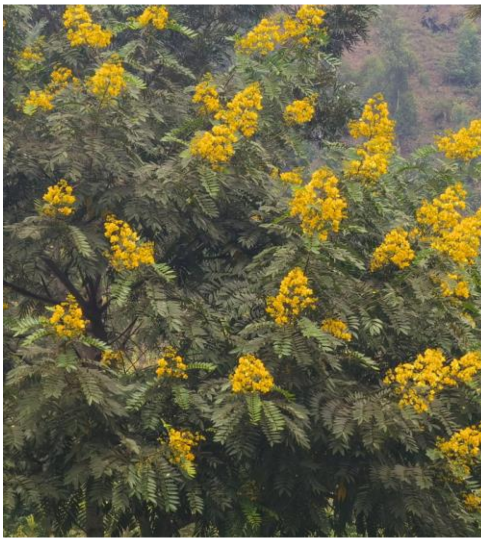
Photo 5. Senna spectabilis


Photo 6. Senna hirsuta

Figure 7-93 Photos of Selected Invasive Alien Plant Species Found in the Project Area

PUBLIC DISCLOSURE AUTHORIZED

Photo 1. Extensive cultivation of the Rubyiro floodplain (downstream of Ruzizi HPP)

Photo 2. Extensive cultivation of the Ruzizi Valley near Kamanyola (DRC) (downstream of Ruzizi HPP)

Photo 3. Cultivation of steep upper slopes of the Ruzizi Valley above the reservoir

Photo 4. Charcoal kiln

Photo 5. Large landslide above the Ruzizi River

Photo 6. Accelerated soil erosion along a footpath

Figure 7-94 Photographs Highlighting Threats to Vegetation Types and Flora

7.8.3.8 Observations of Landcover Change between 2022 and 2024

Based on observations made during the 2024 survey, there were distinct, albeit minor, landcover changes from the 2022 survey, specifically within the Rwanda territory of the PAOI. The only habitat type with observed changes was the Hillslope Grassland/Open Savanna habitat which was re-delineated on imagery and found to have reduced by approximately 17 ha from 65 ha to 48 ha, which equates to a 26% loss. The loss of this habitat type was caused largely by portions being altered into agricultural areas or more heavily encroached by alien plants.

Selected areas of proposed infrastructure were visited during the supplementary survey to confirm the status of the habitats. All proposed construction sites visited were confirmed to be modified habitats possessing minimal biodiversity importance. Figure 7-95 provides photographs of the habitats within the proposed infrastructure areas.

	
Employer's village including disposal area	Surge shaft, Penstock, Powerhouse & Tailrace Channel
	
Disposal area & access to HRT Adit	Diversion tunnel portal works, Spillway works, Damsite and Laydown areas

Figure 7-95 Photographs Showing Degraded Habitats in Project Construction Footprints

7.8.4 Birds

7.8.4.1 Bird Diversity and Habitat Types

The project area is located in the southern part of the Albertine Rift Montane Forests terrestrial ecoregion, which supports an estimated 732 avifauna species, the highest avifaunal diversity of any ecoregion in Africa (Burgess *et al.,* 2004). However, this diversity is supported by a diverse range of habitats and landscape types, many of which are absent from the project area and avifaunal species richness is likely to be significantly lower. Rwanda has an exceptionally rich avifaunal diversity, with 701 species currently listed for the country (Vande weghe & Vande weghe, 2011). Distribution data for the birds of Rwanda indicate that 200 species have been recorded in the 7' x 7' mapping grids in which the project area is located (B14 and C14) (Vande weghe & Vande weghe, 2011). However, several common species recorded during fieldwork have not been recorded in these grids before and it appears that the grids have not been thoroughly surveyed. The project area does not support all the habitats represented in the two mapping grids and it is unlikely that it will support the full species list. However, species richness is still moderately high, and 115 species were recorded during the six field days during 2022 (Annex C). This is significantly higher than the avifauna list from the previous survey, i.e. 16 species (SOFRECO, 2011). The supplementary survey undertaken in May 2024 recorded an additional 13 widely distributed and non-threatened species, thereby recording a total of 128 bird species within the PAOI.

Bird families/groups that were particularly well represented were weavers and bishops (11 species), diurnal raptors (10 species), sunbirds (8 species), cuckoos and coucals (7 species), and doves and pigeons (6 species). Fish-eating birds such as kingfishers, herons and cormorants were either absent or present in remarkably lower numbers than would be expected along a large river, reflecting the low fish abundance reported by the aquatic specialist. The high daily discharge variation due to hydropeaking likely negatively influences piscivorous bird feeding capability. A species accumulation curve from the 10-species lists generated during the SLR 2022 survey is presented in Figure 7-96. Although the curve has not yet flattened, it has levelled enough to indicate that habitats within the AOI were sufficiently sampled. Tabulated data that were used to generate this curve are presented in Annex C.

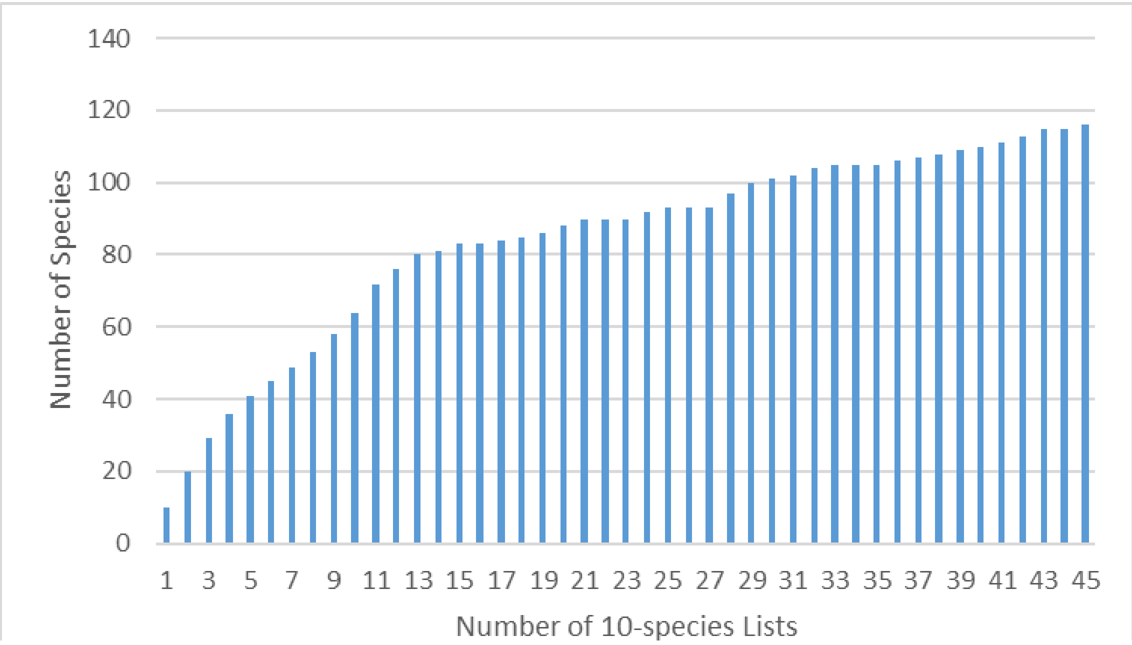

Figure 7-96 Species Accumulation Curve from 10-species List Data from 2022 Bird Survey

Seven distinct avifaunal assemblages were recorded in the project area, corresponding to specific vegetation communities or habitats. Each of these assemblages is briefly described in Table 7-31 including mention of dominant and diagnostic species.

Table 7-31 Avifaunal Assemblages

Assemblage	Description
Hillslope Grassland / Savanna	This habitat was difficult to access and was not thoroughly sampled. However, 47 species were recorded; 41% of the project area species list. No species were noticeably dominant in this assemblage, although four species were only found in this habitat, namely African black swift, common kestrel (breeding pair), familiar chat and cinnamon-breasted bunting. No additional dominant species were observed in the May 2024 survey.
Hillslope Thicket	This is the second most diverse assemblage in the project area, with 56 species recorded, representing 49% of the project area species list. Dominant species included white-browed robin-chat, tropical boubou, red-eyed dove, speckled mousebird, African thrush, blue-spotted wood dove, grey-backed camaroptera, African paradise flycatcher and brown-throated wattle-eye. Five species were only recorded in this assemblage, namely African green pigeon, eastern olivaceous warbler, white-chinned prinia, African yellow white-eye and olive-bellied sunbird.
Riparian Thicket	Thicket habitat usually supports rich avifaunal diversity but only 26 species were recorded in the riparian thicket assemblage, which indicates the fragmented state and small size of thicket patches. Dominant species were white-browed robin-chat, tropical boubou, speckled mousebird, African thrush, blue-spotted wood dove and grey-backed camaroptera. Only one species was diagnostic for this assemblage, namely ashy flycatcher, while numerous species were shared with the Hillslope Thicket assemblage.
Riparian Wetland	This is another species-poor assemblage, with only 26 species recorded, or 23% of the project area species list. The most frequently recorded species were red-faced cisticola, village weaver, southern red bishop, bronze mannikin and tawny-flanked prinia. Only two species were apparently confined to this assemblage, namely greater swamp warbler and red-chested sunbird.
Open Water	This is the most species-poor assemblage in the project area, with only 18 species recorded. It is associated mostly with the surface water of the Ruzizi River and fishponds near the Burundi border. The only frequently occurring species in the Project footprint were reed cormorant and African pied wagtail, whereas four species were only recorded in the open water community downstream near Bugarama, namely white-faced whistling duck, western great egret, white-breasted cormorant and red-knobbed coot.
Cultivation	This is the dominant assemblage in the project area and is associated with currently cultivated lands, exotic tree plantations and secondary shrubland in fallow lands. Seventy-nine species, or 69% of the project area species list, were recorded in this assemblage. Dominant species include dark-capped bulbul, bronze mannikin, tropical boubou, red-eyed dove, northern fiscal, scarlet-chested sunbird, speckled mousebird, blue-spotted wood dove and red-faced cisticola. Three species were only found in this assemblage, i.e. are diagnostic, namely great reed warbler, spotted flycatcher and village indigobird.
Towns & Villages	This was a surprisingly diverse assemblage, with 33 species recorded. Dominant species are northern grey-headed sparrow, house sparrow, pied crow and yellow-fronted canary, while the only species confined to this assemblage were speckled pigeon, western barn owl and house sparrow.

7.8.4.2 Priority Bird Species

Priority bird species identified in the project area are those that have been classified by the IUCN as threatened (CR, EN or VU), species classified by the IUCN as Near Threatened (NT), species restricted to Endemic Bird Areas (EBAs) such as the Albertine Rift Mountains EBA, or species restricted to biomes such as the Afrotropical Highlands or Lake Victoria Basin biomes (Kanyamibwa, 2001). A description of priority birds is summarised in the sections below.

A Threatened Species

Thirty-nine threatened and NT avifauna species have distribution ranges that broadly overlap with the project area according to distribution maps in IUCN assessments (Table 7-32).

Three of these are Critically Endangered (CR), 11 are classified as EN, 12 as VU and 13 as NT. Fine-scale distribution maps in Vande weghe & Vande weghe (2011) indicate that many of these species do not occur in western Rwanda, including a number of papyrus endemics such as papyrus gonolek (*Laniarius mufumbiri*) and papyrus yellow warbler (*Calamonastides gracilirostris*). Most of the species that do occur in western Rwanda occur in habitats or at altitudes that are not represented in the project area (especially montane forest species). Otherwise, they are species that do not tolerate the disturbance levels typical of densely settled areas such as the project area. Only one EN species (bateleur *Terathopius ecaudatus*) and one NT species (pallid harrier *Circus macrourus*) have a moderate likelihood of occurring in the project area, as described below. However, neither were seen during the 2022 or 2024 surveys.

A.1 Bateleur

Bateleur is a relatively common resident throughout sub-Saharan Africa and the Arabian Peninsula, only avoiding the heavily forested Congo Basin. It is a widespread species in East Africa, most common in open savannah, arid or semi-arid bushland, woodland and grassland (Britton, 1980). It is a common breeding resident throughout Rwanda, although there have been substantial population declines in the past 30 years (Vande weghe & Vande weghe, 2011). Foraging habitat includes a variety of grassland and savannah types, only avoiding densely wooded and forested areas. Breeding appears to be confined to Akagera National Park in the eastern part of the country, where 20-25 pairs were recorded in 1980. Breeding has been recorded from October to June. The global population is estimated to be 10,000 to 100,000 individuals (Ferguson-Lees and Christie, 2001) and it has an EOO of 23,500,000 km^2. However, the species Is suspected to have undergone moderately rapid declines during the past three generations (41 years) as a result of habitat loss and incidental poisoning and has recently been uplisted from NT to EN (BirdLife International, 2021a). No birds were recorded in the project area during fieldwork, but suitable habitat is present and it is possible that these birds may forage over the area occasionally.

A.2 Pallid harrier

This is a Palearctic non-breeding migrant to Africa, breeding mainly in the steppes of Russia, Kazakhstan and north-west China. While small numbers winter in south-east and central Europe, north Africa and the Middle East, most birds migrate to tropical Africa (BirdLife International, 2021b). Pallid Harrier is an uncommon passage migrant in Rwanda, with some birds overwintering (Vande weghe & Vande weghe, 2011). Most birds are present in the country from December to February and occur in open grassland and lightly wooded savannah, with more birds generally occurring in central and western Rwanda than the east. It has also been recorded foraging over cultivated lands in Rwanda and thus potentially occurs in the broad parts of the Ruzizi River valley downstream of Bugarama. Pallid harrier is unlikely to occur in the reservoir area or along the downstream reaches to Bugarama, and the grassland habitat along much of the transmission line route is unsuitable for this species; slopes are too steep for its foraging strategy.

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B Biome restricted Endemics

Twenty-eight (28) species that are confined to the Albertine Rift Mountains Endemic Bird Area (EBA) occur in Rwanda. Of these, only two species occur at altitudes represented in the project area (Ruwenzori nightjar *Caprimulgus ruwenzorii*, Ruwenzori hill babbler *Sylvia atriceps*), while the rest only occur at much higher altitudes, mostly in Nyungwe Forest and the Volcanoes National Park, and are unlikely to be present in the project area. More details regarding the two potentially occurring species are provided in Table 7-33.

Three biomes are represented in Rwanda (as defined by Fishpool & Evans, 2001), of which two are represented in the project area, namely the Lake Victoria Basin (11 species) and Afrotropical Highlands (60 species) biomes (Kanyamibwa, 2001). Four species endemic to the Lake Victoria Basin and ten species endemic to the Afrotropical Highlands are known to occur in south-western Rwanda and are described in Table 7-34. Eight of these species were confirmed to occur within the project area during fieldwork. The higher altitude habitats, such as the upper slopes of the Ruzizi valley, supported the most endemics, including cinnamon-chested bee-eater (*Merops oreobates*), Chubb's cisticola (*Cisticola chubbi*), black-lored babbler (*Turdoides sharpei*), bronzy sunbird (*Nectarinia kilimensis*), baglafecht weaver (*Ploceus baglafecht*) and western citril (*Dendrospiza frontalis*). The reservoir and downstream reaches to Bugarama only supported three species (baglafecht weaver, western citril & slender-billed starling *Onychognathus tenuirostris*), while the only species located along the Ruzizi River downstream of Bugarama was red-chested sunbird (*Cinnyris erythrocerca*).

However, none of the above species has a global Extent of Occurrence (EOO) of less than 50,000 km^2 and thus do not qualify as restricted-range species as defined in IFC Performance Standards (IFC 2012).

C High-Risk Species

The supplementary bird survey undertaken in May 2024 was targeted mainly at confirming bird species at risk of collision and electrocution on transmission lines. It revealed that high risk avifauna species are relatively scarce within the PAOI and proximal landscape due to the widescale level of anthropogenic activities and habitat modification. However, there are some raptor species that are at risk of electrocution due to their wingspan or streamers[18] s Nevertheless, there are raptor species occurring within the PAOI that are potentially at risk of electrocution due to their wingspan or streamers. Below is a basic description of the ecology of the species recorded.

A pair of Lanner Falcons (*Falco biarmicus*) were recorded adjacent to the clay borrow area. Lanner Falcons are generally resident although they exhibit extensive movements in arid regions, especially juveniles and non-breeding adults. The pair were exhibiting typical hunting behavior, and no nest site was located while scanning the cliffs and erosion gulleys, albeit it is expected to be in the locality of where the pair was recorded based on behavior. The activities of the borrow area are unlikely to considerably influence the behavior of the pair, as they are currently inhabiting a highly modified portion of the landscape with associated erosion and noise impacts. The species predominantly feeds on smaller birds, with rodents, bats, reptiles and insects forming a smaller component of the diet. Columbidae (doves and pigeons) likely dominate their diet within the area, and this group is tolerant to disturbance, and so borrow pit activities are unlikely to considerably influence the Lanner Falcons prey resource. The species hunts mainly by fast aerial pursuit from a perch or horizontal chase. While the species hunting behavior suggests that it is at risk of collision with the transmission line, there are no records of the species colliding with overhead lines during hunting. The species is known to nest on pylons and as such, may utilize these, posing an electrocution risk.

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A pair of Common Kestrels (*Falco tinnunculus*) were previously recorded to nest within the PAOI during the 2022 survey, and the same pair were observed during the 2024 survey proximal to the proposed transmission line (Figure 7-97). The species comprises of six subspecies, with the nominate race occurring within the region. The nominate race is migratory in N & E of breeding range but is sedentary or dispersive in the rest of the range. Based on the repeated recording of the species within the same locality, the species exhibits strong site fidelity within the PAOI. Although rodents comprise the majority of the diet within the European range, in Africa, insects, especially termites, beetles and locusts, dominate the diet, even with regards to biomass. This denotes that the species plays an important role in controlling the populations of potential pest species.

The remarkably low diversity of fish-eating birds indicates that there may be an unnaturally low fish abundance in the river, possibly as a result of the hydropeaking regime of the Ruzizi I and II HEPP

Figure 7-97 Photograph Illustrating the Pair of Common Kestrel (*Falco tinnunculus*) recorded within the Project Area of Influence

A single Long-crested Eagle (*Lophaetus occipitalis*) was recorded within the planar agricultural areas within the transmission line corridor. The species predates predominantly on small rodents which it hunts by visually scanning from a prominent perch and descending on the prey item. The species was therefore dependent on large trees within the transmission line corridor (*Mangifera indica* and *Eucalyptus* sp.) in order to hunt. In congruency with the Long-crested Eagle, a single Wahlberg's Eagle (*Hieraaetus wahlbergi*) was recorded within the planar agricultural areas within the transmission line corridor. Although the species has a more diverse diet, it hunts in a similar technique to Long-crested Eagles. Consequently, the transmission line will provide an alternative perching site for these species, posing an electrocution risk.

The only migratory species recorded during the May 2024 survey within the PAOI was a pair of Lesser Kestrels (*Falco naumanni*). The species is a non-breeding migrant, mainly trans-Saharan, although some birds winter in NW Africa and in various regions of S Europe and S Asia.

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Individuals enter and leave Africa via Gibraltar and Italy–Sicily/Malta–Tunisia in the west, via the Nile and Rift Valleys in the east, and maybe also via Iran–Saudi Arabia–Somalia/Ethiopia further east. Passage in the boreal autumn is apparently largely at high altitude, is rapid and direct, and on a broad front, but may be more concentrated, at lower altitude and more leisurely on northbound migration in the boreal spring. The species predates predominantly on Orthopterans (Locusts and Grasshoppers) and Coleopterans (Beetles) thus making them important in controlling agricultural pest species. In certain areas within southern Africa, they roost in large numbers on transmission lines. These numbers were not recorded within the PAOI, and the PAOI is unlikely to support the abundance recorded in southern Africa roosting sites, due to the lack of a hyperabundance of Orthoptera, i.e. plagues or swarms of Locusts.

Figure 7-98 illustrates the location of the high-risk avifauna species recorded within the supplementary field survey.

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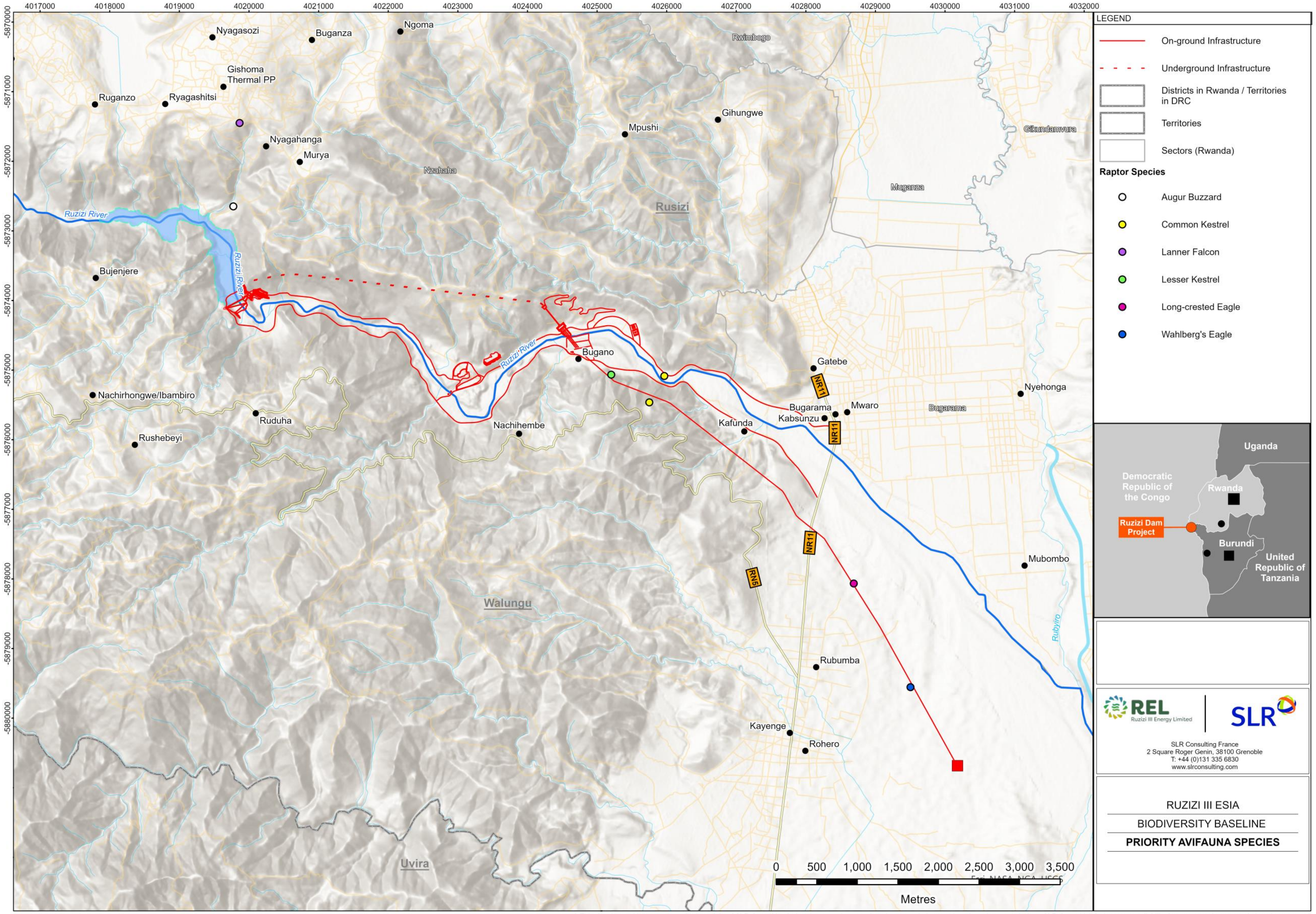

Figure 7-98 Map Illustrating the Location of High-Risk Avifauna Species Recorded during the Supplementary Field Survey

7.8.4.3 Threats to Birds and Bird Habitats

The main current threat facing birds in the project area is loss of habitat, particularly vast areas of the floodplain that have been converted to agriculture, but even the steep slopes of the Ruzizi valley above the reservoir have been severely modified. It is possible that birds are hunted on a limited scale by local residents, but the presence of fair numbers of gamebirds, such as Red-necked Spurfowl and Scaly Francolin, is an indication that hunting is probably very limited. Very few dogs were seen and none that were unaccompanied by people, so it is unlikely that gamebirds are being hunted by dogs either. While the Endangered Grey-crowned Crane occurs in the downstream Ramsar site this area is not impacted by the flow regime from the existing hydropeaking projects (Ruzizi I and II; ~100 km upstream).

The construction of transmission lines, including for the proposed Ruzizi III HPP, is likely to introduce an additional threat to High-Risk Species. Raptor species will utilise the pylons and cables as a perching spot for hunting and possibly nesting. This is especially within the flat terrain agricultural areas, where Wahlberg's Eagle and Long-crested Eagle were recorded. These raptors were located within areas where the presence of tall mango (*Mangifera indica*) and *Eucalyptus* species provided a suitable hunting perch. These species are important in controlling pest rodent populations and the loss of these species from area due to electrocution will lead to an increase in the rodent population.

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Table 7-32 Threatened and Near Threatened Bird Species Potentially Occurring in the general vicinity of the Project Area

Common Name	Scientific Name	IUCN Status	Habitat	Likelihood	Rationale
Hooded vulture	*Necrosyrtes monachus*	CR	Occurs in open grassland, forest edge, wooded savanna and desert, often associated with human settlements north of the Equator.	Low	Absent from western Rwanda; habitats mostly degraded; high human density.
White-backed vulture	*Gyps africanus*	CR	Occurs in open wooded savanna, particularly areas of *Acacia.*	Low	Absent from western Rwanda; habitats mostly degraded; high human density.
Rüppell's vulture	*Gyps rueppelli*	CR	Prefers open landscapes such as open Acacia woodland, grassland and montane regions.	Low	Absent from western Rwanda; habitats mostly degraded; high human density.
Congo bay-owl	*Phodilus prigoginei*	EN	Occurs in a mosaic of grassland and either montane or bamboo forest, above 1,800 masl.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.
Lappet-faced vulture	*Torgos tracheliotos*	EN	Found in dry savanna, arid plains, deserts and open mountain slopes, up to 3,500 masl.	Low	Absent from western Rwanda; habitats mostly degraded; high human density.
Secretarybird	*Sagittarius serpentarius*	EN	Prefers open landscapes, ranging from open plains and grasslands to lightly wooded savanna, but is also found in agricultural areas and semi-desert.	Low	Very rare in Rwanda and not recorded in the west; habitats mostly degraded; high human density.
Steppe eagle	*Aquila nipalensis*	EN	Occurs in open habitats such as grasslands, lightrly wooded savannah and semi-desert shrublands during passage and when overwintering.	Low	Very rare in Rwanda and not recorded in the west; habitats mostly degraded; high human density.
Madagascar pond-heron	*Ardeola idae*	EN	Prefers freshwater wetlands, particularly shallow waterbodies fringed with vegetation and adjacent trees.	Low	Absent from western Rwanda; limited suitable habitat.
Grey parrot	*Psittacus erithacus*	EN	Occurs in dense forest, including forest edges and clearings; also in gallery forest, mangroves, wooded savannah and cultivated areas close to forest.	Low	At edge of its known distribution; habitats mostly degraded; high human density.
Grey crowned crane	*Balearica regulorum*	EN	Occurs in shallow wetlands such as marshes, pans and dams with tall emergent vegetation, as well as riverbanks, shallowly flooded plains and temporary pools, sometimes foraging in adjacent grasslands, open savannas and croplands.	Low	No suitable breeding habitat present within the reservoir and downstream reaches of the Ruzizi River (at least until the Burundi border). Nearest known locality is the large Butambamo wetland to the north of the project area at 1,600 masl. Unlikely to forage in habitats in the Ruzizi valley upstream of Bugarama but may occasionally forage in cultivated lands downstream of the town.
Shelley's crimsonwing	*Cryptospiza shelleyi*	EN	Prefers the understorey of closed-canopy moist forest, often in valleys near water; also in low secondary growth at forest edges, forest clearings and glades; above 1,900 masl.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.
Red-collared mountain-babbler	*Kupeornis rufocinctus*	EN	Confined to montane forest and bamboo at altitudes of 1,500-3,200 masl.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.

Common Name	Scientific Name	IUCN Status	Habitat	Likelihood	Rationale
Bateleur	*Terathopius ecaudatus*	EN	Frequents open country, including grasslands, savanna and semi-desert, often foraging over secondary vegetation near towns.	Moderate	Suitable foraging habitat present; unlikely to breed in the project area.
Martial eagle	*Polemaetus bellicosus*	EN	Occurs in open woodland, wooded savanna, grassland and open thornbush; avoids densely populated areas.	Low	Absent from western Rwanda; habitats mostly degraded; high human density.
Lesser flamingo	*Phoeniconaias minor*	NT	Occurs on large undisturbed alkaline and saline lakes and salt pans, occasionally occurring at other shallow open-water wetlands when on passage.	Low	Absent from western Rwanda; limited suitable open-water habitat present.
Black-winged pratincole	*Glareola nordmanni*	NT	Occurs in open landscapes such as grasslands or large salt pans in its overwintering grounds in southern Africa.	Low	Very rare in Rwanda and not recorded in the west.
Eurasian curlew	*Numenius arquata*	NT	Mostly coastal habitats during the austral winter, rarely occurring inland at lakes and rivers.	Low	Very rare in Rwanda and not recorded in the west, although known to occur in the lower Ruzizi floodplain in Burundi.
Pallid harrier	*Circus macrourus*	NT	Occurs in open landscapes such as grasslands or lightly wooded savannah in its overwintering grounds in southern Africa.	Moderate	Scattered records from western Rwanda; known to forage over cultivated lands, so suitable habitat present.
Black-tailed godwit	*Limosa limosa*	NT	Occurs in freshwater habitats during the austral winter, such as swampy lake shores, pools, flooded grassland and irrigated rice fields.	Low	Very rare in Rwanda and not recorded in the west.
Great snipe	*Gallinago media*	NT	Occurs in marshlands and short grass or sedges on lake edges or in flooded fields.	Low	Absent from western Rwanda; limited suitable habitat present.
White-naped pigeon	*Columba albinucha*	NT	Occurs in dense lowland forest and forested slopes, usually below 1,500 masl.	Very Low	Not yet recorded in Rwanda; no suitable habitat present.
Bedford's paradise-flycatcher	*Terpsiphone bedfordi*	NT	Occurs in lowland and transitional forest at altitudes of 980-1,500 m; prefers undisturbed primary forest.	Very Low	Not yet recorded in Rwanda; no suitable habitat present.
Papyrus gonolek	*Laniarius mufumbiri*	NT	Occurs in papyrus swamps and adjacent thicket vegetation.	Low	Absent from western Rwanda; no suitable habitat observed during fieldwork.
Crowned eagle	*Stephanoaetus coronatus*	NT	Occurs in forests and dense woodland, avoiding open habitats except where forest fragments are present; also occurs in plantations and secondary growth.	Low	Riparian forest fragments are very small and fragmented; habitats mostly degraded and prey base (monkeys) is limited; high human density.
Lagden's bush-shrike	*Malaconotus lagdeni*	NT	Inhabits montane forest up to 2,500 masl.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.
Mountain buzzard	*Buteo oreophilus*	NT	Occurs in montane forest, exotic plantations and adjoining grassland between 2,000 m and 3,500 masl.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.

Common Name	Scientific Name	IUCN Status	Habitat	Likelihood	Rationale
Oberländer's ground-thrush	*Geokichla oberlaenderi*	NT	Occurs in lowland and transitional riparian forest at altitudes of 700-2,000 masl; avoids secondary or degraded forest.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.
Albertine owlet	*Glaucidium albertinum*	VU	Found in very open montane and transitional forest, with many clearings and a dense understorey.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.
Red-footed falcon	*Falco vespertinus*	VU	Occurs in open landscapes such as grasslands or lightly wooded savannah in its overwintering grounds in southern Africa.	Low	Occurs on passage over the project area, usually flying at great height, so unlikely to forage within the project area.
Shoebill	*Balaeniceps rex*	VU	Breeds and forages in seasonally flooded marshes that are dominated by a mixture of papyrus, reeds, cat-tails and grasses.	Very Low	Absent from central and western Rwanda; no suitable present
Southern ground-hornbill	*Bucorvus leadbeateri*	VU	Frequents woodland and savanna, as well as grassland adjoining patches of forest; avoids areas of high human density but does well in sparsely inhabited agricultural landscapes.	Low	Absent from western Rwanda; habitats mostly degraded; high human density.
Yellow-crested helmetshrike	*Prionops alberti*	VU	Occurs in mid-altitude and montane forest above 1,400 masl.	Very Low	Not yet recorded in Rwanda; no suitable habitat present.
Grauer's swamp-warbler	*Bradypterus graueri*	VU	Occurs in montane marshes, usually dominated by grass or sedge.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area.
Papyrus yellow warbler	*Calamonastides gracilirostris*	VU	Found mainly in papyrus-swamps but occasionally in other marshy habitats, especially reeds.	Very Low	Absent from central and western Rwanda; no suitable present.
Tawny eagle	*Aquila rapax*	VU	Occurs in dry open habitats across a wide elevation range, including both woodland and wooded savannah.	Low	Habitats mostly degraded; high human density.
Rockefeller's sunbird	*Cinnyris rockefelleri*	VU	Prefers thickets along streams in bamboo forest, as well as montane forest and afro-alpine moorland.	Very Low	No suitable habitat present and does not occur at similar altitudes as project area
Grauer's broadbill	*Pseudocalyptomena graueri*	VU	Inhabits interior of primary rainforest, occasionally at edges or clearings.	Very Low	Not yet recorded in Rwanda; no suitable habitat present.
Chapin's flycatcher	*Fraseria lendu*	VU	Occurs in dense montane forest between 1,470 and 1,820 masl.	Very Low	Not yet recorded in Rwanda; no suitable habitat present.
Blue swallow	*Hirundo atrocaerulea*	VU	Preferred wintering habitat is open grassland, often with bushes and trees and marshy areas.	Low	Very rare in Rwanda with no records from the west; habitats mostly degraded; high human density.

Table 7-33 Albertine Rift Mountains Endemic Bird Area Species Potentially Occurring in the Project Area

Common Name	Scientific Name	Distribution	Habitat	Occurrence in project area
Ruwenzori nightjar	*Caprimulgus ruwenzorii*	Distributed throughout the Albertine Rift region, with outlying populations in W Angola and NE Tanzania.	Prefers scrubby habitats, edges of montane wetlands and open clearings in montane forest.	Not recorded in the project area; potentially only occurs in the scrubby parts of the Hillslope Grassland / Savanna habitat along the highest sections of the transmission line route but this was not confirmed.
Ruwenzori hill babbler	*Sylvia atriceps*	Mostly endemic to the Albertine Rift, with a small outlying population in SE Nigeria and W Cameroon.	Occurs various montane forest types between 1,500 and 3,000 masl; prefers open forest and dense scrub at forest edges.	Not recorded in the project area; potentially only occurs in forest patches in the upper plateau areas but this was not confirmed.

Table 7-34 Biome-restricted Bird Species Confirmed to Occur or Potentially Occurring in the Project Area

Common Name	Scientific Name	Biome	Distribution[1]	Habitat[2]	Occurrence in Project Area
Cinnamon-chested bee-eater	*Merops oreobates*	Afrotropical Highlands	Occurs throughout the East African Highlands and Albertine Rift mountains; widespread in Rwanda above 1,300 masl.	Inhabits edges of montane forest, riparian forest, cultivated lands, gardens and tree plantations.	Recorded only at the highest altitudes in the project area.
Ruwenzori hill babbler	*Sylvia atriceps*	Afrotropical Highlands	Mostly endemic to the Albertine Rift, with a small outlying population in SE Nigeria and W Cameroon.	Occurs various montane forest types between 1,500 and 3,000 masl; prefers open forest and dense scrub at forest edges.	Not recorded in the project area; potentially only occurs in the forest patches in the upper plateau areas but this was not confirmed.
Carruther's cisticola	*Cisticola carruthersi*	Lake Victoria Basin	Locally in northeast and eastern DRC (northeast (Uele) and east (Ituri, Kivu)); southweast and southeast Uganda (Toro, west Ankole, Kigezi, and Sizibwa Swamp); north, central and eastern Rwanda; and central and eastern Burundi; also SW Kenya (Lake Victoria, from Yala Swamp south to Kisumu and Kendu Bay) and northern Zambia (R Luapula).	Interior of dense papyrus (Cyperus) swamps; in Rwanda, also mixed papyrus-*Miscanthidium* stands.	Not recorded in the project area; potentially occurs in riparian wetlands along the lower reaches of the Ruzizi downstream of Bugarama, but this could not be confirmed.
Chubb's cisticola	*Cisticola chubbi*	Afrotropical Highlands	Occurs throughout the Albertine Rift and western Kenya, with an isolated population in Cameroon and Nigeria; common breeding resident throughout much of Rwanda above 1,300 masl.	Prefers scrubby edges of montane forest, clearings in forest, cultivated lands and tree plantations.	Recorded only at the highest altitudes in the project area in the upper slopes of the Ruzizi valley above the reservoir.
Black-lored babbler	*Turdoides sharpei*	Lake Victoria Basin	Extreme eastern DRC, Rwanda, Burundi, Uganda (except the north), southwest Kenya and northwest and west Tanzania.	Forest-edge thickets and scrub, wooded plains and Acacia savanna, dense bushland, riverine woodland, elephant grass, gardens; where sympatric with *T. plebejus*. Appears to prefer more open areas.	Recorded mainlyat the highest altitudes in the project area, as well as at lower altitudes in the dam basin.

Common Name	Scientific Name	Biome	Distribution[1]	Habitat[2]	Occurrence in Project Area
Slender-billed starling	*Onychognathus tenuirostris*	Afrotropical Highlands	Throughout the eastern Afrotropical Highlands from Ethiopia to Malawi; occurs mostly in e Rwanda above 1 850 masl but has been recorded wandering to lower altitudes.	Montane forests and adjacent cultivated areas, wandering widely in search of fruiting trees.	A pair seen in tall Ficus trees at the dam wall site. Potentially occurs widely throughout the reservoir and upper slopes.
White-eyed slaty flycatcher	*Melaenornis fischri*	Afrotropical Highlands	Widespread throughout the mountains of East Africa (south to Malawi) and the Albertine Rift; common breeding resident throughout much of Rwanda above 1,300 masl.	Occurs in open-canopy forest or edges of closed forest, bamboo thickets, cultivated lands, gardens and tree plantations.	A single bird observed at the edge of a cultivated field at an aquatic sampling site along the upper reaches of the Rubyiro River (1,570 masl); not observed in the project area.
Bronzy sunbird	*Nectarinia kilimensis*	Afrotropical Highlands	Widespread throughout the eastern Afrotropical Highlands (south to Zimbabwe), with an isolated population in Angola; common breeding resident throughout much of Rwanda.	Edges of forests, riparian thickets and scrub, cultivation, gardens and tree plantations.	Common at high altitudes in the project area; recorded in the upper slopes of the Ruzizi valley above the reservoir.
Northern double-collared sunbird	*Cinnyris reichenowi*	Afrotropical Highlands	Found throughout the Albertine Rift and western Kenya, with an isolated population in Cameroon and se Nigeria; confined to western Rwanda, usually above 1,500 masl.	Occurs in montane forest, riparian forest, bracken scrub and tree plantations.	Not recorded in the project area; potentially only occurs in the forest patches in the upper plateau areas but this was not confirmed.
Red-chested sunbird	*Cinnyris erythrocerca*	Lake Victoria Basin	South Sudan, eastern DRC, Rwanda, Burundi, Uganda, western Kenya and northwest & extreme western Tanzania; unrecorded from south-western Rwanda.	Edges of rivers and wetlands in savanna areas; also near water in forest, cultivations and gardens.	Recorded once in riparian wetlands along the Ruzizi River downstream of Bugarama.
Baglafecht weaver	*Ploceus baglafecht*	Afrotropical Highlands	Throughout the eastern Afrotropical Highlands from Ethiopia to Malawi; very common resident throughout most of Rwanda.	Occurs in any open habitat such as cultivated lands and gardens; also found in tree plantations, riparian thicket and scrub.	Common in the project area, occurring throughout the reservoir and upper slopes; also observed in gardens in Bugarama.
Black-billed weaver	*Ploceus melanogaster*	Afrotropical Highlands	Found throughout the Albertine Rift and western Kenya, with an isolated population in Cameroon and SE Nigeria; occurs mostly in western Rwanda, usually above 1,500 masl.	Prefers open-canopy forest, occasionally occurring in riparian forest.	A pair observed building a nest at the edge of montane forest at an aquatic sampling site along the upper reaches of the Rubyiro River (1,488 masl); not observed in the project area.
White-collared oliveback	*Nesocharis ansorgei*	Lake Victoria Basin	Albertine Rift region of E DRC, Uganda, Rwanda, Burundi and extreme NW Tanzania; scattered records from across Rwanda between 1,000 and 1,400 masl.	Marshy forest edge, streams bordered by bushes and trees, lakeshore thickets, and papyrus (*Cyperus papyrus*) swamps.	Not recorded in the project area, but potentially occurs in the small strips of riparian thicket in the reservoir area although this could not be confirmed.
Western citril	*Dendrospiza frontalis*	Afrotropical Highlands	Albertine Rift region of E DRC, Uganda, Rwanda, Burundi and extreme NW Tanzania; widespread in Rwanda, except the eastern parts.	Marshy forest edge, streams bordered by bushes and trees, lakeshore thickets, and papyrus (*Cyperus papyrus*) swamps.	Common at high altitudes in the project area; recorded in the upper slopes of the Ruzizi valley and the reservoir.
1 Birds of The World website (https://birdsoftheworld.org/bow/) for global distribution and Vande weghe and Vande weghe (2011) for Rwanda distribution					
2 Vande weghe and Vande weghe (2011)					

7.8.5 Mammals

7.8.5.1 Diversity and Habitat Types

Mammals are poorly represented in the project area. Most large mammals have been eradicated through hunting and habitat loss and local people report that mammals such as antelope species, carnivores and elephants have not been seen in many years. Only eight mammal species were recorded in the Project AOI during the field surveys and are listed in Table 7-35. However, rodents and bats, which usually make up a large portion of mammal assemblages (especially in modified habitats), were not sampled and true mammal species richness is likely to be higher than currently reflected. No trapping of small mammals was performed due to the need to cover as much ground as possible. No motion-detecting cameras were placed as a result of the high human density and the lack of suitable habitat in which to place cameras. The previous survey for the Ruzizi III HPP (SOFRECO, 2011) recorded four mammal species during fieldwork, three of which were recorded during this study. The only species not recorded during this study was African wild cat (*Felis sylvestris lybica*).

No Chiropteran (bat) species inventory has been provided due to the lack of passive and active sampling. Nevertheless, caves and other potential roost sites were looked for within the PAOI but no caves or bat roosts were located. Insectivorous bat species were recorded feeding in Kamanyola, but it is highly likely that these species roosted in the eaves of houses rather than within the habitats of the PAOI.

Five broad mammal assemblages are likely to be present, with a Cultivation / Secondary Shrubland assemblage as the dominant one. Other minor assemblages are likely to be Riparian Thicket, Riparian Wetland, Hillslope Thicket / Forest and Hillslope Grassland / Savannah assemblages. Five species were recorded in Cultivation / Secondary Shrubland, followed by four species in Riparian Thicket and Hillslope Thicket / Forest (Table 7-35). The most frequently recorded mammal according to local people is Boehm's bush squirrel (*Paraxerus boehmi*), which most people mentioned as being a minor pest in their fields.

Two threatened (Vulnerable) mammal species were identified during fieldwork, namely (*Hippopotamus amphibius*) and Angolan Colobus (*Colobus angolensis*). The colobus was not seen but reported by local villagers as occasional visitors to a village on the DRC side of the Ruzizi River. . The occurrence of these two species in the project area is described in the following section.

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Table 7-35 Species Composition of the Mammal Assemblages in the Project Area

Common Name	Scientific Name	Data Source	IUCN Red Data	Assemblages				
				Riparian Thicket	Riparian Wetland	Hillslope Thicket	Hillslope Grassland / Savannah	Cultivation / Shrubland
ORDER: PRIMATES								
Family Cercopithecidae								
Vervet monkey	*Chlorocebus pygerythrus*	V	LC	x		x		x
Olive baboon	*Papio anubis*	V	LC	x		x	x	x
Angolan Colobus	*Colobus angolensis*	V	VU	x				x
ORDER: RODENTIA								
Family Sciuridae								
Boehm's bush squirrel	*Paraxerus boehmi*	O	LC	x		x		x
Red-legged sun squirrel	*Heliosciurus rufobrachium*	O	LC			x		
Family Nesomyidae								
Gambian rat	*Cricetomys kivuensis*	V	LC	x				x
Family Muridae								
Striped field rat	*Lemniscomys striatus*	O	LC					x
ORDER: CARNIVORA								
Family Herpestidae								
Marsh mongoose	*Atilax paludinosus*	O	LC		x			
Family Viverridae								
Genet	*Genetta maculata*	V	LC	x		x	x	
ORDER: CETARTIODACTYLA								
Family Hippopotamidae								
Hippopotamus	*Hippopotamus amphibius*	O	VU		x			
		8	**8**	**4**	**2**	**4**	**1**	**5**

LC = Least Concern; VU – Vulnerable; O = Observation; V = discussion with villagers

7.8.5.2 Priority Mammal Species

Nineteen (19) threatened and nine NT mammal species have distribution ranges that broadly overlap with the project area according to distribution maps in IUCN assessments (Table 7-36). One of these is classified as CR, five are EN and 13 as VU. Ecological information contained in IUCN assessments indicate that many of these species do not occur in habitats or at altitudes represented in the project area or are species that do not tolerate the disturbance levels typical of densely settled areas such as the project site. Four NT species have a moderate or high likelihood of occurring in the project AoI, two of which are bat species and two otter species. Two VU species has been confirmed to occur in the project area, namely hippopotamus (*Hippopotamus amphibius*) and Angolan colobus (*Colobus angolensis*). These species are described in more detail below.

7.8.5.3 Hippopotamus (Hippopotamus amphibius)

Hippopotamus occurs along rivers and lakes throughout the savanna zone of Africa, and in the main rivers of the forest zone in Central Africa (Lewison & Pluháček, 2017). The largest African populations have always been in East and Southern Africa, with an estimated East African population of about 50,000 animals (Lewison & Pluháček, 2017). The Rwandan population is estimated to be approximately 1,000 animals, although this is probably an underestimate since a 2013 census in Akagera National Park recorded 800-1,000 animals, and the species is also known from several Rwandan lakes as well as the Ruzizi River (Lewison & Pluháček, 2017). The

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largest Burundi population is in the Ruzizi Delta, where an estimated 500 animals occur (Lewison & Pluháček, 2017).

Global populations of hippopotamus experienced considerable declines in the mid-1990s and early 2000s, resulting in the species being classified as Vulnerable. It appears that populations have largely remained stable since then, although the species is still classified as VU.

Hippos generally spend the day in water and emerge at night to feed, which is when they regularly damage crops planted along rivers. Hippos typically do not eat aquatic vegetation, but forage on grass or crops close to the river, lake or wetland that they are resting in. Hippos require permanent water, particularly during the dry season, when they are likely to be concentrated along the Ruzizi River. The only population figures for the Ruzizi River are for the animals in the Ruzizi Delta, where 500 are estimated to be resident (Lewison & Pluháček, 2017). Animals or evidence of occurrence (spoor, dung) were seen at three different localities along the Ruzizi River between Bugarama and the Burundi border during January 2022 fieldwork). People were questioned throughout the project area about the presence of hippos and the consensus was that hippos generally do not occur upstream of the bridge connecting Bugarama and Kamanyola, i.e. they do not occur in the vicinity of the reservoir and associated infrastructure.

7.8.5.4 Angolan Colobus (*Colobus angolensis*)

The Angolan Colobus (*Colobus angolensis*) ranges from northeast Angola north to the Congo-Ubangui River system, eastwards (with a disjunct range) to the montane and coastal forests of Tanzania and southeastern Kenya. The species was reported within the PAOI by anecdotal evidence of observations by residents of Bugarama (Rwanda) and Kafunda village (DRC). The Angolan Colobus typically occupies forest habitats such as gallery forests, swamp forest, coastal forest, montane forest, and seasonally flooded forests, but reportedly ventures into the PAOI during extensive crop harvesting. The species is listed as VU on a global scale (de Jong *et al.*, 2020). The primary threats are habitat loss and degradation, as well as poaching. Habitat loss, degradation and fragmentation is driven mainly by collection of timber and fuelwood, conversion of forest to farmland, and the expansion of human settlements (de Jong *et al.*, 2020). In addition, hunting has caused several populations to be extirpated, even from suitable habitats. Within the PAOI, it was reported by locals that the species is hunted within the DRC, but not within Rwanda.

Populations within the eastern part of the range are more fragmented than populations within the Congo Basin, with species density also dependent on location (de Jong *et al.*, 2020). Figure 7-100 illustrates the species distribution with respect to the PAOI. It can be noted that the species distribution does not necessarily overlap with the PAOI, but this is likely attributed to lack of data. Nevertheless, the density of Angolan colobus overlapping the PAOI is expected to be low, and the species is not regarded as a permanent resident, but rather an opportunist.

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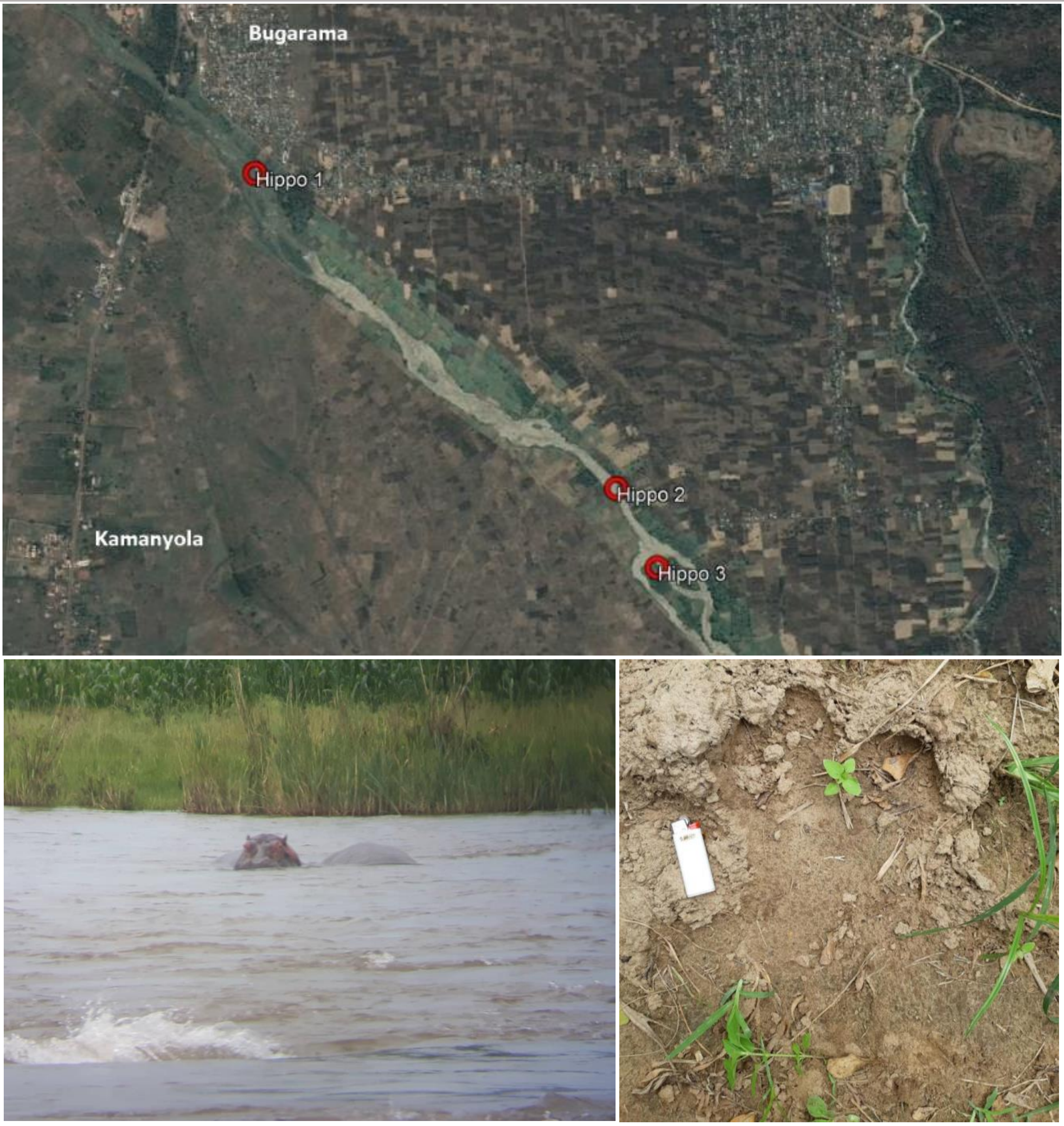

Figure 7-99 Confirmed Occurrence of Hippopotamus in the Project Area

Clockwise from top: Map showing locations where hippos were confirmed during fieldwork; spoor of hippo; sighting of two hippo surfacing in the Ruzizi River (Source: N. Glenat (SLR); E. Sinayitutse)

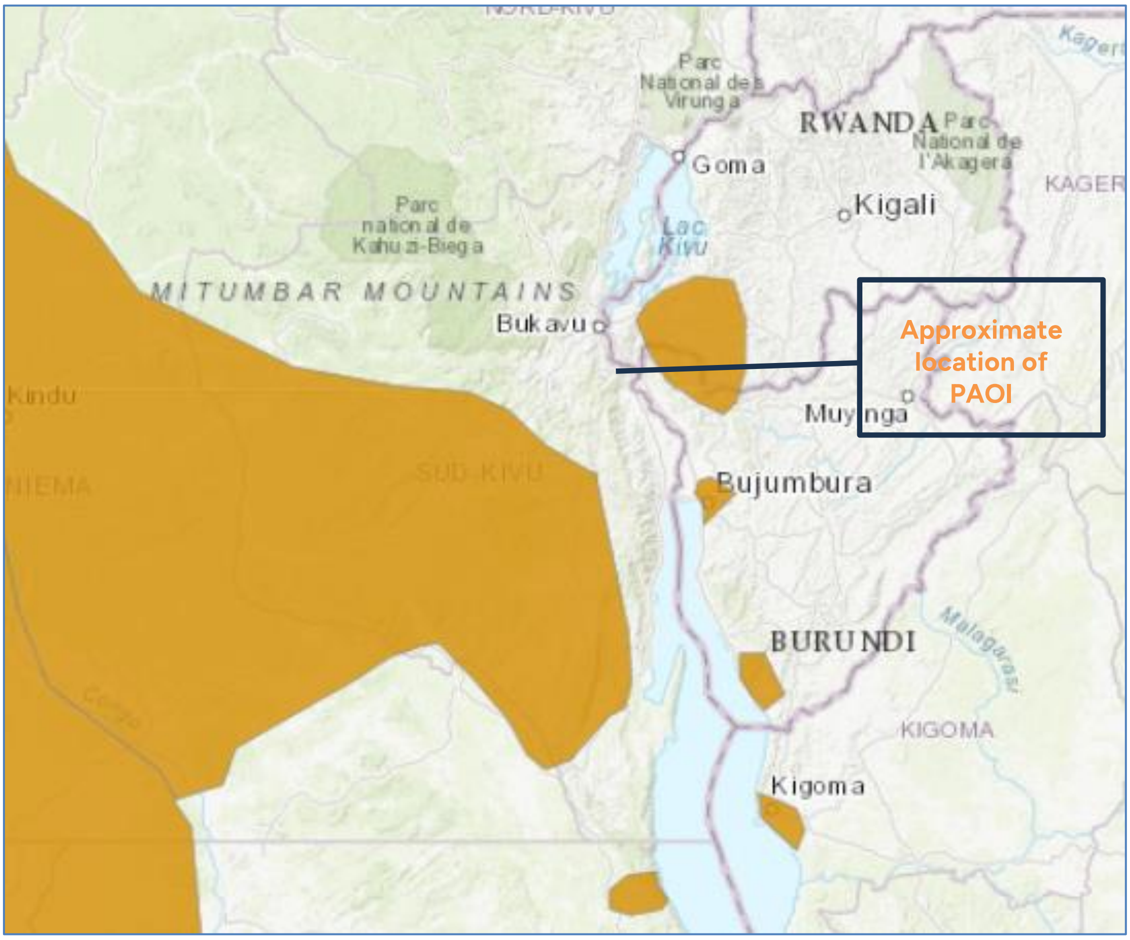

Figure 7-100 Map Illustrating the Distribution of Angolan Colobus (*Colobus angolensis*) in Relation to the Project Area of Influence. Source: (de Jong *et al.*, 2020)

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Table 7-36 Potentially occurring Threatened and Near Threatened Mammals in the Project Area

Common Name	Scientific Name	IUCN Status	Habitat	Likelihood	Rationale
African forest elephant	*Loxodonta cyclotis*	CR	Occurs in a variety of forest habitats including lowland humid forest, swamp forests, lower reaches of Afromontane forests, dry forests and forest-savanna mosaics.	Very Low	No suitable habitat present and high disturbance levels.
Chimpanzee	*Pan troglodytes*	EN	Occurs in primary and secondary moist lowland forest, swamp forest, submontane and montane forest, dry forest, forest galleries in savanna woodland, and farmland.	Low	Limited suitable habitat present, habitat degradation is severe and human density is high.
Foa's red colobus	*Piliocolobus foai*	EN	Occurs in primary montane and submontane forest from 800 to 2,270 masl.	Very Low	No suitable habitat present and high disturbance levels.
White-bellied pangolin	*Phataginus tricuspis*	EN	Occurs in moist tropical lowland forests and secondary growth, but also occurs in dense woodlands, especially along water courses; associated with abandoned oil palm plantations in some areas.	Low	Limited suitable habitat present, habitat degradation is severe and human density is high.
Ulindi River red colobus	*Piliocolobus lulindicus*	EN	Poorly known; recorded from primary lowland forest and along rivers.	Very Low	No suitable habitat present; high human density.
Giant ground pangolin	*Smutsia gigantea*	EN	Occurs in primary and secondary rainforest forest formations, gallery forests, swamp forests, forest-savannah mosaic habitats and wooded savannah.	Very Low	No suitable habitat present; high human density.
Yellow-backed duiker	*Cephalophus silvicultor*	NT	Occurs in moist lowland and montane forests (primary and secondary), forest-savanna mosaics, gallery forests, thickets; also in plantations and farmbush.	Low	Even though some suitable habitat present, habitat degradation is severe and human density is high.
Spotted-necked otter	*Hydrictis maculicollis*	NT	Prefers freshwater habitats where water is unsilted, unpolluted, and rich in small to medium sized fishes, including lakes and other shallow water habitats.	Moderate	Some suitable habitat although possibly too silted for this species.
Congo clawless otter	*Aonyx congicus*	NT	Occurs in tropical rainforests and lowland swamps of the Congo River basin.	Moderate	Some suitable habitat although habitats are degraded and human density is high.
Bay duiker	*Cephalophus dorsalis*	NT	Frequents primary and relatively unmodified lowland to mid-altitude forests; prefers primary forest but has been recorded in secondary forest and farmbush.	Low	Limited suitable habitat present, habitat degradation is severe and human density is high.
African buffalo	*Syncerus caffer*	NT	Occurs in a wide range of woodland, savannah and forest habitats.	Low	Limited suitable habitat present, habitat degradation is severe and human density is high.
Rahm's brush-furred rat	*Lophuromys rahmi*	NT	Inhabits dense primary montane forest; has been recorded in secondary forest and sparse bamboo stands covered with grass.	Very Low	No suitable habitat present.
Moon forest shrew	*Sylvisorex lunaris*	NT	Occurs in primary and secondary montane tropical moist forest and swamps above 1,700 masl.	Very Low	No suitable habitat present.
African straw-coloured fruit-bat	*Eidolon helvum*	NT	Occurs in a very wide range of habitats; can also inhabit wooded areas in large urban areas, often rossting in cities and towns	High	Suitable habitat present; can persist in degraded habitats and densely settled areas

Common Name	Scientific Name	IUCN Status	Habitat	Likelihood	Rationale
Large-eared free-tailed bat	*Otomops martiensseni*	NT	Occurs in a very wide range of habitats; can also tolerate urban or agricultural areas.	Moderate	Some suitable habitat present; can tolerate urban and agricultural habitats.
Hippopotamus	*Hippopotamus amphibious*	VU	Occurs along rivers and lakes throughout the savanna zone of Africa, and in the main rivers of the forest zone in Central Africa.	Confirmed	Several animals were observed at one location and villagers reported the species from three other localities along the Ruzizi River downstream of Bugarama.
Leopard	*Panthera pardus*	VU	Occupies a very wide range of habitat types	Low	Limited suitable habitat present, habitat degradation is severe and human density is high.
Temminck's pangolin	*Smutsia temminckii*	VU	Occurs in savannas and woodlands in low-lying regions, as well as floodplain grassland, rocky slopes and sandveld; avoids true forest and heavily populated areas.	Very Low	No suitable habitat present and high disturbance levels.
Grey-cheeked mangabey	*Lophocebus albigena*	VU	Found in both primary and secondary forest, although it prefers undisturbed forest.	Very Low	No suitable habitat present and high disturbance levels.
L'Hoest's monkey	*Allochrocebus lhoesti*	VU	Occurs in primary lowland, submontane and montane forests, avoiding degraded habitats and densely populated areas.	Very Low	No suitable habitat present and high disturbance levels.
African golden cat	*Caracal aurata*	VU	Occurs in primary moist equatorial forest, although on the edge of its range it enters savanna regions along riverine forest.	Very Low	No suitable habitat present and high disturbance levels.
Ruwenzori shrew	*Ruwenzorisorex suncoides*	VU	Associated with damp and dense mossy vegetation in montane primary tropical moist forest.	Very Low	No suitable habitat present.
Delany's swamp mouse	*Delanymys brooksi*	VU	Confined to high altitude marshes within bamboo and montane forest.	Very Low	No suitable habitat present.
Lemara shrew	*Crocidura lanosa*	VU	Prefers primary montane forest, Cyperus swamps, and bamboo forests; has been recorded from secondary montane forest and in disturbed areas above 1,850 masl.	Very Low	No suitable habitat present.
Angolan colobus	*Colobus angolensis*	VU	Occurs in evergreen and semi-deciduous forest, including gallery forests, swamp forest, montane forest and seasonally flooded forests; avoids degraded habitats and densely settled areas.	Reported	Opportunistic visitor in PAOI as reported by local residents in Rwanda and DRC.
Owl-faced monkey	*Cercopithecus hamlyni*	VU	Occurs in lowland to mid-montane tropical moist forest and montane bamboo forest; avoids degraded forest and densely settled areas.	Very Low	No suitable habitat present; high human density.
Medium-tailed brush-furred rat	*Lophuromys medicaudatus*	VU	Inhabits montane forests and swamps, avoiding modified habitats.	Very Low	No suitable habitat present.
Kemp's thicket rat	*Thamnomys kempi*	VU	Occurs in thickets in open areas of montane secondary forests (and occasionally in primary forests).	Very Low	Project area well below the altitudinal limit for this species.

7.8.5.5 Threats to Mammals

No evidence of hunting was seen during fieldwork with no observations of dogs or traps/snares encountered. However, evidence of hunting was reported within the DRC territory of the PAOI with pictures provided of animals used for bushmeat or skins. Interviews with the community on the Rwandan side indicated that hunting does not occur as it is well acknowledged that bushmeat is a punishable offence. The group that appears to be the most hunted are mesocarnivores such as mongooses (Herpestidae) and genets (Viverridae) (Figure 7-101A-B). Mesocarnivores are an ecologically important group and considerably influence trophic interactions, especially in landscapes where large carnivores are absent. The reduction in carnivores will likely have led to an increase in rodent populations, especially in cultivated areas where there is an abundance of food, although rodents are also targeted for food.

The loss of habitat and high human density in the project area makes it unlikely that hunting would be productive, apart from trapping of Kivu Giant pouched rats (Figure 7-101C), which does take place in the Bukavu area in the DRC (McCleland, *pers. obs.*). Farmers were observed shooting at bird pests in their fields with catapults and may do the same to mammal pests (such as squirrels and baboons) although this could not be confirmed. Existing threats to hippopotamus are not known but may include harassment and occasional hunting by local residents as they pose a safety risk to farmers along river banks and fishermen.

Figure 7-101 Photographs Illustrating Mammal Species Hunted within the DRC Territory of the Project Area of Influence. A) Marsh mongoose (*Atlilax paludinosus*), B) Large-spotted genet (*Genetta maculata*) and C) Kivu Giant ouched rat (*Cricetomys kivuensis*).

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7.8.6 Herpetofauna

7.8.6.1 Diversity and Habitat Types

High herpetofauna species diversity is expected to occur within the project area of influence with a total of 66 amphibian and 89 reptile species with a Medium or higher likelihood of occurrence. The Hillslope Grassland / Savannah habitat has the highest expected species diversity for both reptiles and amphibians (Figure 7-102). Lists of potentially occurring reptiles and amphibians are provided in Annex C.

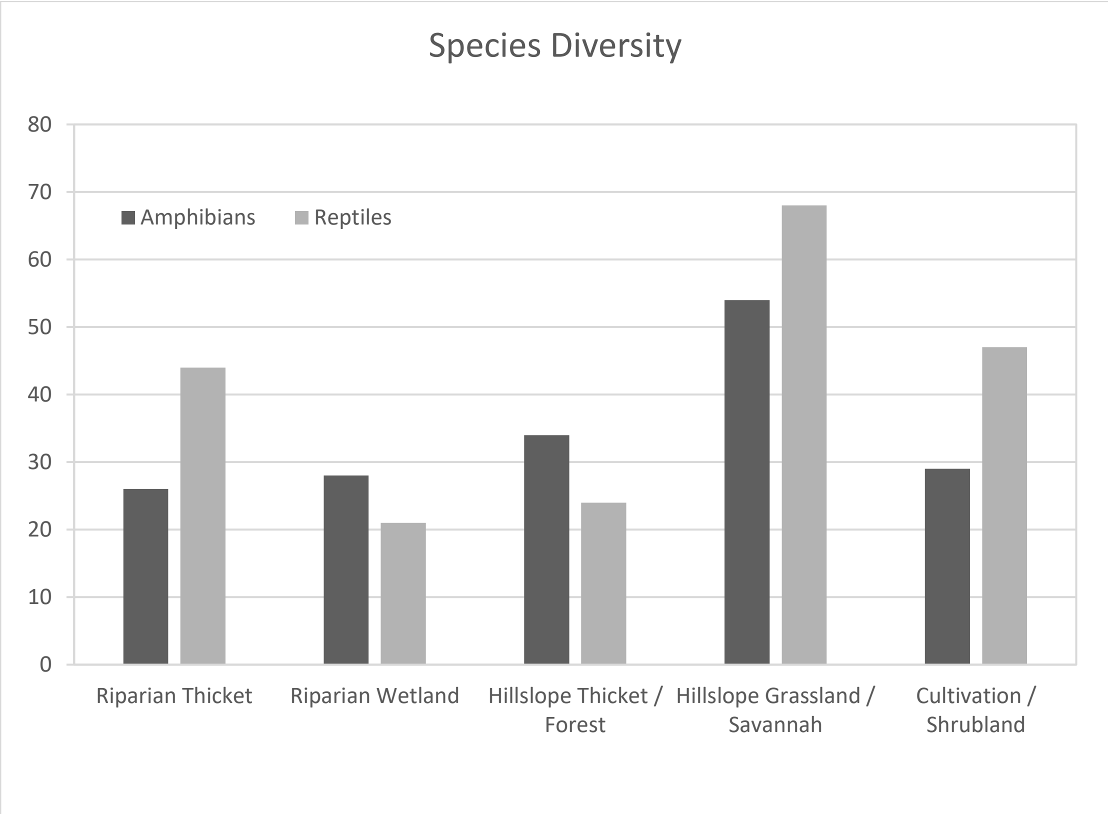

Figure 7-102 Species Diversity of Each Herpetofauna Assemblage Expected in the Project Area

7.8.6.2 Priority Herpetofauna Species

Priority herpetofauna species identified as likely to occur in the project area are those that have been classified by the IUCN as threatened (CR, EN or VU), species classified by the IUCN as Near Threatened (NT) or Data Deficient[19] (DD), species with an EOO of 50,000 km^2 or less (restricted-range species) and species restricted to the Albertine Rift Montane Forests Ecoregion (Olson *et al*., 2013) as evaluated by Ayebare *et al*. (2018). Table 7-37 provides a complete list of the priority herpetofauna expected in the project area with descriptions of the species summarised in the sections below.

[19] It is necessary to include these species as a precautionary approach because numerous DD species have in the past been evaluated as threatened once more information becomes available. Typically, DD species are those with narrow restricted geographic ranges and strong habitat requirements, making them highly susceptible to threats.

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Table 7-37 Priority Herpetofauna Species Expected in the Project Area

Family	Common Name	Scientific Name	IUCN Red Data	Endemic	Likelihood of occurrence	EOO (km²)
Amphibians						
Arthroleptidae	Kivu screeching frog	*Arthroleptis pyrrhoscelis*	LC	X	H	34,662
Arthroleptidae	Bururi long-fingered frog	*Cardioglossa cyaneospila*	NT	X	M	24,458
Arthroleptidae	Fizi tree frog	*Leptopelis fiziensis*	DD	X	M	< 50,000
Hyperoliidae	Kivu banana frog	*Afrixalus orophilus*	LC	X	H	46,537
Hyperoliidae	Ahl's reed frog	*Hyperolius castaneus*	LC	X	M-H	73,498
Hyperoliidae		*Hyperolius diaphanus*	DD	X	M	< 50,000
Hyperoliidae		*Hyperolius discodactylus*	LC	X	M	12,383
Hyperoliidae	Bushoho reed frog	*Hyperolius frontalis*	LC	X	M-H	26,818
Pipidae		*Xenopus vestitus*	LC	X	M	>50,000
Pipidae		*Xenopus wittei*	LC	X	H	>50,000
Pyxicephalidae	De Saeger's River frog	*Amietia desaegeri*	LC	X	H	37,203
Reptiles						
Chamaeleonidae	Rugege Highlands forest chameleon	*Kinyongia rugegensis*	-	X	M	< 50,000
Chamaeleonidae	Johnston's three-horned chameleon	*Trioceros johnstoni*	LC	X	H	88,000
Chamaeleonidae	Rwenzori bearded chameleon	*Trioceros rudis*	LC	X	H	130,000
Chamaeleonidae	Schoutenden's montane dwarf chameleon	*Trioceros schoutedeni*	DD	X	M-H	14,000
Colubridae	Ruanda emerald green snake	*Philothamnus ruandae*	LC	X	H	>50,000
Gekkonidae	Sternfeld's gecko	*Cnemaspis quattuorseriata*	NT	X	M-H	>50,000
Lamprophiidae	Tanganyika water snake	*Lycodonomorphus bicolor*	LC	X	M	>50,000
Leptotyphlopidae	Uvira thread snake	*Leptotyphlops latirostris*	NT	X	M	14,000
Pythonidae	Central African rock python	*Python sebae*	NT		H	>50,000
Scincidae	Rwanda five-toed skink	*Leptosiaphos graueri*	EN	X	M	<50,000
Testudinidae	Speke's hinge-back tortoise	*Kinixys spekii*	VU		H	>50,000
Viperidae	Great Lakes bush viper	*Atheris nitschei*	LC	X	H	>50 000
Viperidae	Gaboon viper	*Bitis gabonica*	VU		H	>50 000

LC = Least Concern; DD = Data Deficient; VU = Vulnerable; NT = Near Threatened; EN = Endangered

M = Medium; M-H = Medium-High; H = High; Endemic = restricted to the Albertine Rift Montane Forests Ecoregion

Three threatened species have a medium likelihood of occurrence in the project area and one other species of importance (Nile crocodile) has been confirmed to occur downstream of the project area in the recent past. These species are dealt with in more detail below.

A **Gaboon adder (*Bitis gabonica*)**

This species has a wide geographic range from Nigeria to East Africa (Uganda to Tanzania) and south to Angola and northern Zambia, with an isolated population in eastern South Africa and Mozambique (Luiselli et al. 2021). The species has been assessed as VU as a result of notable population declines, particularly in Nigeria and the DRC. Although this is primarily a forest-dwelling species, it does also occur in forest-plantation mosaics and agricultural areas and thus potentially occurs in the project area. However, given the extensive habitat modification and human presence it is likely targeted by local residents if encountered and likely to be scarce if present at all.

B **Speke's hinge-backed tortoise (*Kinixys spekei*)**

This tortoise has an extensive geographic range, occurring from southern Kenya southward to eSwatini (formerly Swaziland). It has been recorded from savanna, tropical bushveld, tropical savanna, sour bushveld, and the thornveld of the Lebombo Plateau but generally prefers moist savanna woodlands, although it also occurs in drier deciduous woodlands and thickets dominated by *Vachellia* and *Commiphora* in the north-eastern part of its range (Ihlow *et al.* 2019). Despite the large geographic range of this species, it has a provisional IUCN Red List evaluation of Vulnerable (VU) assigned by the IUCN SSC Tortoise and Freshwater Turtle Specialist Group in 2013 (TTWG, 2021) and is not currently globally evaluated by the IUCN (IUCN, 2022). Major threats to its survival include consumption by humans, habitat loss, susceptibility to climate change and to a lesser degree, international trade (Hailey *et al.* 2021). The project area of influence does not contain ideally suitable habitat for this species, although it has been observed in close proximity (Ihlow *et al*. 2019). The secondary shrubland associated with the cultivation and where this interfaces with the savanna habitats could provide appropriate habitat for this species, but it is only assigned a medium likelihood of occurrence.

C **Rwanda five-toed skink (*Leptosiaphos graueri*)**

The Endangered Rwanda five-toed skink (*Leptosiaphos graueri*) is an Albertine Rift Endemic with a wide altitudinal range (1,200-2,500 masl.) which occurs in wet montane forest (Wagner, 2021), flooded depression marshes (Roelke & Smith, 2016) and moss-covered rock ledges (Spawls *et al.,* 2018). It is a restricted-range species with an area of occupancy (AOO) of only 496 km^2 (Wagner, 2021). It is a fossorial species found in leaf litter. Its distribution overlaps with that of the project area of influence and consequently has a medium likelihood of occurrence. However, its preferred habitats are not extensively represented within the project area of influence and (given the high proportion of transformed habitat and mostly low altitude of the project area) it is likely that only very few individuals and/or populations will be affected by the proposed hydropower project, if at all.

D **Nile crocodile (*Crocodylus niloticus*)**

The Nile crocodile has a highly fragmented distribution, occurring in a wide diversity of water bodies in eastern, central and southern Africa (Isberg *et al.* 2019). Despite some evidence of localised population declines, Nile crocodile is still a widespread species and the population declines have not been significant enough to change its assessment of Least Concern (LC). Within Rwanda it is known to occur on the Kagera River system in the east, and a recent aerial wildlife census of the Akagera National Park counted 198 animals[20], although no information could be found regarding the presence of Nile crocodile in Lake Kivu or the upper Ruzizi River. The species is known to occur in the lower Ruzizi in Burundi, specifically in the vicinity of the Ruzizi Delta and Lake Tanganyika. All of the villagers and fishermen that were questioned within the reservoir area insisted that the species is not present. Villagers along the downstream reaches between Bugarama and the Burundi border stated that Nile Crocodiles were recorded

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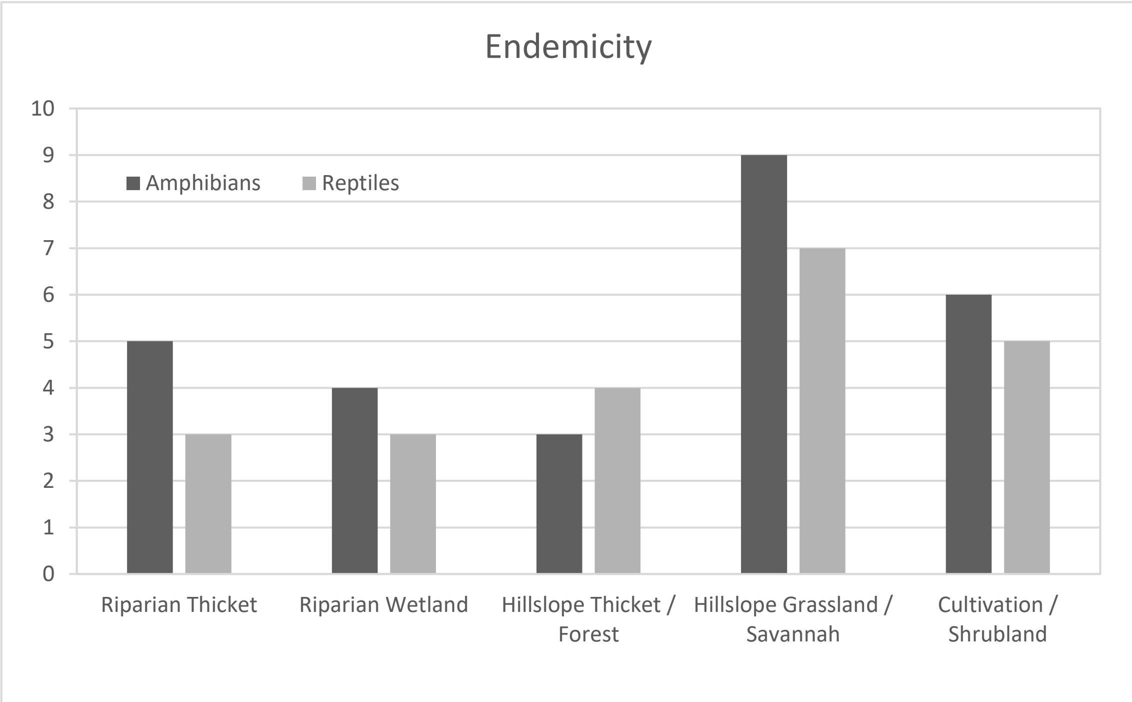
[20]www.africanparks.org/sites/default/files/uploads/newsroom_file_upload/2017-05/Akagera_Aerial_Census_Report_Summary_-_August_2015_%281%29.pdf

in the past but have not been seen for several years. No evidence of this species could be found during fieldwork, and it is unlikely to be impacted by the project development.

In addition to the above species, 29 amphibian and 11 reptile species are endemic to the Albertine Rift Montane Forests Ecoregion (Ayebare *et al.* 2018). Of these, 13 amphibian and nine reptile species are expected to occur within the project area of influence with at least a Medium or higher likelihood of occurrence of which ten amphibians and three reptile species are considered to be restricted-range species, having and extent of occurrence (EOO) of less than 50,000 km^2 (Table 7-37). The highest species diversity for amphibian and reptile species endemic to the ecoregion is likely to be in the Hillslope Grassland / Savannah habitat (Figure 7-103). Such high levels of endemicity, coupled with the previously described high levels of species diversity (Figure 7-102), elevates the conservation importance of this habitat type.

Figure 7-103 Endemism of Herpetofauna Assemblages Expected in the Project Area



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7.8.7 Threats to Herpetofauna

Given the high human population density in the project area and transformed nature of most of the habitats, the major current threat to herpetofauna in the project area of influence is habitat degradation and transformation. Chance encounters of large bodied species such as larger snakes (Figure 7-104) and tortoises by people are expected to result in consumption thereof, but densities are likely to be too low for targeted hunting efforts. The major impact resulting from the proposed Ruzizi III hydropower dam would be the further loss of habitats, particularly areas of Natural Habitat (e.g. riparian thicket, riparian wetlands).

Figure 7-104 Photograph Illustrating a Puff Adder (*Bitis arietans*) killed within the DRC Territory of the Project Area of Influence

7.8.8 Terrestrial Ecological Importance

Ecological importance of the different terrestrial habitats is assessed here. Habitat status according to ESS6 and IFC PS6 and its thresholds are assessed in the Critical Habitat Assessment in Chapter 9.

7.8.8.1 Ecological Importance

A Method for Determining Ecological Importance

The method used for assessing site-specific Ecological Importance (EI) in South Africa (SANBI, 2019) has been applied in this study. Since this method is not restricted to specific terrestrial ecosystems, it can be used in any environment. EI provides a basis to inform the assessment of impact significance that a project may have on the receiving environment.

EI is considered to be a function of the Biodiversity Importance (BI) of a particular receptor (e.g. species of conservation concern, vegetation/fauna community or habitat type) and its resilience to impacts (Receptor Resilience) as follows:

$$EI = BI + RR$$

BI is a function of Conservation Importance (CI) and the Functional Integrity (FI) of the receptor as follows:

$$BI = CI + FI$$

CI is defined as "the importance of a site for supporting biodiversity features of conservation concern present e.g. populations of IUCN Threatened and Near-Threatened species (CR, EN, VU & NT), Restricted-range species, globally significant populations of congregatory species, and areas of threatened ecosystem types, through predominantly natural processes" (SANBI, 2019). The fulfilling criteria for CI are presented in Table 7-38.

Table 7-38 Criteria for Determining Conservation Importance of a Receptor

Conservation Importance	Fulfilling Criteria
Very High	Confirmed or highly likely occurrence of CR, EN, VU or Extremely Rare or Critically Rare species that have a global Extent of Occurrence of < 10 km^2, or Any area of natural habitat of a CR ecosystem type or large area (> 0.1% of the total ecosystem type extent) of natural habitat of EN ecosystem type, or Globally significant populations of congregatory species (>10% of global population)
High	Confirmed or highly likely occurrence of CR, EN, VU species that have a global EOO of > 10 km^2. IUCN threatened species (CR, EN, VU) must be listed under any criterion other than A. If listed as threatened only under Criterion A, include if there are < 10 locations or < 10,000 mature individuals remaining; or Small area (> 0.01% but < 0.1% of the total ecosystem type extent) of natural habitat of EN ecosystem type or large area (> 0.1%) of natural habitat of VU ecosystem type; or Presence of Rare species; or Globally significant populations of congregatory species (> 1% but < 10% of global population)
Medium	Confirmed or highly likely occurrence of populations of NT species, threatened species (CR, EN, VU) listed under A criterion only and which have > 10 locations or > 10,000 mature individuals; or Any area of natural habitat of threatened ecosystem type with status of VU; or Presence of range-restricted species; or > 50% natural habitat with potential to support SCC
Low	No confirmed or highly likely populations of Species of Conservation Concern; or No confirmed or highly likely populations of range-restricted species; or < 50% of natural habitat with limited potential to support SCC

Conservation Importance	Fulfilling Criteria
Very Low	No confirmed and highly unlikely populations of SCC; or No confirmed and highly unlikely populations of range-restricted species; or No natural habitat remaining.

FI of the receptor (e.g. the vegetation/faunal community or habitat type) is defined here as "a measure of the ecological condition of the impact receptor as determined by its remaining intact and functional area, its connectivity to other natural areas and the degree of current persistent ecological impacts". Fulfilling criteria for determining FI are given in Table 7-39.

Table 7-39 Criteria for Determining Functional Integrity of a Receptor

Functional Integrity	Fulfilling Criteria
Very High	Very large (>100 ha) intact area for any conservation status of regional vegetation type or > 5 ha for CR regional vegetation types; or High habitat connectivity serving as functional ecological corridors, limited road network between intact habitat patches; or No or minimal current ecological impacts with no signs of major past disturbance (e.g. ploughing)
High	Large (> 20 ha but < 100 ha) intact area for any conservation status of regional vegetation type or > 10 ha for EN regional vegetation types; or Good habitat connectivity with potentially functional ecological corridors and a regularly used road network between intact habitat patches; or Only minor current ecological impacts (e.g. few livestock utilising area) with no signs of major past disturbance (e.g. ploughing) and good rehabilitation potential
Medium	Medium (> 5 ha but < 20 ha) semi-intact area for any conservation status of regional vegetation type or > 20 ha for VU regional vegetation types; or Only narrow corridors of good habitat connectivity or larger areas of poor habitat connectivity and a busy used road network between intact habitat patches; or Mostly minor current ecological impacts with some major impacts (e.g. established population of alien and invasive flora) and a few signs of minor past disturbance; moderate rehabilitation potential
Low	Small (> 1 ha but < 5 ha) area Almost no habitat connectivity but migrations still possible across some transformed or degraded natural habitat; a very busy used road network surrounds the area. Low rehabilitation potential Several minor and major current ecological impacts
Very Low	Very small (< 1 ha) area No habitat connectivity except for flying species or flora with wind-dispersed seeds. Several major current ecological impacts

BI can be derived from a simple matrix of CI and FI as indicated in Table 7-40.

Table 7-40: Biodiversity Importance Two-way Matrix

Biodiversity Importance		Conservation Importance				
		Very High	High	Medium	Low	Very Low
Functional Integrity	Very High	Very High	Very High	High	Medium	Low
	High	Very High	High	Medium	Medium	Low
	Medium	High	Medium	Medium	Low	Very Low
	Low	Medium	Medium	Low	Low	Very Low
	Very Low	Medium	Low	Very Low	Very Low	Very Low

Receptor Resilience (RR) is defined as "the intrinsic capacity of the receptor to resist major damage from disturbance and/or to recover to its original state with limited or no human intervention". The fulfilling criteria for RR are presented in Table 7-41.

Table 7-41 Criteria for Determining Receptor Resilience

Receptor Resilience	Fulfilling Criteria
Very High	Habitat that can recover rapidly (~ less than 5 years) to restore > 70% of the original species composition and functionality of the receptor functionality, or species that have a very high likelihood of remaining at a site even when a disturbance or impact is occurring, or species that have a very high likelihood of returning to a site once the disturbance or impact has been removed.
High	Habitat that can recover relatively quickly (~ 5-10 years) to restore > 70% of the original species composition and functionality of the receptor functionality, or species that have a high likelihood of remaining at a site even when a disturbance or impact is occurring, or species that have a high likelihood of returning to a site once the disturbance or impact has been removed.
Medium	Will recover slowly (~more than 10 years) to restore > 70% of the original species composition and functionality of the receptor functionality, or species that have a moderate likelihood of remaining at a site even when a disturbance or impact is occurring, or species that have a moderate likelihood of returning to a site once the disturbance or impact has been removed.
Low	Habitat that is unlikely to be able to recover fully after a relatively long period: > 15 years required to restore ~less than 50% of the original species composition and functionality of the receptor functionality, or species that have a low likelihood of remaining at a site even when a disturbance or impact is occurring, or species that have a low likelihood of returning to a site once the disturbance or impact has been removed.
Very Low	Habitat that is unable to recover from major impacts, or species that are unlikely to remain at a site even when a disturbance or impact is occurring, or species that are unlikely to return to a site once the disturbance or impact has been removed.

Once BI and RR have been calculated through the use of the above two matrices, EI can be determined using the matrix in Table 7-42.

Table 7-42 Ecological Importance Matrix

Ecological Importance (EI)		Biodiversity Importance (BI)				
		Very High	High	Medium	Low	Very Low
Receptor Resilience	Very Low	Very High	Very High	High	Medium	Low
	Low	Very High	High	Medium	Low	Low
	Medium	High	Medium	Medium	Low	Very Low
	High	Medium	Low	Low	Low	Very Low
	Very High	Low	Low	Very Low	Very Low	Very Low

Guidelines for how to interpret EI of a project in terms of impact mitigation are given in Table 7-43.

Table 7-43 Guidelines for Interpreting Ecological Importance of Receptors

Ecological Importance	Interpretation in Relation to Proposed Development Activities
Very High	Avoidance mitigation - No destructive development activities should be considered. Offset mitigation not acceptable/not possible (i.e. last remaining populations of species, last remaining good condition patches of ecosystems/unique species assemblages. Destructive impacts for species/ecosystems where <persistence target remains.
High	Avoidance mitigation wherever possible. Minimization mitigation – Changes to project infrastructure design to limit the amount of habitat impacted; limited development activities of low impact acceptable. Offset mitigation may be required for high impact activities.
Medium	Minimization & restoration mitigation - Development activities of medium impact acceptable followed by appropriate restoration activities.
Low	Minimization & restoration mitigation - Development activities of medium to high impact acceptable followed by appropriate restoration activities.
Very Low	Minimization mitigation - Development activities of medium to high impact acceptable and restoration activities may not be required.

B Assessment of Ecological Importance

The integrated assessment of EI is presented in Table 7-44 and the spatial extent of the EI categories and habitat status are shown on the map in **Figure 7-105**. This assessment integrated the results of separate EI assessments of the five vegetation communities and seven faunal assemblages, which represented seven distinct habitats as indicated in Table 7-45. A quantification of the areal extent of each vegetation community or habitat type in the direct and indirect AOI is summarised in Table 7-29.

- One of the vegetation communities in the project area has been assessed as having a **High** Integrated EI, namely Hillslope Grassland / Savannah. Although this community occupies only ~22 ha, its high EI value is driven by High Functional Integrity and Very Low Receptor Resilience. Hillslope Grassland / Savannah is situated on extremely steep slopes with shallow, unstable soils and is an important vegetation community with regards to slope stability. It would be almost impossible for grasslands on these steep slopes to be restored to original species composition with intact ecological processes and functions if the vegetation cover was removed during infrastructure construction, hence the Very Low RR score.
- Four vegetation communities/faunal habitats have been classified as having a **Medium** Integrated EI, namely Riparian Thicket, Hillslope Thicket / Forest, Riparian Wetlands and Open Water. These communities cover 68 ha, or 28% of the project footprint (Figure 7-105). Riparian Thicket and Hillslope Thicket / Forest both have only Medium Functional Importance as a result of severe fragmentation and reduced ecological functionality and have Medium Conservation importance as a result of the potential to support SCC as well as confirmed occurrence of one NT tree species. Riparian Wetlands and Open Water both have High Conservation Importance as a result of the confirmed occurrence of hippopotamus (VU), although this is only relevant to the river downstream of Bugarama, and only Medium Functional Importance as a result of some compromised ecological functionality (e.g. as a result of invasion by alien plants) and habitat degradation.
- The Integrated EI of the Cultivation / Secondary Shrubland Mosaic community (which occupies the majority (154 ha/62%) of the project area) has been classified as **Low** and the EI for Towns & Villages as **Very Low**, mostly as a result of loss or degradation of Natural Habitat and natural ecological processes, low potential to support SCC and a high proportion of alien species present.

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Table 7-44 Summary of the Integration of Ecological Importance of Vegetation Communities and Faunal Habitats

Vegetation Community	Riparian Thicket	Hillslope Thicket / Forest	Hillslope Grassland / Savannah	Riparian Wetlands	Cultivation / Secondary Shrubland Mosaic		
	M	M	H	L	L		
Faunal Assemblage	Riparian Thicket	Hillslope Thicket / Forest	Hillslope Grassland / Savannah	Riparian Wetlands	Cultivation / Secondary Shrubland Mosaic	Open Water	Towns & Villages
	M	M	H	M	L	M	VL
Integrated Ecological Importance (EI)	M	M	H	M	L	M	VL

Table 7-45 Assessment of Ecological Importance by Habitat Type/Vegetation Community in PAOI

Vegetation Community / Habitat	Conservation Importance		Functional Importance		Biodiversity Importance	Receptor Resilience	Ecological Importance
Riparian Thicket	M	Modified Habitat with minimal SCC	M	Low habitat connectivity with diminished capacity to function as ecological corridors Visible ecological impacts with signs of forest loss in the past	M	M	M
Hillslope Thicket / Forest	M	Natural Habitat with minimal SCC Confirmed occurrence of *Milicia excelsa* (NT)	M	Low habitat connectivity with diminished capacity to function as ecological corridors Visible ecological impacts with signs of forest loss in the past	M	M	M
Hillslope Grassland / Savannah	M	Natural Habitat with potential to support SCC No SCC confirmed.	H	Good habitat connectivity with functional ecological corridors and processes Some habitat loss and fragmentation but some significant patches still present	M	VL	H
Riparian Wetlands	H	Modified Habitat with low potential to support SCC Confirmed occurrence of hippopotamus (VU)	M	Moderate to poor habitat connectivity with potentially functional ecological corridors Visible ecological impacts (e.g. established populations of alien invasive flora) and signs of minor past disturbance; moderate rehabilitation potential	M	M	M
Cultivation / Secondary Shrubland Mosaic	L	Modified Habitat with limited potential to support SCC	L	No remaining Natural Habitat	L	N/A	L

Vegetation Community / Habitat	Conservation Importance		Functional Importance		Biodiversity Importance	Receptor Resilience	Ecological Importance
Open Water	H	Modified Habitat but with potential to support SCC Confirmed presence of hippopotamus (VU) down-stream of Bugarama	M	Flowing water sustains some fish, hippopotamus and a few waterbirds but much reduced due to hydropeaking releases.	M	H	M
Towns & Villages	L	No Natural Habitat; unlikely to support SCC	VL	No remaining Natural Habitat	VL	N/A	VL

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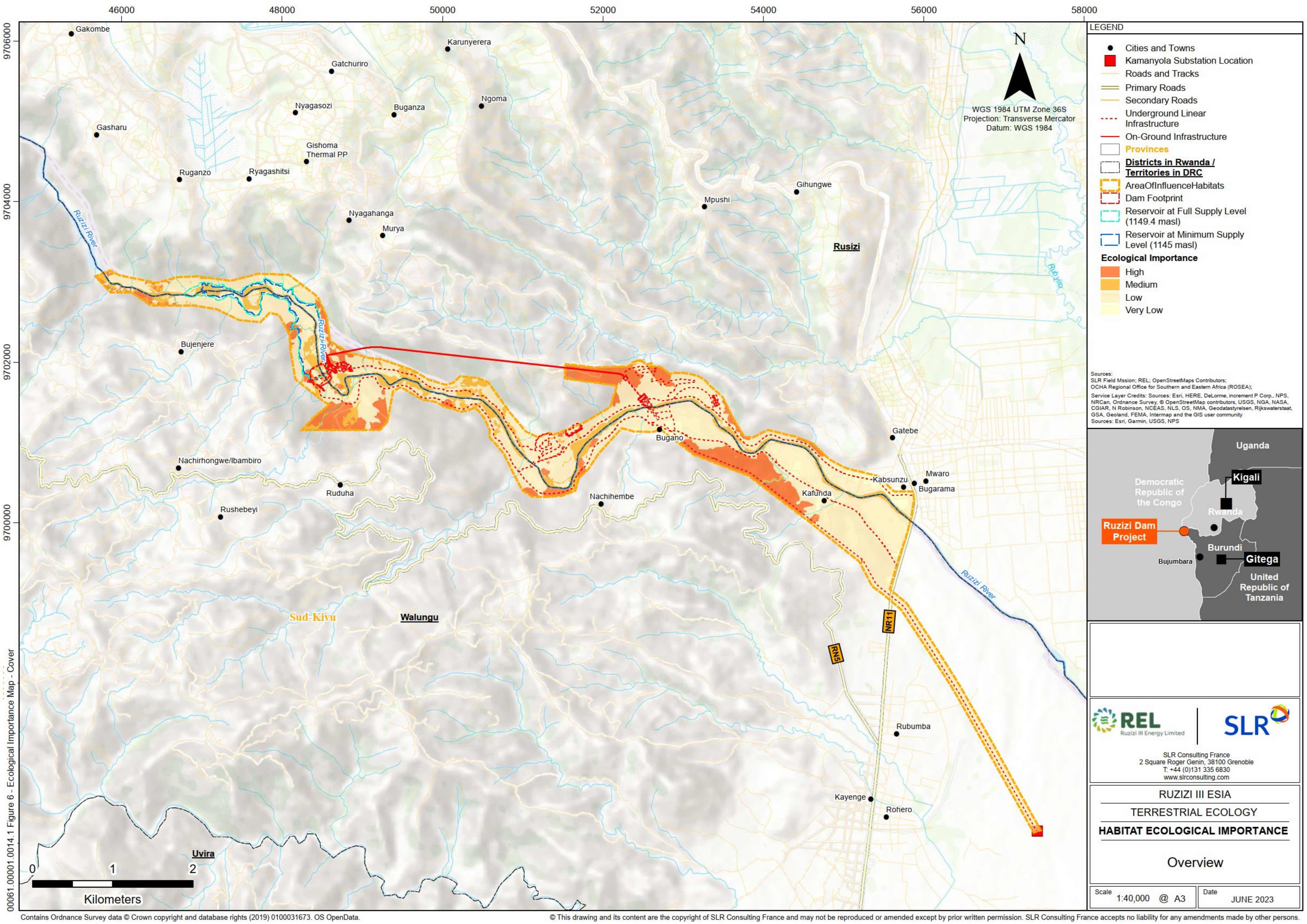

Figure 7-105a Ecological Importance of Habitats represented in the Project Area: Cover Map

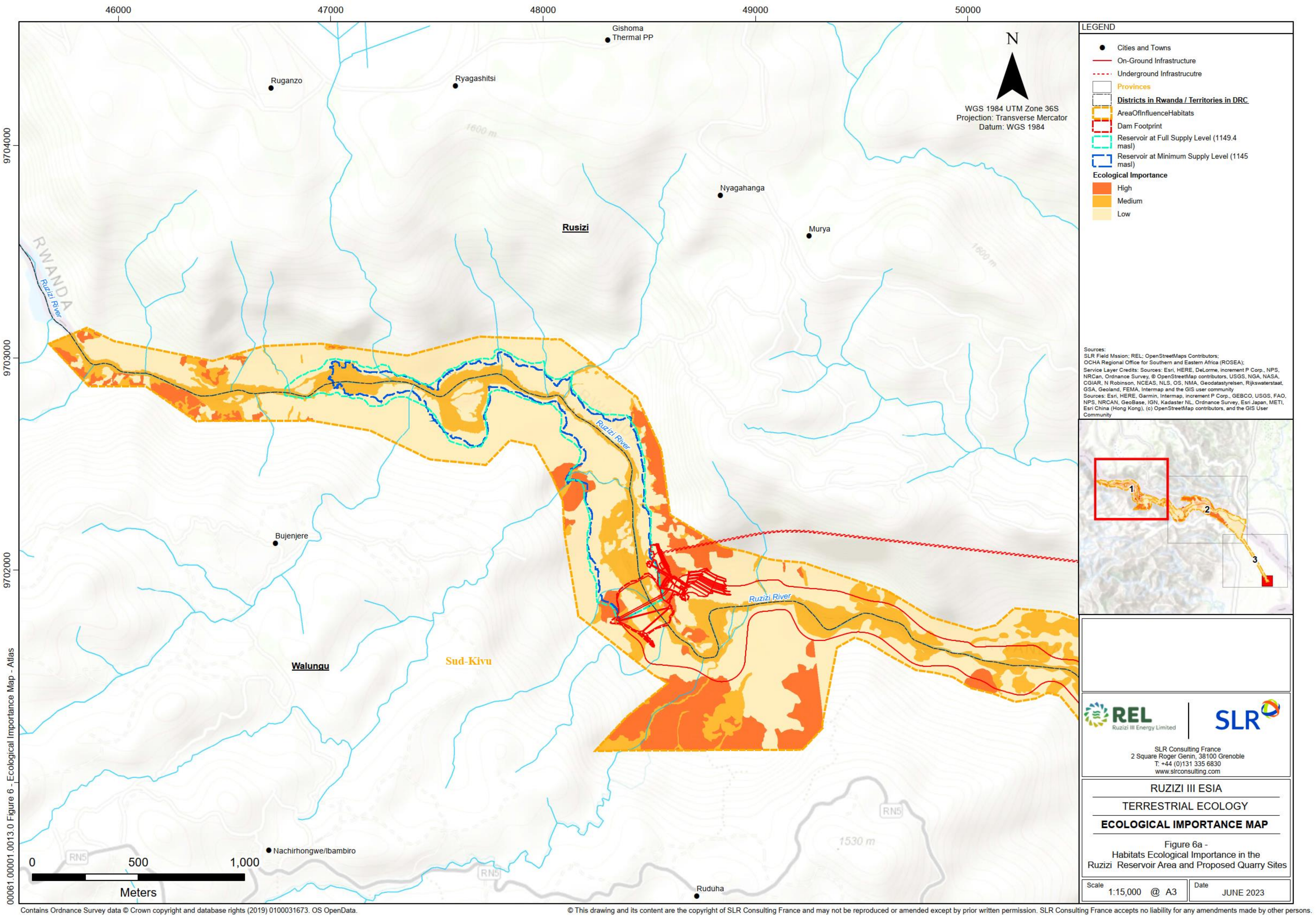

Figure 7-105b Ecological Importance of Habitats represented in the Project Area: Reservoir and Immediate Downstream Area

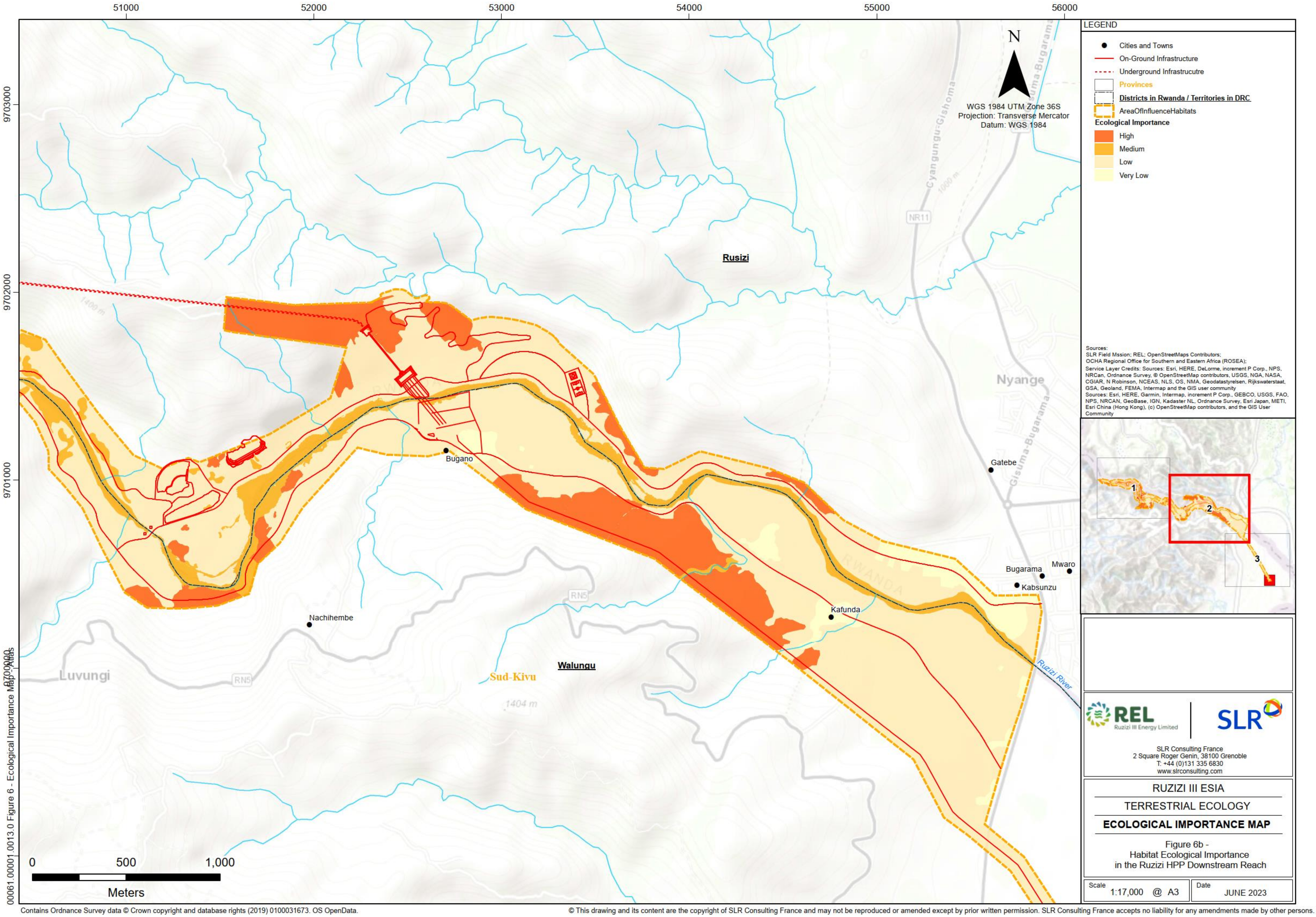

Figure 7-105c Ecological Importance of Habitats represented in the Project Area: Downstream Reaches

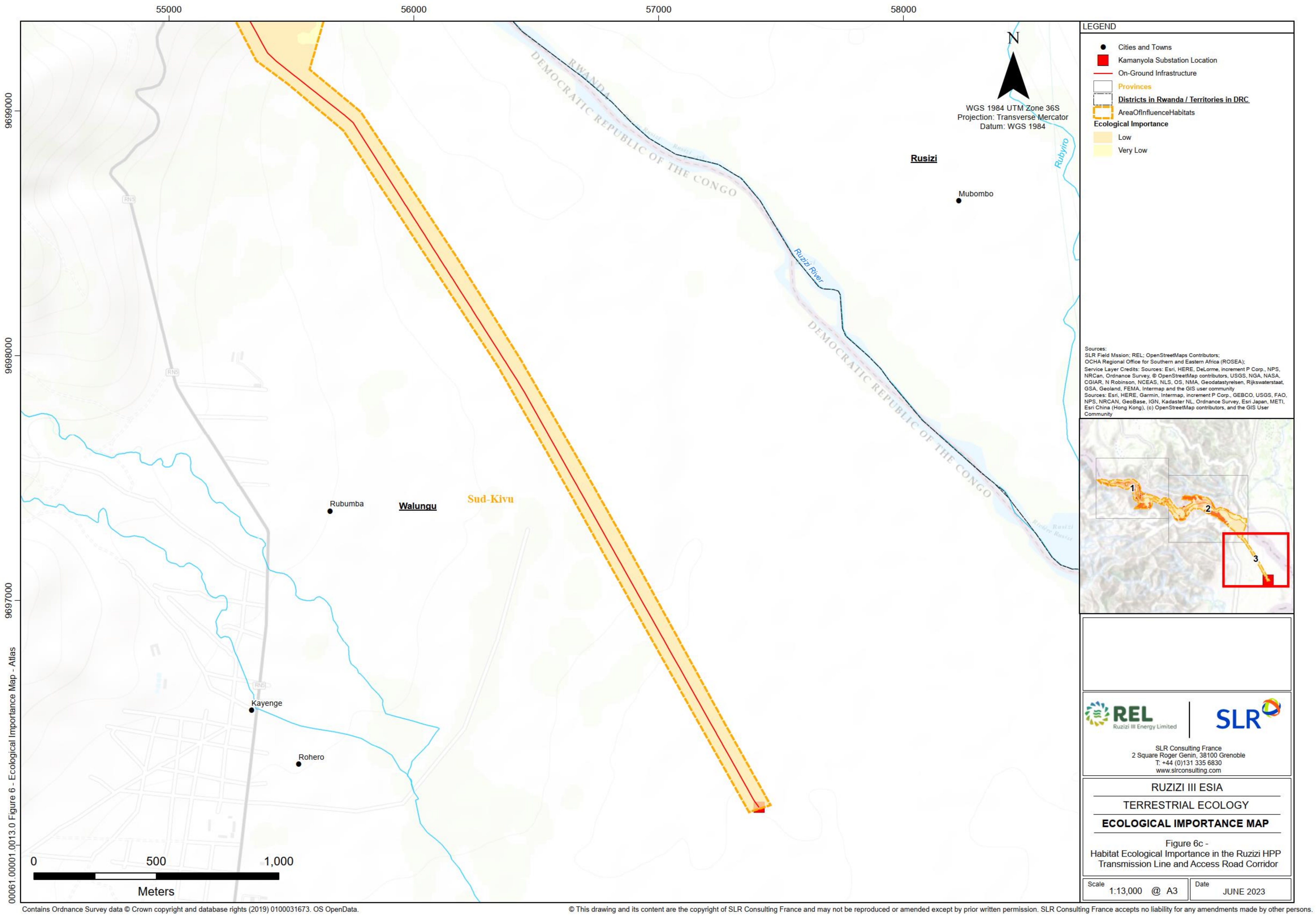

Figure 7-105d Ecological Importance of Habitats represented in the Project Area: Transmission Line and Access Road