Lower Mara River Environmental Flow Assessment

Final Resource Quality Objectives and Reserve Assessment Report

NELSAP Technical Reports: Basin Development Series 2020 - 01

APRIL 2020

NELSAP-CU
NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

Biodiversity Conservation and Sustainable Utilization of Ecosystem Services of Wetlands of Transboundary Relevance in the Nile Basin

Determination of environmental flow requirements for the lower Mara as part of the Transboundary Water Allocation Planning in the Lower Mara River Basin (Tanzania)

Prepared by the Nile Basin Initiative Nile Equatorial Lakes Subsidiary Action Program Coordination Unit (NELSAP-CU) with financial support from Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under the International Climate Initiative for the Ministry of Water of the United Republic of Tanzania under technical support from IHE Delft Institute for Water Education.

April 2020

The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

Funding source: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under the International Climate Initiative
Project title: Conserving biodiversity in the Nile Basin transboundary wetlands
Project number: 14.9029.1

A SECTION OF THE LOWER MARA RIVER IN TANZANIA

EXECUTIVE SUMMARY

Introduction and Study Area

This report presents the resource quality objectives (RQOs) and a reserve assessment for the Lower Mara River Basin (Lower MRB) of Tanzania. Activities reported are part of the project "Biodiversity Conservation and Sustainable Utilization of Ecosystem Services of Wetlands of Transboundary Relevance in the Nile Basin", which seeks to build consensus and enhance cooperation in water resources management and development between the Nile Basin's riparian countries. Results also contribute to the development of a water allocation plan for the Lower MRB under the Memorandum of Understanding signed by Tanzania and Kenya in 2015 for Joint Water Resources Management of the Transboundary Mara River Basin. The environmental Flow assessment report was developed and in close cooperation with and direct involvement of the Lake Victoria Basin Water Board (LVBWB) under of the Ministry of Water of Tanzania, which is the authority legally responsible for setting and protecting RQOs and the reserve in water resource management.

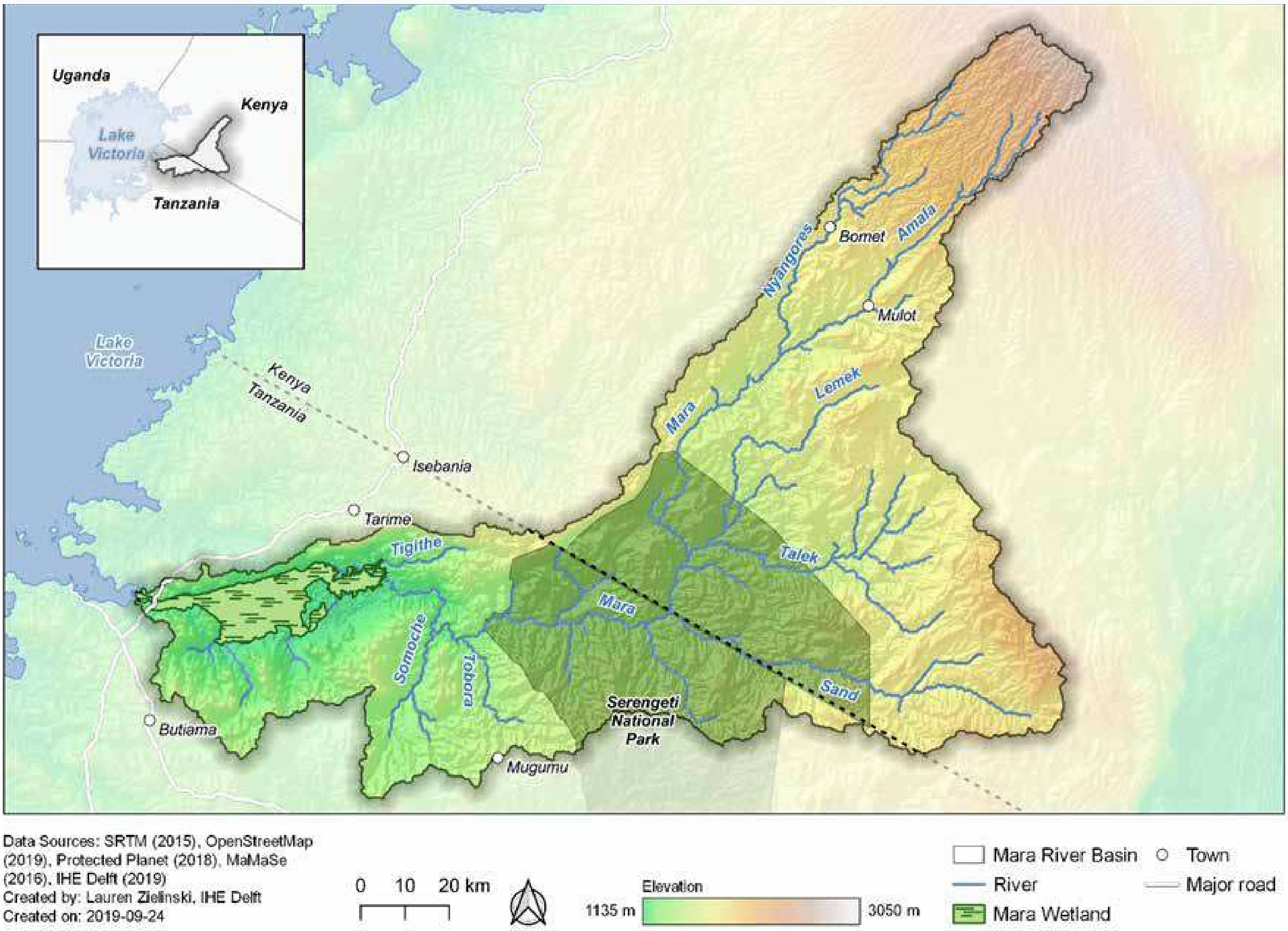
The process involved Resource Quality Objective (RQO) setting through a stakeholder's workshop, Environmental flow assessment and Reserve flow setting by specialists and water authorities. RQOs and the reserve are a requirement in Part VI (Protection of Water Resources) of the 2009 National Water Resources Management Act of Tanzania. RQOs are intended to protect water and related aquatic biological resources at levels needed to meet the needs of resource users and maintain ecosystems in a desired environmental management class. The reserve is defined as the quantity and quality of water required for;

(a) satisfying basic human needs by securing a basic water supply for people who are now or who shall in the reasonably for near future, be;
(i) relying upon
(ii) taking water from; or
(iii) being supplied from the relevant water resources; and

(b) protecting aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resources.

The reserve contributes to achieving the RQOs and consists of two parts. Part 1 is focused on meeting basic human needs, which can be considered a component of the domestic water demand, and part 2 is focused on protecting aquatic ecosystems. In this study we distinguish between the basic human needs component of the reserve and the ecological component of the reserve, known as environmental flows. Environmental flows are defined in the NBI's Strategy for Management of Environmental Flows in the Nile as the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon these ecosystems.

Setting RQOs and the reserve in the Lower MRB is a priority because of the need to balance the growing water needs of the population with the conservation of world-class ecosystems of the basin. The 2018 population of the Lower MRB is estimated at 396,000 and is projected to grow to more than 700,000 by 2030. To develop sustainably, this population must share the basin's limited water resources with ecosystems of Serengeti National Park, the Mara Wetland, and aquatic ecosystems extending up into each of the Mara River's tributaries. Protecting aquatic ecosystems is not only a requirement of the law, it is also important to people's health and livelihoods as communities rely on these ecosystems for many services, including i) clean water for people, agriculture, and livestock, ii) food in the form of fish and edible wild plants, iii) herbal medicines and other natural products, and iv) religious and cultural services central to the identities of the



communities. All of these factors are taken into account in setting RQOs for the Lower MRB and assessing the reserve flows needed to meet them.

FIGURE ES 1: MAP OF THE MARA RIVER BASIN

Process for Setting RQOs and the Reserve

The determination of the reserve and the related RQOs was completed using the NBI Environmental Flows Framework (NBI, 2016a, 2016b). This framework was developed by NBI to ensure a standard process is followed for the increasing number of environmental flow assessments being conducted in the Nile Basin. There are seven main steps in this framework, which are summarized in Figure ES-2.

Phase 1 included a policy review, compiled available information related to environmental flows (including field data, scientific literature, project reports, and other environmental flow assessments completed in the Mara River Basin and Tanzania), integrated our efforts with on-going water resources related work in the basin, and strengthened partnerships with relevant government organizations, projects, and non-government organizations, with a focus on partnerships and capacity building within the LVBWB and the Ministry of Water.

Phase 2 initiated the process of setting RQOs for individual resource units (Figure ES-3) by assembling a group of stakeholders to contribute to the process and holding a workshop to gather their inputs. These efforts produced assessments of pressures, important activities, and conditions in each resource unit, preferred management class for each resource unit, and draft RQO statements for each resource unit for quantity, quality, habitat, and biota. The involvement of the Water User Associations was central to this effort.

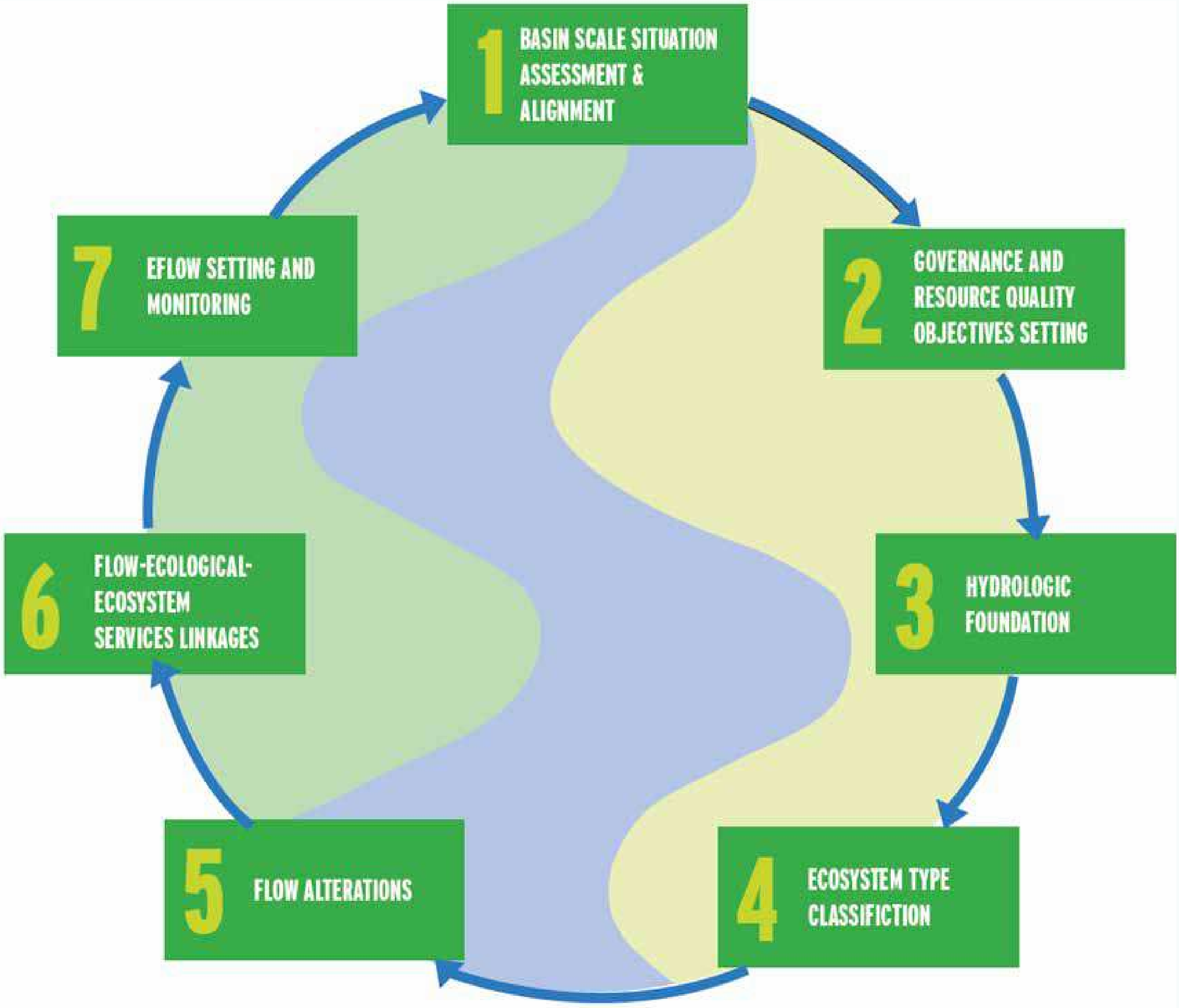


FIGURE ES 2: SUMMARY OF THE STEPS INVOLVED IN THE NBI E-FLOWS FRAMEWORK (NBI, 2016B)

Phase 3 analysed the hydrological foundation by regionalizing available datasets to quantify monthly and average annual discharge, minimum and maximum discharge values, annual and monthly flow duration curves, and maximum daily flow frequency analysis.

Phase 4 reviewed existing ecosystem and river classification systems or maps used in Tanzania and conducted ecological, biological, and geomorphology assessments to determine the characteristics of study sites selected for more detailed investigation. This resulted in the classification of areas by mainsteam, tributary, and wetland features.

Phase 5 evaluated the potential deviation of current-condition flows from baseline- (or natural-) condition flows. Significant flow alterations occur in river basins regulated by large infrastructure or with high water demand relative to water availability. In the Mara, there are currently no engineered structures that significantly alter flows. Thus, under most flow conditions the flow regime is near natural.

Phase 6 implemented a modified Building Block Methodology to assess flow-ecology ecosystem services linkages. This involved detailed analyses by a team of specialists in hydrology, hydraulics, water quality, geomorphology, fish, macroinvertebrates, riparian vegetation, and social use. Social surveys were carried out in 14 villages and biophysical surveys were conducted at seven sites, including two on the mainstem Mara River, three near the mouths of major tributaries, and two in the Mara Wetland (Figure ES-4). Biophysical surveys were conducted during two time periods. Reporting of the findings from this work forms the bulk of this document.

Phase 7 consisted of a flow setting technical meeting to synthesize the results of the team of specialists and

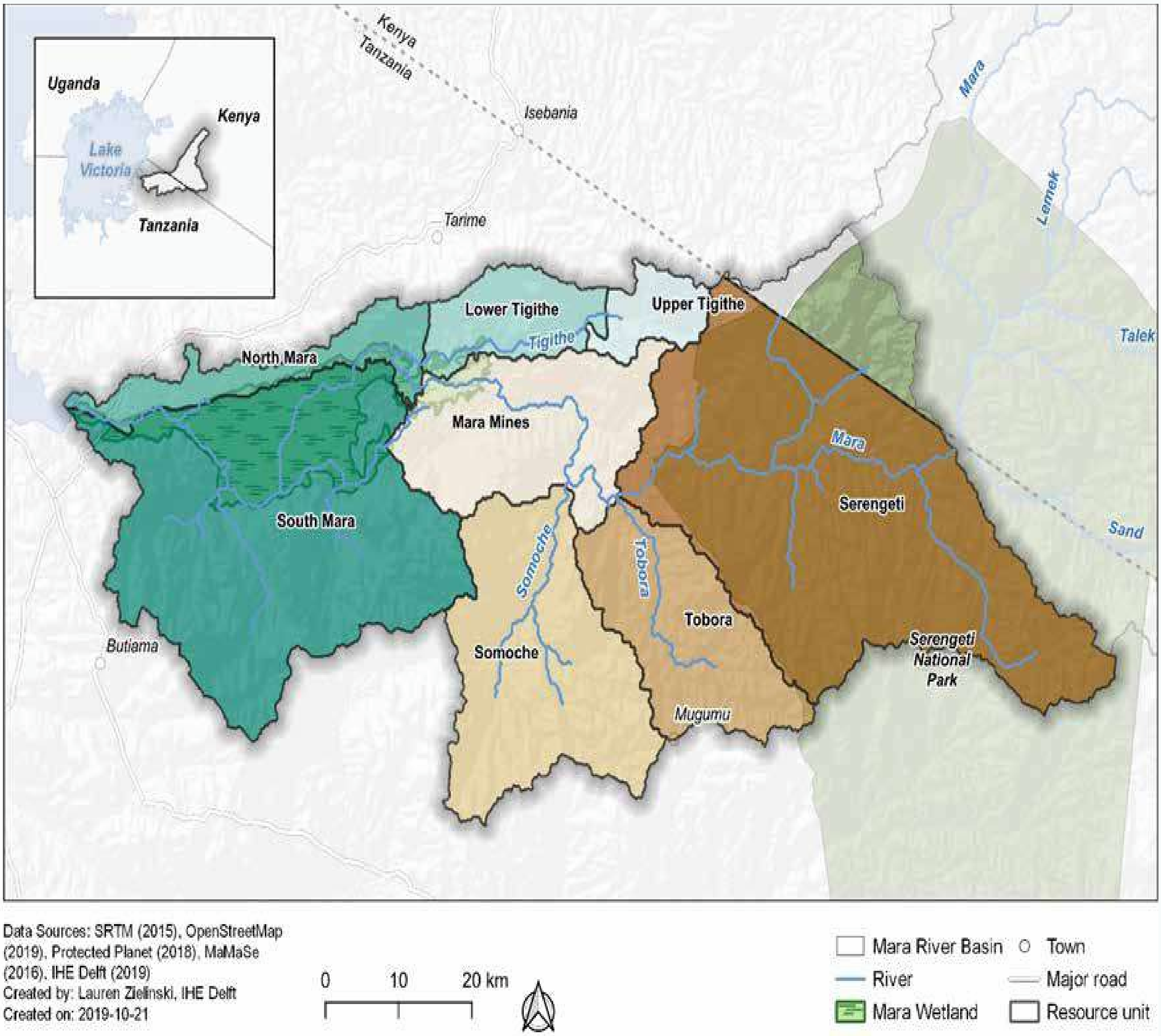


FIGURE ES-3: RESOURCE UNITS FOR THE LOWER MRB

set values for the ecological component of the reserve that met RQOs. It also included quantification of the basic human needs component of the reserve and recommended monitoring activities for compliance and effectiveness monitoring.

Results

RQOs set during the project reflect the close and multifaceted interdependencies of people and water and aquatic ecological resources in the Mara River Basin of Tanzania. People depend on river flows to meet water needs for domestic purposes, livestock, and agriculture across the basin. Groundwater is also an important source for domestic water. Special emphasis was given to dry season flows, but the importance of wet season flows was also highlighted for supporting floodplain agriculture and replenishing surface and groundwater storage for use in subsequent dry seasons.

The importance of ecosystem processes is recognized as maintaining an ambient level of water quality needed for healthy fisheries and water for domestic uses, livestock, and agriculture. Instream and riparian habitats and related biota are valued for the direct resources they provide (fish, building materials) as well as their role in supporting biodiversity. Biodiversity protection is recognized as the predominate use for water in Serengeti National Park but was also noted as important to inhabitants in all parts of the basin. These dependencies and values are recorded in the RQOs set by stakeholders. In all resource units (aligned with sub-basins) of the Mara, objectives were set to maintain ecosystems in no less than a somewhat altered condition, which corresponds to a class of B in the draft River Classification System for Tanzania. In this class, the "natural flow regime is affected by water withdrawals, impoundments and/or discharges, but the critical aspects of the flow regime are retained so that effects on the ecosystem are small."

The final estimates for flow requirements for basic human needs were calculated in units of m3/day and also m3/s to align with the environmental flow values. The basic human need values are approximately based on

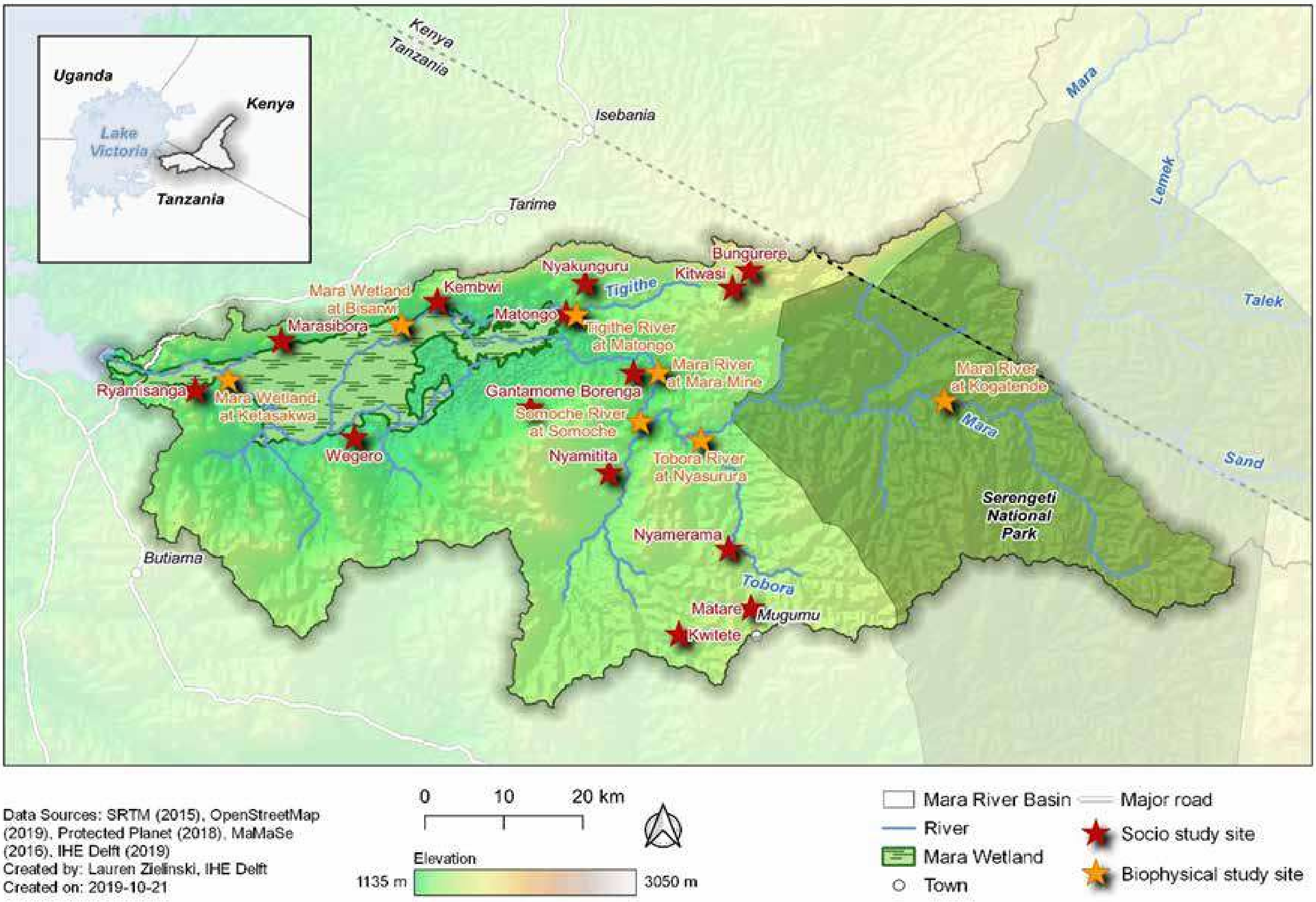


FIGURE ES 4: MAP OF THE STUDY SITES FOR THE SOCIAL SURVEY, BIOPHYSICAL FIELD CAMPAIGNS, AND RUS

the resource units to align with the planning units used in the water allocation planning effort. Upper and Lower Tigithe resource units have been combined as "Tigithe" and North Mara and South Mara RUs as "Mara Wetland", for a total of 6 resource units. The basic human need values for 2018 ranged from 0.009 m3/s in

Table ES-1: Basic human needs estimates for 2018 by resource unit

Resource Unit	Estimated Population (2012)*	Estimated Population (2018)	Water Demand for Basic Human Needs (m^3/day)	Water Demand for Basic Human Needs (m^3/s)
Serengeti	41,570	48,137	1,203.43	0.014
Tobora	32,930	38,133	953.33	0.011
Somoche	47,459	54,958	1,373.95	0.016
Upper Tigithe	25,641	29,692	742.30	0.009
Lower Tigithe	31,476	36,450	911.24	0.011
Mara Mines	54,517	63,130	1,578.25	0.018
North Mara	17,067	19,763	494.08	0.006
South Mara	88,560	102,552	2,563.80	0.030
Total	**339,219**	**392,815**	**9,820.37**	**0.114**

**NBS, 2012*

Tobora resource unit to 0.039 m3/s in the Mara Wetland resource unit (Table ES-1). The values for basic human needs are based on a daily requirement of 25 liters/person/day and are expected to remain constant throughout the year.

Monthly low flows for the ecological component of the reserve at riverine sites are presented relative to average flows in Figure ES-5. Flows, or depth in the case of the Mara Wetland site, during the driest and wettest months are presented in Table ES-2 (maintenance year) and Table ES-3 (drought year). Also presented are high flows characterized by a magnitude, duration, and timing.

During years of normal rainfall, results for the environmental flow of mainstem Mara River sites corresponded to 28 percent of the value of the average flow of the wettest month (May) and 22 to 27 percent of the average flow of the driest month (August). Flows in excess of the environmental flow are expect at least 95 percent of the time based on the available hydrological data. Environmental flows determined for mainstem sites during drought years were roughly 33 percent lower than those for normal years. Environmental flows for tributaries and the wetland correspond to larger or smaller proportions of estimated average monthly flow and may even exceed the monthly average during the driest month. The more extreme proportions at these sites are predominantly due to uncertainties in the estimation of hydrological regimes, which were regionalized from the relationships between precipitation data and mainstem hydrological records.

Environmental flows for normal years are intended to support the full range of ecological processes needed to

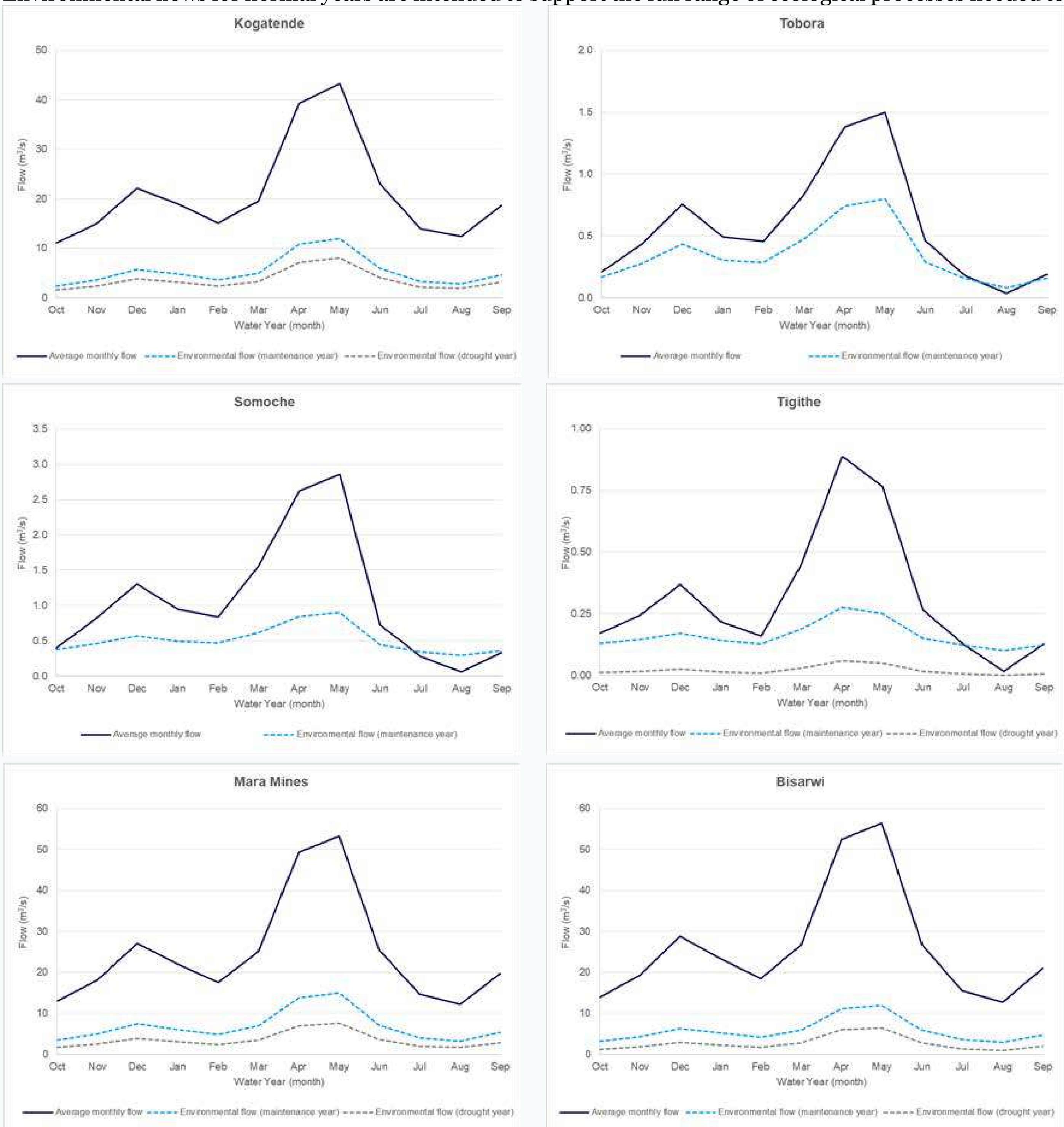


FIGURE ES 5: MONTHLY LOW FLOW REQUIREMENTS OF THE ECOLOGICAL COMPONENT OF THE RESERVE FOR RIVERINE STUDY SITES. BECAUSE OF EXPECTED NO-FLOW CONDITIONS DURING DROUGHT IN THE TOBORA AND SOMOCHE TRIBUTARIES, DROUGHT FLOW LEVELS WERE NOT SET FOR THESE SITES.

Table ES-2: Flow and depth values for the ecological component of the reserve during a maintenance year

	Hydrological Component	Kogatende	Tobora	Somoche	Tigithe	Mara Mines	Bisarwi	Mara Wetland*
Maintenance Year	Low flow, driest month	Month: Feb Flow (m^3/s): 2.4	Month: Aug Flow (m^3/s): 0.15	Month: Aug Flow (m^3/s): 0.3	Month: Aug Flow (m^3/s): 0.1	Month: Oct Flow (m^3/s): 3.5	Month: Feb Flow (m^3/s): 3.0	*Month: Aug* *Depth (m): 2.7*
	Low flow, wettest month	Month: May Flow (m^3/s): 12	Month: May Flow (m^3/s): 0.8	Month: May Flow (m^3/s): 0.9	Month: Apr Flow (m^3/s): 0.25	Month: May Flow (m^3/s): 15	Month: May Flow (m^3/s): 12	*Month: May* *Depth (m): 3.3*
	High flow, freshets and/or floods	– 1 freshet of 52 m^3/s for 21 days in Apr-May – 4 freshets of 30 m^3/s for 4 days each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 160 m^3/s for 3 days in May (annual) – 1 flood event of 490 m^3/s flood for 1 day in May (1 in 5 years)	– 1 freshet of 1.7 m^3/s for 14 days in Apr-May – 3 freshets of 1.7 m^3/s for 7 days each (2 in Nov-Dec, 1 in Mar-May) – 1 flood event of 24 m^3/s during 2 days in May (annual) – 1 flood event of 97 m^3/s during 3 days in May (1 in 3 years)	– 1 freshet of 2 m^3/s for 21 days in Apr-May – 4 freshets of 2.7 m^3/s for 2 days each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 20 m^3/s for 3 days in Apr-May (annual) – 1 flood event of 70 m^3/s for 2 days *in* May (1 in 3 years)	– 1 freshet of 1.2 m^3/s for 14 days in Apr-May – 3 freshets of 1 m^3/s for 7 days each (2 in Nov-Dec, 1 in Mar-May) – 4 freshets of 2.9 m^3/s for 1 day each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 26 m^3/s for 2 days (annual) – 1 flood event of 43 m^3/s for 2 days (1 in 3 years)	– 1 freshet of 46 m^3/s for 21 days in Apr-May – 3 freshets of 25 m^3/s for 7 days each (2 in Nov-Dec, 1 in Mar-May) – 4 freshets of 10 m^3/s for 2 days each (2 in Mar-May, 2 in Nov-Dec) – 1 flood event of 74 m^3/s for 1 day (annual) – 1 flood event of 334 m^3/s for one day (1 in 3 years) – 1 flood event of 498 m^3/s for 1 day (1 in 6 years)	– 1 freshet of 50 m^3/s for 10 days in May – 1 freshet of 50 m^3/s for 1-2 days in Dec – 2 freshets of 20 m^3/s for 2 days each (1 in Nov-Dec, 1 in Mar-May) – 1 flood event at 75 m^3/s for 2 days (annual) – 1 flood event at 100 m^3/s for 3 days (1 in 2 years)	*– 1 freshet at 4 m for 14 days (annual)* *– 2 freshet at 5 m for 10 days each in May and Nov (annual)* *– 1 flood event at 4.8 m for 14 days (1 in 2 years)*

**Only depth requirements were provided at this site due to an incomplete hydraulic cross-section, low confidence in the hydraulic model, and potential effects from the level of Lake Victoria*

Table ES-3: Flow and depth values for the ecological component of the reserve during a drought year

	Hydrological Component	Kogatende	Tobora	Somoche	Tigithe	Mara Mines	Bisarwi	Mara Wetland*
Drought Year	Low flow, driest month	Month: Feb Flow (m^3/s): 1.6	None	None	Month: Aug Flow (m^3/s): 0.0	Month: Oct Flow (m^3/s): 1.8	Month: Feb Flow (m^3/s): 1.0	*Month: Aug* *Depth (m): 2.4*
	Low flow, wettest month	Month: May Flow (m^3/s): 8.0	None	None	Month: Apr Flow (m^3/s): 0.05	Month: May Flow (m^3/s): 7.6	Month: May Flow (m^3/s): 6.5	*Month: May* *Depth (m): 2.8*
	High flow, freshets and/or floods	– 1 freshet of 20 m^3/s for 21 days in Apr-May – 4 freshets of 10 m^3/s for 7 days in Apr-May, Nov-Dec – 3 freshets of 30 m^3/s for 2 days each in Apr-May (2 in Nov-Dec, 1 in Mar-May) – 1 flood event of 56 m^3/s for 1 day in May (annual)	None	None	– 1 freshet of 0.25 m^3/s for 14 days in Apr-May – 4 freshets of 0.6 m^3/s for 7 days each (2 in Nov-Dec, 2 in Mar-May) – 3 freshets of 2.9 m^3/s for 1 day each (2 in Nov-Dec, 1 in Mar-May) – 1 flood event of 26 m^3/s for 2 days in May (annual)	– 1 freshet of 22 m^3/s for 21 days in Apr-May – 4 freshets of 10 m^3/s for 7 days each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 122 m^3/s peak for 2 days in May (1 in 3 years)	– 2 freshets of 12 m^3/s for 10 days each in May and Dec	*– 1 freshet of 3.2 m for 14 days (annual)* *– 1 flood event of 4.4 m for 14 days (1 in 2 years)*

**Only depth requirements were provided at this site due to an incomplete hydraulic cross-section, low confidence in the hydraulic model, and potential effects from the level of Lake Victoria* maintain healthy plant and animal communities in the river system. Protection of ecological processes in the river also ensured continued delivery of ecosystem services beneficial to human communities. Environmental flows for drought years are intended to sustain life in the system until higher flow levels return.

Conclusions

The RQOs and reserve levels determined in this project comply with all requirements and approved guidelines under Tanzanian law and thus qualify for notice in the Gazette and application in continued water resource planning. They are judged to be valid for a period of five years, which corresponds to the validity period of the basin Integrated Water Resource Management and Development Plan. After this period, and in the context of regular water resource planning and management, they should be reviewed and revised if judged necessary. Both the RQOs and reserve flows set in this assessment are relevant for the water allocation plan currently under development by the LVBWB and the Ministry of Water. According to the draft guidelines for water allocation planning developed by the Ministry of Water, water resources allocation is "a means by which regulation of water use is done through sharing water resources among competing users, with due regard for the environment, the economy, and the social wellbeing of all Tanzanians". Setting RQOs is a required step in this process and a mechanism to incorporate stakeholder interests and align them with the requirements of Tanzanian laws and regulations. The reserve is a term required in the water balance to be calculated for each water allocation planning unit, represented by the equation:

Water Balance = Available Water – (Reserve + Transfers + Summation of Water Allocations)

A positive water balance indicates that there is sufficient available water to meet all water demands, while a negative balance indicates a state of over allocation. The water balance can be calculated at monthly, seasonal, or annual time intervals. The results of this assessment quantified both the basic-human-need and ecological components of the reserve at monthly intervals, which allows them to be incorporated into the water balance at whatever time interval is chosen. It will still be necessary, however, to extrapolate reserve values to the outlets of final planning units. This can be done by adjusting the values reported in this document in proportion to the upstream contributing area of each planning unit.

The reserve values are also relevant to the management stage of water allocation planning, including aspects of compliance and enforcement. In the implementation of the water allocation plan, river levels are to be monitored to determine whether water users may continue to withdrawal water at the full limit of their permit or whether restrictions should be imposed to protect reserve flows in the river.

Current estimates are that 75 percent of the water flowing in the Mara River in Tanzania comes from Kenya. Thus, close coordination is necessary between the countries in water allocation and management. This also applies to consideration of the reserve. Fortunately, Tanzanian and Kenyan water laws are consistent in their definition of the reserve and assigning it highest priority in water allocation. Both countries include basic human needs and ecosystem protection as components of the reserve. Both countries recognize the basic human need to be 25 liters/person/day, and both countries have adopted the Nile E-Flows Framework for the determination of the ecological component for transboundary rivers. This consistency in laws, definitions, and approaches greatly enhances the potential for harmonious management of water resources across the border.

Care must also be taken that numerical values of reserve flows and implementation measures are consistent in a manner that ensures Kenyan reserve flows crossing the border are sufficient to meet Tanzanian reserve flow levels. The environmental management objectives of Tanzania and Kenya at the border are similar given the juxtaposition of Serengeti National Park and Maasai Mara National Reserve. This should lead to similar determinations of the ecological component of the reserve. The reserve determined in this assessment at Kogatende in Serengeti National Park is judged sufficient to meet downstream reserve requirements in the 5-year time period these determinations will remain valid.

Knowledge Gaps

Uncertainty is inevitable in any scientific assessment of reserve levels, especially in data scarce systems like the Mara River Basin. This assessment has been transparent in acknowledging uncertainties and taking steps to minimize risks associated with them. The assessment team stands behind the reserve flows reported here but also strongly recommends that actions be taken to improve knowledge and understanding of key components of the resource system.

Urgent action is needed to restore the hydrometeorological monitoring network of the Mara River Basin. There are currently no functional river discharge or precipitation stations in the basin. In this assessment, suitable historical data were available from only one river discharge station (Mara Mines) and two precipitation stations (Nyabassi and Mugumu) which are near but outside the basin. Almost nothing is known about groundwater, which was not explicitly considered in the reserve assessment. The lack of historical hydrological data had a minimal impact on reserve flows determined in this assessment because the modified building block method used is based primarily on data collected during the assessment itself. Daily precipitation and flow data are necessary for proper implementation of the reserve, and long-term data sets are necessary for broader planning of water resource use and allocation.

The lack of long-term hydrological data for the Somoche, Tobora, and Tigithe Rivers is of concern for water allocation because of the high uncertainties associated with the regionalized data from the water resource assessment. This leads to uncertainty in the total quantity of water available during different months of the year and between different years. So, while there is higher confidence in the reserve flows, the uncertainty in the total water available is transferred to the water balance and volume of water available for allocation to uses like domestic, livestock, irrigation, and industry. If regionalized data overestimate the total water available this could lead to over-allocation of water in permits.

The hydrology and hydraulics of the Mara Wetland also remain largely unknown. During the field assessments the team measured flows in the wetland that significantly exceeded flows into the wetland at Mara Mines. This indicates that flows in the wetland included drainage of stored water as well as inflows from the Mara River. Water levels in the lower portions of the wetland also appear to be influenced by the level of Lake Victoria, which diminishes the degree to which these portions of the wetland are dependent on Mara River flows. Improved knowledge of these hydraulic characteristics of the wetland, bathymetry of the wetland, and associated plant and animal communities is needed to set appropriate reserve levels in Mara River.

Finally, because the Mara River is presently most vulnerable to flow alterations under low flow conditions, there is urgency to improve knowledge of how aquatic ecosystems function during low flows. Low flows are a natural part of the river's hydrograph and riverine and wetland species are adapted to cope with natural

low flow conditions. But the increasing water demands of basin inhabitants during dry periods are likely to reduce river flows to unnatural levels and to extend the duration of low flows. This will increase stress on river organisms to levels beyond their adapted tolerance levels.

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Acknowledgements

Development of this Environmental Flow Report is made possible through technical support from UNESCO-IHE Delft through its consultacy services.

Special thanks are to the Federal Government of Germany, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) for their financial support and Nile Basin Initiative (NBI) Nile Equatorial Lakes Subsidiary Action Program Coordination Unit (NELSAP CU) and through Gesellschaft für Internationale Zusammenarbeit (GIZ) for their Strategic and programmatic support of the project given by Juan Carlos Sanchez, Advisor for GIZ, and Sadiki Lotha Laiser, Biodiversity Conservation and Sustainable Utilization of Ecosystem Services/wetlands Expert for NBI.

The Initiative extends its thanks to Lake Victoria Basin Water Board (LVBWB) for engaging fully in the project from day one, including providing institutional knowledge on the water resources management in the Lower Mara River Basin, planning and logistical support on field work and workshops, connecting the team with the right partner agencies, and providing guidance on local customs to make the project a success. The technical expertise and hard work of Eng. Florence Mahay, Lake Victoria Basin Water Board Officer, Mwita Mataru, Environmental Expert, John Ngawambala, Community Development Officer, Wiston Robert Agwaro, Hydrologist, Ogoma Mangasa Nyamhanga, Hydrologist, and Gerald Itimbula, Communications Officer, were critical for the success for the project. The project team would also like to thank the LVBWB drivers for their dedication transporting the field team and their equipment across the basin: Friday Mwanizumbha, William Sanda, Amosi Kishebuka, and Constantine Mirumbe.

The Water Allocation Planning task force members from the Ministry of Water in Tanzania for their active participation, policy guidance, and review of technical documents: Modestus Herman Mballa, Estella Mgala, David Manyama Jamberi, Ramadhani Hamza Singano, and Hosea Sanga.

The entire EFA technical team and project assistants for their strong dedication to the project and providing valuable contributions to all aspects of the project, including Anne Siema, Dr. Gordon O'Brien, Dr. Jochen Wenninger, Dr. Bennie van der Waal, Dr. Frank Masese, Dr. Samora Macrice, Dr. Felister Mombo, Patrick Meya Wadheir, Qambemeda Nyanghura, David Bigirwa, Christian Fry, Andrew Husted, and Elizabeth Grater. Partners agencies who assisted during the field campaigns and workshops, including Kelvin Mollel, Park Ecologist, and William Mwakilema, Chief Park Warden, from Serengeti National Park; Jonas Nyandwi, Fisheries Officer, Mlela Noah, Assistant Fisheries Officer, and Mohamed Ngauna, Rajabu Hegga, and Gosbeth Buchard, boat engineers and drivers, from the Musoma District Fisheries Department for their generous assistance with fisheries equipment and expertise; and the Water Resources Authority in Kenya for their continued cooperation in the transboundary management of the Mara River Basin as well as providing technical staff and equipment vital to the project.

Long-standing project partners, USAID's Sustainable Water Partnership and WWF Tanzania for their continued contributions and support of this project and promoting sustainable water management in the Mara River Basin.

The Initiative offer thanks to the many members of local government and the community who assisted our field campaigns, including water users' associations, district water and environment officers, and local villagers who provided critical local knowledge and insight to the project.

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List of Acronyms and Abbreviations

Acronym	Definition
ASPT	average score per taxon
BBM	Building Block Methodology
DO	dissolved oxygen
EC	electrical conductivity
EFA	environmental flow assessment
EIS	Ecological Importance and Sensitivity
EMC	Ecological Management Class
FD	fast deep (habitat)
FS	fast shallow (habitat)
HCR	Habitat Cover Rating
HU	hydrological unit
IHE Delft	IHE Delft Institute for Water Education
GHU	Geomorphic Habitat Units
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GLOWS-FIU	Global Water for Sustainability program, Florida International University
km	kilometer
LVBWB	Lake Victoria Basin Water Board
m/s	meters per second
m3/s	cubic meters per second
m	meter
MaMaSe	Mau Mara Serengeti Sustainable Water
Mm3	million cubic meters
mm	millimeter
MoU	Memorandum of Understanding
MoW	Ministry of Water
MRB	Mara River Basin
NBI	Nile Basin Initiative
NELSAP-CU	Nile Equatorial Lakes Subsidiary Action Program Coordination Unit
PREPARED	Planning for Resilience in East Africa through Policy, Adaptation, Research and Economic Development
PES	Present Ecological State
RQO	Resource Quality Objective
RU	resource unit
SASS/SASS5	South African Scoring System
SENAPA	Serengeti National Park
SIS	Social Importance and Sensitivity
SD	slow deep (habitat)
SS	slow shallow (habitat)
TARISS	Tanzania River Scoring System
ToC	Trajectory of Change
USAID	United States Agency for International Development
WAP	water allocation plan
WUA	water users association

WWF	World Wide Fund for Nature
yr	year

1.1 Project Scope and Objectives

This report presents the results of the determination of environmental flow requirements in the Lower Mara River Basin. The Lower Mara Environmental Flow Assessment (EFA) was carried out by The Nile Basin Initiative, Nile Equatorial Lakes Subsidiary Program (NBI/NELSAP) in collaboration with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) through technical support provided by IHE Delft Institute for Water Education (IHE Delft) under the project Biodiversity Conservation and Sustainable Utilization of Ecosystem Services of Wetlands of Transboundary Relevance in the Nile Basin, which seeks to build consensus and enhance cooperation in water resources management and development between the Nile Basin's riparian countries.

The objective of the project is to determine the flow requirements needed to meet the reserve in the Tanzanian part of the Mara River Basin (referred to in this document as the Lower Mara River Basin, or Lower MRB) using the Nile E-flows Framework developed by NBI. The study builds upon a similar EFA study conducted by NBI in cooperation with the Mau Mara Serengeti Sustainable Water Initiative (MaMaSe) project in the Kenyan part of the basin (more details in Section 3.1.3). Mara River is a transboundary river originating from the partially deforested Mau Escarpment of Kenya, flowing through the savanna landscapes of Maasai Mara National Reserve and Serengeti National Park (SENAPA), and emptying into Lake Victoria via an extensive wetland of high conservation value. Despite its modest area (13,750 km2), the basin contains a wide variety of ecosystem types characteristic of some of the most valued natural features of the Nile Basin.

The Mara is also home to approximately 1 million inhabitants dependent on the river's water resources for a wide variety of livelihoods. These characteristics, in additional to the relative abundance of past studies and available data, make the Mara a valuable model for learning and demonstration in the wider Lake Victoria and Nile Basin context. More details on the biophysical and social characteristics of the basin are presented in Chapter 2. The effort was planned and carried out in close cooperation with and direct involvement of the Lake Victoria Basin Water Board (LVBWB) and the Ministry of Water (MoW) of Tanzania, which is the authority legally responsible for setting and protecting environmental flows in water resource management. Officers of LVBWB were engaged in every aspect of the project and MoW task force members were engaged during all major project activities, including field work, stakeholder workshops, and technical meetings.

1.2 Resource Quality Objectives, Environmental Flows and the Reserve

This study focuses on setting RQOs and quantification of environmental flows and the reserve in the Lower MRB. These are related components of sustainable water resource management featured in management frameworks for the Nile Basin as well as Tanzanian laws and regulations. RQOs and the reserve setting is a requirement as stipulated in Part VI (Protection of Water Resources) of the 2009 National Water Resources Management Act of Tanzania. RQOs are intended to protect water and related aquatic biological resources at levels needed to meet the needs of resource users and maintain ecosystems in a desired environmental management class.

The detailed aspects of RQOs are not specified by the Tanzanian MoW but are described in the technical manual accompanying the NBI E-Flows Strategy (NBI, 2016a) which have been adopted by the United Republic of Tanzania through its membership in the NBI. The NBI E-Flows Framework adopts the description of RQOs specified in the 2004 South African National Water Resource Management Strategy , which states that "resource quality includes water quantity and water quality, the character and condition of in-stream and riparian habitats, and the characteristics, condition and distribution of the aquatic biota.

Environmental flows and the reserve are closely related instruments to meet RQOs. The Nile E-flows Strategy defines environmental flows as describing "the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon these ecosystems". This definition is consistent with the internationally recognized definition included in the 2007 Brisbane Declaration . The term environmental flows is not used in Tanzanian water laws or regulations. Instead the 2009 National Water Resources Management Act of Tanzania refers to the "reserve", which is defined as the quantity and quality of water required for -

(a) satisfying basic human needs by securing a basic water supply for people who are now or who shall in the reasonably for near future, be
(i) relying upon
(ii) taking water from; or
(iii) being supplied from the relevant water resources; and

(b) protecting to protect [sic] aquatic ecosystem in order to secure ecologically sustainable development and use of the relevant water resources.

The reserve thus consists of two parts. Part 1 is focused on meeting basic human needs, which can be considered a component of the domestic water demand, and part 2 is focused on protecting aquatic ecosystems. In this study we distinguish between the basic human need component of the reserve and the ecological component of the reserve, referred to as environmental flows. More details on the Tanzanian policy context for this study are presented in Section 3.1.1.

1.3 Cooperation with National and Transboundary Water Allocation Planning Activities

This report is a complete and independent report documenting the details of the reserve determination process for the Lower MRB. However, this project was developed and carried out in close cooperation with parallel activities of the LVBWB to develop a WAP for the Lower MRB. A central component of the WAP is the water balance of the basin, which is defined as the difference between the total available water in the basin and the sum of the reserve and demands of other water users. Under a parallel effort by the Sustainable Water Partnership financed by the United States Agency for International Development (USAID), IHE Delft is supporting the LVBWB to quantify the total available water and demands of other users in the Lower MRB. World Wide Fund for Nature (WWF) Tanzania is also supporting the stakeholder engagement aspects of this effort.

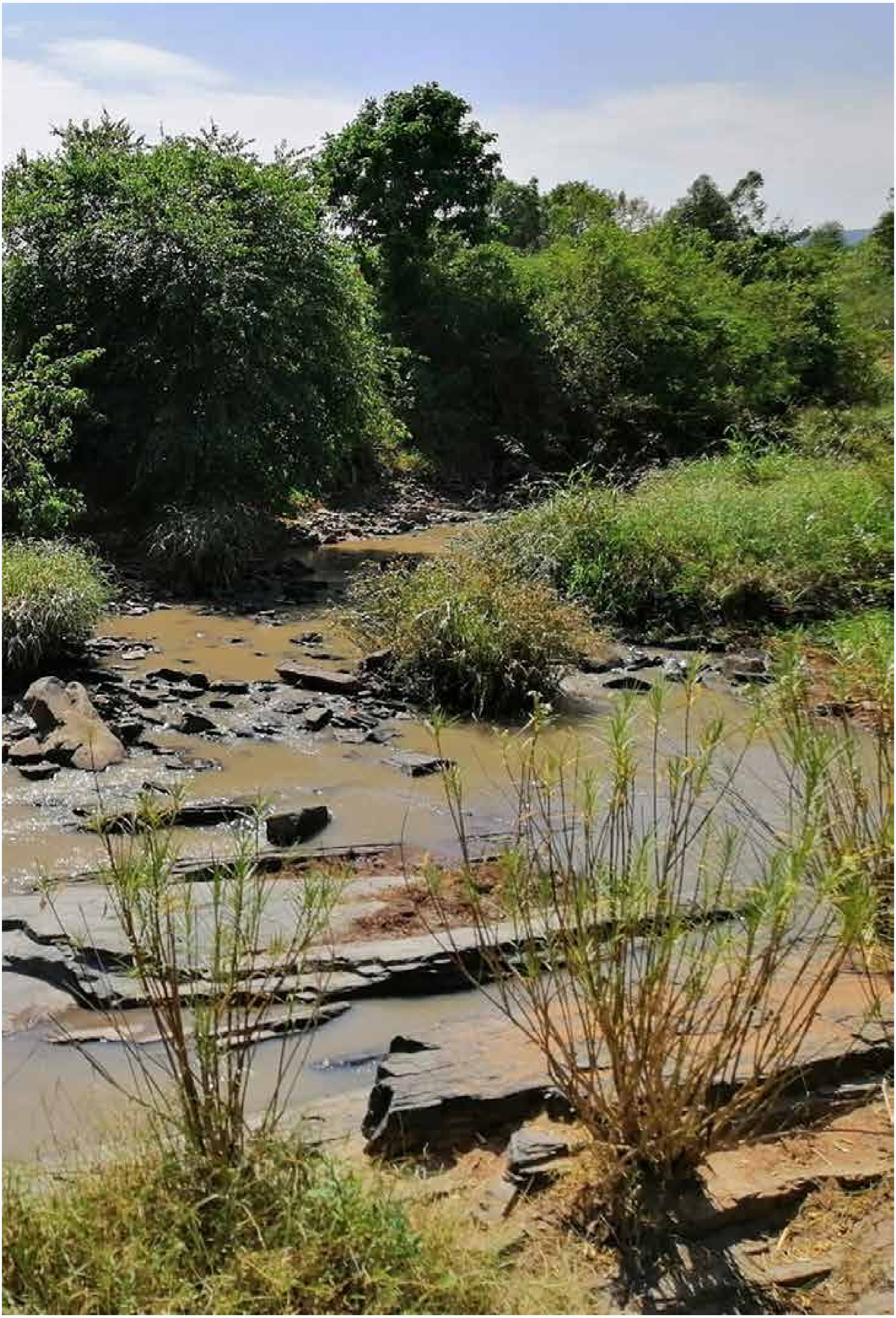
The results of this EFA will therefore be carried forward to become an input to the Tanzania Mara WAP. (More details on the WAP process, including transboundary aspects, are presented in Section 3.1.4). Upon its completion, efforts will be made to harmonize the Tanzania Mara WAP with a similar plan that has been developed and is undergoing modification for the Kenya part of the basin. The ambition is to develop a single, transboundary WAP that can be agreed by Tanzania and Kenya within the framework of the Memorandum of Understanding (MoU) for Joint Water Resources Management of the Transboundary Mara River Basin signed between Kenya and Tanzania in September 2015. As such, this document will act as a direct input into both the Tanzanian and transboundary WAP efforts.

1.4 Content of this Report

This report consists of eight chapters. Following this introduction chapter, Chapter 2 presents an overview of the features of the Lower MRB, including its administrative boundaries, hydrology, climate, land use, physiography and geomorphology, basin communities and social importance. Chapter 3 presents the methodology used in the assessment, addressing each of the seven phases of the NBI E-flows Framework. Although Tanzania has developed draft guidelines on the methods to be used for assessing environmental water requirements, these have not been approved. In consultation with the Tanzanian water authorities we have chosen to apply the framework developed by the NBI, as this also meets the highest level of methodologies proposed in the draft Tanzanian guidelines.

Chapter 4 describes key features of the seven sites chosen for detailed assessment in this study. These include two mainstem sites, three tributary sites, and two sites in Mara Wetland. Features described include surveyed social data and observed characteristics of hydrology, hydraulics, geomorphology, riparian vegetation, macroinvertebrates, fish, and water quality at each site. Chapter 5 presents the reserve assessment results, organized according to the seven phases of the Nile E-flows Framework and includes the final results of the RQO process, quantification of basic human needs requirements, and the environmental flow values and motivations for each EFA study site. Chapter 6 includes discussions on specific topics including uncertainties encountered while carrying out the

[1] http://www.dwa.gov.za/Documents/Policies/NWRS/Default.htm
[2] The 2007 Brisbane Declaration is accessible via http://riverfoundation.org.au/wp-content/uploads/2017/02/THE-BRISBANE-DECLARATION.pdf



NBI E-Flows Framework. Chapters 7 and 8 present references and annexed material, respectively.

The MRB basin is a transboundary river basin located in Kenya and Tanzania. The entire MRB covers about 13,750 km2 and begins in the Mau Forest in Kenya which feed two perennial rivers, the Amala and Nyangores, which provide for the main year-round source of water in the Mara River. It passes through villages, wildlife conservancies, and Maasai Mara National Reserve in Kenya, and then through SENAPA, more villages, gold mining operations, and the Mara Wetland in Tanzania before flowing into Lake Victoria. The Lower MRB is the part of the MRB

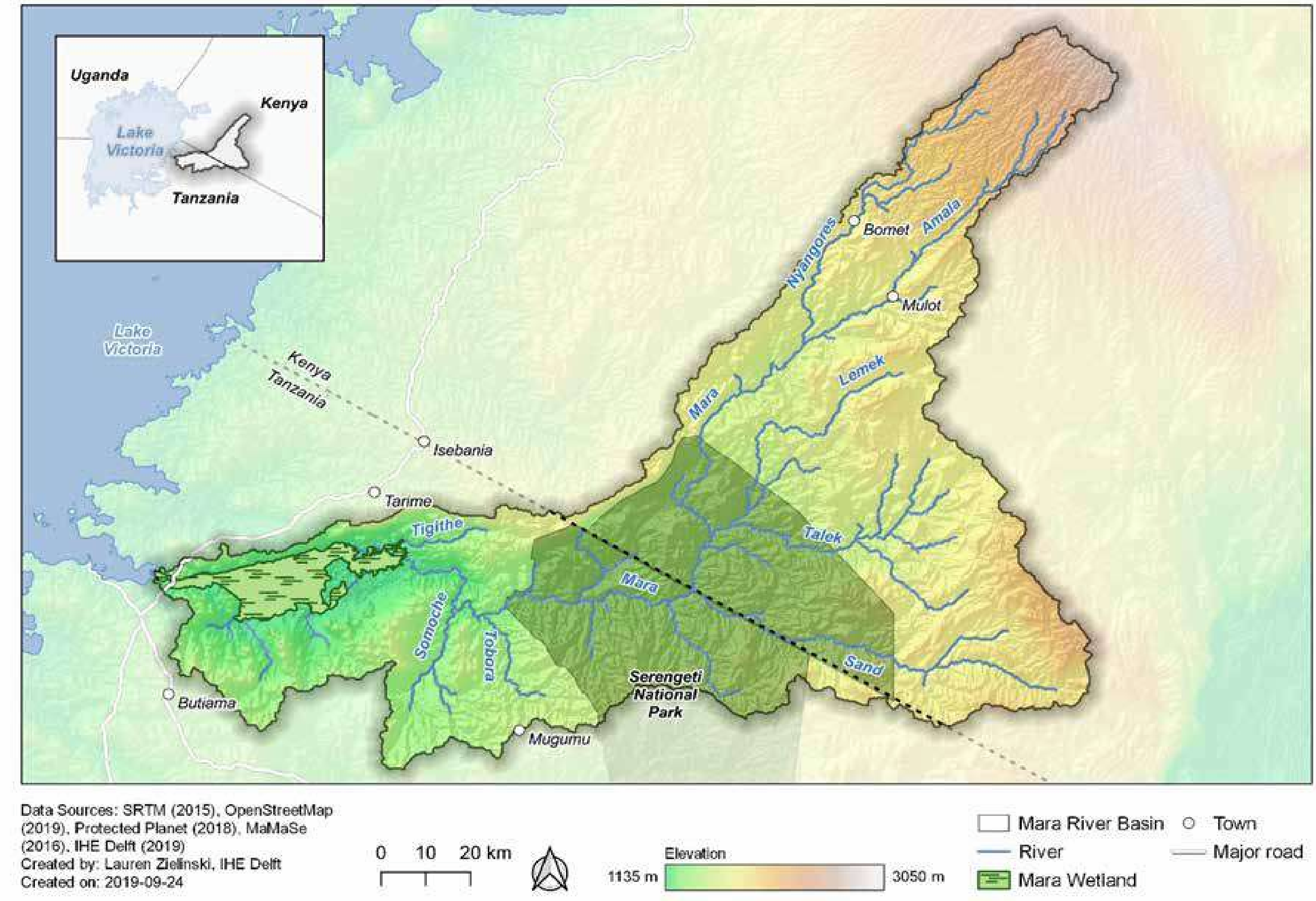


FIGURE 2 1: MAP OF THE MARA RIVER BASIN

located downstream of the Kenya-Tanzania border and covers an area of 5,047 km2.

2.1 Administration

The Lower MRB is included within the Lake Victoria Basin, which is one of nine major river basins in Tanzania and is managed by the LVBWB. The LVBWB was formed in 2000 with the role of water allocation and pollution control, issuing of water use and discharge permits, billing and collection of water use fees, and engagement of communities on water resources management. The main office for the LVBWB is located in Mwanza, with two sub-offices in Bukoba and Musoma. The Musoma sub-office is where the primary location for management decisions and actions related to the Lower MRB. Within the Lower MRB, a Mara Subcatchment Committee as

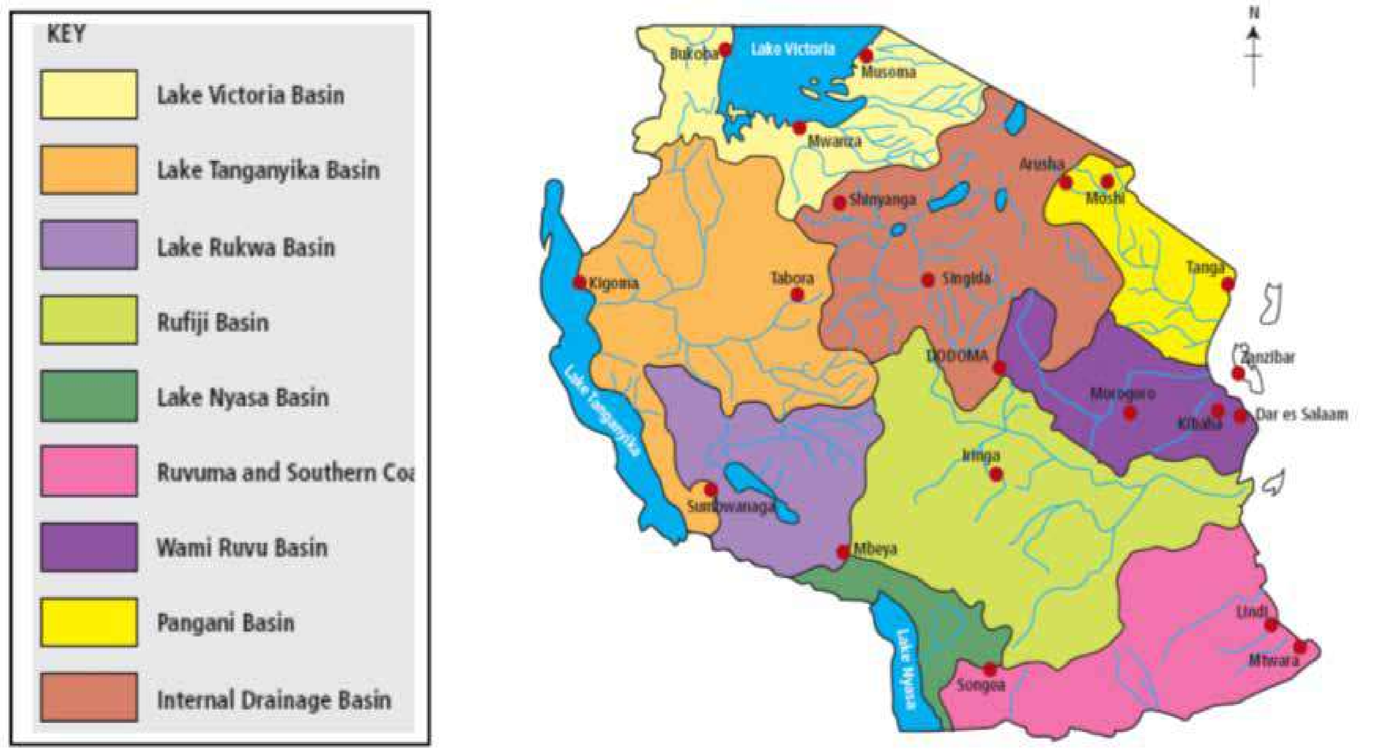


FIGURE 2 2: MAJOR RIVER BASINS LOCATED IN TANZANIA

well as six water user associations (WUAs) have been established.

The Lower MRB is also located within the Mara Region in Tanzania and includes four districts (Figure 2 3, Table 2 1). Serengeti District contains the largest portion of the Lower MRB (65 percent), followed by Butiama (16 percent), Tarime (15 percent), and Rorya Districts (4 percent). Each district has its own district governments, including district water engineers and environmental officers, while the Mara Region has its own government officials located in Musoma,

Table 2-1: Area of districts inside the Lower MRB

District	Total Area of District (km^2)	Area Inside Lower MRB (km^2)	% of District	% of Lower MRB
Butiama	2,168	812	37%	16%
Rorya	2,002	178	9%	4%
Serengeti	11,157	3,280	29%	65%
Tarime	1,534	776	51%	15%
Total	*16,861*	*5,046*	-	*100%*

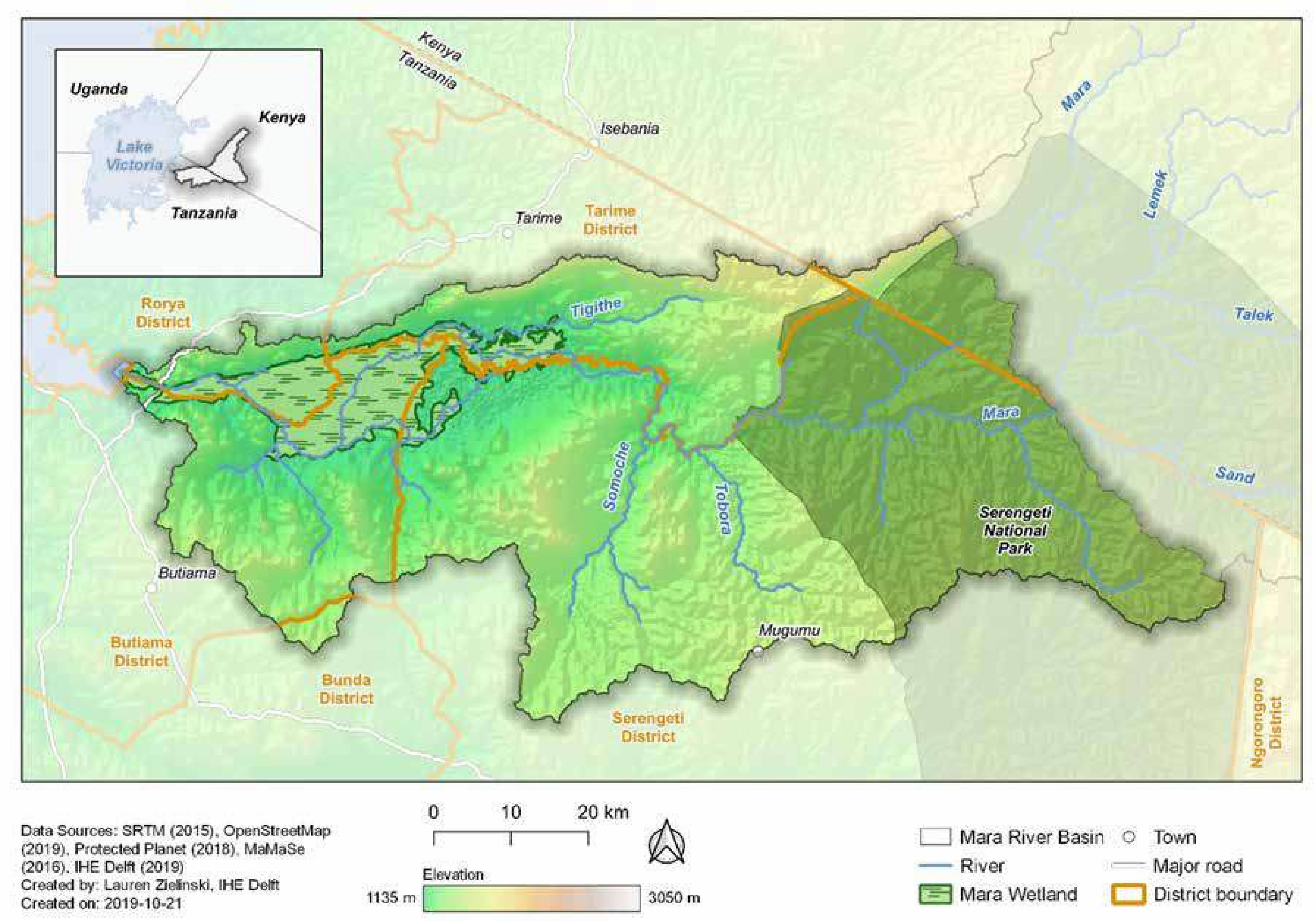


FIGURE 2 3: DISTRICTS LOCATED IN THE LOWER MRB

including the regional administrative secretary and zonal irrigation office.

2.2 Hydrology

The Mara River enters Tanzania at Purungat on the border of Maasai Mara National Reserve in Kenya and SENAPA in Tanzania. It is joined by a seasonal tributary called the Sand River only a couple of hundred metres downstream. The river flows through SENAPA and passes the gauging station Kogatende. Shortly after leaving SENAPA, it is joined by the Tobora River, a tributary flowing into the mainstem from the south. Beyond the bridge at the Tarime-Mugumu road, with the gauging station Nyasurura, the Somoche River (largest southern tributary) joins the Mara River. At this point the river course turns north, passing the gauging station at Mara Mines, and then turns east again before passing the North Mara Gold Mine.

There the Mara flows into Mara Wetland. The Tigithe River, an important northern tributary, enters the Mara Wetland east of Bisarwi. Flow in the 250 km2 Mara Wetland is dispersed in multiple channels that become obscured by vegetation and indistinct in the wetland core. Near the western margin, the river passes the gauging station at the Kirumi Bridge, and enters Lake Victoria at the Mara Bay close to Musoma.

As part of previous and on-going efforts related to environmental flows and water allocation planning, the entire Mara River Basin has been divided into hydrological units (HUs). These HUs combine drainage areas that share similar characteristics in topography and rainfall patterns. The Lower MRB contains three HUs: Serengeti, Somoche and Mara (Figure 2 4). Only a very small portion of a fourth HU; Sand, lies within Tanzania and was not included in this effort. Table 2 2 provides a summary of the characteristics of the HUs including their long-term average water balance values. Annual precipitation in the Lower MRB ranges between 926 and 1,009 mm, generating an annual runoff of 45 to 54 mm. The resulting annual actual evaporation from the three sub-catchments varies between 881 and 956 mm.

Based on the lower precipitation amounts within the Lower MRB compared to the values in the upper part of the catchment, the runoff contribution

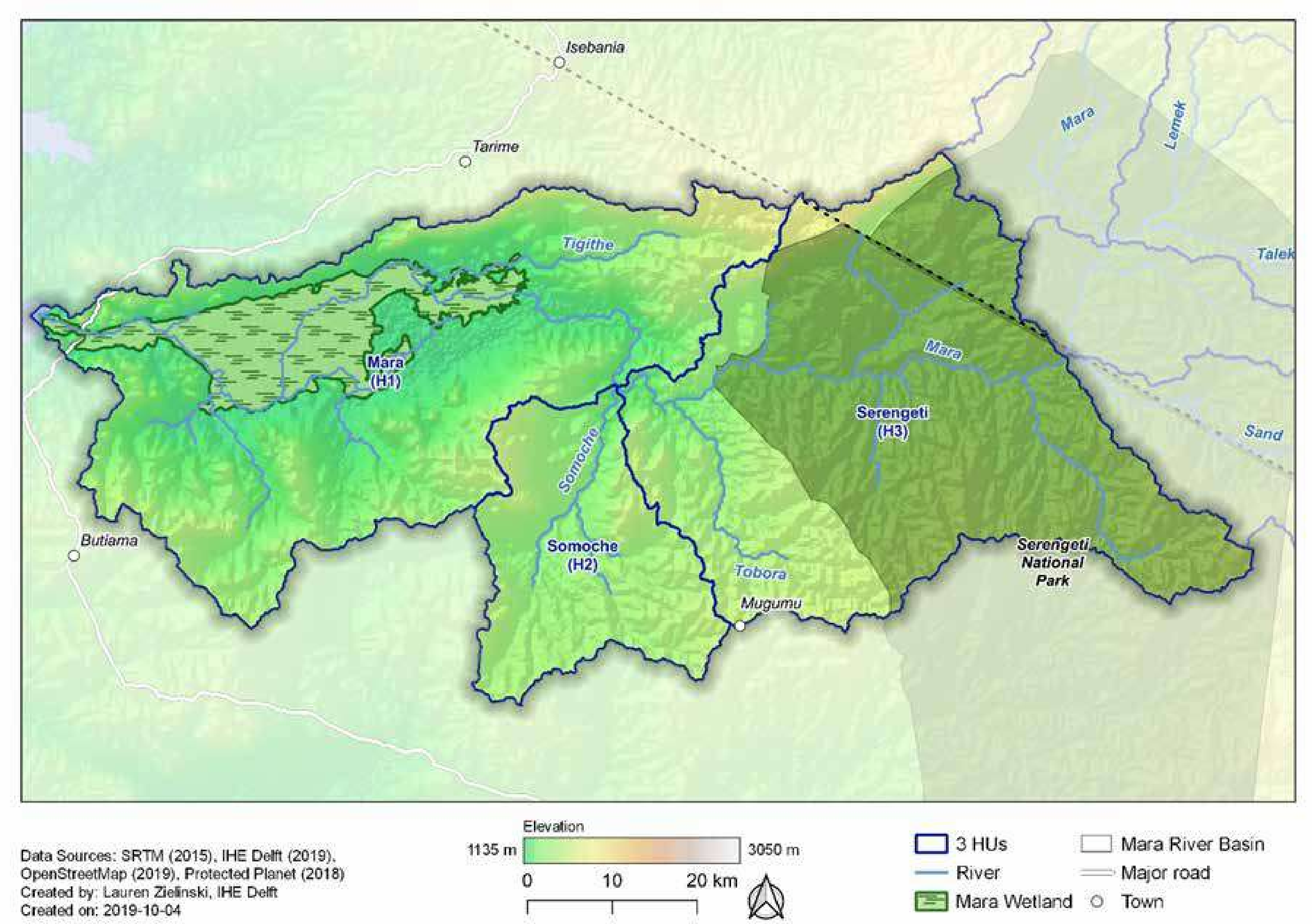


FIGURE 2 4: HUS CONTAINED IN THE LOWER MRB

Table 2-2: Hydrological units in the Lower MRB

HU Code	Name	Area [km²]	Precipitation [mm/yr]	Actual Evaporation [mm/yr]	Runoff [mm/yr]	Area Fraction [%]	Runoff Fraction [%]
1	Mara	2275	926	881	45	17	10
2	Somoche	690	957	909	48	5	3
3	Serengeti	2225	1009	956	54	16	11
	Lower MRB	**5190**	**966**	**917**	**49**	**38**	**24**

accumulates to only 24 percent of the total runoff, despite the relatively large areal extent of the Lower MRB, which is 38 percent of the total area.

2.3 Climate

The annual average precipitation of stations in and around the Lower MRB varies from 680 mm at Musoma to 1,336 mm at Kichwa Tembo. The northern and north-eastern parts of the catchment receive the highest precipitation, whereas the southern and western parts receive considerably lower precipitation (Figure 2 5 and Figure 2 6). Monthly precipitation data clearly indicate a bimodal regime

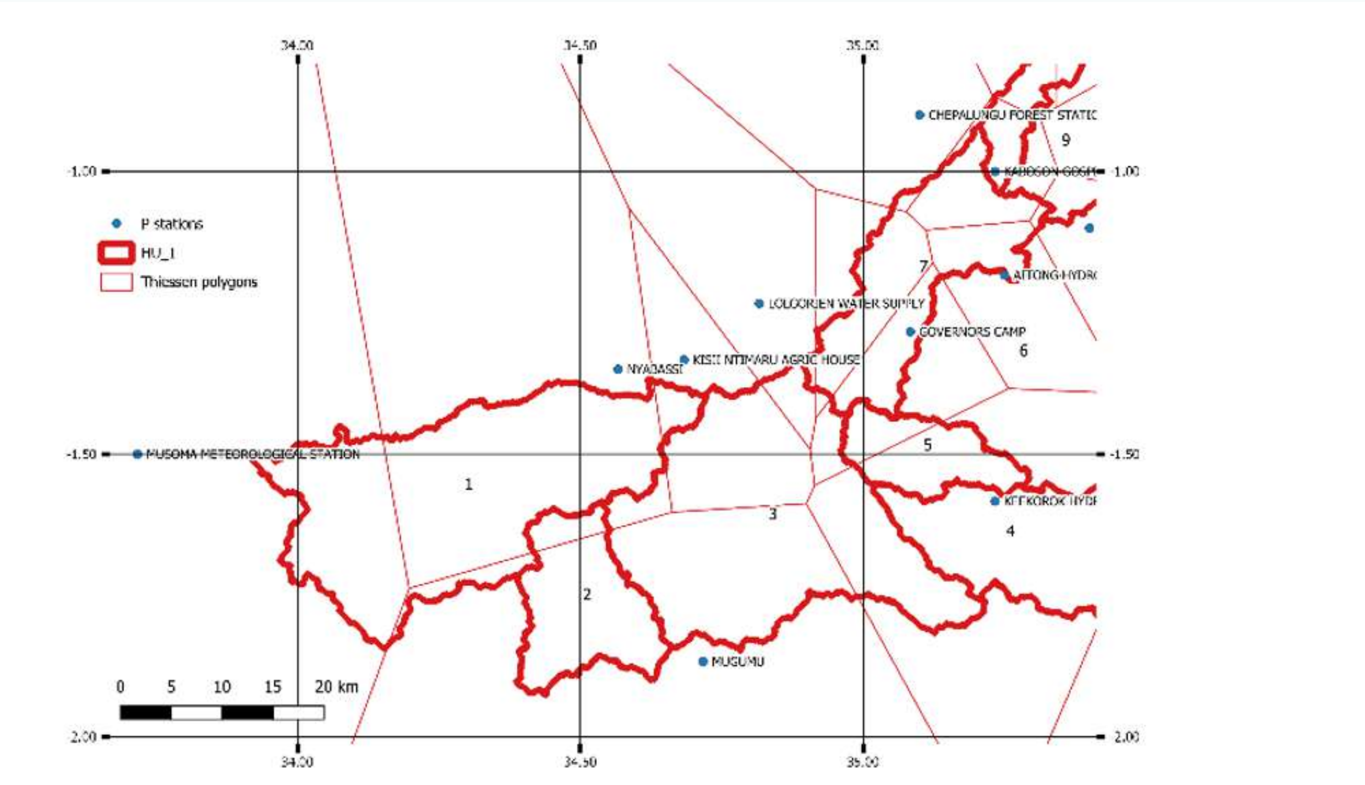


FIGURE 2 5: SPATIAL DISTRIBUTION OF PRECIPITATION STATIONS IN THE LOWER MRB AND THIESSEN POLYGON AREAS

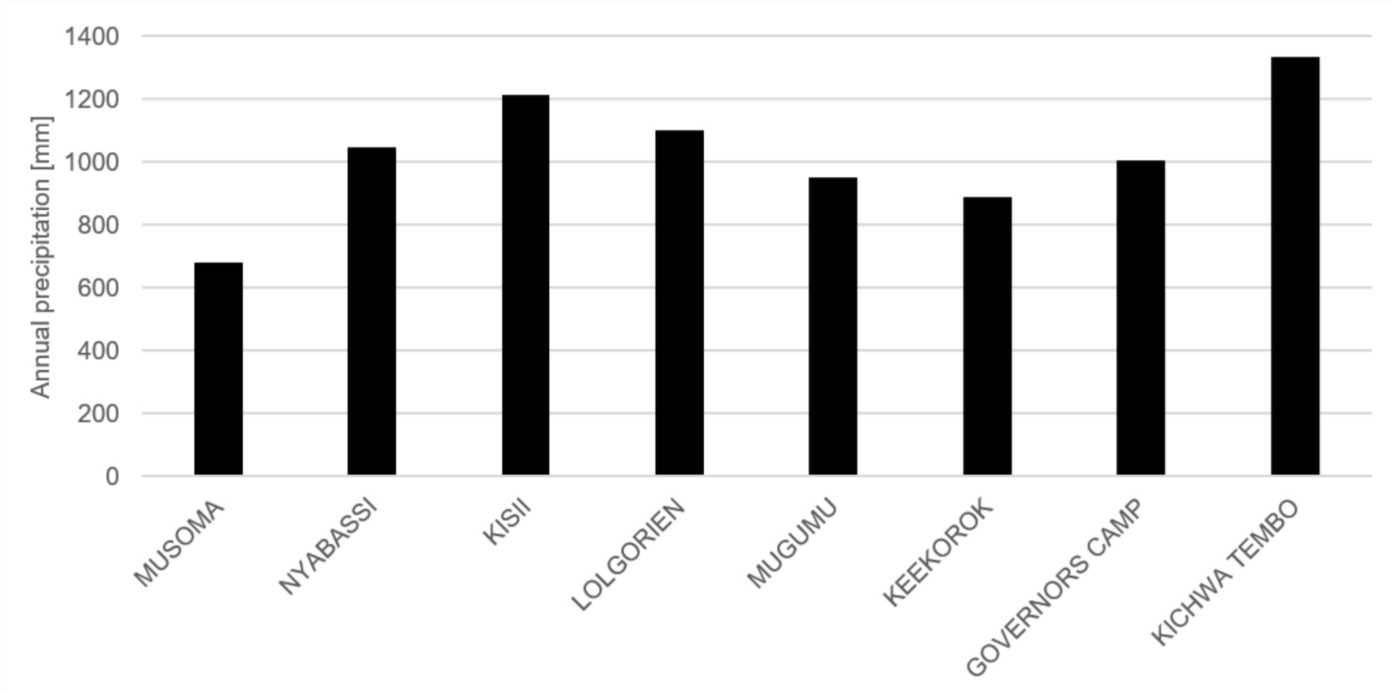


FIGURE 2 6: AVERAGE ANNUAL PRECIPITATION AT STATIONS RELEVANT TO THE LOWER MRB

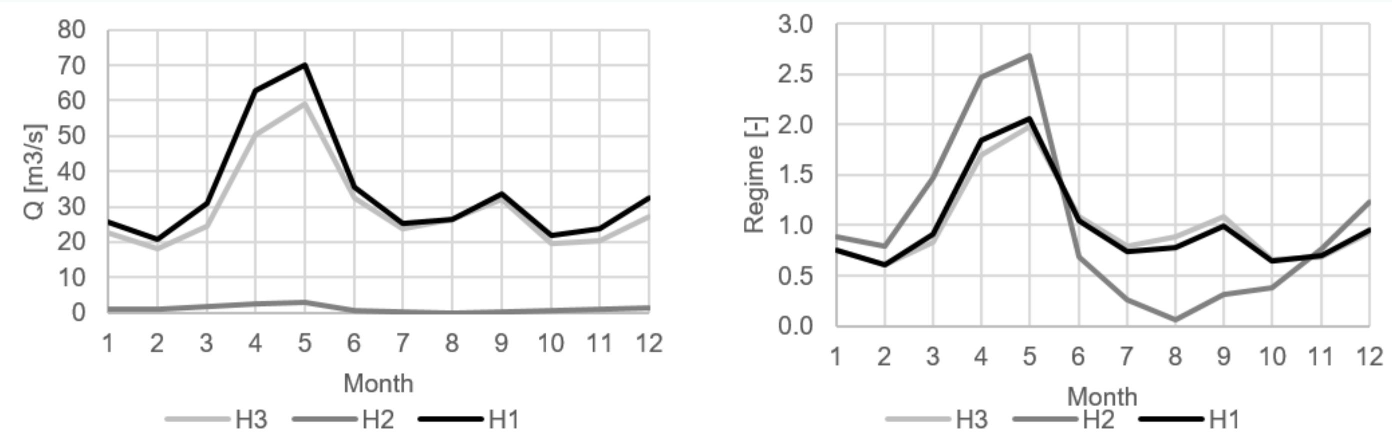


FIGURE 2 7: AVERAGE MONTHLY DISCHARGE (LEFT) AND RUNOFF REGIMES (RIGHT) AT HU1 OUTLETS

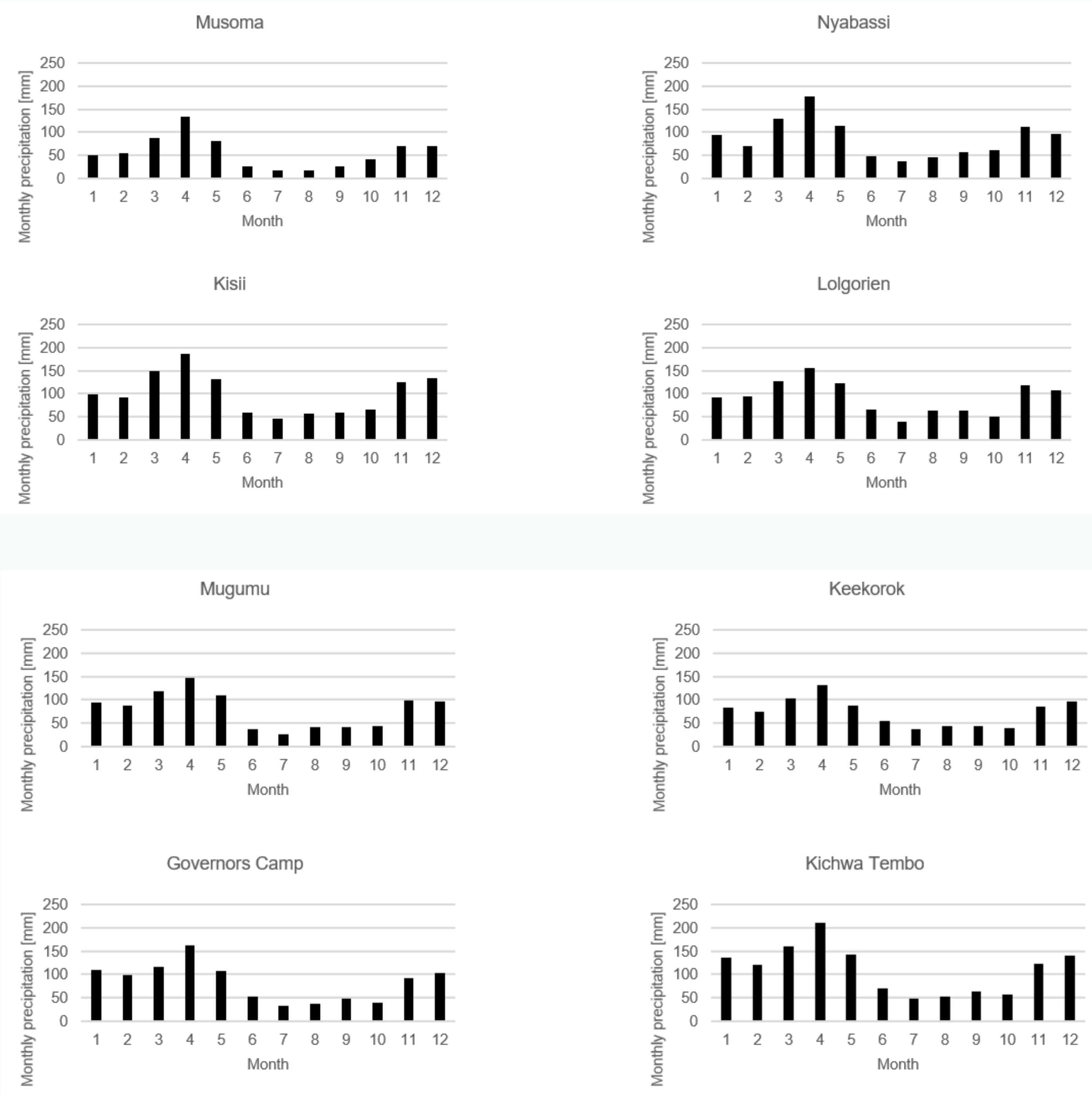


FIGURE 2 8: AVERAGE MONTHLY PRECIPITATION AT STATIONS RELEVANT FOR THE LOWER MRB

with two rainfall seasons. The long rains occur from March to May and the shorts rains from November to December while dry seasons are experienced from June to October and January to February.

The intra-annual variability of flows in the Lower MRB reflects the rainfall pattern in the catchment as well as the dependency of flows from the upstream catchment in the case of the mainstem Mara River. The highest monthly flows occur in April and May; lowest flows are in August for the Somoche HU2, and in October for the Mara and Serengeti HUs (Figure 2 7).

Somoche HU2 is only influenced by local precipitation inputs, whereas Serengeti HU3 and Mara HU2, on the mainstem of the Mara, also receive flows from the upper parts of the catchment. This difference can be seen in the right graph of Figure 2 8. This graph shows the runoff regimes using the Pardé coefficients. Pardé coefficients are calculated by dividing the mean

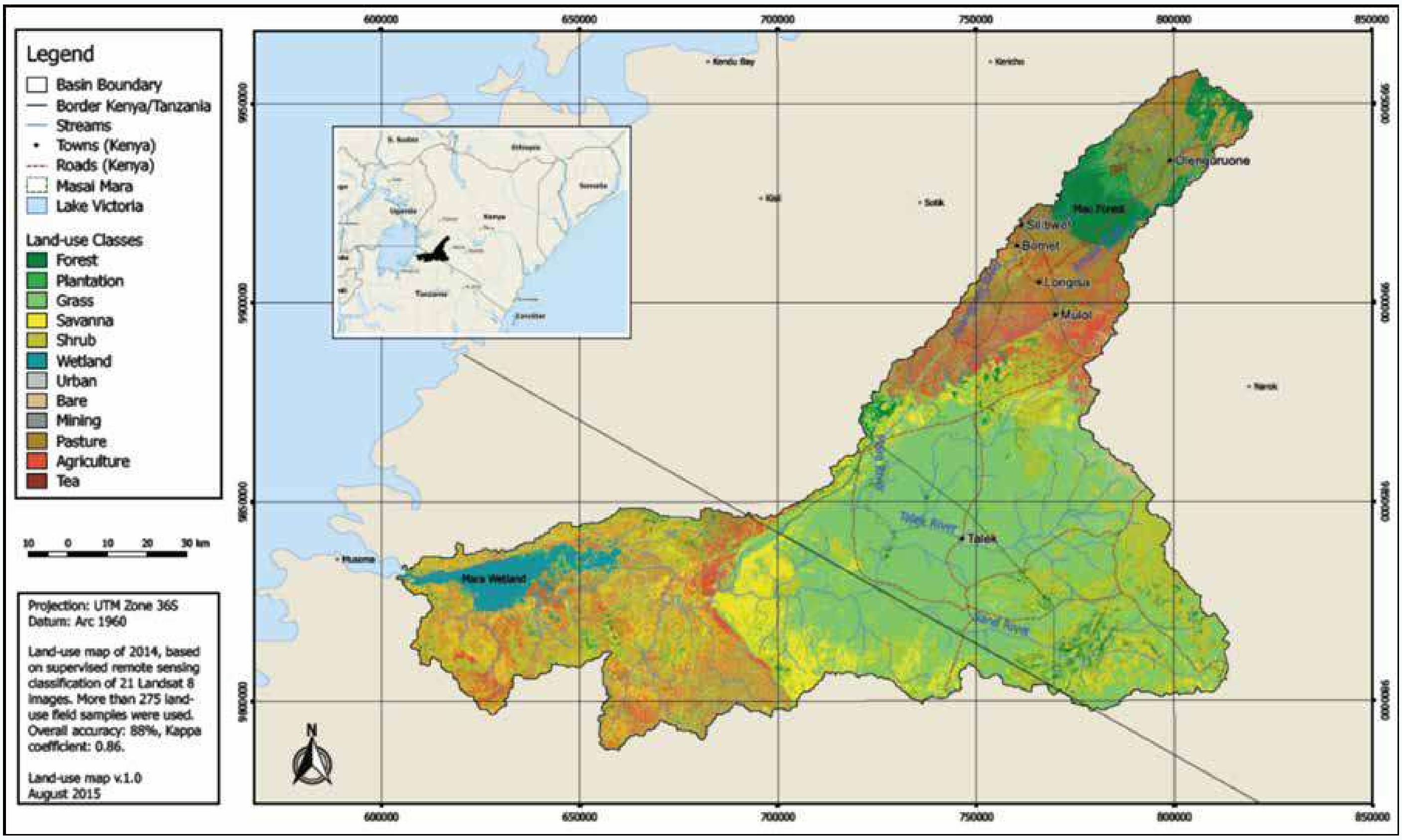


FIGURE 2 9: LAND USE MAP OF THE MARA RIVER BASIN (MAMASE, 2019)

monthly value by the annual average.

2.4 Land Use

Land use in the basin varies significantly from the headwaters in Kenya to the lower basin in Tanzania (Figure 2 9). The most upstream part of the basin, where the river originates, is mostly made up of forest plantations. Further down, a buffer zone comprising of tea estates separates the forest from the agricultural lands and was meant to prevent encroachment by the locals into the forested areas. Small scale, rainfed, subsistence farming is mostly carried out in areas near the tea plantations. A variety of crops are grown including maize, potatoes, beans, vegetables etc. Livestock farming is also practiced in these areas although at a smaller scale. Some small to medium sized urban centers are found within the basin, namely Olenguruone, Bomet, Mulot, Longisa, and Talek in Kenya and Mugumu in Tanzania.

The middle part of the basin is mostly dominated by savannah and grassland vegetation. Some large-scale irrigation farms are located around this area and crops grown are mostly cereals, French beans and avocados for export. This savanna area stretches into the protected areas of the well-known Maasai Mara National Reserve and SENAPA. These protected areas are home to a variety of wild animals and attract tourists from all over the world.

A mixture of small and large-scale gold mines, agricultural areas and livestock dominate the areas west of the SENAPA. Before the Mara River flows into the lake, it enters the floodplains of the Mara Wetland (covering 17 percent of the Mara HU1, Figure 2 10) which plays a significant role in terms of trapping sediments flowing from the upstream areas, purifying water, providing habitat for aquatic organisms and birds, and recharging ground water among other services. The wetland provides food (fish) for local populations, papyrus for making mats and other artefacts and water for irrigating small

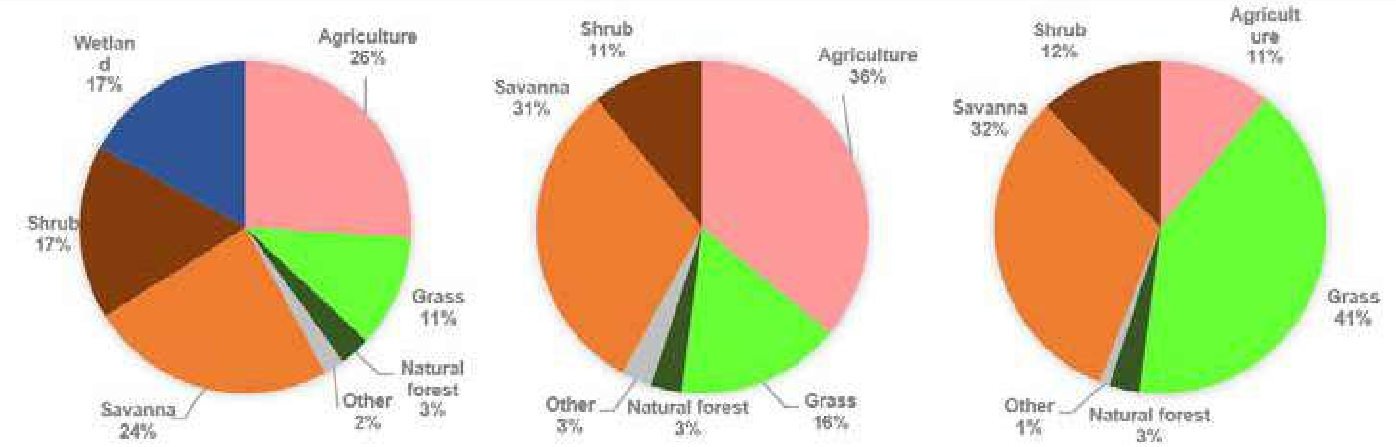


FIGURE 2 10: LAND USE CLASSES WITHIN THE LOWER MRB CATCHMENTS HU1 (LEFT), HU2 (CENTRE), AND HU3 (RIGHT)

farms nearby.

2.5 Physiography and Geomorphology

The Lower MRB is situated along a half-graben that has been influenced by tectonic activity related to the Eastern Rift Valley. This might have rejuvenated, straightened and incised the Mara River since the formation of Eastern Rift Valley. This rejuvenation is visible along the longitudinal profile where it forms a convex (see 220-280 km along the profile in Figure

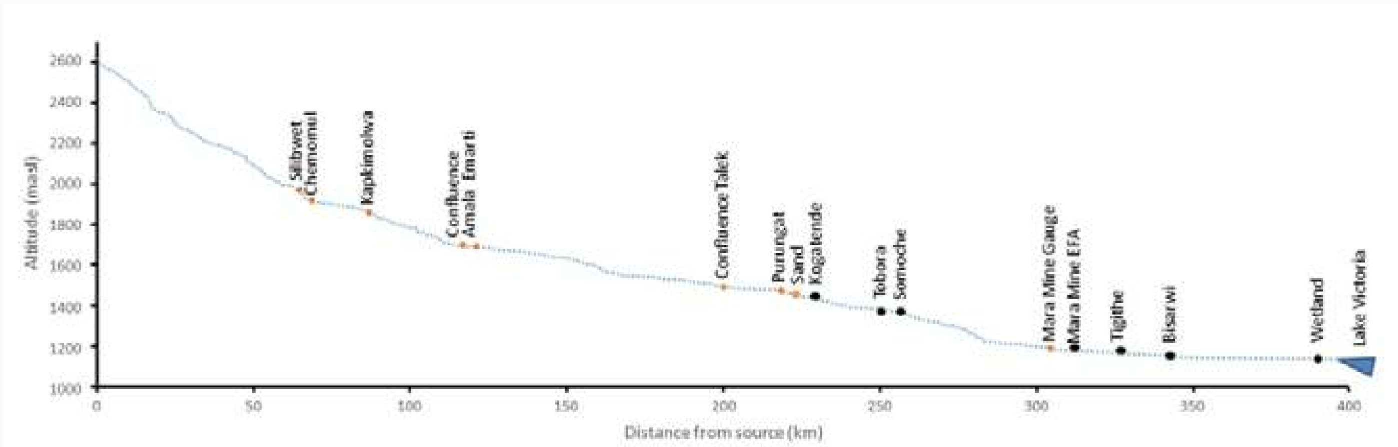


FIGURE 2 11: A LONGITUDINAL PROFILE OF THE MARA RIVER SHOWING THE EFA SITES OF 2016 AS ORANGE DOTS AND THE CURRENT BIOPHYSICAL STUDY SITES AS BLACK DOTS

2 11). The base-level control at the lower-end of the system is provided by Lake Victoria.

This base-level control created a low gradient, low energy environment that promoted sediment deposition and dense vegetation growth. This led to the formation of the Mara floodplain and the Mara Wetland (Figure 2 12).

The elevation of the Lower Mara River varies from 1,400 m at the Kenya-Tanzania border to 1,133 m at the mouth where the river flows into the Lake Victoria

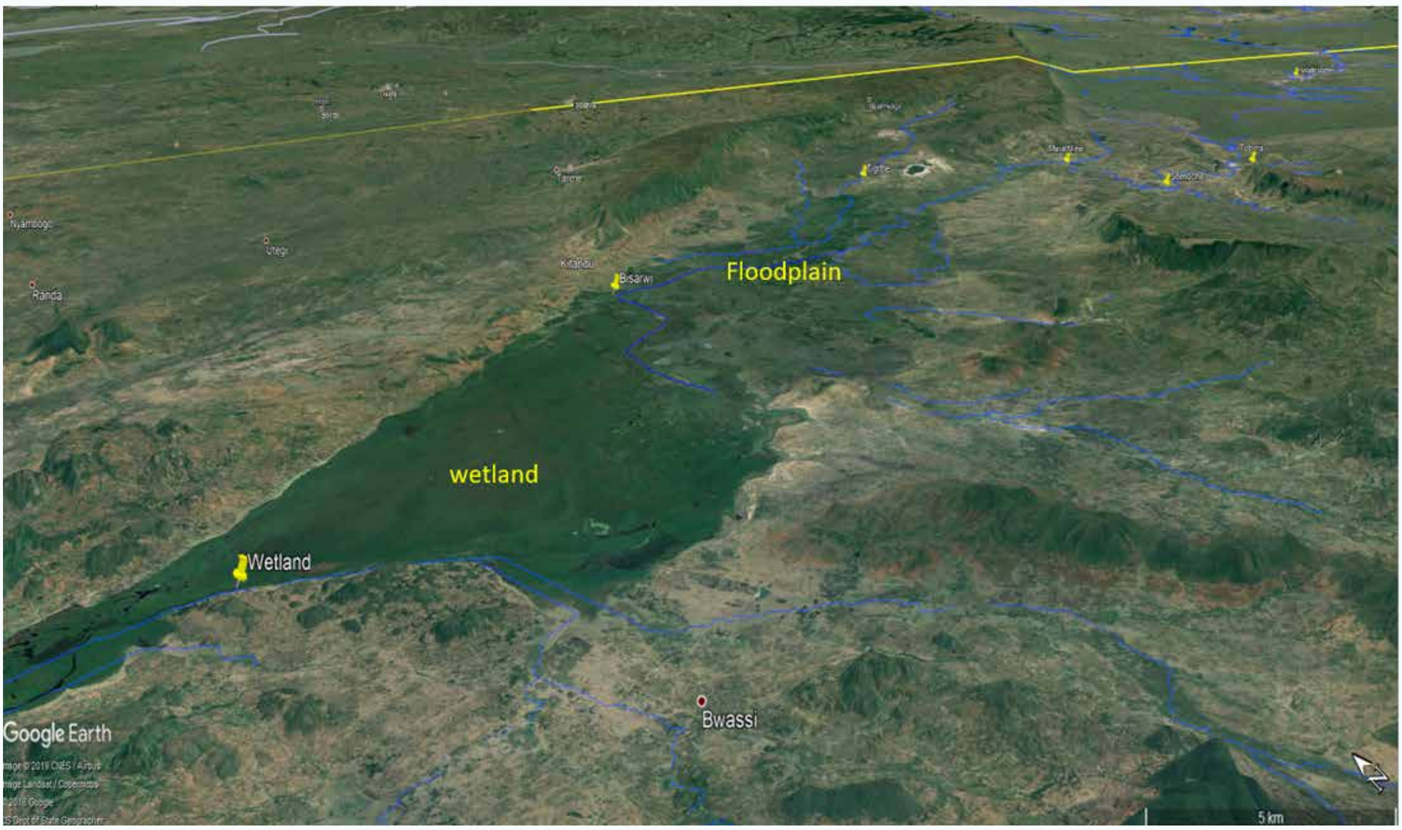


FIGURE 2 12: LOCATION OF THE SAMPLING SITES (SHOWN BY THE PINS) AND THE MAIN WETLAND AND FLOODPLAIN AREA (IN YELLOW TEXT)

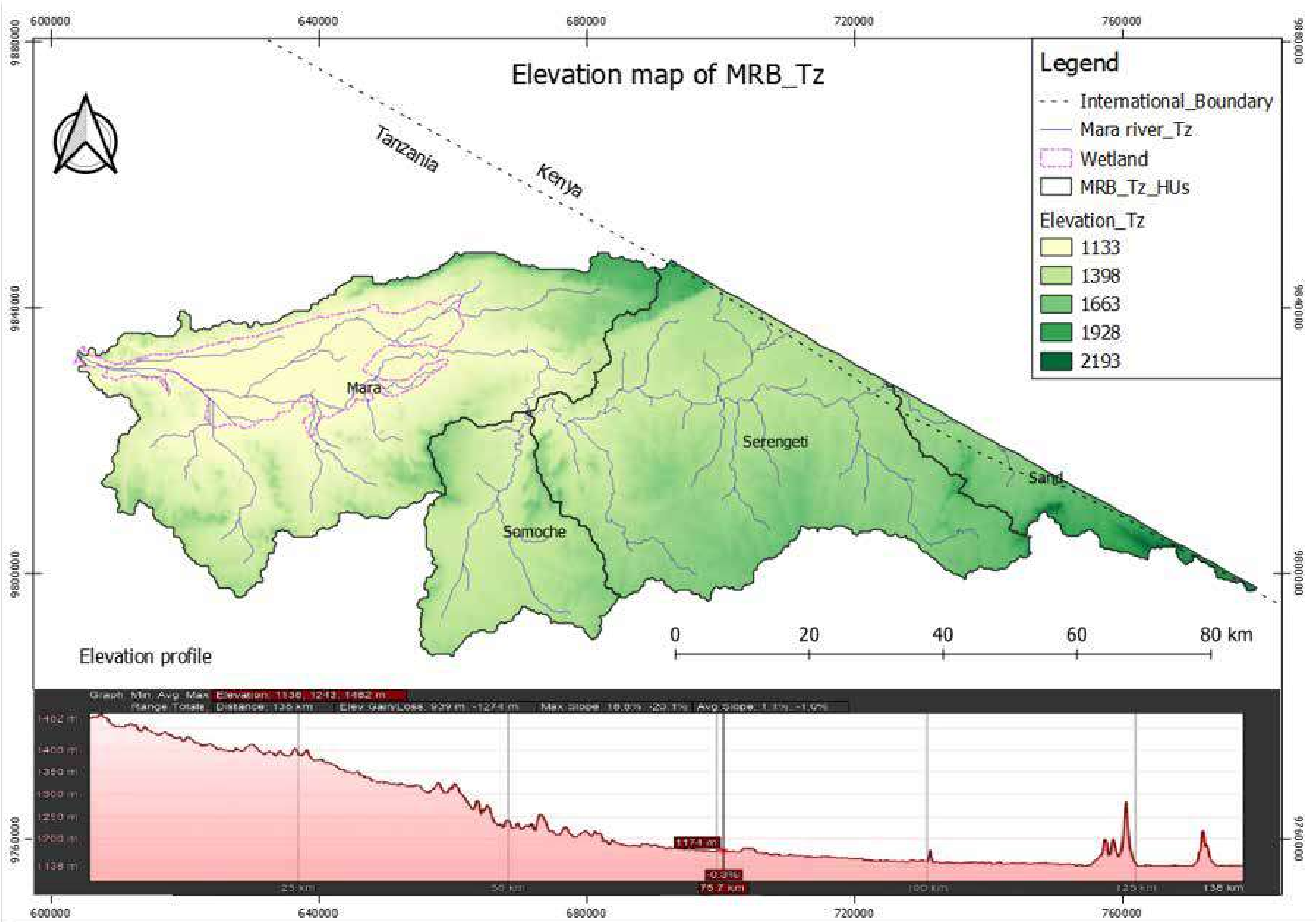


FIGURE 2 13: ELEVATION MAP AND PROFILE OF LOWER MRB

(Figure 2 13). The average elevations are 1,517 m in Serengeti HU3, 1,419 m in Somoche HU2, and 1,277 m in Mara HU1.

2.6 Communities and Social Importance

The dominant tribes in the Lower MRB are the Kurias, mainly found in the upper part of the basin, followed by the Luos who mostly reside along the wetland in the lower part of the basin. Migration from outside is uncommon although some locals move from rural areas to other rural areas. Economic activities carried out in this area include mining, sand harvesting, livestock keeping, agriculture and fishing, and this varies from village to village. The estimated population for the Lower Mara was 335,000 in 2012. The population growth for each district varies but is between 2 and 3.5 percent (Table 2 3). Based on the 2012 census data and growth rates, the 2018 estimated population is 396,000. The population estimates for the districts and HUs are provided in Table 2 4 and Table 2 5, respectively. It should be noted that the population estimate is for the proportion of the districts located within the

Table 2-3: District population growth rates

District	Growth Rate
Butiama	2.2%
Rorya	2.0%
Serengeti	3.5%
Tarime	2.2%
Average	2.5%

Source: (NBS, 2012)

Table 2-4: Population data by district

District	2012	2018
Serengeti	165,040	202,876
Tarime	97,575	111,184
Butiama	62,855	71,622
Rorya	9,315	10,490
Total	334,785	396,173

Source: (NBS, 2012)

Table 2-5: Population data by HU

HU	2012	2018
Serengeti	81,773	98,354
Somoche	55,454	68,167
Mara	197,558	229,652
Total	334,785	396,173

Source: (NBS, 2012)

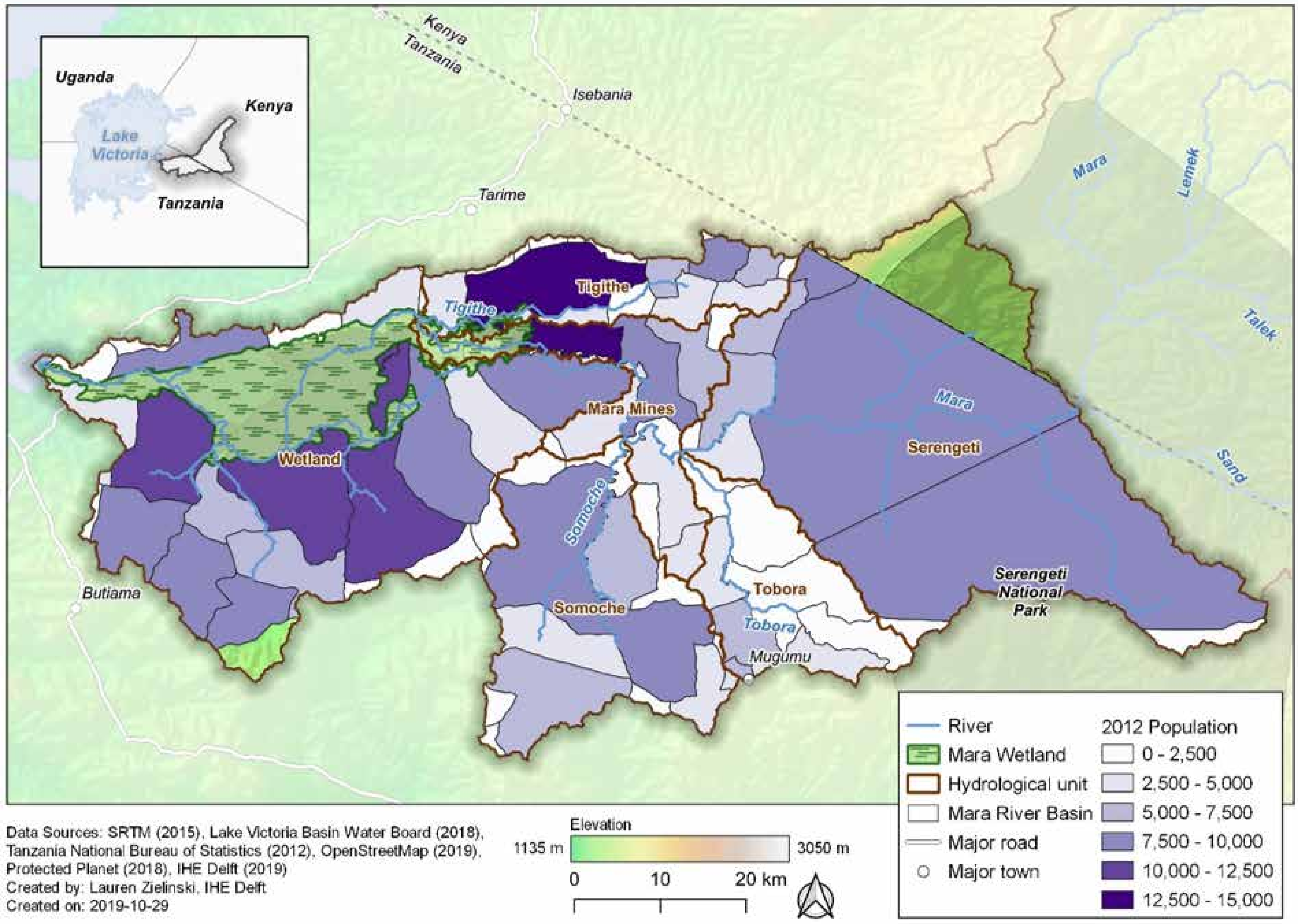


FIGURE 2 14: ESTIMATED POPULATION AT THE WARD LEVEL FOR 2012 BY RESOURCE UNIT

Lower Mara and not the entire district. Figure 2 14 shows the estimated 2012 population by ward and separated into the different RUs.

The wetland, including areas along the river banks is an important area for farming activities, especially in the lower Tigithe. Flooding is the main challenge to farming in these areas, critically affecting the lower part of the basin. Unlike other areas, limited crop farming is practiced in some parts of the upper Tigithe. This is as a result of widespread planting of exotic trees (eucalyptus) which has largely substituted other economic activities.

With the exception of the Upper Tigithe, fish is commonly harvested in the rivers and natural ponds. However, the importance of fish to the communities' livelihood is relatively minimal (less than one percent). Fish is generally of low importance compared to other resources, except in the lower parts of Mara Wetland where it is of higher importance. This is because there is relatively more fishing in the lower part of the basin. Livestock keeping constitutes one of the most important economic activities in the basin. Wetland pastures are key resources of importance for livestock. Roofing grass and wood fuel are harvested by most communities. Other resources such as natural vegetables, building sand, natural fruits, building stones, weaving grass and medicinal plants

are also collected. Most of these resources can also be obtained in areas away from wetlands and rivers. Building poles are another important resource.

The determination of the reserve and the related RQOs was completed using the NBI Environmental Flows Framework (NBI, 2016a, 2016b). This framework was developed by NBI to ensure a standard process is followed for the increasing number of EFAs being conducted in the Nile Basin. There are seven main steps in this framework, which are summarized in Figure 3 1 and Table 3 1 and described in detail in this chapter. Discussions on specific topics, including

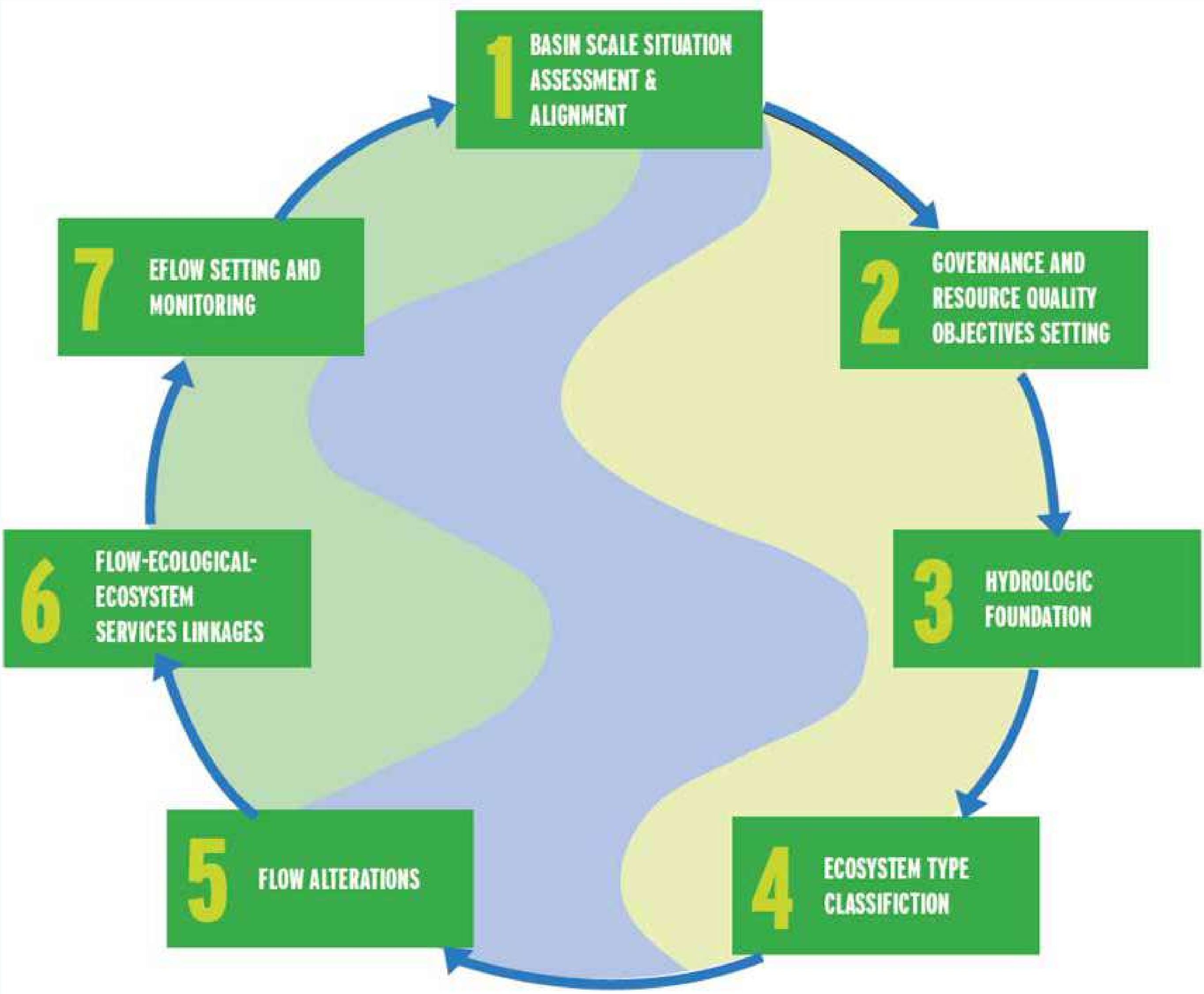


FIGURE 3 1: SUMMARY OF THE STEPS INVOLVED IN THE NBI E-FLOWS FRAMEWORK (NBI, 2016B)

Phase	NBI Recommended Tasks (NBI, 2016a)	Tasks Completed under the Lower Mara EFA
Phase 1: Basin Scale Situation Assessment and Alignment Process *Location in document: Section 3.1*	– Review existing local and trans-boundary governance structures relevant to E-flows management activities, – Review available information (incl. knowledge) relevant to E-flow assessments /management, – Align E-flow activities to existing local and trans-boundary activities, – Describe available resources, evidence for E-flows assessment and monitoring and management capacity, and – Describe uncertainties and provide recommendations.	– Completed policy review related to the reserve in TZ, – Compiled available information related to environmental flows, including field data, scientific literature, project reports, and other EFAs completed in the MRB and TZ, – Integration with on-going water resources related work in the Mara River Basin, both on the TZ side and basin-wide, and – Strengthening of partnerships with relevant gov't organizations, projects, and non-government organizations, with a focus on capacity building within the LVBWB and MoW
Phase 2: Resource Quality Objectives Setting *Location in document: Sections 3.2 and 0*	– Establish suitable stakeholder group for RQO determination, – Determine Resource Quality Objectives for E-flows assessment: o Rapid preliminary Vision and RQO setting, o Vision and RQO setting, and o Describe spatial area (risk region) demarcation process to choose suitable spatial areas for E-flows assessment. – Consider adaptive management processes/requirements, and – Describe uncertainties and provide recommendations.	– Worked with local partners to determine group of stakeholders for RQO workshop, – Determined resource units (RUs) for the RQO process, and – Held RQO stakeholder workshop in Tarime, Tanzania on Nov. 7 & 8, 2018, with the following outputs: o Assessments of pressures, important activities, and conditions in each RU, o Preferred management class for each RU, o Draft RQO statements for each RU for quantity, quality, habitat and biota, and o Workshop report (Annex A)

TABLE 3 1: LIST OF TASKS RECOMMENDED AND UNDERTAKEN FOR EACH STEP OF THE NBI E-FLOWS FRAMEWORK

Phase	NBI Recommended Tasks (NBI, 2016a)	Tasks Completed under the Lower Mara EFA
Phase 3: Hydrological Foundation *Location in document: Section 3.3*	– Generate reference hydrology/hydrographs for EFA, – Generate developed hydrographs for EFA, – Descriptive hydrology using appropriate statistics and update database, and – Describe uncertainties and provide recommendations.	– Regionalization analyses completed for the Lower MRB to develop the following for each EFA study site: o Monthly and average annual discharge, minimum and maximum discharge values o Annual and monthly flow duration curves o Maximum daily flow frequency analysis – *Full analysis, including uncertainties, can be found in the hydrology starter document (Annex C)*
Phase 4: Ecosystem Type Classification *Location in document: Section 3.4*	– Classify ecosystems types of E-flow assessments based on: o Hydrological Characteristics, o Geomorphic Characteristics, and o Biological Characteristics. – Consider the effect of existing ecosystem wellbeing on response of socio-ecological components to different types of ecosystems, – Provide descriptive maps and update database, and – Describe uncertainties and provide recommendations.	– Review of existing ecosystem and river classification systems or maps used in Tanzania, – Ecological, biological, and geomorphology assessment to determine classification of EFA study sites – Results found three distinct types: o Mainstem river sites o Tributary sites o Wetland sites
Phase 5: Flow Alterations *Location in document: Section 3.5*	– Evaluate flow alterations for E-flow assessment, – Develop hydrological scenarios to represent flow options, – Provide descriptive hydrological statistics and update database, and – Describe uncertainties and provide recommendations.	– No major flow alterations in the Lower MRB o No large infrastructure or water users with high water demand o Potential minimal effects from domestic and agricultural use at low flows, but unquantified – Degradation in ecological condition likely from non-flow related pressures

TABLE 3 1: LIST OF TASKS RECOMMENDED AND UNDERTAKEN FOR EACH STEP OF THE NBI E-FLOWS FRAMEWORK

Phase	NBI Recommended Tasks (NBI, 2016a)	Tasks Completed under the Lower Mara EFA
Phase 6: Flow-Ecological-Ecosystem Services Linkages *Location in document: Sections 3.6 and 4*	– Describe flows-ecosystems-ecosystem services relationships for assessment, – Consider additional non-flow drivers of change, – Establish Flows-ecosystems-ecosystem services hypotheses, and – Describe uncertainties and recommendations.	– Implemented a modified Building Block Methodology, with a starter document developed for each ecological and social component (hydrology, hydraulics, water quality, geomorphology, fish, macroinvertebrates, riparian vegetation, and social use) which details the field work conducted and relationships to flow. Each starter document contains: o Site description and metrics, o Indicators and management objectives, and o Required conditions for different hydrological conditions (built off of flow-ecology-ecosystem linkages) o Confidence levels and data gaps – *Starter documents can be found in Annex B through Annex I*
Phase 7: E-Flows (Reserve) Setting and Monitoring *Location in document: Sections 5 and 6*	– Set E-flow requirements through application of selected method (note: highlight the importance of discussing the E-flow requirements, particularly on a site or micro-basin scale, in the context of upstream/downstream users etc.), o Describe uncertainties associated with E-flow requirements; o Describe uncertainty associated with the cumulative effects of non-flow drivers of change, and o Discuss uncertainty associated with the EFM used and resource and evidence availability. – Provide recommendations to reduce uncertainty for E-flow requirements and establish adaptive management process, and – Develop a monitoring plan and recommendations for adaptive management.	– Developed reserve values by calculating needs for: o Basic human needs o Environmental flows by EFA study site – Recommended monitoring activities for compliance and effectiveness monitoring – Suggested methodology for including monitoring data into short- and long-term adaptive management of the reserve – Discussions on uncertainties and special considerations

TABLE 3 1: LIST OF TASKS RECOMMENDED AND UNDERTAKEN FOR EACH STEP OF THE NBI E-FLOWS FRAMEWORK

uncertainties encountered during the process, have been included in Section 6.

3.1 Basin Scale Situation Assessment and Alignment Process

Before any physical studies are undertaken for determining environmental flows, it is important to have a good understanding of the current legislative and management mandates. To do this, a review of the policies in Tanzania was conducted to better understand the national and regional requirements and how environmental flows could be properly implemented in Tanzania.

A review of existing information related to environmental flows and water resources management was also completed so previously collected information could be utilized and project activities could be aligned with on-going projects. Finally, important local and regional partners were identified and included in all relevant project activities to promote cooperation and capacity building.

3.1.1 Tanzania Policy Review

There are a variety of pieces of legislation and guidance documents related to the environmental flows and the reserve in Tanzania. The following policy review divided these documents into three groups: regulations related to water in Tanzania, regulations related to the environment in Tanzania, and international agreements. For each section, the documents have been arranged in chronological order from oldest to newest. For national regulations, they have also been organized in hierarchical structure from most broad to most specific (i.e., policy, strategy, programme, act, and manual/guideline). This policy review outlines the water governance structure with

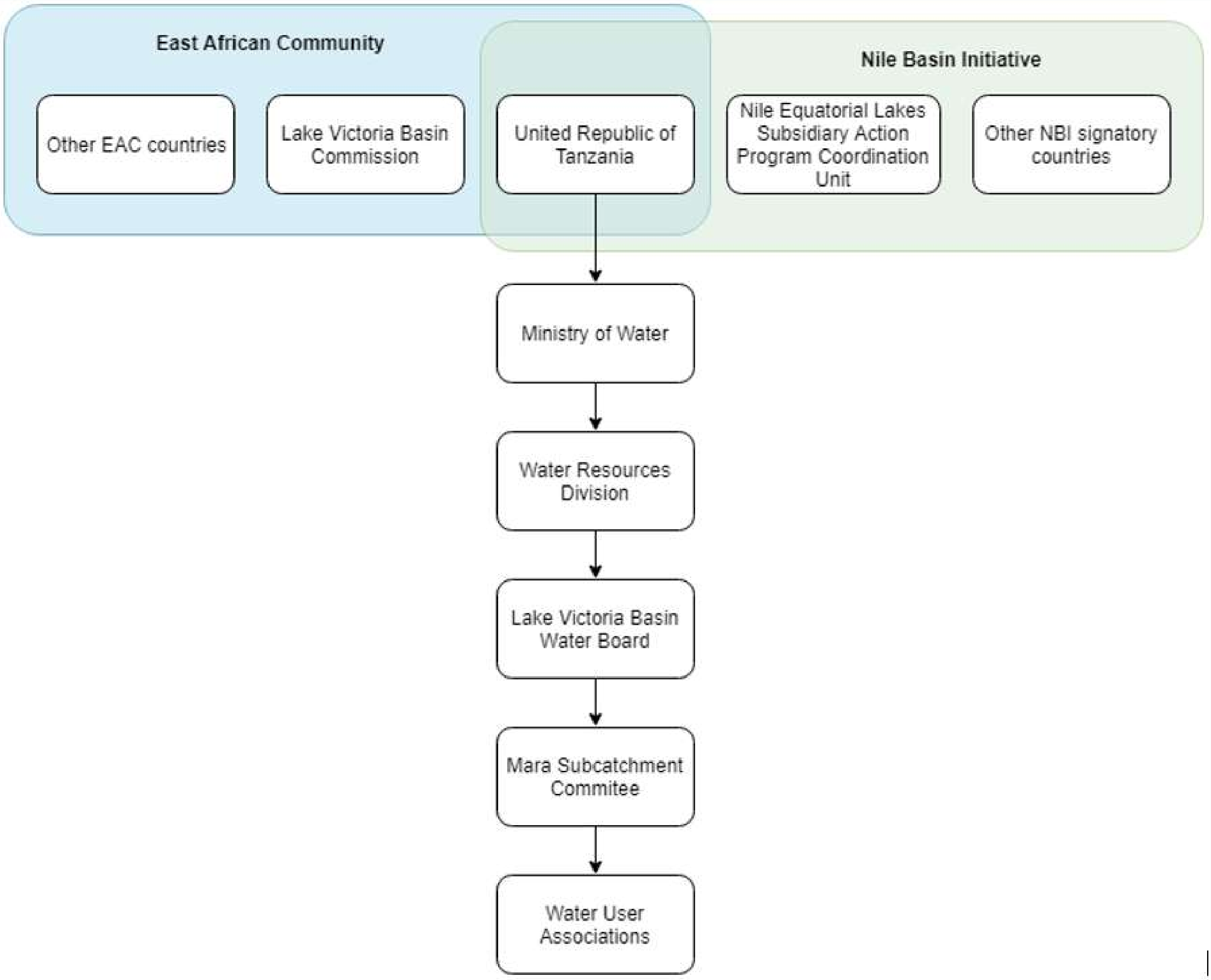


FIGURE 3 2: WATER GOVERNANCE STRUCTURE FOR THE RESERVE IN TANZANIA

Tanzania related to the reserve in the Lower MRB as well as important international agreements Tanzania is a signatory to in the region (Figure 3 2).

3.1.1.1 Regulations Related to Water

National Water Policy, 2002

The National Water Policy (URT, 2002) sets out long-term objectives for water resources management across the country, with a specific focus on rural water supply, urban water supply and sanitation, and how the development of water resources intersects with the economic development of water-dependent sectors. With regard to water and the environment, the National Water Policy contains the following objective:

"To have in place water management system which protects the environment, ecological system and biodiversity...Water for the environment, in terms of quantity and quality, and levels, and for both surface and groundwater resource shall be determined on the best scientific information available considering both the temporal and spatial water requirements to maintain the health and viability of riverine and estuary ecosystems, and associated flora and fauna."

This lays the foundation for the importance of protecting and conserving river and estuary ecosystems as well as the plants and animals that depend on them.

National Water Sector Development Strategy, 2006 to 2015

The National Water Sector Development Strategy (URT, 2008) is the blueprint for implementing the National Water Policy, laying the framework for water resources assessment, planning, and development at the local, national, and international scale. For each water resources management component, it defines a problem statement, policy direction, goals, strategies, and activities to guide future implementation.

Environmental Protection and Conservation
Goal: Increased environmental protection and conservation measures contribute to the sustainability of all aspects of water development, management and use.

Activity: Determine environmental flow requirements for ecosystems for all key rivers.

Water Utilization and Allocation
Goal: Implementation of a responsive, effective and sustainable water resources utilisation and allocation system based on social and economic priorities whilst maintaining minimum reserves for

the protection of eco-systems.
Activity: Develop water allocation criteria, procedures and guidelines for water basins.

Water Sector Development Programme, 2006 – 2025

The Water Sector Development Programme (URT, 2006) is a direct output of the National Water Sector Development Strategy and is critical for the implementation of the National Water Policy. It combines the strategies for the three sub-sectors outlined in the National Water Policy: Water Resources Management, Rural Water Supply and Sanitation, and Urban Water Supply and Sewerage.

Specifically, the Water Resources Management sub-sector is the most extensive of the three and supports the strengthening of basin water offices (also known as basin water boards) in their efforts for water resources monitoring, assessment, and enforcement. Important activities related to environmental flows includes the protection of important water sources, including to "empower the Minister to establish and set aside a "reserve" before water allocation decisions are made". It also notes that specific operational manuals and guidelines should be created to provide advice for topics specific to each sub-sector.

Water Resources Management Act, 2009

The Water Resources Management Act (URT, 2009) establishes the hierarchical government structure for water management as prescribed in the documents above, including the Minister of Water, the Director of Water Resources, the National Water Board, basin water boards (including the LVBWB), subcatchment committees, and WUAs. It also provides specific details on how water is to be managed, including permitting, fees, protected areas, and risk management. The Water Resources Management Act includes the formal definition of the reserve:

The "reserve" means the quantity and quality of water required for -
(a) satisfying basic human needs by securing a basic water supply for people who are now or who shall in the reasonably for near future, be
(i) relying upon
(ii) taking water from; or
(iii) being supplied from the relevant water resources; and

(b) protecting to protect [sic] aquatic ecosystem in order to secure ecologically sustainable development and use of the relevant water resources.

Design Manual for Water Supply and Waste Water Disposal, 2009

The MoW of the United Republic of Tanzania has published and regularly updates a design manual that provides standard values for water resources planning and development that can be used across the country (MoWI, 2009). In this design manual are numerical values for domestic water requirements for different types of areas (rural vs. urban), income levels, and the type of payment or tariff structure

Consumer Category	Rural Areas (litres/person/day)			Urban Areas (litres/person/day)			Remarks
	FR	M-UT	M-PBT	FR	M-UT	M-PBT	
Low income using kiosks or public taps	25	25	25	25	25	25	Most squatter areas, to be taken as the minimum
Low income multiple household with yard tap	50	45	40	50	45	40	Low income group housing, no inside installation and pit latrine
Low income, single household with yard tap	70	60	50	70	60	50	Low income group housing, no inside installation and pit latrine
Medium income household	-	-	-	130	110	90	Medium income group housing, with sewer or septic tank
High income household	-	-	-	250	200	150	High income group housing, with sewer or septic tank

FR = flat rate; M-UT = metered with uniform tariff; M-PBT = metered with progressive block tariff
(MoWI, 2009)

TABLE 3 2: DOMESTIC WATER REQUIREMENTS FOR WATER RESOURCES PLANNING IN TANZANIA

available (Volume 4, Design of Piped Water Systems, Page 4-13). The minimum amount of domestic water to be supplied is 25 liters/person/day.
While Tanzania does not define the amount required for basic human needs, this value of 25 liters/person/day will be used in this effort. This also aligns with the recommendations provided in the draft Guidelines for Water Allocation Planning (see below).

Environmental Water Requirements Assessment Guidelines for Tanzania (Final Draft, 2016)
Guidelines for determining environmental water requirements (also known as environmental flows) were developed to help basin water boards determine the aquatic ecosystem protection requirements of the reserve as defined in the Water Resources Management Act of 2009 (URT, 2016). It recommends methodologies for different types of water bodies, including rivers, lakes, estuaries, and wetlands. It suggests methodologies for rapid assessments (level 1) as well as more detailed holistic assessments (level 2). Level 2 assessments should be completed "for specific rivers or river reaches where such existing environmental problems are caused by anthropogenic activities and a compromise is needed between environmental health of rivers and human development". It outlines potential methodologies that could be used (including the BBM) but suggests that any methodology could be used as long as it is capable of providing environmental water requirement values for different management classes. These guidelines are still under review by the MoW and have yet to be finalized and approved.

Guidelines for Water Allocation Planning (Draft, 2018)
These guidelines were drafted in May 2018 and outline specific methodologies and considerations when basin water boards develop their water allocation plan, as mandated in the Water Resources Management Act of 2009 (URT, 2018a). It provides guidance on the quantification of the reserve, including how to calculate water requirements for basic human needs and for the environmental component of the reserve, which follows the recommendations provided in the Environmental Water Requirements Assessment Guidelines for Tanzania. The WAP guidelines are still under development and have yet to be finalized and approved by the MoW.

3.1.1.2 Regulations Related to the Environment
While less directly related to the reserve, the national legislative documents for environmental management also provide legal support for the implementation, monitoring, and adaptive management of the reserve. The two main documents in this sector are the National Environmental Policy (URT, 1997) and the Environmental Management Act (URT, 2004).

National Environmental Policy, 1997
"The environmental objective in the Water, Sewerage and Sanitation sector is to support the overall national objective of providing clean and safe drinking water to within easy reach, to satisfy other water needs, to protect water sources and to prevent environmental pollution. In order to achieve this, the following policy objectives shall be pursued...planning and implementation of water resources and other development programmes in an integrated manner and in ways that protect water catchment areas and their vegetation cover."

Environmental Management Act, 2004
"Basin Water Boards in prioritizing different uses of water shall ensure that adequate water is made available for environmental purposes."

3.1.1.3 Regional and International Agreements

East African Community and the Lake Victoria Basin Commission
The East African Community is a regional intergovernmental organisation made up of six countries in the east African region: the Republics of Burundi, Kenya, Rwanda, South Sudan, the United Republic of Tanzania, and the Republic of Uganda. It was established in 1999 with the mission "to widen and deepen economic, political, social and cultural integration in order to improve the quality of life of the people of East Africa through increased competitiveness, value added production, trade and investments". This is carried out across a variety of sectors including the environment and natural resources. In particular, it is important the East African Community member states cooperate in the sustainable management of "biologically significant transboundary freshwater ecosystems", which includes ecosystems like the Mara River Basin.

A specialized institution within the East African Community is the LVBC, which has the special mission of coordinating sustainable development and management of resources within the countries that are included in the Lake Victoria Basin. They have the role of providing neutral oversight and coordination between countries when working on transboundary issues related to water resources management.

Nile Basin Initiative and Nile Equatorial Lakes Subsidiary Action Program
Tanzania joined the NBI in 1999 as one of the original nine countries to create the partnership. Through this partnership, it agrees to follow transboundary water management strategies developed by NBI, which include the Wetland Management Strategy (NBI, 2013) and the Strategy for Management of Environmental Flows in the Nile Basin (NBI, 2016b). The Strategy for Management of Environmental Flows in the Nile Basin is being applied to the MRB due to its transboundary status with Kenya.

NELSAP is one of two investment programs under NBI with the mission of "to contribute to the eradication of poverty, promotion of economic growth, and reversal of environmental degradation" in the Nile Equatorial Lakes Region". NELSAP also provides funds and support for various transboundary projects related to water and energy between Tanzania and its neighboring countries in the Nile River Basin, including the Mara River Basin Management Project.

Memorandum of Understanding for Joint Water Resources Management of the Transboundary Mara River Basin

In 2015, the governments of the Republic of Kenya and the United Republic of Tanzania signed the "Memorandum of Understanding between the Government of the Republic of Kenya and the Government of the United Republic of Tanzania for Joint Water Resources Management of the Transboundary Mara River Basin" (URT and Republic of Kenya, 2015). This document lays out the responsibilities of both countries when it comes to the dual management of the MRB, including the establishment of joint institutions for the "sustainable development, management, and equitable utilization of water resources, including water allocation, water supply and sanitation, capacity building, data and information sharing, research and development." This MoU is facilitated and supported by the LVBC. While environmental flows or the reserve are not specifically stated in the MoU, it is a critical component of water allocation planning. When appropriate, the government of Kenya has been involved in the EFA in Tanzania and outcomes from previously completed activities in Kenya have been incorporated into the process, following the mandate of this MoU.

> Similar to Tanzania, Kenya uses the concept of a reserve for the implementation of environmental flows. In Kenya, the reserve is giving the highest priority in water resources allocation (WRMA, 2009). The reserve is defined in the revised Water Act (Republic of Kenya, 2012) as:
>
> *…in relation to a water resource, means that quantity and quality of water required -*
>
> *(a) to satisfy basic human needs for all people who are or may be supplied from the water resource; and*
>
> *(b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource*

3.1.2 Available Information

Data and information relevant to the EFA activities were collected from online sources and from the participating institutions. The data and information were uploaded to central storage location during the project where the team members could view, upload, and download files (documents, spreadsheets, photos, videos, spatial data, etc.). In this way, a database of information related to the project was developed that will be delivered to the LVBWB, the MoW, and NELSAP CU at the completion of the project for their records and continued use.

Available data resources utilized for this project included:

- Foundational documents for the project, including the Nile Environmental Flow Framework, information on setting RQOs, and the Technical Offer for this project.
- Hydrological data collected from the LVBWB and analyzed by IHE Delft.
- Previous EFAs conducted in the Mara River from 2012 and 2017 and their associated reports and datasets (where available), as well as other EFAs conducted in Tanzania.
- The Integrated Management Plan for the Mara Wetland (2018, developed by IHE Delft, Birdlife International, and WWF) and associated reports and datasets.
- Information from a geomorphological study of the Mara Wetland conducted by IHE Delft, including drone footage, photographs, and spatial data.
- Datasets and a literature review the MaMaSe project, a project that was completed in the Upper Mara River Basin in Kenya from 2014 – 2018.
- National laws and guidelines for the United Republic of Tanzania related to water, wetlands, and environmental protection
- Spatial data, reports, scientific papers, master's theses and PhD dissertations related to the Lower MRB

3.1.3 Previous EFAs in the Mara River Basin

The first phase of EFAs in the Mara River Basin was completed between 2006 and 2008 under the consortium by a team of experts from the United States, Kenya and Tanzanian universities, water management authorities in both countries, the Lake Victoria Basin Commission, and WWF among other stakeholders. The study aimed to determine the minimum flow levels required to maintain the reserve in the Mara River. Three sites were selected all located within MRB in Kenya. The findings of this study were adopted and summarized in a 2010 report by Lake Victoria Basin Council of Ministers.

The recommendations from the 2006-2008 EFA called for additional studies on the Mara to provide more information on the status of the rivers, to assess the accuracy of the flow recommendations given at that time and suggest any necessary improvements. As a result, further studies were conducted from 2008 to 2010; low flow EFA sampling and long term monitoring to address these recommendations. The low flow sampling focused on the physical and biological characteristics of the river at critical flow levels while the long term monitored water quality and discharge relationship as well as macroinvertebrate communities every two weeks. The findings from these studies showed that the 2006-2008 EFA recommendations were sufficient to maintain a healthy river ecosystem with the necessary control of the abstractions. The third phase building upon phase two called for the extension of field sampling to Tanzania and this was undertaken between 2011 and 2012. In this study, two sites in Tanzania were added for assessment in addition to the three original sites in Kenya and flow recommendations given for each site. Reports for these earlier EFA studies outlining the methodology and results were developed and disseminated.

The latest EFA assessment was conducted during the MaMaSe project which was funded by the Embassy of the Kingdom of the Netherlands in Nairobi, Kenya from 2014 to 2018. The EFA was undertaken in collaboration with the Kenyan Water Resources Authority, Water Resources Users Associations in Kenya, County governments (Bomet and Narok), the LVBWB in Tanzania, NBI, Lake Victoria Basin Commission and a host of various stakeholders in the basin. Two field assessments were conducted between November and December 2015 during the wet period and February and March 2016 representing the dry period. Seven sites were selected for assessment: 6 located in Kenya and one (Mara Mines) in Tanzania (same site where the 2006-2008 EFA was conducted). This EFA was part of the water allocation planning effort for the Kenyan portion of the Mara River Basin, which included other demands in the basin i.e. domestic, irrigation/agricultural, industrial, livestock, wildlife etc. All these demands were used to calculate the water balance for the Mara River in the upper part of the basin and subsequently the WAP, which is still in review by the relevant ministries in Kenya.

Water Resources Activities in the Mara River Basin

Water Resources Planning Activities in the Mara Catchment, Tanzania

Water resources planning in Tanzania is organized within nine major river basins, each administered by a Basin Water Board. The Mara River is a sub-basin of Tanzania's Lake Victoria Basin and is administered by the LVBWB. According to the Water Resources Management Act (2009), each Basin Water Board is to develop an Integrated Water Resources Management and Development Plan. The plan for the Lake Victoria Basin is currently under development and will include the Mara among other sub-basins.

Over the past decade, various activities and projects in support of water resources planning in the Lower MRB have been conducted by the Lake Victoria Basin Commission, NELSAP CU, WWF, and numerous other organizations. In 2014, NELSAP CU supported the development of Sub-Catchment Management Plans for the Somoche and Tobora sub-catchments of the Mara. The plans considered management topics including i) water allocation and use; ii) water resources protection; iii) institutional development and collaboration; iv) infrastructure development; v) resource mobilization and financial management; and vi) livelihoods and entrepreneurship. Implementation of these plans has been limited.

Water Allocation Planning Activities in the Mara River Basin

Water allocation planning is an integral component of Integrated Water Resources Management and Development plans being developed by Water Boards in Tanzania and will be incorporated into the Lake Victoria Basin Plan as it is developed. In addition, activities specific to water allocation planning are being, and have been, carried out in cooperation with the efforts of the Water Board. Currently, NBI-NELSAP, the Sustainable Water Partnership, and WWF are supporting the development of a WAP for the Lower MRB. The reserve assessment reported here is a component of this cooperation. Upon its completion, efforts will be made to harmonize the Tanzania Mara WAP with a similar plan that has been developed and is undergoing modification for the Kenya part of the basin. The ambition is to develop a single, transboundary WAP that can be agreed by Tanzania and Kenya within the framework of the MoU for Joint Water Resources Management of the Transboundary Mara River Basin signed between Kenya and Tanzania in September 2015.

In 2013, the Lake Victoria Basin Commission also supported the development of a Mara River Basin-Wide Water Allocation Plan. That 5-year plan was intended "to establish a reasonable and practical framework for water allocation and water abstraction within the Mara River basin". The authors of the plan noted that it was developed in the context of major information constraints and should be revised within 5 years. The information generated as part of this study and others supported by current water allocation planning efforts is intended to fill information gaps and enable develop of a more detailed and well-informed WAP of the basin.

Water allocation planning activities began with the formation of the Transboundary Water for Biodiversity and Human Health in the Mara River Basin Project that started in October 2005 and ended in September 2012. The project was a collaborative effort under the Global Water for Sustainability program (GLOWS) with participation from several organizations including Florida International University (FIU), WWF Eastern and Southern Africa Regional Programme, World Vision, CARE Tanzania and the Mara River Water Users Association. This undertaking was funded by USAID and the adoption and implementation of findings done through the Lake Victoria Basin Commission. One of the objectives of the project was to support governments as well as local partners in Kenya and Tanzania to develop a water resources management plan for the Mara River Basin.

Mara River Basin Management Project

In the Mara River Basin, NELSAP operates the Mara

River Basin Management Project which began in 2006 and has the objectives of "improved water resources development through development multipurpose storage reservoirs for Irrigation, water supplies and small hydroelectric power, and improved river basin management through integrated watershed management projects"(NBI, 2015). It continuously promotes the harmonization of policies and management actions between Tanzania and Kenya, has completed feasibility studies for large-scale water infrastructure projects (including Borenga Dam), and has implementing small-scale water infrastructure projects. It also provides investments for water quantity and quality monitoring networks, trainings for technical staff, and community outreach on environmental management issues and development options in the MRB.

3.1.5 Partnerships and Capacity Building

The EFA assessment was carried out in close collaboration with many local and international partners. NBI and GIZ provided the funding for the field work, guidance, and day to day liaison to the project on the content and process of the assignment. The field work was conducted by the EFA technical team, staff from the LVBWB (Tanzania), the Water Resources Authority (Kenya), IHE Delft (Netherlands), University of KwaZulu-Natal and Rhodes University (South Africa), University of Eldoret (Kenya) and Sokoine University of Agriculture (Tanzania). The EFA technical team were also assisted by staff from the MoW, the Musoma District Fisheries Department, SENAPA, local government leaders from the wards and villages, members of the water users associations (WUAs) and community members.

Capacity building was incorporated into all major activities in the project through hands-on learning and interaction with experts. This project is the first time that RQOs have been developed for a basin inside Tanzania as well as the first full implementation of the NBI E-Flows Framework, which were described in detail during stakeholder workshops. During the field work campaigns, local participants were encouraged to work with different experts to learn about their field of study and gain hands-on experience conducting different field work methodologies. In particular, knowledge exchange between the water authority staff in Kenya and Tanzania was considered a high priority. Community members also provided the technical experts with information about the local conditions and recent changes in ecosystem condition. The final flow setting workshop also discussed environmental flow science and implementation in detail, providing examples from other projects around the world to improve the knowledge of those who will be implementing the reserve in the Lower MRB.

3.2 Resource Quality Objective Setting

RQOs are set to guide actions to protect water resources in the rivers, wetlands, aquifers, and lakes. RQOs are intended to protect water and related aquatic biological resources at levels needed to meet the needs of resource users and maintain ecosystems in a desired environmental management class. The assessment and implementation of the reserve is one of a number of management actions to be guided by RQOs. Others include pollution prevention actions and regulations, and related actions controlling direct resource extractions such as fishing, sand mining, etc. In the case of the reserve, aspects of RQOs related to meeting basic human needs for water and protecting ecosystems are most relevant. RQOs are identified in Part VI of the Tanzanian Water Resource Management Act (2009) as an instrument of water resource protection. The text of the Act calls for the MoW to "establish procedures which are designed to satisfy the quality requirements of water users as far as is reasonably possible, without significantly altering the natural water quality characteristics of the water resource" [Part VI(a)32(2)(b)(ii)]. The requirement to establish procedures for determining the reserve is also cited in Part VI of the Act, as the two instruments are intended to work together in water resource protection.

The articulation of RQO's in the Act and link to the determination of the reserve is consistent with the NBI E-Flows Strategy (NBI, 2016a), which includes the setting of RQOs in the initial phases of e-flow assessments. The RQOs are to be set in accordance with local, national and regional governance (legal and institutional). In the Mara River Basin, this refers to the Act as the legal basis and the LVBWB as the responsible institution. The detailed aspects of RQOs are not specified by the Tanzania MoW but are described in the technical manual accompanying the NBI E-Flows Strategy, which have been adopted by the United Republic of Tanzania through its membership in the NBI. The NBI manual adopts the description of RQOs specified in the 2004 South African National Water Resource Management Strategy, which states that "resource quality includes water quantity and water quality, the character and condition of in-stream and riparian habitats, and the characteristics, condition and distribution of the aquatic biota : Resource quality objectives will be defined for each significant resource to describe its quality at the desired level of protection" [3.1.1]. Reference to "the desired level of protection" is important because it acknowledges that RQOs will not be the same for all water bodies. RQOs may be set higher or lower depending on the needs of water users and legal requirements for environmental protection.

RQOs are expressed as narrative statements of the desired quality aspects of the resource. For example, the RQO related to water quantity may be "maintain dry season low flows at levels sufficient to meet domestic and livestock needs but with only moderate alternation of the ecosystem". The advantage of narrative statements is that they are more effective for communication, enabling stakeholders to better understand the stated objectives. Narrative statements are not, however, sufficient to guide water resource managers because they are not measurable. The manager must know "how much" flow during the dry season is necessary to meet domestic and livestock needs but with only moderate alternation of the ecosystem. This then requires measurable targets for "what is" moderate alternation of the ecosystem. Therefore, narrative statements must be accompanied by measurable targets that the resource manager can set and monitor to check that objectives are being met.

3.2.1 Resource Units

Spatial areas needed to be determined for which RQOs were developed. They were selected to align both with existing management structures, in particular the WUAs, as well as the biophysical study sites selected to study flow-ecology relationships. In total, seven resource units (RUs) were delineated for the Lower MRB (Figure 3 3). Working upstream to downstream, they are:

Serengeti: This RU includes SENAPA and many of the tributaries that flow into that area. There is no WUA established in this region, however the RQO process is being conducted in close collaboration with SENAPA technical and management staff.

Tobora: This RU follows the sub-basin boundary for the Tobora River, which flows into the mainstem of the Mara River downstream of SENAPA. The Tobora WUA is established in this RU.

Somoche: This RU follows the sub-basin boundary of the Somoche River, which flows into the mainstem of the Mara River downstream of the Tobora River. The Somoche WUA is established in this RU.

Upper Tigithe: This RU is the upstream portion of the Tigithe River and flows into the Lower Tigithe RU. The Upper Tigithe (Tigithe Juu) WUA is established in this RU.

Lower Tigithe: This RU is the downstream portion of the Tigithe River and flows into the Mara Wetland. The Lower Tigithe (Tigithe Chini) WUA is established in this RU.

North Mara: This RU encompasses the area on the north side of the Mara Wetland, approximately between the inflow of the Tigithe River and the outlet to Lake Victoria. The North Mara (Mara Kaskazini) WUA is established in this RU.

South Mara: This RU includes the area to the south of the Mara Wetland, approximately between the southern tributaries to the wetland and the outlet to Lake Victoria. The South Mara (Mara Kusini) WUA is established in the RU, although only within the area adjacent to the wetland boundary.

There is an additional area labelled Mara Mines in the central part of the river basin that is not included in an RU. This section does not have an established WUA or management authority and was not assessed in this RQO workshop. However, RQO statements were developed during the EFA process.

3.2.2 Stakeholder Workshop

An RQO stakeholder workshop was held on November 7th and 8th, 2018 in Tarime, Tanzania. The objective of the workshop was to develop narrative RQOs for the RUs of the Lower MRB with local stakeholders. Participants in the workshop were guided to this objective by working through a series of activities designed to develop understanding of the process, gather needed information, and articulate the narrative RQOs. It was also a chance to encourage knowledge exchange and build relationships between different types of stakeholders in the basin through

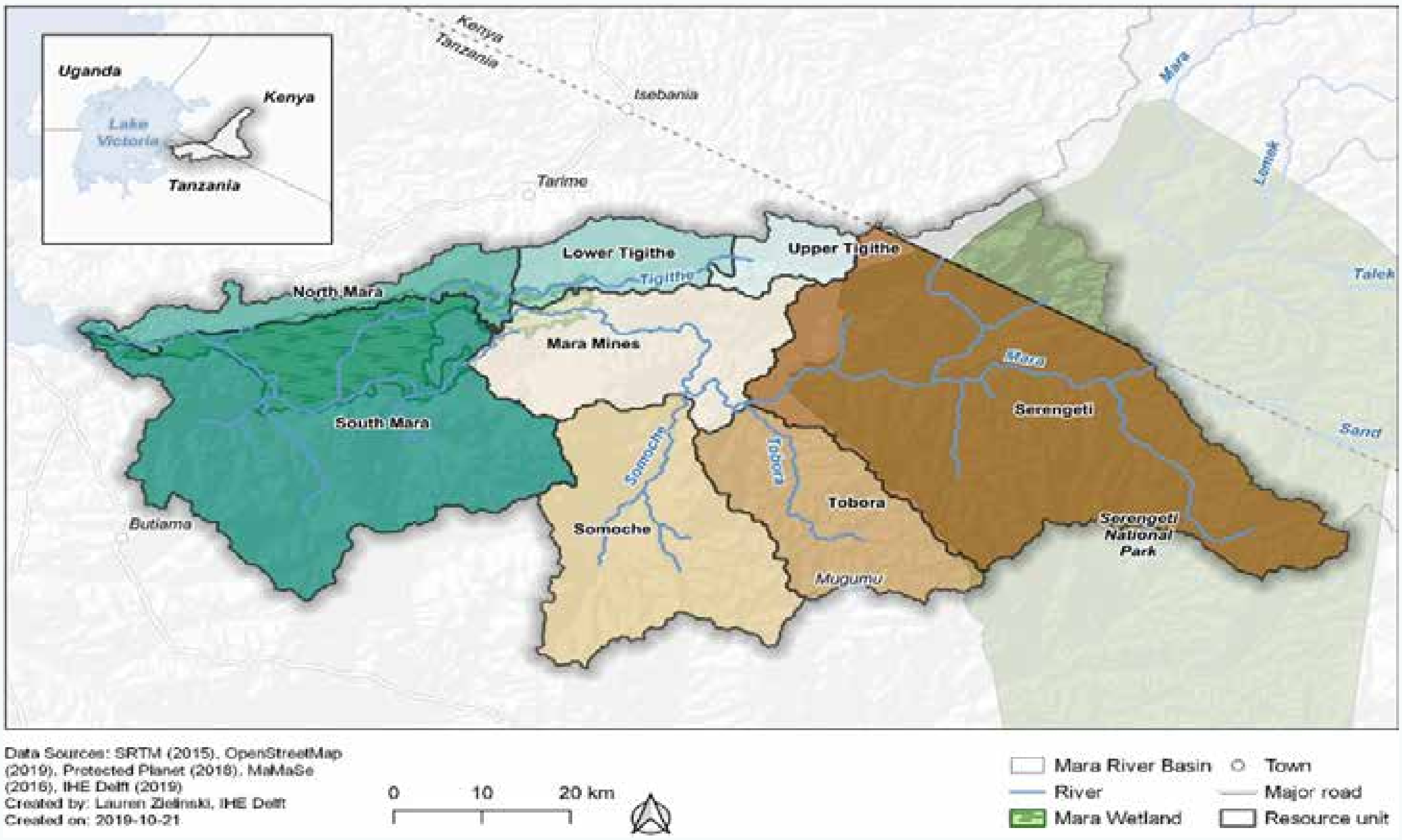


FIGURE 3 3: RESOURCE UNITS FOR THE LOWER MRB

These terms are defined as the following: [3] *Quantity: Including pattern, timing, water level and assurance of instream flow. Quality: Including physical, chemical and biological character of the water. Habitat: Including character and condition of the instream and riparian habitat. Biota: Including character, condition and distribution of the aquatic biota* small group discussions. All workshop materials and results can be found in the full RQO workshop report found in Annex A.

The RQO Stakeholder Workshop was attended by 57 participants from 19 organizations, including local, regional, and national stakeholders, project partners, and support staff. The stakeholder organizations included all six WUAs, the Mwanza and Musoma offices of the LVBWB, the Tanzanian MoW, the Zonal Irrigation Office in Mwanza, SENAPA, Tanzanian universities, and local and national non-governmental organizations. Partner organizations included IHE Delft, NBI-NELSAP, WWF-Tanzania, the Sustainable Water Partnership, USAID Kenya, and the Stockholm Environment Institute.

The participants were split into smaller groups, one group for each RU. The participants were asked to place themselves in a group where they lived in the RU, were familiar with the conditions inside the RU, or had a professional or personal connection with the RU. Each group contained 4 to 7 participants, with two representatives from the WUA residing within the RU and a mix of participants from other organizations and government institutions. The groups were intentionally mixed to provide a combination of local knowledge, academic understanding, and professional decision-making. Each group was asked to complete four activities:

- Assess the impacts on resource qualities from external pressures.

- Assess the importance of resource qualities to water users.

- Assess the fitness for use of resource qualities.

- Develop draft RQO statements.

The draft RQOs were then reviewed and revised by the EFA technical team. Final RQO statements can be found in Section 5.1.

3.3 Hydrologic Foundation

The following is a summary of hydrological analyses completed in the hydrology starter document for the Lower Mara EFA (Annex C) as well as the hydrological analysis completed in the Water Availability Assessment (SWP, 2019) for the water allocation planning activities in the basin. For full details, please refer to these reports.

The hydro-meteorological observation network in the Lower MRB is limited. In total, 13 stations are located in the Lower MRB: four automatic weather stations, five rainfall stations, and four hydrometric stations. In June 2018, only one rainfall station was fully operational and three of the hydrometric stations were partially operational (SWP, 2018). Available flow data are limited to the Mara Mines site with data being available from 1969 to 2018. A large data gap is present in the 1990's, and within the 49 years of data 30 percent is missing.

3.3.1 Data Regionalization

Because of the limited availability of long-term hydro-meteorological data sets in the catchment, the reconstruction of river flow data was based on earlier works carried out under the MaMaSe and Sustainable Water Partnership projects. A detailed description of the methodology can be found in the reports MaMaSe, 2017 and SWP, 2019 , and here only a summary of the methodology is given. The reports describe the methodology for a water availability assessment using long-term historical data sets of precipitation and discharge. Objectives of these assessments were (i) to regionalize average monthly and average annual discharge data, (ii) estimate flow duration curves, (iii) to setup long-term water balances for the sub-catchments within the Lower MRB, and (iv) to assess changes in the hydro-meteorological time series data sets (SWP, 2019).

Methods used for reconstruction of river flow series:

1. Catchment delineation based on SRTM 90 meter data using the Pfafstetter coding system.

2. Monthly precipitation time series of 25 stations in and around the Mara River Basin.

3. Areal precipitation estimation using the Thiessen polygon method.

4. Monthly discharge time series of four gauging stations.

5. Regionalization of discharge values using a runoff coefficient approach.

6. Filling of missing data using cross-correlation between the two neighbouring stations.

3.3.2 Long-term Annual Water Balance

Results of the regionalized long-term annual water balances for the EFA sites are given in Table 3 3. Annual precipitation values range from 936 to 1,100 mm/yr, and evaporation values from 860 to 1,018 mm/yr. The Tigithe EFA catchment shows the highest precipitation and evaporation values, whereas the Kogatende EFA catchment has the lowest values. This can be explained by the fact that the upstream area of Kogatende has the highest relative contribution of the dryer and lower yielding sub-catchments of Talek and Sand (located in Kenya) in comparison to the more downstream EFA sites. Regarding the runoff contributions, most of the EFA sites have comparable values around 70 to 80 mm/yr. One exception is the

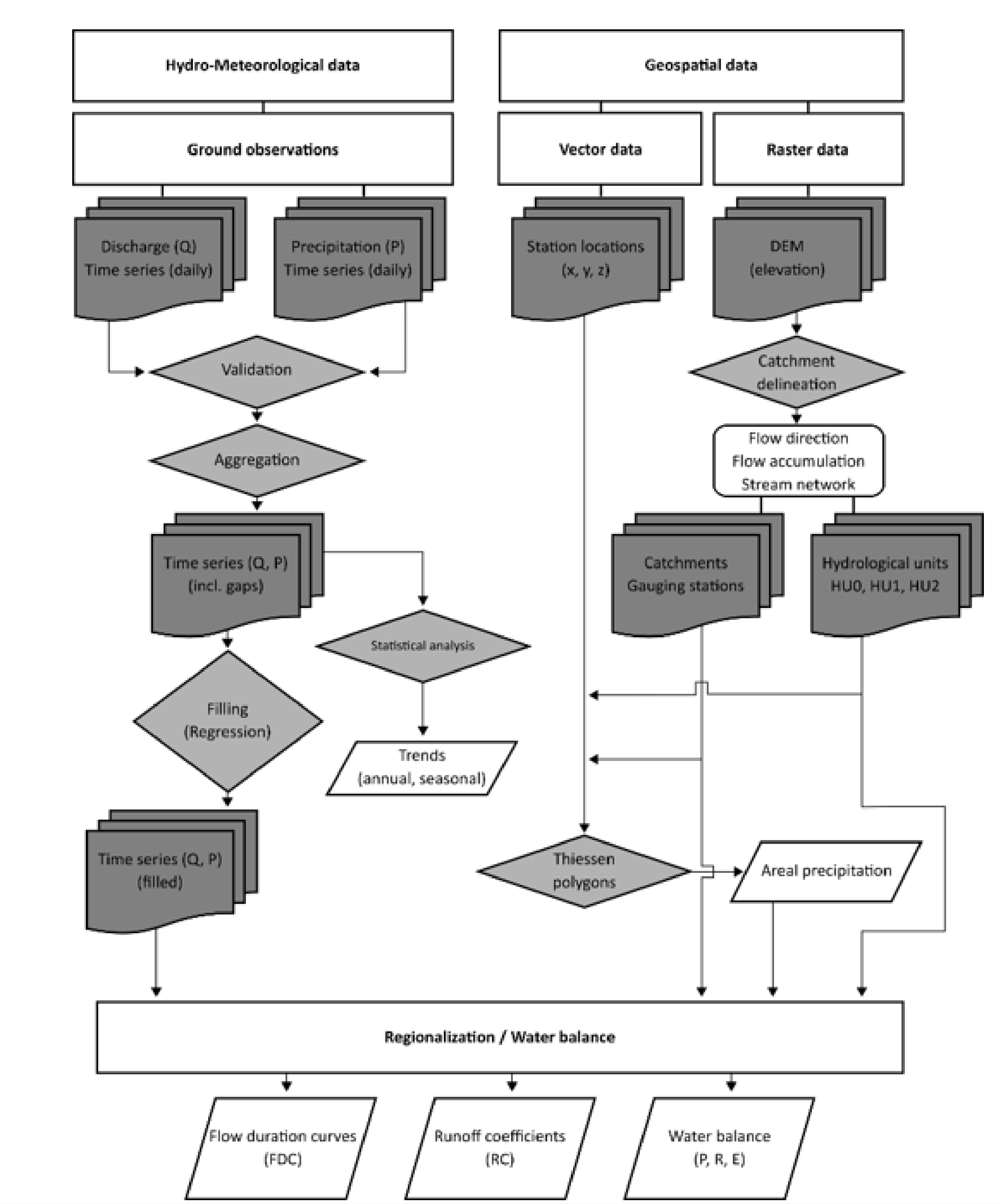


FIGURE 3 4: METHODOLOGY FLOW CHART FOR THE WATER AVAILABILITY ASSESSMENT IN THE LOWER MRB (SWP, 2019)

Table 3-3: Catchment characteristics of the EFA sub-catchments

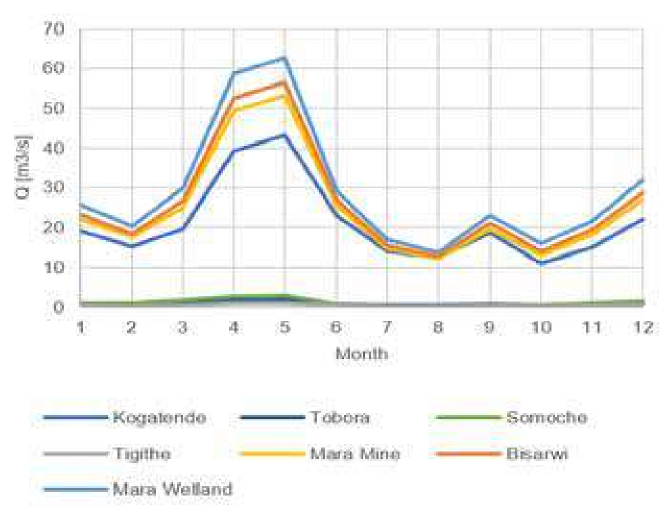
Site	Name	Latitude [d.ddddd]	Longitude [d.ddddd]	Area [km²]	Precipitation [mm/yr]	Evaporation [mm/yr]	Runoff [mm/yr]
1	Kogatende	-1.56114	34.88502	8926	936	860	76
2	Tobora	-1.60891	34.60744	361	945	869	77
3	Somoche	-1.58775	34.53835	690	957	909	48
4	Tigithe	-1.46001	34.46568	183	1100	1018	82
5	Mara Mines	-1.55012	34.55368	11283	954	884	71
6	Bisarwi	-1.47257	34.26638	11903	960	889	71
7	Mara Wetland	-1.53749	34.06905	13272	985	912	73

TABLE 3 3: CATCHMENT CHARACTERISTICS OF THE EFA SUB-CATCHMENTS

Somoche EFA catchment with a value of 48 mm/yr.

3.3.3 Regionalized Monthly and Annual Flow Values

In Figure 3 5 a summary of the regionalized flow values for the EFA sites is presented. The hydrographs for average monthly discharge are similar for the EFA sites located on the mainstem Mara River and the wetland, while the three tributaries follow a similar pattern but much smaller in magnitude. The runoff regimes are also fairly similar across the EFA sites, with Somoche having the highest runoff ratio. The numerical flow values can be found in Annex C.



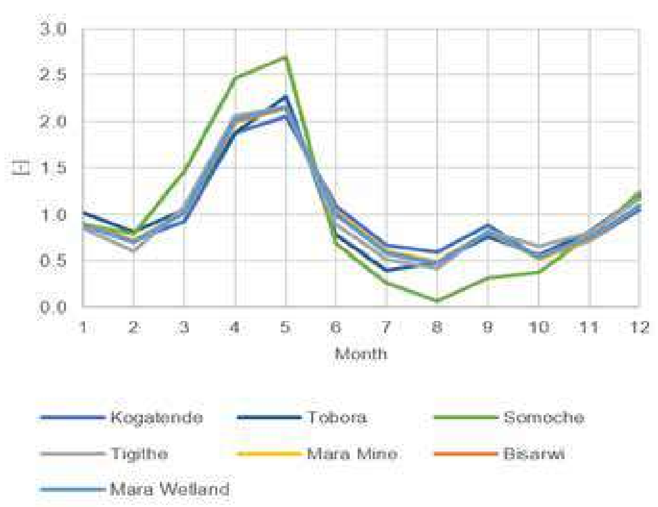


FIGURE 3 5: AVERAGE MONTHLY DISCHARGE (LEFT) AND RUNOFF REGIMES (RIGHT) AT THE EFA SITES

3.3.4 Frequency Analysis

A frequency analysis was carried out for annual maximum daily flow values at each EFA site. Daily time series for the EFA sites were generated using a linear reservoir based rainfall-runoff model. As precipitation input data gap filled daily time series of available stations were used. After extracting the annual maximum flow values from the time series a Gumbel distribution (Generalized Extreme Value distribution Type-I) was used and fitted to the data sets. Results of the frequency analysis for the EFA sites can be found in Table 3 4 and Annex C. Although the model was calibrated against measured station data, this approach contains considerable uncertainties, and should only be seen as a first attempt to estimate return periods of annual maxima.

		Return Period (yr)						
Site	Name	2	3	5	10	20	50	100
1	Kogatende	176.45	223.42	275.74	341.47	404.53	486.15	547.31
2	Tobora	6.22	8.52	11.08	14.30	17.39	21.38	24.38
3	Somoche	10.74	14.68	19.06	24.57	29.85	36.69	41.81
4	Tigithe	3.10	4.85	6.79	9.24	11.58	14.62	16.89
5	Mara Mines	199.15	252.63	312.20	387.06	458.86	551.80	621.44
6	Bisarwi	203.59	259.21	321.17	399.01	473.69	570.34	642.77
7	Mara Wetland	209.49	267.32	331.72	412.65	490.27	590.75	666.05

TABLE 3 4: SUMMARY OF FREQUENCY ANALYSIS FOR MAXIMUM DAILY FLOW VALUES

3.3.5 Trend Analysis

A trend analysis of hydro-meteorological parameters within the Lower MRB was carried out using the DScreen software tool (Venneker, 2011) and the Indicators of Hydrologic Alteration package (Richter et al., 1996; The Nature Conservancy, 2009). A detailed description of the methodology can be found in the report (SWP, 2019). None of the seven considered precipitation stations in the Lower MRB showed a significant positive or negative trend in the annual precipitation amounts. Autocorrelation was detected for the station 9134027 Lolgorien, and the calculated pre-whitened trend was not significant. For the discharge trend analysis the average annual (MQyear) as well as the maximum (HQmonth) and minimum (NQmonth) average monthly discharge values were selected for the station 5H2 Mara Mines.

Autocorrelation was detected for the minimum monthly discharge values and therefore a pre-whitened trend was calculated in this case. The time series of 5H2 Mara Mines show diverse trends, but none of them is statistically significant. The daily discharge values of the station Mara Mines also showed no statistically significant trends.

3.3.6 Hydrological Assessment of EFA Study Sites

Using the regionalization approach, hydrological analyses were conducted for each EFA study site. Summarized information on land use, catchment size, and discharge information can be found for each site in Section 4. More detailed information can be found in the full hydrology starter document in Annex C.

Ecosystem Classification

There is no official ecosystem classification map or methodology defined for Tanzania. As part of previous environmental flow work, a national river classification methodology was proposed and carried out using available information on 20 different environmental attributes, including average channel slope, catchment area, elevation, annual rainfall, and soil porosity, among others (USAID, 2018). The methodology was applied in detail to the Rufiji River Basin in central Tanzania, and then applied to all nine river basins in Tanzania at a coarser level (Figure 3 6).

According to this analysis, almost the entire Lower MRB is classified as Class H, which is defined as:

his river class is found in every major Tanzanian river basin, with major concentrations in the central parts of the Pangani and Wami-Ruvu Basins as well as along the eastern and western shores of Lakes Victoria and Tanganyika. Defining environmental characteristics include moderate elevation and slope; moderate to low (variable) precipitation with low (variable) seasonality; lowest subsoil porosity, and high vegetation cover and low agricultural land cover.

While this classification allows the rivers and streams in the Lower MRB to be compared to other rivers nationally, it is not at a fine enough scale to show differences within the basin. It is important to recognize the differences in the river attributes during an EFA, even in a generalized way, during the selection process to determine EFA study sites. This helps to ensure that different types of river systems are analyzed and incorporated into the study, particularly since the management recommendations often change due to the natural river types. Since RUs were already defined in the RQO process, these boundaries were used to provide general classifications based on known information and experience working in the lower MRB. During the site selection process, the technical team generalized the hydrological characteristics of the RU to ensure each were captured. In general, there are three distinct hydrological areas: the mainstem of the Mara River with perennial flow, tributaries which have very low base flows and high flows are driven by rainfall events, and the wetland which acts as a gradient between the influence of Lake Victoria downstream and the Mara River upstream (Figure 3 7). Additional biological and geomorphological attributes were also discussed, including habitat function, approximate slope, and substrate. In general, these also align

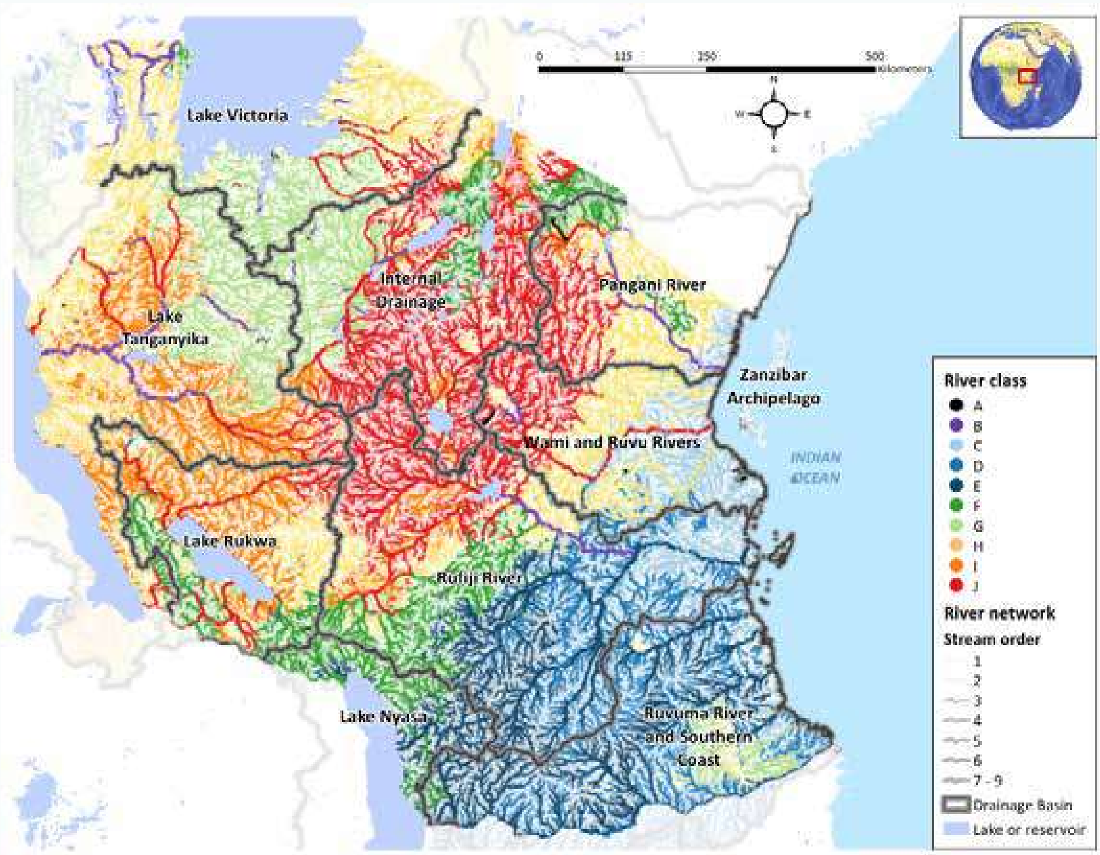


FIGURE 3 6: PREDICTED RIVER CLASSES OF ALL RIVER SEGMENTS IN TANZANIA ACCORDING TO THE DEDUCTIVE CLASSIFICATION (USAID, 2018).

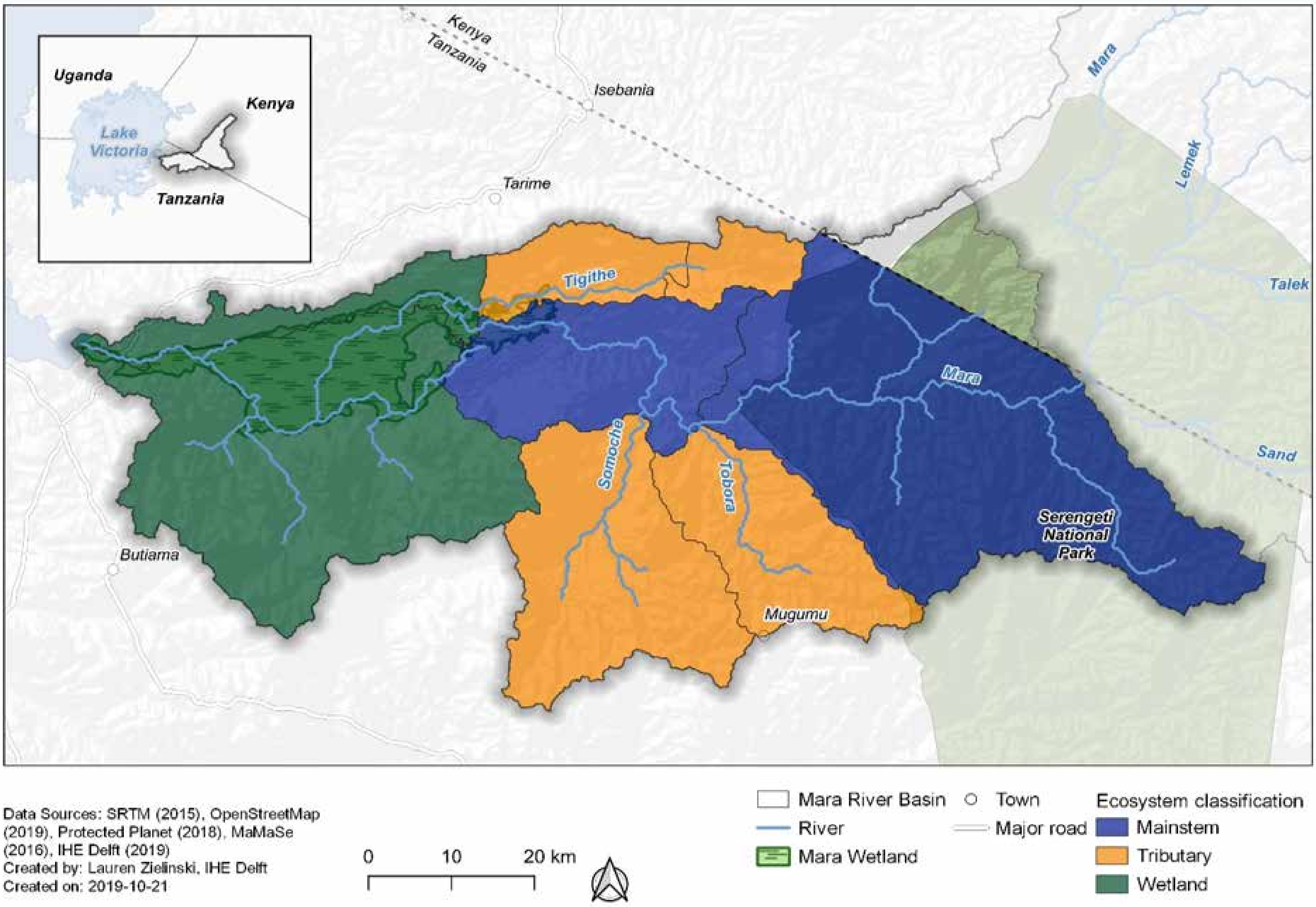


FIGURE 3 7: GENERAL ECOSYSTEM CLASSIFICATION OF THE RESOURCE UNITS IN THE LOWER MRB

Resource Unit	Hydrological	Biological (Habitat)	Geomorphological
Serengeti	Mainstem, perennial flow	Movement up and downstream	Floodplain, moderate slope, primarily sand with bedrock outcrops
Tobora	Tributary, flows into Mara River, small amount of perennial baseflow, event-based flows	Refuge area	Bedrock driven, moderate to high slope, primarily stones and cobbles
Somoche	Tributary, flows into Mara River, small amount of perennial baseflow, event-based flows	Refuge area	Bedrock driven, moderate to high slope, primarily stones and cobbles
Upper and Lower Tigithe	Tributary, flows into Mara Wetland, small amount of perennial baseflow, event-based flows	Refuge area	Bedrock driven, moderate to low slope, primarily stones and cobbles
Mara Mines	Mainstem, flows into Mara Wetland, perennial flow	Movement up and downstream	Floodplain, moderate slope, primarily sand
Mara North	River/wetland transition (water confined to channel in dry season, on floodplain in rainy season), perennial flow	Connection between Lake Victoria and Mara River	River/wetland transition, low slope, prone to avulsions, primarily fine sediment
Mara South	Very slow moving, highly influenced by Lake Victoria, always contains water	Connection between Lake Victoria and Mara River	Very low slope, primarily very fine sediment, very stable

TABLE 3 5: ECOSYSTEM CLASSIFICATION DETAILS FOR EACH RESOURCE UNIT AND ASSOCIATED EFA STUDY SITE with the hydrological characteristics, maintaining three distinct classifications. Details on all ecological classification attributes can be found in Table 3 5.

3.5 Flow Alterations

Flow alterations are a measure of the deviation of current-condition flows from baseline- (or natural-) condition flows. Significant flow alterations occur in river basins regulated by large infrastructure or with high water demand relative to water availability. In the Mara, there are currently no engineered structures that significantly alter flows. Thus, under most flow conditions the flow regime is near natural. During periods of low flow, direct river water withdrawals for domestic and agricultural use may have a measurable effect on flow levels, but no data are available and the magnitude of the effect is likely minimal in most reaches of the river system. Mango et al., 2011 modelled the effect of land use change on hydrological runoff in the Nyangores tributary of the Upper Mara in Kenya, and their results did suggest a small decrease in dry-season flows and increase in flood flows, but the results remain to be verified by flow data and cannot be directly extrapolated to conditions in the Lower MRB in Tanzania. In this study we have therefore not considered current flows to deviate significantly from baseline or natural flows. The ramifications of this consideration is that observed degradation in ecological condition of the river system is assumed to be caused by pressures other than flow alterations, which may include contaminant discharges and direct human interventions (like over-fishing or clearing of riparian vegetation).

3.6 Flow-Ecology Ecosystem Services Linkages

The relationships between flow and dependent ecological and human communities can be complex, and often require detailed scientific studies to understand how these relationships change over a hydrologic year and over many years. In high conservation value rivers like the Mara, it is advised to use a holistic EFA methodology to help determine these linkages. In this study of the Lower Mara River we have applied a modified Building Block Methodology (BBM, King, Tharme and Villiers, 2008), which is consistent with the methodology applied in the Upper Mara River in Kenya. This methodology, developed in South Africa and cited in the Nile E-Flows Framework, combines existing scientific literature, detailed field studies, and the knowledge of a team of experts to determine flow-ecology and social relationships. These are then applied to set environmental flow levels that meet the RQOs.

The BBM assesses flow-ecology ecosystem services linkages for different components of the hydrograph (or “building blocks”, Figure 3 8). These include low flows, small to medium floods, and large floods. The flow requirements of these building blocks are determined using physical and biological requirements of fish, macroinvertebrates, and riparian vegetation (flow-ecology relationships) as well as the use of the ecosystems by local communities (ecosystem services). Specific indicator(s) for each component are determined by specialists based on available data and professional judgement. The indicator(s) selected then determine the specific data collection methodologies used in the field. The information for each component (hydrology, hydraulics, water quality, geomorphology, riparian vegetation, fish, macroinvertebrates, and social uses) are combined in technical documents (called starter

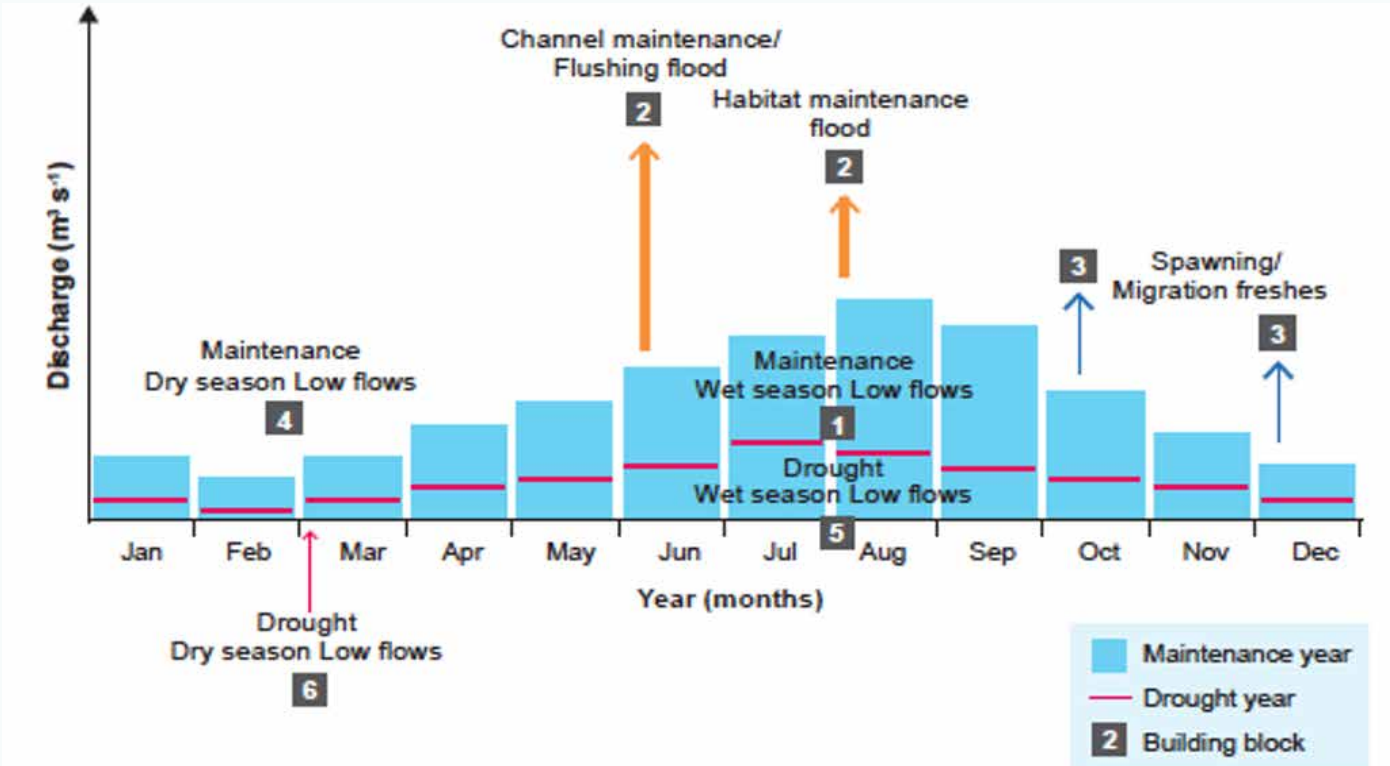


FIGURE 3 8: SCHEMATIC ILLUSTRATION OF THE MAIN COMPONENTS OF A GENERIC FLOW REGIME (COMPRISED OF INDIVIDUAL FLOW BUILDING BLOCKS) CONSIDERED IN THE BBM (FROM CDM SMITH, 2016).

documents), that serve as the technical inputs to the flow setting technical meeting, where detailed environmental flow levels are set.

In addition to collecting physical data, the BBM calls for collection of social data to assess how communities make use of ecosystem services provided by the river, its riparian corridor, and related wetlands. Emphasis is then devoted to protection of underlying ecological processes providing the most valued services.

Detailed descriptions of the different BBM components are described in the following sub-sections.

3.6.1 Flow-Ecology Components

Social Uses

The objective of the social study was to provide information from the perspective of the community members on how they utilize riverine resources for sustaining their livelihoods. This could be either in terms of food, crop farming, source of building material, medicinal value, fuel and other purposes. The study also identified key issues of concern raised by the community members relating to these resources and what improvements they may wish to see in order to promote a healthy ecosystem that will be beneficial not only to the ecology but to them as well. It also provided an opportunity to learn from the community some of the historical changes that may have happened to the resource in terms of its availability, quantity or quality and making a comparison to what is currently the situation. Participatory Rural Appraisal was the approach employed by the social scientist for data collection while Focus Group Discussion was the technique selected for this purpose.

Hydrology

Hydrological analysis of the EFA sites was done in order to determine the flow regime of the Mara River over several timescales. The regime reflects the annual variability, timing and seasonal distribution of flows and the extent to which these flows keep re-occurring (return period). Hydrological assessment is important as it impacts on the ecological and geomorphological processes such as shape and size of the river channel and behavior of the aquatic organisms. The analysis was done by combining field observations (on-site discharge measurements), literature studies of existing technical reports and analysis of available precipitation and discharge time series.

Discharge measurements at the EFA sites during the field campaign were carried out using three different devices depending on the flow situation and cross-section characteristics:

- ADCP = SonTek River Surveyor M9; Acoustic Doppler Current Profiler.

- OTT ADC = OTT Acoustic Digital Current meter.

- Flow Tracker = SonTek Flow Tracker handheld Acoustic Doppler Velocimeter.

Observed parameters included discharge, cross-section area, mean and maximum depth, width, mean and maximum velocity, and the water temperature. For discharge measurements using the SonTek River Surveyor M9, final discharge values were determined using the River Surveyor Live software. All measurements of the River Surveyor at one cross-section were checked regarding their quality, and before calculation an average doubtful measurements were excluded from the analysis. In case of the OTT Acoustic Digital Current meter and the SonTek Flow Tracker, the Velocity-Area method was used to determine discharges. Sampling verticals were spaced 0.5 – 1m, with velocity measurements being done at 0.6 of the depth at each vertical. To determine the average discharge, the Mid-Section and Mean-Section method was used.

Measurement of the cross-sections were carried out using the real-time kinematic global navigation satellite positioning system EMLID Reach RS/RS+ (Emlid, 2019). The first receiver was installed on a fixed tripod as the base station, and a second receiver was used as a mobile rover to determine the locations and elevations of the cross-section points. The receivers were used in differential mode to correct the cross-section point positions relative to the base station and to obtain centimetre accuracy.

In order to reconstruct the historical flow regime, data regionalization method was used because of limited availability of long term meteorological data for the sites. This is the process of using known hydrologic characteristics (catchment size, areal rainfall, evaporation) of a particular catchment/ hydrological unit to calculate similar variables in an area with no/ insufficient data. See Section 3.3 for details.

Hydraulics

The aim of the hydraulic assessment is to extrapolate and translate flows into stage and velocity data for the various sites. This is a crucial link between the hydrology/water allocation and hydraulic habitat/ channel maintenance.

A single transect for hydraulic observations and modelling was selected per site based on its importance as critical habitat for organisms and sensitivity to low flows. Transects were then marked and 50m tape measures or ropes were used to guide surveying. Data gathering involved surveying the topographic data along the transect (perpendicular to flow); survey of water levels and measurement of depth and velocity along each transect.

Land based surveying was done with survey grade equipment (Topcon Total Station or EMLID Differential GPS). For sites with deeper water with potential wildlife dangers, a SonTek River Surveyor M9/S5 using acoustic Doppler technology was used to determine depth and velocity at a large number (>100) of verticals along each transect. For very shallow depths where the River Surveyor could not capture meaningful data, a handheld acoustic Doppler OTT ADC was used to capture flow velocity and depth. For measuring the discharge, the channel was divided into 20 verticals to capture depth and flow velocity data.

The observed hydraulic data were used to develop and calibrate hydraulic models using Hydrologic Engineering Centre's River Analysis System (HEC RAS) software. Frequency distributions of depth-velocity classes were calculated using Habitat Flow Simulation Software (HABFLO).

Geomorphology
The shape of the river channel results from fluvial processes of erosion, transport and deposition. Geomorphic features in the channel play a significant role in determining the availability and diversity of physical habitat and will influence the nature of the aquatic ecosystem.

Fieldwork methods included in-depth channel surveys, more general reach descriptions and broader landscape assessments. A single river cross section was surveyed per site with a Total Station or Differential GPS for terrestrial sections and a SonTek hydro surveyor for the portions of deep and fast flow (for crocodile infested water). Georeferenced land based photos were taken and sketches were made of geomorphic features and their sediment composition. Sediment from the riverbanks, inset benches and river bed were collected using a 30 mm diameter hand corer to a depth of 50 mm. Five samples were taken per feature and composited to form a representative sample. A subsample of the composite sample was used for particle sizing. Particle size was determined using a Malvern Mastersizer 3000 (for silt and clay samples), the Eijkelkamp Sand Ruler (for sand sized particles) or tape measure (for larger particles). For the larger particles, a sample of 100 randomly selected clasts were measured with a tape measure along the b-axis to determine the grain size distribution.

River reaches upstream and downstream of the cross section were explored to develop an understanding of river character, geomorphic habitat template and key sediment processes taking place. Catchment-wide landscape connectivity and erosion extent and severity was assessed visually while driving to and between sites. Satellite images in Google Earth were used to explore and qualitatively assess areas of the catchment that was difficult to access by road in the given time.

Riparian Vegetation
Riparian zones connect terrestrial and aquatic ecosystems and are important in providing food to instream organisms, soil conservation and regulating water temperature from their canopy cover among other uses. Different riparian plants are adapted to different flows and can be used to indicate high and low flows. Description of surveyed sites was made to highlight key landscape information including dominant vegetation types and site conditions e.g. highly degraded, moderately degraded, slightly degraded and not degraded. Plan view and sketches of cross sections were drawn and photographs taken at each site. Along the set transects, riparian vegetation zones and sub-zones (marginal, lower, upper) were both identified. Sub-zones were also identified because species composition and distribution differ in different sub-zones with implications on flow requirements and flow related impacts. Other zones were floodplain and macro-channel bank. All encountered plants were recorded and subsequently identified i.e. family, genus and species in the field (whenever possible) and confirmed at the National Herbarium of Tanzania in Arusha where all voucher specimens are deposited. Estimation of aerial cover (in percent) was done using visual observation. Information on extent, period and duration of inundation was collected through interviews.

Fish
Fish can be used to reflect the combined effects of environmental changes that have happened and can be used to reflect the environmental health of the river. The presence of a large diversity of fish species and abundance can help in understanding the functioning of a river. Knowledge of the conditions needed by fish for spawning, hatching, growth etc. can be used as a guide for recommending flow requirements. Fish species were sampled to represent the species composition and proportional abundance of the assemblage for each site. Fish were primarily sampled by electrofishing different Geomorphic Habitat Units (GHU). Cast netting, fyke nets and seine netting were also undertaken in suitable GHUs, with species diversity and abundances recorded for respective efforts. The catches of local fishermen were also considered for the study, but only for the Mara Wetland system. Fish were identified in the field, photographed, measured (standard length) and released back into the respective systems.

The Habitat Cover Rating (HCR) method described by Kleynhans, 1999 was adapted and implemented for the study to characterize habitat for each survey site. The HCR was calculated according to the rating of the relative contribution of various velocity-depth classes, where 1 = Rare/poor (<5 percent), 2 = Sparse/poor (5-25 percent), 3 = Moderate (25-75 percent), and 4 = Extensive (>75 percent). An overview of the velocity depth classes described by the HCR approach is presented in Table 3 6.

Cover features are rated within each depth-flow class using the same scale in order to calculate the HCR. The cover features were summed for each of the depth-flow classes. The HCR at each site was then calculated based on the contribution of each depth-flow class multiplied by the summed cover feature ratings for each depth-flow class. To complete linear redundancy analysis and to determine the relationships between habitat ratings and fish species

Acronym	Velocity-depth Class
SS	Slow (<0.3m/s) Shallow (<0.5m)
SD	Slow (<0.3 m/s) Deep (>0.5m)
FD	Fast (>0.3m/s) Deep (>0.5m)
FS	Fast (>0.3m/s) Shallow (<0.5m)

TABLE 3 6: THE HCR CLASSIFICATIONS FOR RESPECTIVE FLOW VELOCITY AND RECORDED DEPTHS

Canoco version 4.5 (Braak and Smilauer, 2002) was used. Species abundance was assessed against depth class and cover feature ratings.

Macroinvertebrates

Macroinvertebrates are good indicators of the ecological health of the river because of their sensitivity to river flow alterations and water quality. Therefore their variation in terms of numbers and species occurrences can be used to explain the biological and/or ecological changes in the river ecosystem.

During field sampling, a modified kick net with a mesh size of 1,000 µm was used to sample the macroinvertebrates within a prescribed time limit and/or areal coverage. The stones-inside-current and bedrock was searched ('kicked') for a period of 2 to 5 minutes. Similarly, stones-out-of-current and bedrock were searched for 1 minute.

The SIC and SOOC samples were combined into a 'Stones' sample. Suitable stretches covering two meter marginal vegetation was swept as well as aquatic vegetation covering one square meter. This represented the 'Vegetation' sample. Gravel, sand and mud sample was stirred and swept for one minute and filtered to check for presence of any macro-invertebrates. Hand picking and visual observation was also employed for 1 minute and biotopes where macro-invertebrates were found recorded in a score sheet. Loose stones were picked and screened for the presence of benthos. The South African sensitivity score (SASS) and the average score per taxon (ASPT) were also used to characterize macroinvertebrates at each site. In addition to the invertebrate sample, water depth and substrate type data were collected for each habitat. All samples from the three habitats were preserved in formalin in separate containers and taken to the laboratory for further processing and enumeration of abundances of the various taxa. These data were particularly useful for statistical analyses to determine the preferences of the various taxa in terms of flow velocity, depth and substrate type. The South African Scoring System version 5 (SASS5), and the Tanzania River Scoring System (TARISS) biotic indices were used for the assessment of the present ecological status of the sampled sites. The EPT index was also applied, which compares the amount of specific taxa sensitive to water quality (Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies)) to the total number of taxa found.

Water Quality

Water quality refers to the physical, biological and chemical characteristics of a water body that determines its suitability for domestic as well as ecological purposes. There are no water quality requirements for ecosystems in Tanzania, and as such, there will be no comparisons made between the field results and any water quality standards. There, however, related national standards, international guidelines, and general ecological requirements that help to put the water quality field results into context.

The Tanzanian National Bureau of Standards developed national standards for drinking water from public water supplies (Table 3 7) and for wastewater discharge from municipal and industrial sources (Table 3 8), which may provide some reference for values obtained in the field. These should not be taken as standards that the water quality measurements in the field should adhere to since these values were developed for water that has undergone human

Group	No. Substance	Unit	Lower Limit	Upper Limit
Affecting human health	Fluoride	mg/L	1.5	4.0
	Nitrate	mg/L	10	75
Organoleptic	Colour	TCU	1.5	50
	Turbidity	NTU	5	25
Salinity and Hardness	pH	-	6.5	9.2
	Total Hardness ($CaCO_3$)	mg/L	500	600
Organic pollution of Natural Origin	Ammonium (NH_3 + NH_4)	mg/L	2	2
	Total Nitrogen (excluding NO_3)	mg/L	1	1
Toxic	Arsenic	mg/L	-	0.05
	Cyanide	mg/L	-	0.20
	Mercury	mg/L	-	0.001

TABLE 3 7: SELECTED PARAMETERS FOR TANZANIA DRINKING WATER STANDARDS

Parameter	Limit	Test Method
Color	300 NTU	ISO 7887: 1994, Water quality examination and determination of colour. Section 3: Determination of true colour using optical instruments
pH range	6.5 – 8.5	EMDCI 1173: Part 2- Electrometric method
Temperature range	20 – 35 °C	
Total suspended solids (TSS)	100 mg/L	EMDCI 1173: Part 1- Gravimetric method
Turbidity	300 NTU	APHA Standard Methods: 2130 B. Nephelometric method
Nitrates (NO_3-)	20	APHA Standard Methods: 4110 B. Ion Chromatography with Chemical Suppression of Eluant Conductivity
Total Kjedahl nitrogen (as N)	15	EMDCI 1173: Part 5- Kjedahl Method

TABLE 3 8: SELECTED PARAMETERS FOR TANZANIA MUNICIPAL AND INDUSTRIAL WASTEWATERS

treatment and were not developed for natural conditions.

The United Nations Environment Programme and the United Nations University Institute for Environment and Human Security also developed a policy-driven process on how countries can develop their own water quality guidelines for ecosystems (UNEP/UNU-EHS, 2016). The intent of this document is that it provides a framework for countries to develop their own water quality guidelines for ecosystems, but it does provide physico-chemical benchmarks that would be considered at both ends of the ecosystem condition spectrum ("high integrity" and "extreme impairment", Table 3 9). The recommendation is that spectrum be separated into four categories, with category 1 being the highest integrity and category 4 being the lowest. These benchmarks are just examples and do not explicitly apply to Tanzania since the intent is that Tanzanian government would develop their own benchmarks that are more representative and suitable to conditions in the country.

Fish and macroinvertebrates have varying degree of tolerance and are therefore considered as good bioindicators of water quality. Whereas macroinvertebrates are normally used for short term indication of water quality, fishes can be used to show the long term variation of the same. The physicochemical properties of water affects not only the health of aquatic ecosystems but also its functioning. Most specifically, pH levels, temperature, dissolved oxygen, specific conductivity, nutrients and

Stressor	High Integrity [1] (Category 1)	Extreme Impairment (Category 4)
Dissolved oxygen saturation (%)	80 – 120	< 30 or > 150
Dissolved oxygen concentration (mg/l)	7.3 – 10.9 [2]	3 or > 13.6 [2,3]
(optional) BOD_5 (mg/l)	-	> 10
Total phosphorus (µg/l)		
- Lakes and reservoirs	< 10	> 125
- Rivers and stream	< 20	> 190
Total nitrogen (µg/l)		
- Lakes and reservoirs	< 500	> 2500
- Rivers and stream	< 700	> 2500
Chlorophyll a (µg/l)		
- Lakes and reservoirs	< 3.0	> 165
- Rivers and stream	< 5.0	> 125
pH	6.5 – 9.0	< 5
Temperature	No deviation from background value or reference systems or optimum temperature ranges of relevant species	Large deviations from background value or the thermal tolerance range for characteristic species
Un-ionized ammonia (µg NH_3/l)	15 [5]	100 [5]
Aluminium (µg/l)		
- pH < 6.5	5	-
- pH > 6.5	10	100
Arsenic (µg/l)	10	150
Cadmium (µg/l) [4]	0.08	1.0
Chromium (µg/l) [4]		
- Cr III	10	75
- Cr VI	1	40
Copper (µg/l) [4]	1	2.5
Lead (µg/l) [4]	2	5
Mercury (µg/l) [4]	0.05	1.0
Nickel (µg/l) [4]	20	50
Zinc (µg/l) [4]	8	50

Annual average total concentrations, unless indicated otherwise

[1] Natural sources and geographical conditions may cause natural background values that differ from the benchmarks for high integrity. Instead of these benchmark values natural background concentrations may be used for setting criteria for high integrity.

[2] Dissolved oxygen concentration varies depending on temperature, pressure and salinity; benchmarks are for freshwater at sea level (760 mmHg) and 20°C based on the DO%.

[3] Daily average.

[4]. Applicable for waters with low hardness (< 60 mg/l $CaCO_3$). In case of higher hardness, the benchmark values may be somewhat higher.

[5] Corresponding total ammonia (NH_3 + NH_4^+) concentration depends on pH and temperature. At pH 7.5 and 20°C, the benchmarks for total ammonia N are 1000 µg/l and 6641 µg/l, respectively.

TABLE 3 9: EXAMPLE PHYSICO-CHEMICAL BENCHMARKS FOR FRESHWATER ECOSYSTEMS (UNEP/UNU-EHS, 2016)

discharge are the main parameters that have a strong effect on the health of aquatic environment (Boney, 1989).
According to studies, low pH and dissolved oxygen levels (Dallas, 2008), high temperatures (Hayes and Young, 2001), increased sedimentation (Koehn, O'Connor and Research, 1990) and decreased flows are some of the changes that may negatively affect the abundance, population, distribution and diversity of aquatic biota. While some aquatic organisms are adapted to specific conditions of the water and a variation may alter how they function (Jackson, 1997), others are able to adapt to the changes over time. For example, macroinvertebrates such as Ephemeroptera (Mayflies) and Trichoptera (caddisflies) are intolerant to low DO while Mollusca (molluscs) and Chironomidae are quite tolerant to low levels of DO (Connolly, Crossland and Pearson, 2004).

For the functioning of the aquatic organisms, an optimal level of the chemical parameters has to be maintained. For example, according to studies conducted by (Camargo, Alonso and De La Puente, 2004), 2 mg/L of nitrate nitrogen is ideal to ensure the conservation of the most sensitive freshwater species. Dissolved oxygen level ranging between 4-6 mg/L and BOD levels > 5 mg/L (Bora and Goswami, 2017) are necessary for creating an ideal environment for aquatic microorganisms. Water quality involved in-situ measurements as well as sample collection for lab analysis. Parameters measured on site included:

- System variables: pH, temperature and dissolved oxygen (DO) measured using the WTW HACH meters.
- Non-toxic constituents: Electrical conductivity (EC) using a WTW meter and turbidity measured with a clarity tube
- Nutrients: Nitrates (NO_3^-), nitrites (NO_2^-) using the nitrate strip

The laboratory samples were collected in 2 * 25 ml plastic bottles after filtering using a 0.45 micron filter except the sample for Total Arsenic which was unfiltered. Samples collected for laboratory measurement included Ammonium (NH_4^+), total organic carbon and total nitrogen. For the total organic carbon, NH_4^+, and total nitrogen samples, preservation was done using two drops of 0.2M sulphuric acid while for Arsenic, Nitric acid was used. These were analysed at the laboratory at IHE Delft following standardized laboratory procedures.

3.6.2 EFA Study Sites and Field Campaigns

To identify the key linkages between flow, ecology, and ecosystem services, two biophysical and one social field campaigns were completed. Study sites were planned to align with the RUs developed during the RQO process, with two villages selected within each RU for the social survey and one biophysical site selected within each RU (Upper and Lower Tigithe RUs share one biophysical site). Figure 3 9 provides a map of the study sites and RUs and Table 3 10 assigns an EFA study site name (which will be used in the remainder of this document) and shows how the different study sites correspond geographically to each other. The details of each field campaign are

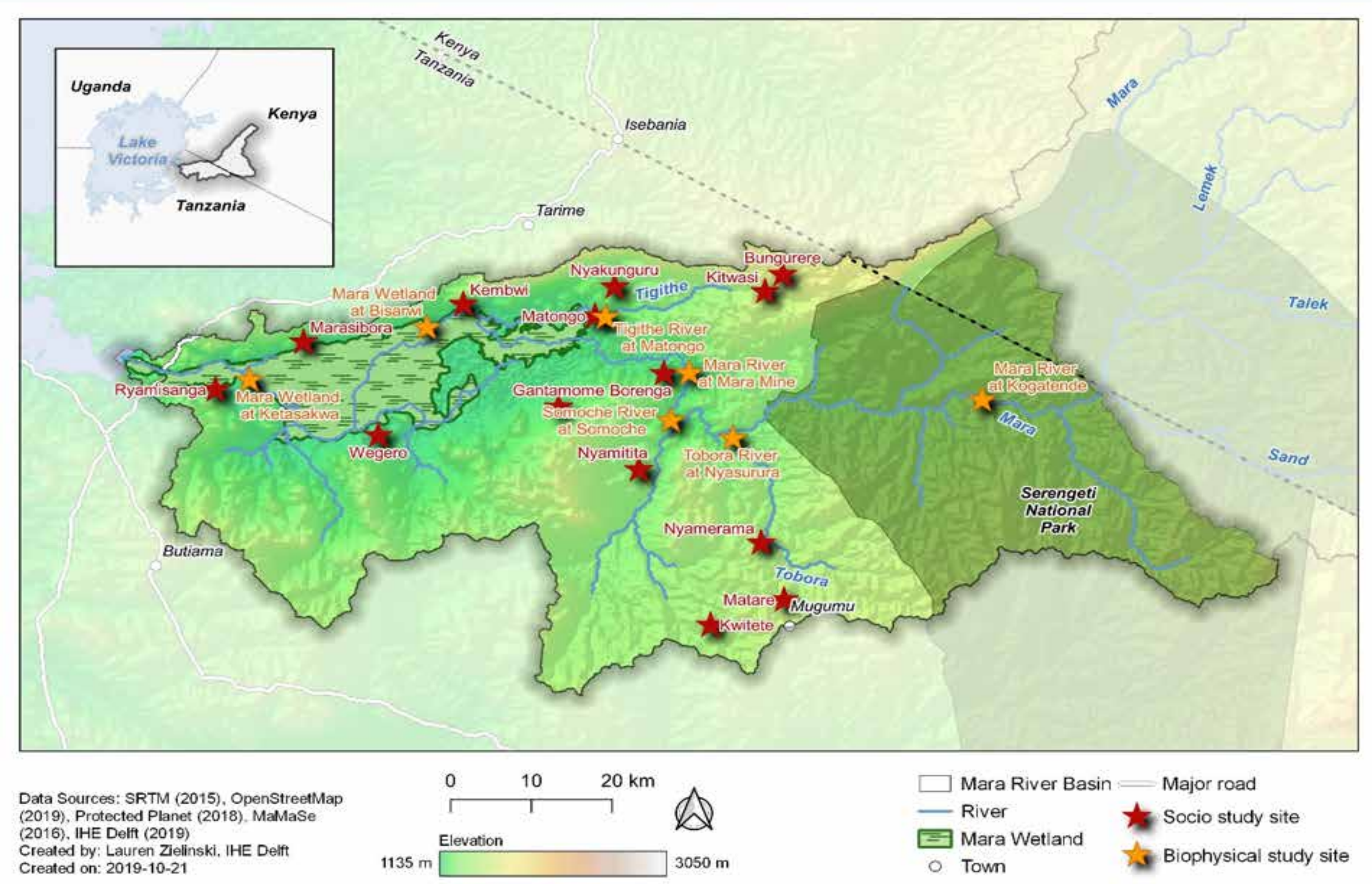


FIGURE 3 9: MAP OF THE STUDY SITES FOR THE SOCIAL SURVEY, BIOPHYSICAL FIELD CAMPAIGNS, AND RUS

EFA Study Site	RQO RU	Social	Biophysical
Kogatende	Serengeti	*None*	Mara River at Kogatende
Tobora	Tobora	Matare, Nyamerama	Tobora River at Nyasurura
Somoche	Somoche	Kwitete, Nyamatita	Somoche at Somoche
Tigithe	Upper Tigithe	Bungurere, Kitawasi	Tigithe River at Matongo
	Lower Tigithe	Matongo, Nyakunguru	
Mara Mines	*None*	Borenga, Gantamome	Mara River at Mara Mines
Bisarwi	North Mara	Kembwi, Marasibora	Mara Wetland at Bisarwi
Mara Wetland	South Mara	Ryamisanga, Wegero	Mara Wetland at Ketasakwa

TABLE 3 10: LIST OF THE CORRESPONDING EFA STUDY SITE NAMES AND RUS

provided in the sections below.

Social Survey

The survey was conducted in seven centers which had been selected prior to the actual day of data collection. The centers include Somoche, Upper Tigithe, Lower Tigithe, Mara North, Mara South, Kogatende and Tobora. From each of the seven centers, two villages were sampled hence a total of 14 villages (Figure 3 9). Selection of the villages was made based on the following considerations:

- Accessibility: Three levels were created to measure accessibility to the study villages and coded using the numbers 1 to 3. 1 represented a village that is hardly accessible, 2; fairly accessible and 3; easily accessible. The scoring values were based on the knowledge and experience of the researcher and key informant interviews. The key informants for this case were the local government officials whom the discussion was made through telephone/skype conferences.
- Diversity of economic activities: Economic activities varied slightly depending on the dominant social groups. In areas where mixed social groups were dominant, more diverse economic activities were practiced and the impact to the quality of the resource predicted, especially when there was limited control mechanism. In this case, the 1 to 3 code was also used representing villages with low, moderate and high diversity of economic activities respectively.
- Proximity to the preferred river/wetland: The location of a household with reference to the resource determines how the resource will be used. In this case, villages close to the resource was selected in some RUs while in others, the preference was for villages located far from the river/wetland.
- Population: The relationship between resource quality and population is evident, particularly in the dimensions of water quality, habitat and biota. The higher the number of water users the more likelihood the resource will be destructed. For this case, villages with high population were preferred for selection.

The total number of participants in each village was about 40 who were selected using the village register with the assistance of the village leader. The selection was random but the gender and age of the participants were taken into consideration. During the Focus Group Discussions, the participants were divided in three groups of 13 people with each group being facilitated by an expert. Each group had a different discussion theme i.e. general village profiles, social and economic issues, natural resources available and their environment, and biophysical analysis of water bodies in each surveyed village. All the information gathered was clearly written on flip charts which were dated and numbered and supported by audio recordings to enhance data transcription when reporting.

3.6.2 1st Biophysical Field Campaign

The purpose of the biophysical field campaigns was to allow the hydrological and ecology experts to collect field data from around the Lower MRB. Seven sites were considered for the biophysical assessment: three sites were selected close to the outlets of the major tributaries on the Mara River (Somoche, Tigithe and Tobora), two sites along the mainstem of the Mara River (Kogatende and Mara Mines) and two sites in the Mara Wetland (Bisarwi and Mara Wetland) (Figure 3 9). Location (latitude and longitude) and channel slope details can be found in Table 3 11 and

Site	Left Bank		Right Bank		Channel Slope
	Long.	Lat.	Long.	Lat.	
Kogatende	34.884638	-1.561636	-	-	0.0017
Tobora	34.607279	-1.608910	34.607549	-1.608837	0.0057
Somoche	34.538042	-1.587532	34.538465	-1.587567	0.011
Tigithe	34.465519	-1.460043	34.465716	-1.460152	0.0078
Mara Mines	34.558273	-1.528472	34.558719	-1.529006	0.0018
Bisarwi	34.266295	-1.472907	34.266398	-1.472549	0.0001
Mara Wetland	34.068933	-1.539057	-	-	0.000025

TABLE 3 11: LOCATION DETAILS FOR THE BIOPHYSICAL STUDY SITES

Site Name	Site and Flow Character
Kogatende	Pool-rapid and pool-riffle sequence. Range of fast turbulent shallow flow to gentle deeper flow. Higher flows are mostly fast and deep.
Tobora	Pool-riffle sequence. Range of fast turbulent shallow flow to gentle deeper flow during low flow conditions. Higher flows are mostly fast and deep.
Somoche	Pool-riffle sequence. Range of fast turbulent shallow flow to gentle deeper flow during low flow conditions. Higher flows are mostly fast and deep.
Tigithe	Pool-riffle sequence. Range of fast turbulent shallow flow to gentle deeper flow during low flow conditions. Higher flows are mostly fast and deep.
Mara Mines	Uniform square sand bed with slightly deeper sections around meander bends. A range of flow velocities with relatively low turbulence.
Bisarwi	Deep uniform V-shaped channel. A range of flow velocities with relatively low turbulence.
Mara Wetland	U shaped channel in extensive papyrus swamp. Deep water with low flow velocities in channel and stagnant water in papyrus.

TABLE 3 12: BIOPHYSICAL STUDY SITE DESCRIPTION (TRANSECT, LOCATION AND FLOW)

site descriptions in Table 3 12.

Selection of sites for the biophysical survey was based on identifying a river section that had a range of environmental conditions characteristic of the whole river section. The following factors were considered:

- Ease of accessibility to the site: Sites that could be easily accessed by vehicles were mostly preferred as this reduced the time taken to walk to the site. A lot of heavy equipment was also carried and used by the team in collecting data and therefore this minimized the need to carry them over long distances.
- Diversity of physical habitat: A good site was one that exhibited a range of diversity in terms of flow sensitive sections with pools and ripples important for aquatic and riparian species as well as for geomorphological analysis.
- A site that did not exhibit signs of being overly modified: Part of the process of selecting a suitable site involved assessing one that had minimal human interference. An overly modified river section would have a bigger effect on the number and species diversity (aquatic and riparian) that can be found and hence may not be a good representative for the river stretch.
- Proximity to an existing monitoring site: Some of the sites selected e.g. at Kogatende and Mara Mines were located close to existing flow gauging stations. This was useful because some of these stations already had some historical flow data and hence provided an opportunity to compare past and present results. The rating curves developed for these sites would also be useful for the LVBWB officers for monitoring the river levels.
- Safety factor: This was a major concern especially when sampling in the SENAPA site (Kogatende) due to the presence of hippos, crocodiles and other wild animals. As a result, it was necessary to hire armed guards to keep a watchful eye on possible dangers and warn the team whenever a wild animal was spotted nearby.
- Alignment with previous EFA sites: Out of the seven sites selected, only two sites; Kogatende and Mara Mines had previously been surveyed during the MaMaSe EFA in 2015 and also by GLOWS-FIU in 2012 (GLOWS-FIU, 2012). These two sites were therefore considered for assessment in order to allow comparison of past and current flow recommendations and also as a means of building information on the same site.

The first biophysical field campaign was conducted when the water level was at its lowest (according to basin hydrograph) and was completed from the 4th to 9th of February 2019. Final analyses of the data collected in the field were included in the individual starter documents (Annex B through Annex I).

3.6.2.3 2nd Biophysical Field Campaign

The second biophysical field campaign was intended to be completed during periods of high flow (according to the basin hydrograph). The rainy season preceding this field campaign was delayed and greatly reduced, resulting in similar conditions to first biophysical field campaign. This is not ideal since the technical team was not able to assess the conditions at higher flows, but they were able to view the system response during a prolonged low flow period, finding a surprising resilience in the system to such conditions. However, it should be noted that the previous year was exceptionally wet and there was at least one freshet that moved through the system between field campaigns.

The second field campaign was conducted from the 21st to 24th of May 2019, with data collected for discharge, hydraulics, fish and water quality. The methodologies used were the same as in the first field campaign.

3.6.3 Starter Documents

One of the critical outputs of the BBM is the development of a starter document for each specialist component. For this effort, starter documents were developed for water quality, geomorphology, fish, macroinvertebrates, riparian vegetation, and social uses. Each starter document contains information that is critical for understanding the flow-ecology-ecosystem services linkages at each site and within the system as a whole. To achieve this, each starter document follows the same structure so the information for each specialist component can be more easily combined and analysed. The structure included providing detailed site descriptions, determining a set of site metrics, deciding the important indicators and their associated management objectives, and then determining the required physical habitat conditions for their indicators (such as water depth, velocity, inundation, and/or water quality as parameters). Also important to this effort is the inclusion of confidence rankings and data gaps to show where there are data inadequacies and how these may have impacted the analysis by the technical team. Brief descriptions of each part of the structure have been included below. Summaries of the study site results are provided in Section 4-14 while the full starter documents are provided in Annex B through Annex I.

3.6.3.1 Site Descriptions

For each ecological and social component, a thorough site description was completed highlighting the unique and important aspects at each site. These site descriptions provide the foundation for the analysis completed in the starter documents, including the site metrics, indicator selection, management objectives and required conditions, which were used in setting the environmental flow values. Reviewing these site descriptions also allows individuals who have not been to the sites an opportunity to understand the conditions found during the field campaign and the information used to make the analyses.

3.6.3.2 Site Metrics

Certain aspects, or metrics, about the system were ranked by each ecological and social component (when possible) to determine the ecological status. The method used in classifying the environmental status of the sites has been adapted from the BBM manual (King, Tharme and Villiers, 2008). The objective of defining the metrics for each site is to categorize them based on how much change has happened when compared to reference/pristine conditions, how the change has occurred and what condition these sites are expected to be in the future. The metrics were arrived at by considering the following sources of information;

1. Analysis of data that were collected in the field by the team of specialist
2. Historical/past data that were collected by various organizations in the basin
3. Literature review: based on published information on similar studies carried out worldwide
4. Information gathered from the community members during field assessment and social studies

The metrics include:

Present Ecological State (PES)

This refers to the present state of the system with relative to the reference condition i.e. how much the system has changed when compared to its original state. King et al., 2008 expresses PES in classes from A through F, where A represents natural/pristine conditions, B slightly modified, C moderately modified, D high degree of modification and E and F representing a highly modified system that may not recover from any interventions.

However, the Tanzanian government has defined its own 3 classes of PES that has been used to classify the sites. To keep the process as country-specific as possible, these following classifications were used:

Quantity Class A: Near-natural: The natural flow regime is to be retained

Quantity Class B: Somewhat altered: The natural flow regime is affected by water withdrawals, impoundments and/or discharges, but the critical aspects of the flow regime are retained so that effects on the ecosystem are small.

Quantity Class C: Significantly altered: The River is affected by water withdrawals, impoundments and/or discharges to the degree that at least one aspect of the natural flow regime is altered with significant negative ecosystem effects.

The Tanzanian system of classification gives a much smaller range between classes B (somewhat altered) and C (significantly altered). It does not provide for a moderate modification with the effect that it might be difficult to classify a system which has undergone some modifications that are beyond the B classification but not as bad as class C. It might therefore be necessary to break down the class B into wider classes such as B1, B2, and B3, each representing some increased level of modification.

Trajectory of Change (ToC)

ToC defines the trend that the system is expected to take assuming no initiative is taken to improve the current/existing condition. It is based on continuation of the current management practices being carried out at a particular site. The trajectories are explained as improving, stable, or declining.

Ecological Importance and Sensitivity (EIS)

EIS expresses the importance of maintaining the diversity of the river and functioning on a local and national scale and the ability of a river system to resist disturbance or to recover from a disturbance. The present state of a river section does not necessarily influences its EIS, however, the level determined for an EIS will have a bearing on what the Ecological Management class (EMC) would be for that particular river section. EIS for the sites was is based on three classification i.e.

- High: Importance of a river in terms of biodiversity at the national scale
- Medium : Importance of a river in terms of biodiversity at the provincial scale
- Low : Rivers that do not have any uniqueness at any scale

Social Importance and Sensitivity (SIS)

Defines the social benefits/importance of the system to the inhabitants who directly depend on the river system. This considers benefits such as fishing, water, navigation, hydropower, cultural beliefs etc. The rating is given based on whether the community utilizes such benefits and not merely by its presence. For example, if a river provides fish but due to various reasons such as cultural beliefs and preferences prevents the community from eating fish, the SIS of that river may be considered low. Similarly to the ecological importance classification, SIS is rated as high, medium or low.

Ecological Management Class (EMC)

This describes the target for ecological management or the desired state for a water resources. The EMC for a resource is usually set last after PES, EIS and SIS have already been determined and cannot be set at a lower class than the PES. The EMC uses the same classification as PES outlined by King, Tharme and Villiers, 2008 but without the E-F classes which are considered unsustainable. Similarly to the PES, the EMC of the sites has been defined based on the Tanzanian classification system. EMC is linked to the RQOs and reflects the specialist team's interpretation of the narrative RQOs set by the stakeholders.

3.6.3.3 Indicators and Management Objectives

Indicators refer to the specific parameters that were used to guide the flow recommendations. This could be the most sensitive species or species whose absence or presence would indicate the state of the ecosystem, or a critical ecosystem function or habitat condition. For example this can be a type of fish or macroinvertebrate or plant that is critical to the area, or adequate flushing of sediments to provide fish spawning habitat.

These indicators were then linked to management objectives, or the conditions in which each indicator should be maintained. These are important because they synthesize the most important linkages between flow and the dependent ecology and social uses into qualitative statements. These statements can then be compared and combined with the draft RQO statements developed by stakeholders to develop final RQO statements to guide management of the natural resources.

3.6.3.4 Required Conditions

The required conditions are the physical aquatic habitat requirements necessary to maintain the functioning of the aquatic ecosystem and important social uses. This can be a requirement for flow, depth, velocity, inundation period, etc. and are driven by the indicators and management objectives. During the flow setting technical meeting, these required conditions were linked with the hydraulic model to turn depths and velocities into flow estimates which were then used to provide the final flow values for the environmental flow component of the reserve.

3.6.3.5 Confidence Rankings

Confidence rankings are used to identify how much weight each specialist has attached to the rating given for a particular site based on available information and/or expert knowledge. They can be used to identify the complexities of a particular site, limitations and/or challenges faced by the specialists in terms of data availability, technique used and timing. These are important to note since river systems are highly interconnected and complex, and the technical experts are often required to make recommendations based on their professional judgement when there aren't adequate data available.

The score for the confidence rankings is given in a five-point scale:

1. Marginal to zero confidence. There is almost no reliable supporting information available.
2. Low confidence: The information available indicates some support but may require extensive research
3. Moderate confidence: Some research may be necessary
4. High confidence: Specific issues may need research to confirm
5. Very high confidence: No more information needed.

3.6.3.6 Data Gaps

These are the unanswered questions arising out of the challenges faced when conducting the assessment. They represent missing information (which often results in a lower confidence ranking) but form the basis for future research. These data gaps inform the environmental flows monitoring plan and adaptive management so that the proper data can be collected to inform future updates to the reserve values (and also increase the confidence of the updated recommendations).

3.6.4 Flow Setting Technical Meeting

The final activity in the BBM methodology is to hold a flow setting technical meeting. The objective of this meeting is to set the environmental flow recommendations for each hydrological component, or building block, at each site. Depending on the various ecological requirements and conditions of each site, the specialists recommend different habitat requirements related to water (such as depth, velocity, and/or inundation) for different hydrological components or "building blocks" (i.e., low flow driest month, low flow wettest month and high flows, freshets and floods for the maintenance and drought years). These requirements are then linked to flow using a hydraulic model and rating curve developed for each study site. Each specialist also provides the rationale for recommending such flows and describes potential consequences of not meeting such flows. Based on the recommended flows, the hydrologist then checks the recommendations against the hydrological record and the regionalized data to assess if flows were feasible in terms of occurrences and if it is possible to achieve them (i.e., not unrealistic based on the hydrological record). From the many flow recommendations given by the individual experts, a consensus must be reached on one recommended flow for each building block at each site that meets the requirements for all the components. In the end, each site will have a monthly low flow value for one hydrological year (for both maintenance and drought years) and recommendations for freshets and floods that together form the final recommendations for the environmental flow.

The flow setting technical meeting was held from 1st July to 4th July 2019 in Musoma, Tanzania. This

[4]A maintenance year is considered a "normal" hydrological year where all aspects of ecological function should occur, while a drought year is a very low flow year where species survival is the primary function (King, Tharme and Villiers, 2008)(King, Tharme and Villiers, 2008)

meeting included the technical team, partners from the LVBWB, MoW, NBI/NELSAP, and WWF. Meeting notes from this meeting can be found in Annex J.

3.7 Reserve Setting and Monitoring

3.7.1 Reserve Values

Following the definition in the Water Resources Management Act of 2009, the reserve includes both the amount of water required for basic human needs and to protect aquatic ecosystems (environmental flows).

The flow requirements for basic human needs are calculated using the value of 25 liters/person/day and the population living in the selected planning area. For this effort, the RUs delineated in the RQO process were used as the planning areas. Population data from the 2012 national census were the latest available with the smallest unit of enumeration being at the ward level (NBS, 2012). To estimate the population living in each RU, a spatial layer with the ward population was overlaid with a spatial layer containing the boundaries of the RUs and the population in each RU was calculated using GIS (geographic information systems). These population values were then projected to the current planning year (2018 for this effort). To estimate growth the growth from 2012 to 2018, the following population project equation was used:

$$P_f=P_p*(1+i)^n$$

where Pf is the future population, Pp is the present population, i is the growth rate, and n is the number of years of growth. A growth rate for each district in the Lower MRB was provided by the 2012 Census, with values ranging from 2.2 percent to 3.5 percent and an average value of 2.5 percent (Table 2 3). Since the RUs often contain areas of multiple boundaries, the average value of 2.5 percent was used for all calculations.

As described previously in this section, the values required for environmental flows were determined using the NBI E-Flows Framework, with a modified BBM used to determine the flow-ecology-ecosystem linkages.

3.7.2 Monitoring and Adaptive Management

Monitoring and adaptive management is a critical part of effectively implementing environmental flows. Monitoring activities should gather information that answers specific management questions and also addresses data gaps that have been identified in the EFA process. The specific activities will need to be customized to the management priorities and capacity of the LVBWB, but recommendations have

been provided for monitoring activities and adaptive management cycles specific for basic human needs and environmental flows.

4.1 Kogatende

The Mara River at Kogatende site is the most upstream EFA biophysical study site, which is located within SENAPA close to the Kogatende ranger station and airstrip. It is about 20 km downstream of the Kenya/Tanzanian border. The channel is quite incised with large, vertical, exposed banks and some evidence of bank collapse. The bed level is controlled by exposed bedrock with areas of riffles, gravel bars, and sand bars. The vegetation appeared to have recruitment in marginal zone and the lower sub-zone. The surrounding landscape has a natural savannah ecosystem due to its location inside the

FIGURE 4 1: SITE PHOTOS OF KOGATENDE

national park, but there are many hippopotamuses at the site which may be impacting the water quality and embeddedness of the substrate.

4.1.1 Social Survey

Since the Kogatende sub-basin lies almost entirely within SENAPA and there are no villages present, the social survey was not conducted at this site.

4.1.2 Biophysical – Mara River at Kogatende

4.1.2.1 Hydrology

Kogatende has a contributing upstream catchment area of 8,926 km2 with a dominated land use of grass- and shrub land (Figure 4 2). Precipitation

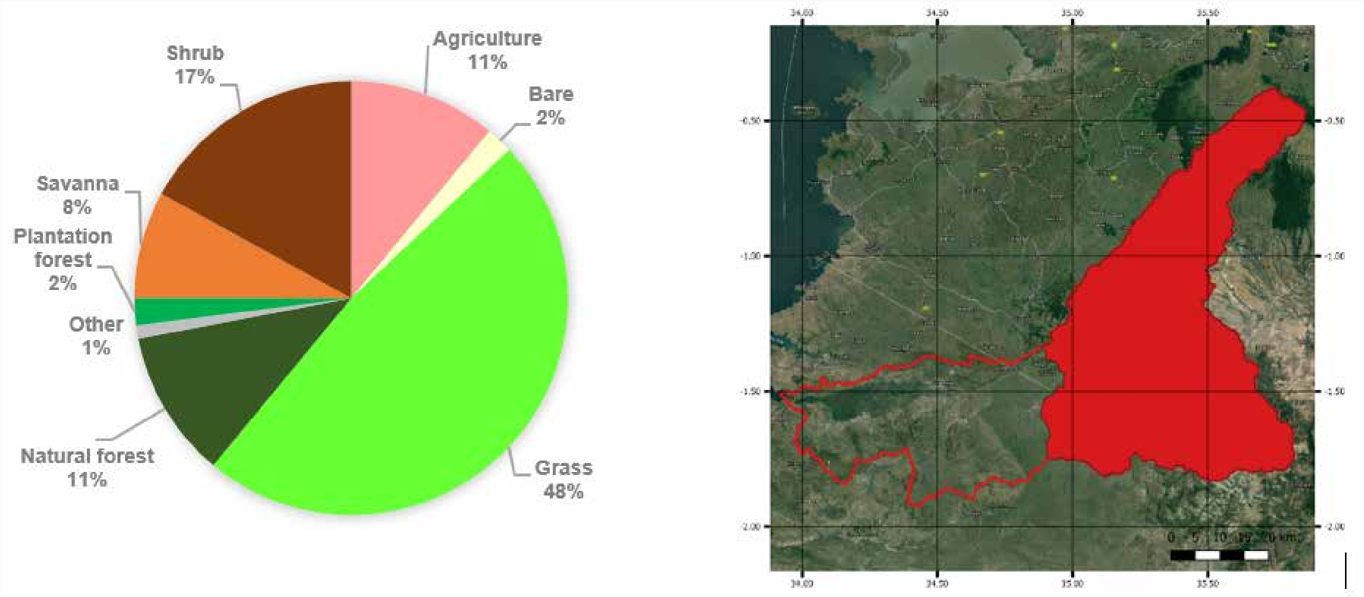


FIGURE 4 2: LAND USE WITHIN KOGATENDE SUB-CATCHMENT (LEFT) AND THE CATCHMENT AREA (RIGHT)

in the catchment sums up to 936 millimeters per annum (mm/yr), resulting in an evaporation value of 860 mm/yr, and a runoff value of 76 mm/yr.

Average monthly, minimum and maximum discharge values for Kogatende EFA site are presented in Figure 4 3. The wettest month is typically May while the driest month is October, although flows can be quite low in all months of the year depending on the rainfall patterns in the upstream portion of the basin. The graphs are generated from regionalized

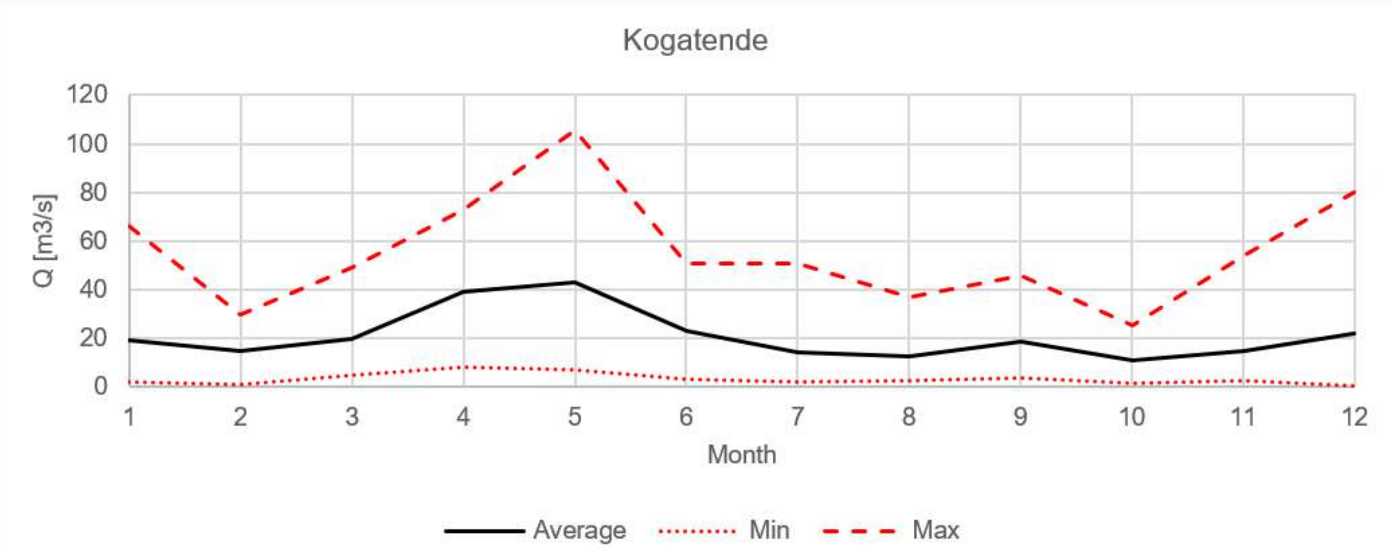


FIGURE 4 3: AVERAGE MONTHLY, MINIMUM AND MAXIMUM DISCHARGE VALUES FOR KOGATENDE data as explained in Section 3.3.1. A full analysis of the hydrological assessment can be found in Annex C.

4.1.2.2 Hydraulics

The Mara River at Kogatende is a steep bedrock controlled reach. The bedrock spurs run across the channel, forming small bedrock steps, chutes, rapids, runs, short riffles and pools. Faster flows were observed along steeper bedrock sections and riffles, with low flow velocities in pools and smaller hollows in bedrock. The channel cross sectional profile and observed flow levels are given in Figure 4 4. Observed flow velocities against depth show a poor positive relationship between depth and velocity ($R2$ =0.1). Velocity tends to increase with depth, but this is not always the case, indicating that there are areas along transects where deeper water is slow flowing or

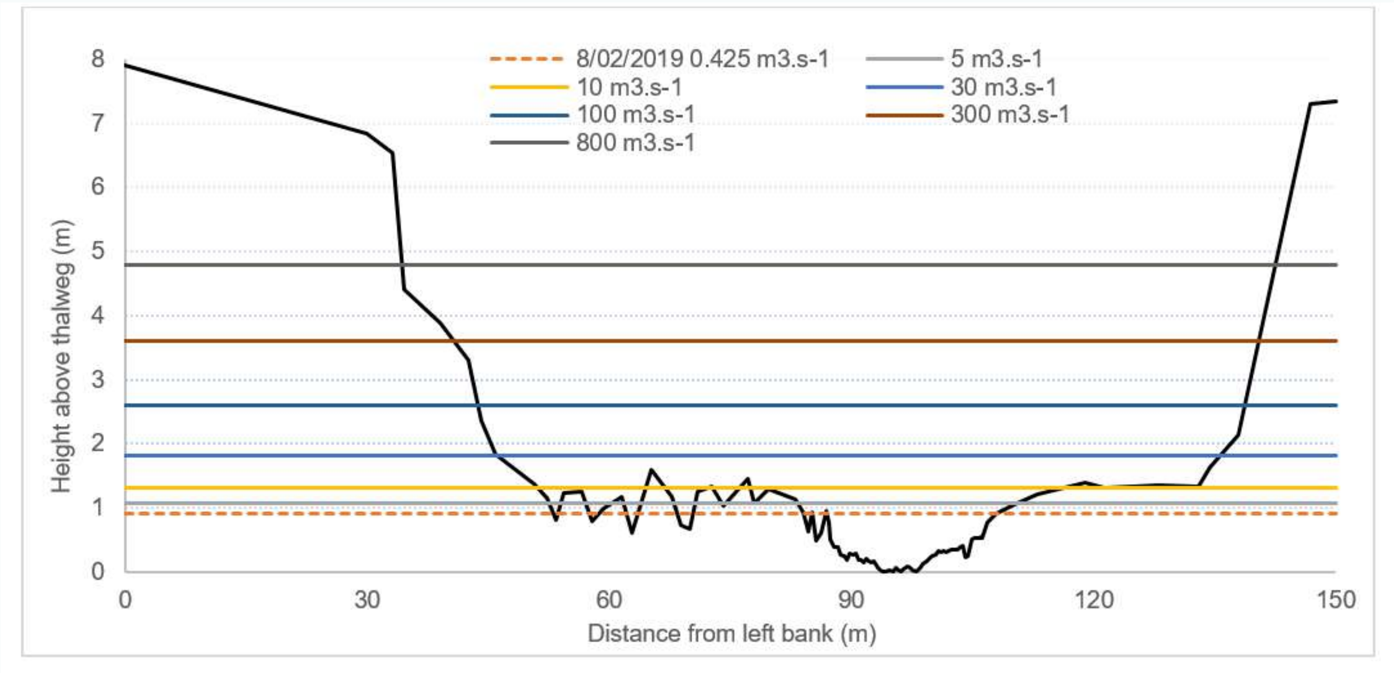
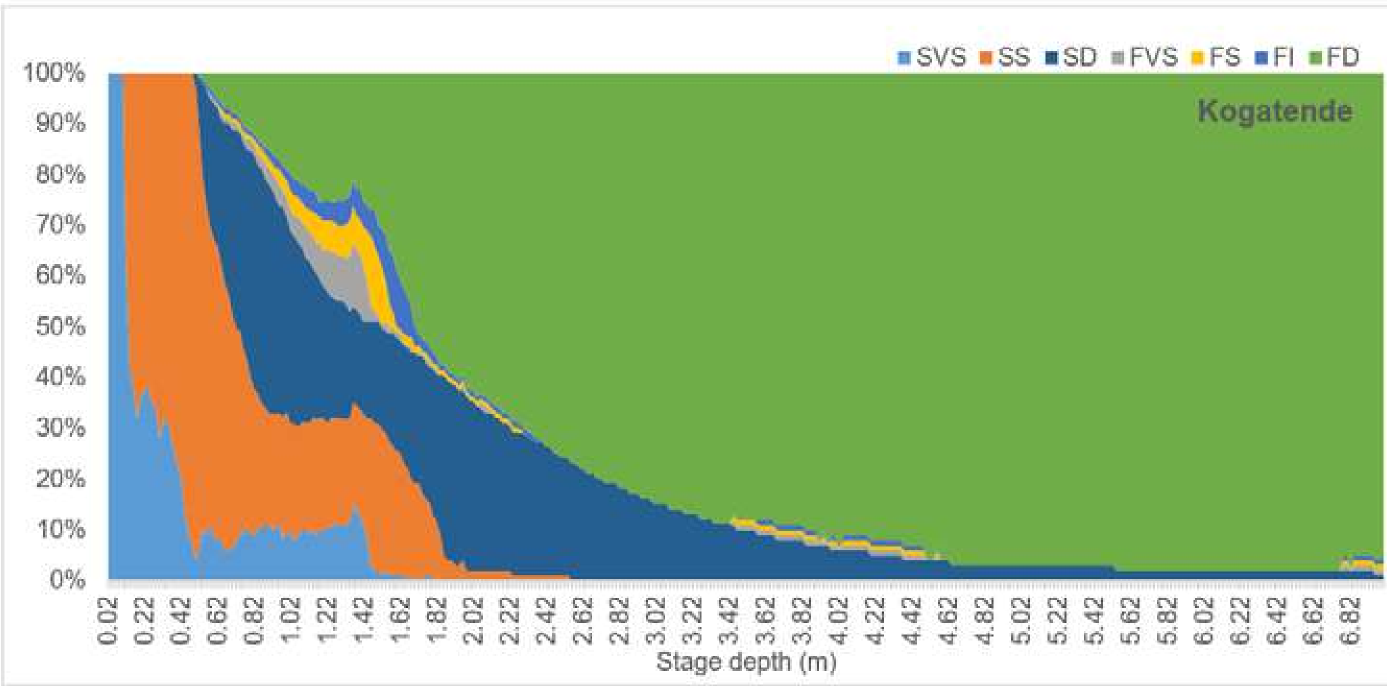


FIGURE 4 4: A SELECTION OF STAGE LEVELS FOR VARIOUS DISCHARGES AT KOGATENDE. OBSERVED DISCHARGES INDICATED BY DOTTED LINE.



SVS: slow, very shallow; SS: slow, shallow; SD: slow, deep; FVS: fast, very shallow; FS: fast, shallow; FI: fast, Intermediate; FD: fast, deep

FIGURE 4 5: FREQUENCY DISTRIBUTION OF DEPTH-VELOCITY CLASSES FOR THE WETTED CHANNEL FOR THE MARA RIVER AT KOGATENDE very shallow water is fast flowing. This shows large variability of hydraulic habitat along the transect (Figure 4 5).

4.1.2.3 Geomorphology

The river with a gradient of 0.001727 has a straight channel type with limited sediment storage along the channel margins due to its incised state (Figure 4 6). The channel is incised with high steep banks (Figure 4 7). Active bank erosion is evident along the right bank and an active flood bench has formed along the left bank. Younger trees, recent fine sand deposits and flood debris indicate flood activity at this level. A small inset bench has formed along both banks, consisting of fine sand and silt. The left side of the channel is dominated with bedrock with small pockets of mobile gravel in between the bedrock. Silt is deposited along the inset benches and on sheltered portions of the bedrock. A thick (5 cm) hippo dung layer is present on the bottom of areas with slow flow and adds a significant covering of organic material over inorganic bed material.

A large embedded gravel bar extends from the sand bar to the right bank inset bench (Figure 4 7). The sand and cobble bar is possibly a tributary bar forming downstream of the additional sediment input. The inset bench consists of silt and fine sand and is sparsely covered with sedges and forbs. The right bank is vertical and is actively eroding.

This site is fairly natural with almost no modifications caused by human activities or altered flows. The main

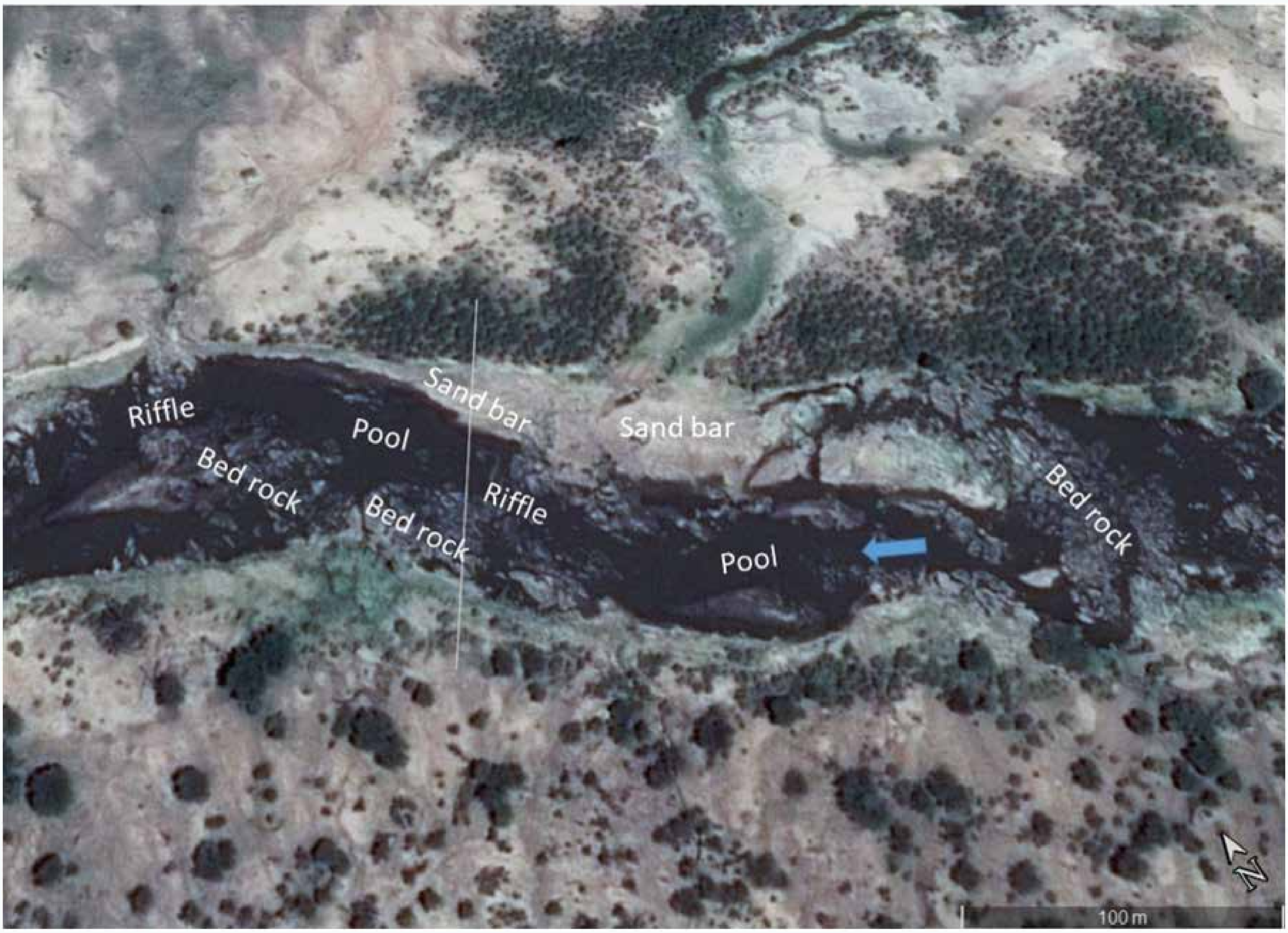


FIGURE 4 6: AERIAL VIEW OF KOGATENDE SITE SHOWING THE LOCATION OF VARIOUS GEOMORPHIC FEATURES AND THE LOCATION OF THE CROSS SECTION.

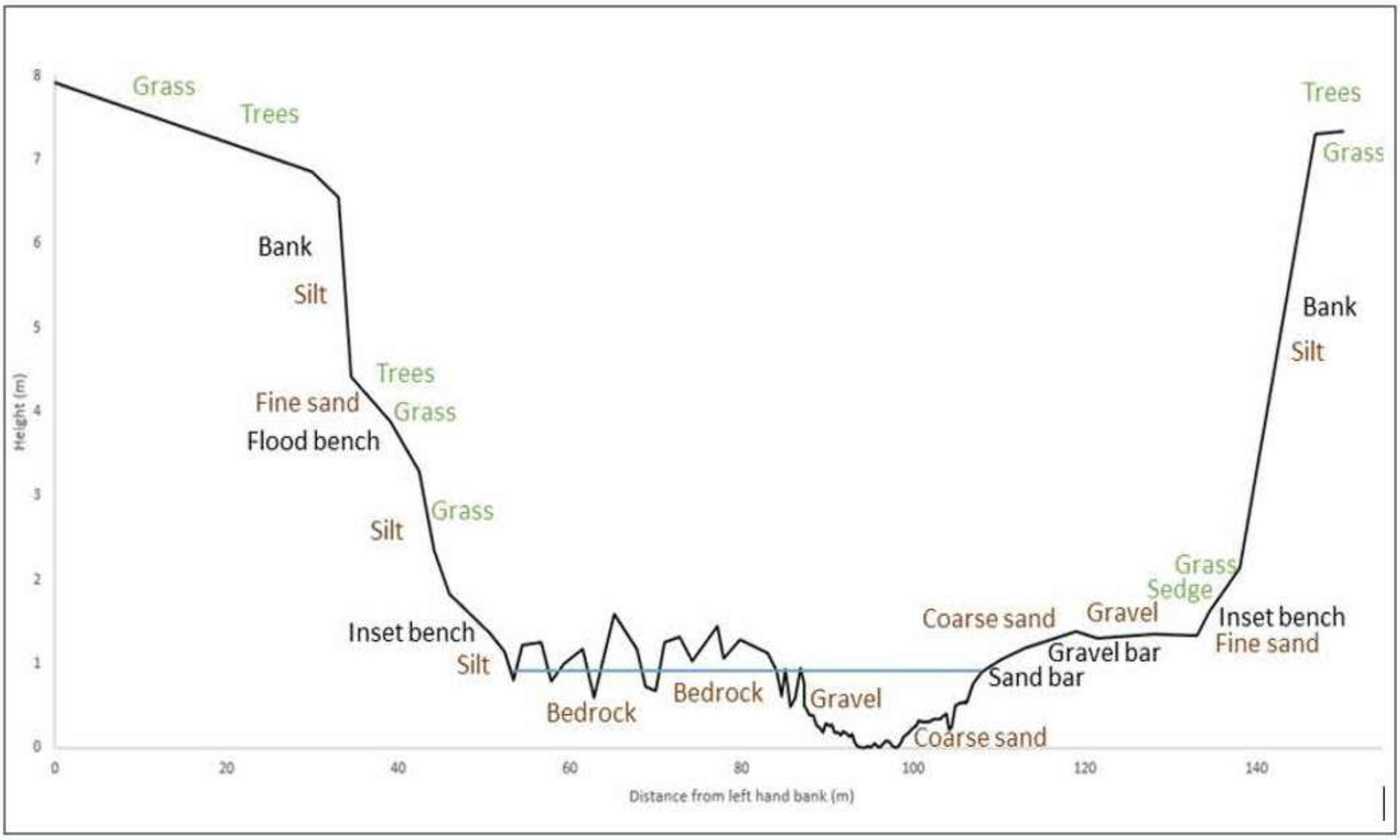


FIGURE 4 7: CROSS SECTION OF THE KOGATENDE SITE SHOWING THE GEOMORPHIC FEATURES, SEDIMENT DEPOSITION AND VEGETATION TYPES.

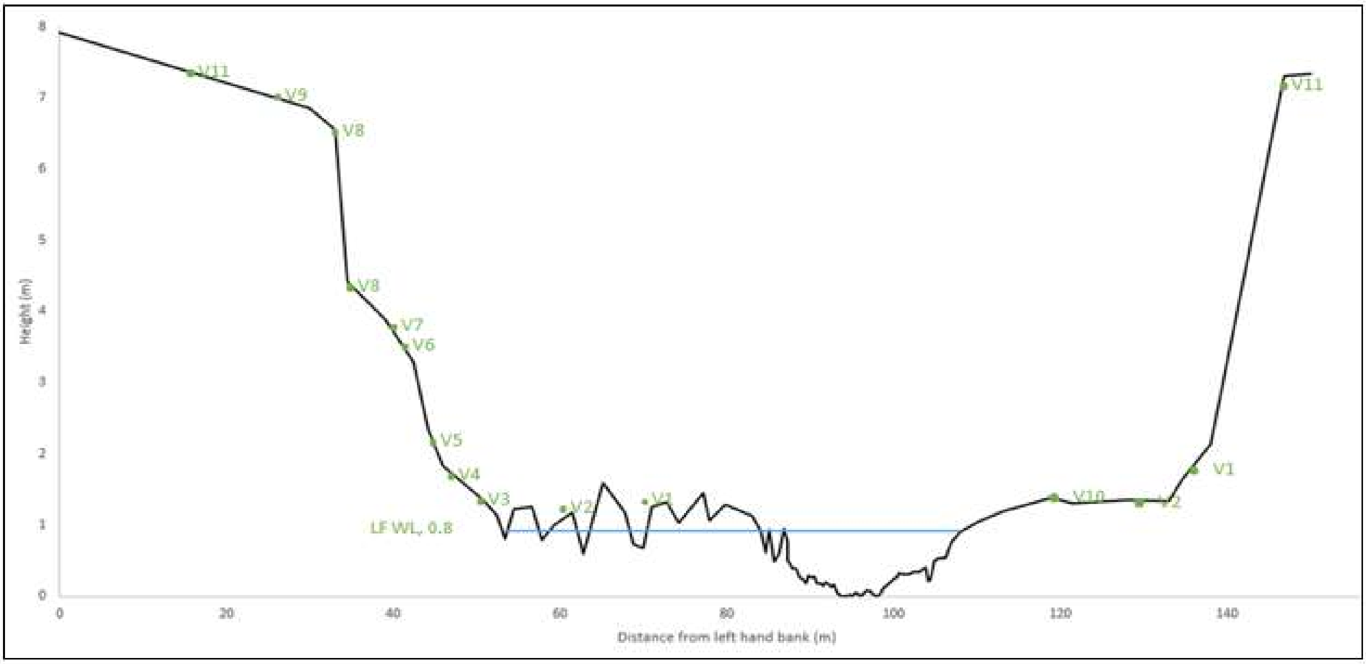
ecological factor driving vegetation in addition to flows is grazing by mega herbivores, such as hippos.

4.1.2.4 Riparian Vegetation

The left bank was more vegetated than right bank with many forbs, grasses and small Acacia trees. At the lower parts there were few plants including a mixture of grasses, sedges and forbs. These were such as Eleusine coracana, Echinochloa haploclada (grasses), Cyperus distans (sedge), and Commelina benghalensis and Sphaeranthus steetzii (forbs). The upper part was covered largely with forb species including Harpachne schimperi, Schkuhria pinnata and Parthenium hysterophorus - an invasive weed and trees like Croton dichogamous and Acacia spp. There was a flood bench (left side) which was covered with mainly grasses of Cynodon nlemfuensis and Dactyloctenium aegyptium species. The site was actively used by hippos and crocodiles at the time of field survey including using pools. Banks were covered with vegetation by almost 40 percent. Bedrock outcrops form refugia for forb and shrub species. Figure 4 8 shows the distribution of plant species along the cross section.

4.1.2.5 Fish

The Mara River at Kogatende is relatively straight with water flowing in a north-westerly direction. Two primary GHUs were identified and delineated for the site, namely a pool and a run. A total of five pools, comprising three shallow and two deep pools were sampled with an electro-fisher, all with a slow velocity (Figure 4 9). The two velocity depths classes include SD and SS. Two runs were identified and delineated, with one run being assigned a velocity depth class of fast shallow and the other run classes as slow shallow. The substrate is dominated by bedrock and boulders, with sand and gravel also present across the reach. No aquatic or marginal vegetation was present at the site, with overhanging vegetation and roots absent from the reach. There was also no evidence of undercut banks. A thick (5 cm) hippo dung layer was present on the bottom of areas with slow flow, notably the pool areas. Dung was also present in the water



Indicator Species	Number	Range	Remarks
Cyperus distans	V1	marginal	
Commelina benghalensis	V2	marginal	forb
Eleusine coracana	V4	lower	
Echinochloa haploclada	V5	lower	
Cynodon nlemfuensis	V6	floodplain	grazing resilient grass
Dactyloctenium aegyptium	V7	floodplain	
Acacia species	V8	upper	young adults
Croton dichogamous	V9	upper	mixture of young and adults
Sphaeranthus steetzii	V10	lower	
Digitaria sp.	V11	upper	grass

FIGURE 4 8: CROSS SECTION OF THE MARA RIVER AT KOGATENDE SHOWING INDICATOR PLANT SPECIES

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	25 – 75%	-	-	Sand & gravel	Tree debris	-
SD	25 – 75%	-	-	Sand & gravel	-	-
FD	5 – 25%	-	-	Bedrock	-	-
FS	5 – 25%	-	-	Bedrock & boulders	-	-

TABLE 4 1: A SUMMARY OF THE HCR FOR THE REACH WITH ASSOCIATED VELOCITY DEPTH CLASS RATINGS AND CORRESPONDING DETAILS

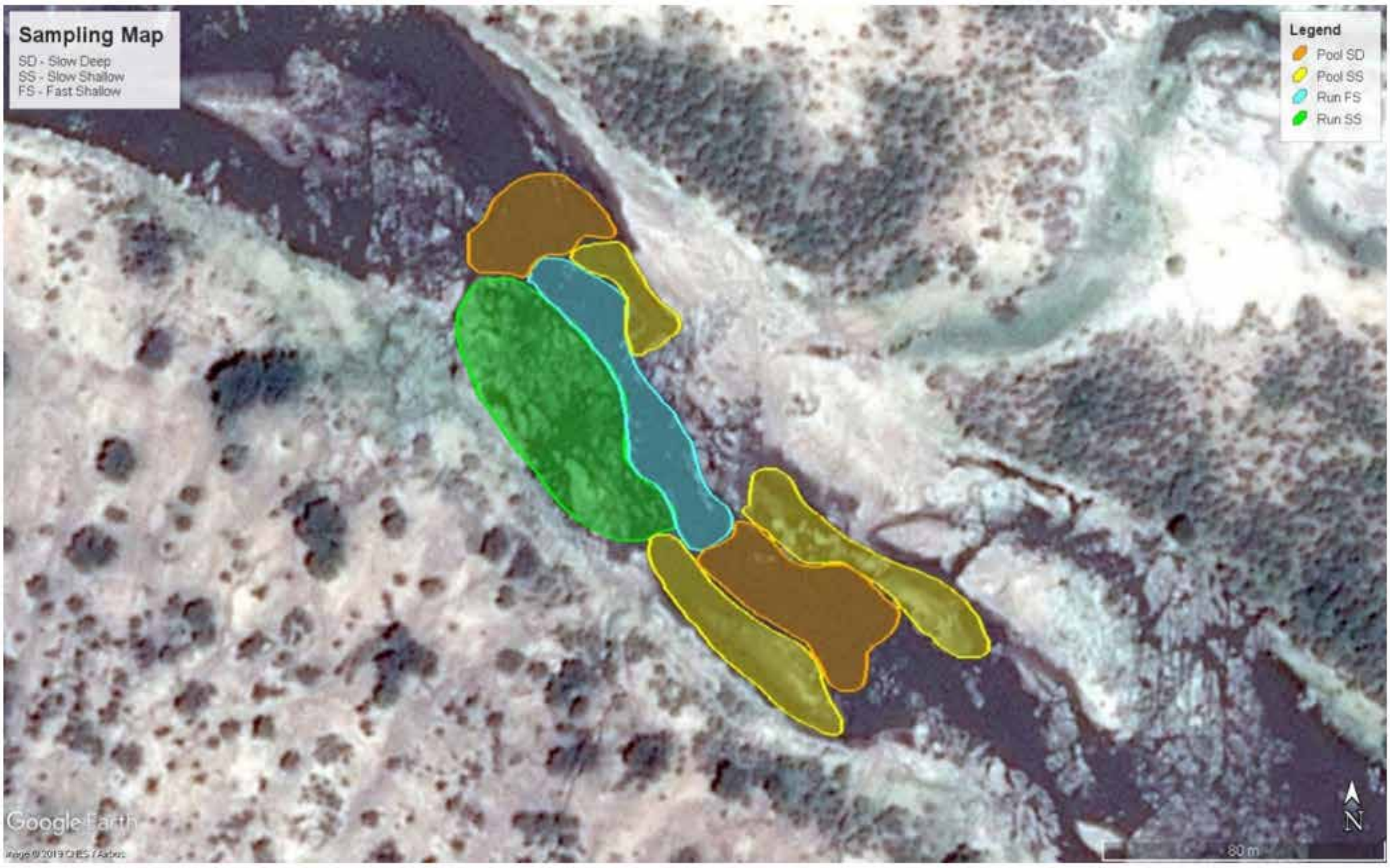


FIGURE 4 9: AERIAL VIEW OF KOGATENDE SHOWING THE DELINEATED GHUS FOR THE SITE (GOOGLE EARTH)

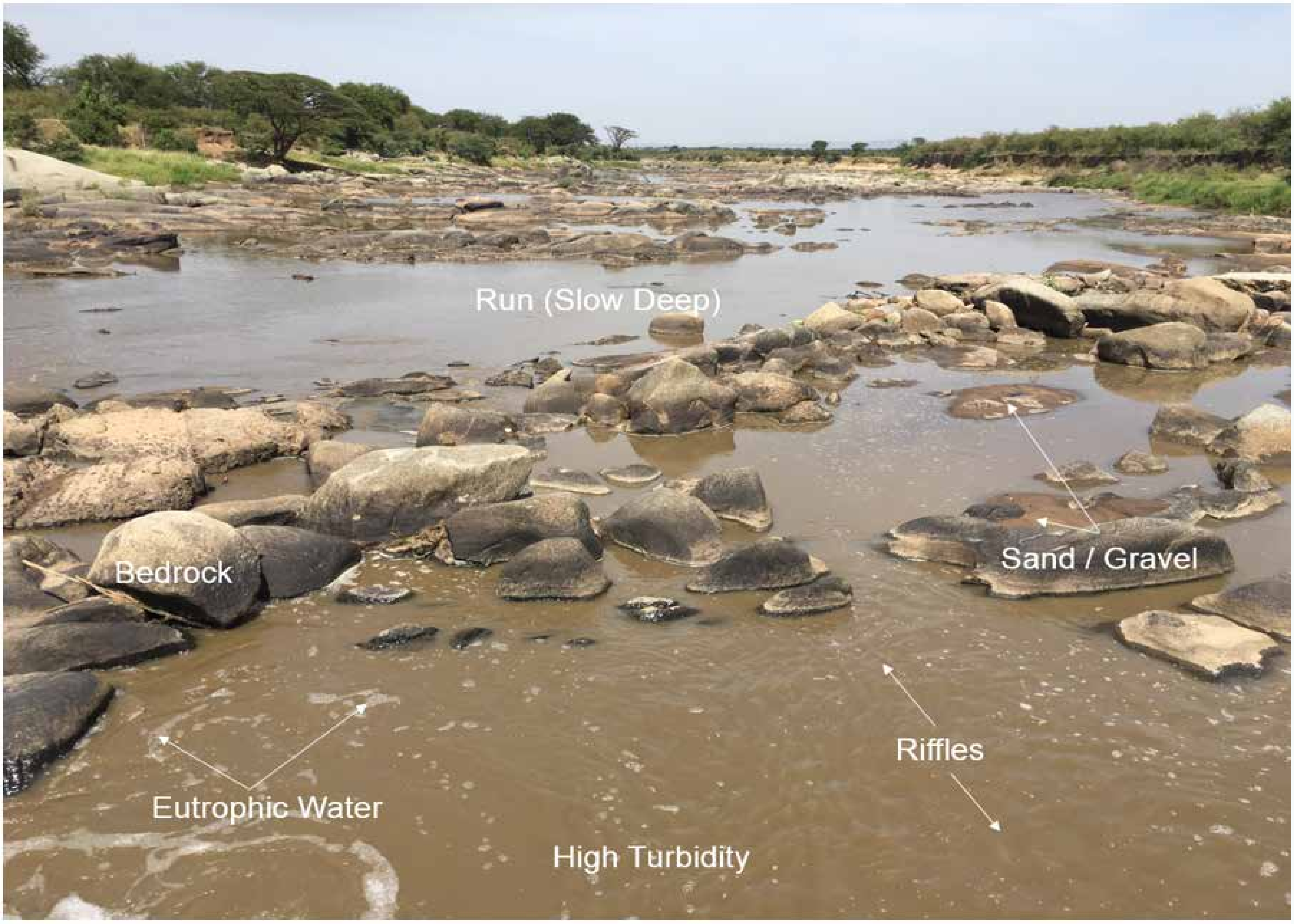


FIGURE 4 10: A PHOTOGRAPH DEPICTING HABITAT CHARACTERISTICS FOR THE KOGATENDE REACH (FEBRUARY, 2019)

column, with the eutrophic levels expected to be relatively high. An overview of the HCR ratings is presented in Table 4 1 and Figure 4 10.
A total of nine fish species were sampled from the site, with a total of 62 individuals recorded for the site. One indicator species were recorded for the site, namely Oreochromis niloticus. The species composition was dominated by Labeo sp and Enteromius sp.
Substrate was dominated by bedrock, with rocks, cobbles and gravel also recorded for the site. Habitat cover is predominantly associated with the identified substrate and water column. Bedrock was covered in silt and sand which has a negative impact on the diatom periphyton layer.
Habitat diversity was considered to be relatively high, with variable velocity-depth classes, but with limited substrate and habitat cover available.

4.1.2.6 Macroinvertebrates

Most of the macroinvertebrate taxa are moderately to highly sensitive to river flow and habitat availability (i.e. Naucoridae, Gomphidae, Lestidae, Baetidae, Caenidae, Simuliidae, Elmidae, Tricorythidae and Hydropsychidae), and some are very sensitive to poor water quality (Oligoneuridae). Table 4 2 and Table 4 3 below indicate the field processed and laboratory processed score results for the site. Despite the presence of some sensitive taxa such as Oligoneuridae, these were in low abundances and there has been

Community Metrics	Score
Total abundance	2040
No. of taxa	39
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	1080
% EPT	52.94
Number rheophilic taxa	7
Abundance of rheophilic taxa	1048
Relative abundance of rheophilic taxa	51.37
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	1037
% STH	50.83

TABLE 4 2: MACROINVERTEBRATE COMMUNITY METRICS FOR KOGATENDE

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	Number of taxa	ASPT	TARISS Score	Number of taxa	ASPT
158	29	5.4	160	29	5.5
Laboratory analysis for the SASS5 Protocol					
Total SASS Score	No. of taxa	ASPT			
207	39	5.3			

TABLE 4 3: RESULTS OF THE SASS5 AND TARISS ON PROCESSED SAMPLES AT KOGATENDE evidence of these disappearing and being replaced by tolerant taxa such as Diptera and Oligochaeta during periods of extreme low flows.

4.1.2.7 Water Quality

Turbidity and conductivity were quite high at this site but the temperature and pH were within the limits set by the Tanzania Bureau of Standards for drinking water. Conductivity increases with increase in temperature. This is because with increase in temperature, more water evaporates from the surface of the river leaving behind salts which contributes to high conductivity. The high conductivity could also be a factor of hippo dung which would also influence the turbidity of the water.

According to Subalusky et al., 2018, organic matter from hippos increase the nutrient loading in rivers which could result in low oxygen. As a result of the hippo influence, highest level of organic matter was recorded at this site in comparison to the other sites during the 1st survey. However, no detectable levels of nitrate was measured. This could have been due to nitrate denitrification resulting from the low oxygen levels in the pools. Table 4 4 shows the field

Parameter	Unit	1st survey	2nd survey
pH	(-)	7.5	ns
Electrical conductivity (EC)	µs/cm	555	ns
Temperature (T)	deg C	27.4	ns
Dissolved oxygen (DO)	mg/L	3.71	ns
Oxygen saturation	%	56.2	ns
Turbidity	TU	500	ns
Nitrate (NO_3^-)	mg/L	0	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	244	ns
Ammonium (NH_4^+)	mg/L	0.88	ns
Non purgeable organic carbon (NPOC)	mg/L	20.4	ns
Total nitrogen (TN)	mg/L	3.4	ns

ns: not sampled

TABLE 4 4: RESULTS OF WATER QUALITY ANALYSIS AT KOGATENDE

Metric	Social	Geomorph.	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	A	B/C	A	C	B	B
ToC	Stable	Stable/ declining	Stable	Stable	Declining	Stable
EIS	High	Medium	High	High	High	High
SIS	High	-	-	Moderate	Medium	Low
EMC	A	B	A	B	B	B

TABLE 4 5: SITE METRICS FOR KOGATENDE

measurements and laboratory results for water

TABLE 4 6: INDICATORS AND MANAGEMENT OBJECTIVES FOR KOGATENDE

EFA Component	Indicator	Management Objective(s)
Social	Site not included in the social assessment	
Geomorphology	Pool depth	Maintain deep (>1 m) pools
	Available gravel and cobble habitat	Scour sand and hippo dung from gravel habitat
Riparian Vegetation	Grass and sedge communities	Continue to maintain abundances of flow sensitive grass and sedge species (e.g. *Echinochloa haploclada* and *Cyperus distans*) at slightly modified conditions
		Continue to maintain abundances of moderately flow sensitive plant species including *Commelina benghalensis* and *Sphaeranthus steetzii*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
	E. haploclada, *C. distans*	Continued presence and occurrence of seedlings and adults of *E. haploclada*, *C. distans* and *C. benghalensis* and the three should together be present at abundance of ≥15 percent as in natural conditions
Fish	Recruitment of indicator cyprinids spp.	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
	Occurrence of indicator species	Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site.
	Fish community wellbeing assessment	If either of the two previous indicators are not observed a fish community wellbeing assessment should be undertaken
Invertebrates	SASS5 or TARISS Index	SASS5 or TARISS Index score >200 and Avg. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
	Ephemeroptera, *Plecoptera*, and *Trichoptera* orders	The following orders should be present in abundances >50 percent of the invertebrate community
	Hydropsychidae, *Simuliidae*, and *Tricorythidae* families	The following flow sensitive families should be present in abundances >30 percent of the invertebrate community
	Target species: *Oligoneuridae sp.*	This family is among the most sensitive taxa of macroinvertebrates that should be present at the site as a sign of good water and habitat conditions (no sedimentation)
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates and riparian vegetation
		Ensure the water quality is within acceptable limits for use by wildlife

quality samples taken at the site.

Table 4 7: Required flow conditions for Kogatende

Hydrological Component		Social	Geomorphology	Riparian Vegetation	Fish	Macroinvertebrates
Maintenance Year	Low flows, driest month	NA	None	Month: October Depth (m): 1.2 Velocity (m/s): 0.21 Flow (m^3/s): 5.2	Month: Feb, Aug, Oct Depth (m): 1.08 (0.53 avg) Velocity (m/s): 0.11 Flow (m^3/s): 2.4	Month: Feb, Oct Depth (m): 0.53 Velocity (m/s): 0.11 (98% velocity 0.41) Flow (m^3/s): 2.3
	Low flows, wettest month	NA	Depth (m): 2.3-2.8 Inundation: peak over 3 days every year in the wet season Flow (m^3/s): 162	Depth (m): 1.7 Velocity (m/s): 0.48 Flow (m^3/s): 30.3	Month: Jan, Mar, Apr-Jul, Sep, Nov- Dec Depth (m): 1.38 (0.45 avg) Velocity (m/s): 0.32 Inundation: >30 days Flow (m^3/s): 12	Depth (m): 0.58 Velocity (m/s): 0.4 (98% velocity 1.27 m/s) Flow (m^3/s): 19.9
	High flows, freshets and/or floods	NA	**Freshets** Depth (m): 1.7 Inundation: average over 2 days 4 times per year in the wet season Flow (m^3/s): 30 **Floods** Depth (m): 4.5 Inundation: peak over 3 days every 1 in 5 to 1 in 10 years. Flow (m^3/s): 580	Month: May Depth (m): 3.2 Velocity (m/s): 1.16 Inundation: 1-2 days Flow (m^3/s): 236.5	Month: Apr, May Depth (m): 1.9 (0.95 avg) Velocity (m/s): 0.6 Inundation: >21 days Flow (m^3/s): 52	**Freshets** Month: Apr-June, Oct, Nov, Dec Depth (m): 0.7 Velocity (m/s): 0.48 Flow (m^3/s): 30.3 **Annual Flood** Depth (m): 1 Velocity (m/s): 0.62 Flow (m^3/s): 50 (Annual flood, April –May)
Drought Year	Low flows, driest month	NA	None	Month: October Depth (m): 0.7 Velocity (m/s): 0.02 Flow (m^3/s): 0.193	Month: Feb, Aug, Oct Depth (m): 1 (0.52 avg) Velocity (m/s): 0.22 Inundation: Not less than 10 days Flow (m^3/s): 1	Month: Feb, Oct Depth (m): 0.53 Velocity (m/s): 0.09 (98% velocity 0.32) Flow (m^3/s): 1.6
	Low flows, wettest month	NA	**Freshets** Depth (m): 1.7 Inundation: 2 days average, 3 times per year Flow (m^3/s): 30	Month: July Depth (m): 1.4 Velocity (m/s): 1.43 Inundation: 1 day Flow (m^3/s): 12.7	Month: Jan, Mar- Jul, Sept, Nov-Dec Depth (m): 1.28 (0.51 avg) Velocity (m/s): 0.26 Inundation: >30 days Flow (m^3/s): 7.8	Month: Apr-May Depth (m): 0.53 Velocity (m/s): 0.19 (98% velocity 0.65) Flow (m^3/s): 4.6
	High flows, freshets and/or floods	NA	**High Flows** Depth (m): 2 Inundation:2 days average 3 times per year Flow (m^3/s): 56	Month: May Depth (m): 2.7 Velocity (m/s): 0.93 Inundation: 2 days Flow (m^3/s): 145.5 Floods	Month: Apr, May Depth (m): 1.54 (0.6 avg) Velocity (m/s): 0.4 Inundation: >21 days Flow (m^3/s): 20	Month: Apr-May, Nov-Dec for 1 week Depth (m): 0.49 Velocity (m/s): 0.3 (98% velocity 0.99) Flow (m^3/s): 10 (Freshets Apr-May, Nov- May)

4.1.3 Site Metrics

4.1.4 Indicators and Management Objectives

TABLE 4.8: CONFIDENCE LEVEL FOR FLOW RECOMMENDATIONS FOR KOGATENDE

Site Name	Rating	Rationale
Social	-	No survey conducted
Hydraulics	3	Straight channel with pool riffle/rapid habitat. Cross section went thought pool. This was done for safety reasons as in order to use the River Surveyor instead of standing in the river for a long time with a handheld flow meter. Rating curve and hydraulic habitat frequency based on one observation
Geomorphology	3	Observations based on a single site visit Observations during low flow only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5 - 4	The site appears to be natural to near natural with expected plant species at different vegetation zones. Even though there are Hippos and the pressure they exalt through grazing and trumping, the system seems to have over time stabilized. Relatively few plant species were recorded particularity on marginal zone but due to the geomorphology and savannah nature of the area.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecology of species and social relationships.
Macroinvertebrates	4	The hydraulic cross-section had clear boundaries, and the flow measurements had high confidence. Given the previous studies at the site and on the Kenyan side of the river, an understanding of flow requirements for macroinvertebrates has been gained, and this gives a lot of confidence to the flow levels I have proposed.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.1.5 Required Conditions
4.1.6 Confidence Ratings

4.2 Tobora

The Tobora biophysical site is located at the downstream end of the Tobora River, about 2.5 km upstream from where it joins the mainstem Mara River. It is a straight channel that is confined to the valley bottom due to geology of the area, with evidence of slight incision. The system is likely very flashy, with rainfall events causing the water level to rise and fall quickly. There are fine and course sand on the bed along with larger cobles and gravels. There are good refuge areas for aquatic species, like fish and macroinvertebrates. No resident fish species found, indicating this river is only used temporarily by fish species. There are likely springs and groundwater flow that maintain at least a small flow in the river during a normal year. Agricultural fields go right up to the banks and there is active sand mining in this river.

FIGURE 4 11: SITE PHOTOS OF TOBORA

4.2.1 Social Survey – Matare, Nyamerama

Tobora River is somewhat degraded, but it has some natural conditions necessary for ecosystem goods and services enhancement. The river Inundations occur mainly at the downstream and more specifically to its tributaries; which last at most three days, extending to a width of about one to three metres mainly in April when the rain is at its maximum. The diversity of fish species is much less compared to other sites. It was mentioned that only two species exist; Mumi and Ningu, mostly available during the flooding season of April and May. The area has fairly diverse riparian vegetation that is important for locals' livelihoods. There is a lot of natural vegetables (11 species identified), tree species that provide fruits (6 species identified), timber and poles (22 species), weaving and thatching materials. The river condition is relatively good but the trend suggests that due to increasing population and anthropological activities including deforestation and cultivation along the river banks, degradation of the river will accelerate in the future.

Among the resources available in the RU, water was reported to be the most important accounting for an average about 74 percent with significant importance recorded in Nyamerama village (98.7 percent) as opposed to Matare (49.7 percent). Crop cultivation was rated second (12.4 percent), followed by livestock

No.	Wetland Resources	Relative Importance (%) per sample villages		Average
		Matare	Nyamerama	
1	Water	49.7	98.7	74.2
2	Cultivation Land	24.8	0.0	12.4
3	Livestock Pastures	12.4	1.0	6.7
4	Building Poles	6.2	0.0	3.1
5	Natural vegetables	3.1	0.0	1.6
6	Building Stones	1.6	0.1	0.9
7	Building Sands	1.6	0.1	0.9
8	Natural fruits	0.3		0.3
9	Weaving grasses	0.3	0.0	0.2
10	Fish	0.1	0.0	0.1
11	Roofing grasses		0.0	0

TABLE 4 9: WETLAND RESOURCES AND THEIR RELATIVE IMPORTANCE TO THE LIVELIHOOD OF COMMUNITIES IN TOBORA pastures (6.7 percent), building poles (3 percent) and natural vegetables (1.6 percent). Other resources accounted for less than 1 percent (Table 4 9).

Economic activities are classified under crop farming, livestock keeping and petty trade (Table 4 10). Farming is common in both villages and the major crops cultivated include maize, sorghum, finger millet, cassava and sweet potatoes. Petty trade involves running small-scale retail businesses dealing in household stuff.

Assessing how the trend of resources utilization and condition of the wetland resources have changed over the years was done and the results indicated in Table 4 11 below. A hypothetical value of 100 was set as a current benchmark and the respondents asked

Activity	Performers	Location	When	Why in that Place	Why in that Time
Crop farming	Members of the household	**Matare village:** Uplands along river banks and plains. **Nyamerama village:** Within the household premises	Twice annually 1. January-March 2. August-October	Good weather condition	Enough rainfall
Livestock keeping	All members of the family	**Matare village:** Within the farm area. **Nyamerama village:** Within the household premises	Year round	Land scarcity	Livestock need food
Petty trade	All members of the family	Within the village	Year round	Customer hotspot	To compensate losses in farming and livestock

TABLE 4 10: ECONOMIC ACTIVITIES IN TOBORA RU

Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Fish	5500	100	5	Population increase which increases the demand for fish River divergence Expansion of charcoal business which facilitate more degradation of fish breeding sites
Wild vegetables	3500	100	60	Population increase which increases the demand for vegetables Expansion of crop farming to the wetlands areas
Wild fruits	750	100	55	High deforestation The values of wild fruits are limited especially to new generations. This facilitate more cutting of fruit trees
Weaving materials	5500	100	60	Environmental degradation River divergence Decrease in water flows as a result of climate change
Building poles	3000	100	20	Increase in dependency to building poles and increase in building activities
Thatching materials	5000	100	03	Increased in livestock which competes with limited pastures Effect of climate change
Degradation of wetland/river ecosystem	05	100	350	Increase in population Increase in the dependency to wetland resources High demand for the wetland areas for crop farming and livestock keeping

TABLE 4 11: TREND OF RESOURCES AND CONDITIONS OF THE WETLAND IN TOBORA

Table 4-11: Trend of resources and conditions of the wetland in Tobora

Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Dependency of community to rivers and other wetland resources for their livelihood	20	100	500	Demand is increasing with limited and expensive alternatives.
Width of the river	10	100	150	Increase in sand mining Crop cultivation near water sources and river banks facilitate increase in siltation Increase in deforestation
Quality of the river/wetland	500	100	35	Increase in deforestation Crop farming near water sources increases pollution

to give their perceived values in the past and future, with reference to the set benchmark. The possible reasons for change were also highlighted.

4.2.2. Biophysical – Tobora River at Nyasurura

4.2.2.1 Hydrology

The EFA site at Tobora has a contributing upstream catchment area of 361 km2 with a dominated land use of agriculture, savanna, and grassland (Figure

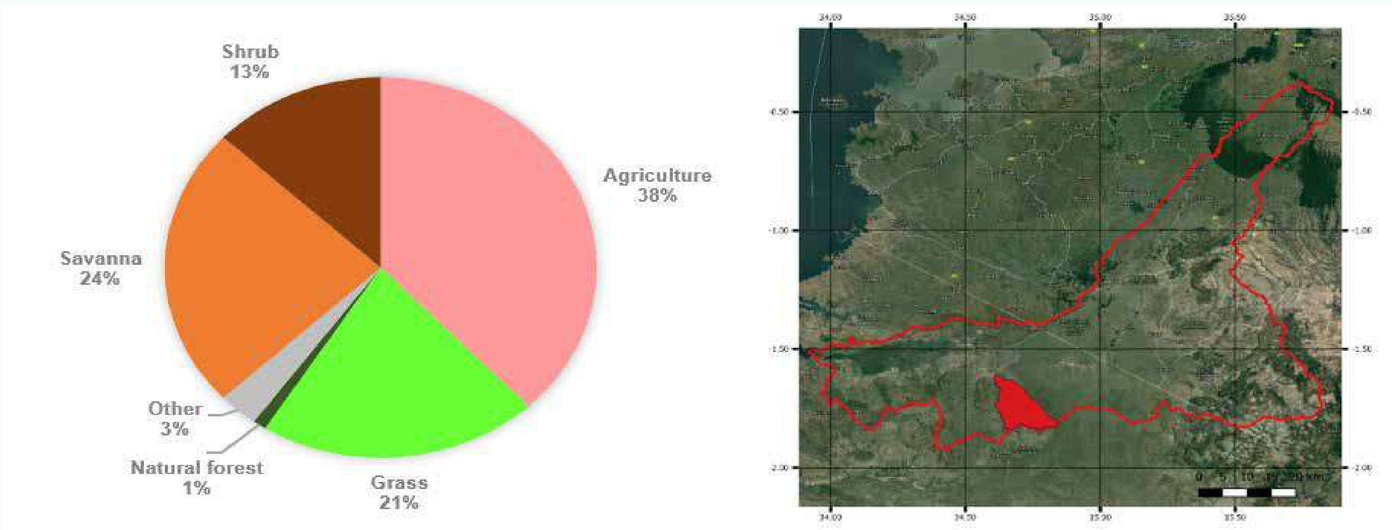


FIGURE 4 12: LAND USE WITHIN THE TOBORA SUB-CATCHMENT (LEFT) AND CATCHMENT AREA (RIGHT)

4 12). Precipitation in the catchment sums up to 945 mm/yr, resulting in an evaporation value of 869 mm/yr, and a runoff value of 77 mm/yr.

Average monthly, minimum and maximum discharge values for Tobora EFA site are presented in Figure 4 13. On average, the wettest month is May while the driest month is August. The flow in the Tobora River can reduce to zero, particularly in drought

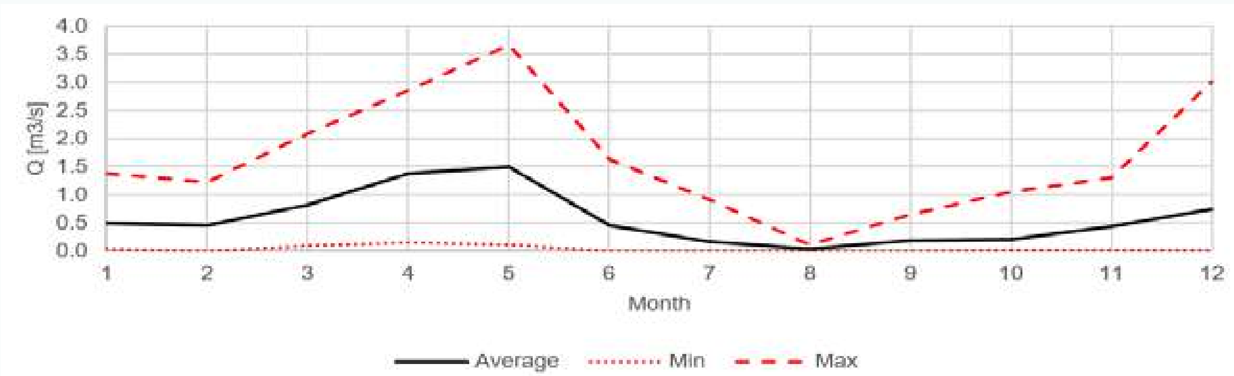


FIGURE 4 13: AVERAGE MONTHLY, MINIMUM AND MAXIMUM DISCHARGE VALUES FOR TOBORA years, where water remains only in pools that are refreshed by groundwater or sub-surface flow.

4.2.2.2 Hydraulics

The Tobora River reach upstream of the confluence with the Mara River is a steep bedrock controlled channel with small pools/areas with slower flow amongst the faster riffles and runs. Cobbles and gravel are present along the steeper riffle section creating faster turbulent flows. The flatter pool sections have a sandy or silty bed resulting in deeper and less turbulent flows. Good vegetation and root structure leads to slower flows along the banks of pools and riffle sections. The shape of the cross section and observed and modelled flow levels are given in Figure 4 14. The relationship between velocity and depth was weak for the low flow ($R^2 = 0.28$) and higher flow ($R^2 = 0.33$). Velocity tends to increase with depth, but this is not always the case, showing that there are areas along transects where deeper water is slow flowing or very shallow water is fast flowing. This

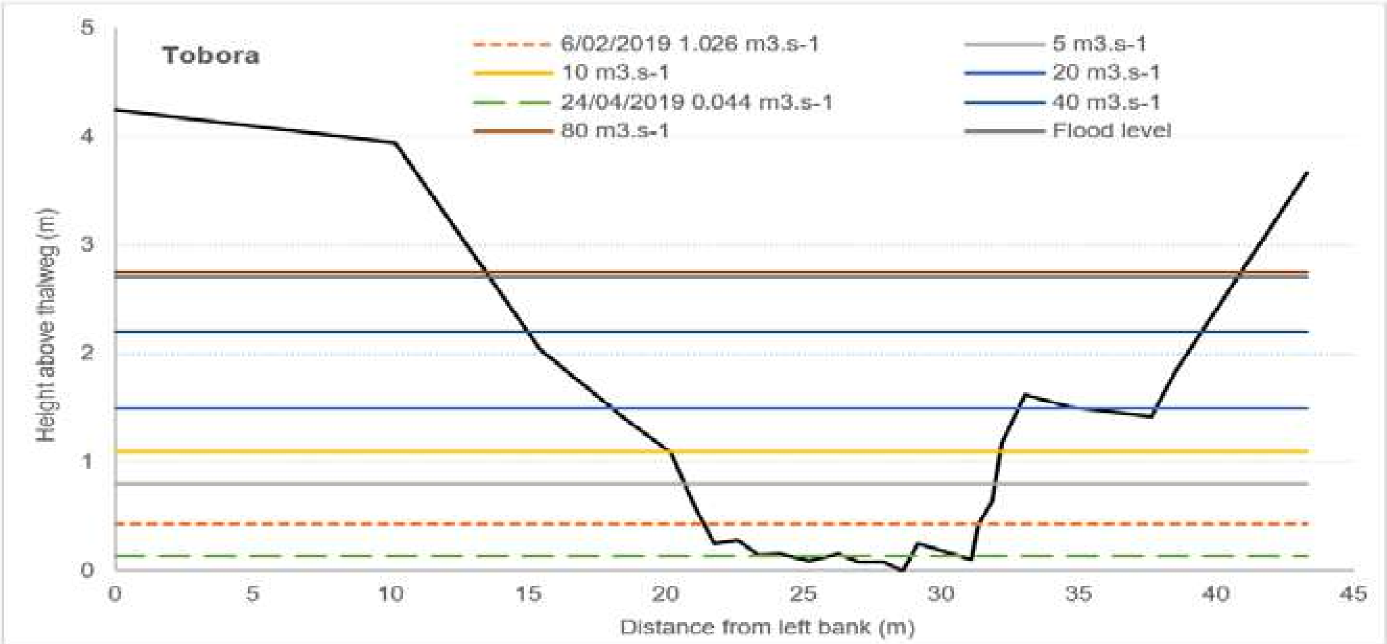


FIGURE 4 14: CROSS SECTION SHOWING OBSERVED AND MODELLED FLOW DATA FOR TOBORA

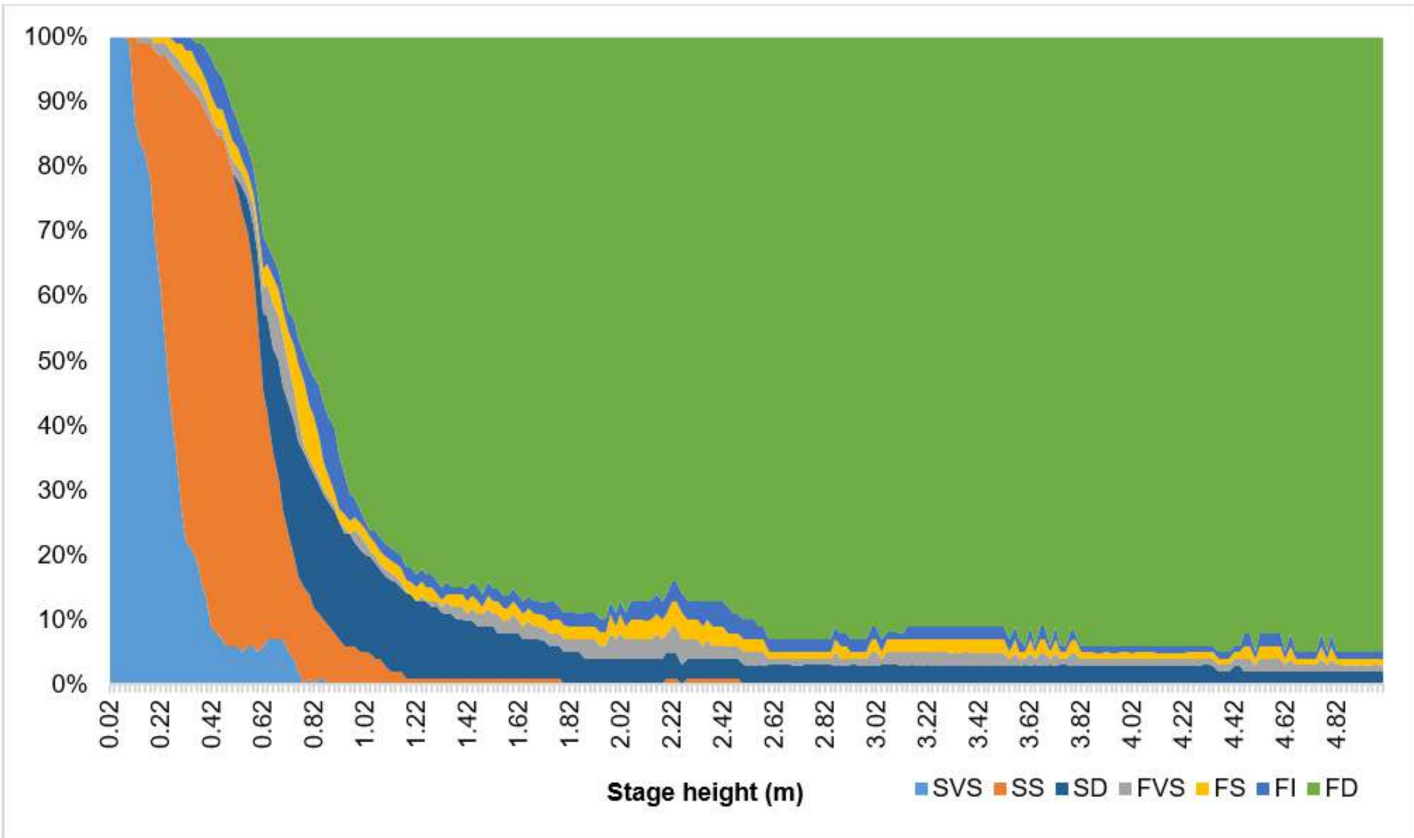


FIGURE 4 15: FREQUENCY DISTRIBUTION OF VELOCITY-DEPTH CLASSES FOR TOBORA shows some of the variability of hydraulic habitat along the transect. The modelled velocity-depth class frequency distributions are given in Figure 4 15.

4.2.2.3 Geomorphology

The Tobora River site has a pool-rapid sequence with pools and riffles of roughly equal length (Figure 4 16). The reach is bedrock controlled and has a local gradient of 0.0057 and can be classified as the upper foothill zone (Rowntree and Wadeson, 1999). Rowntree and Wadeson describe the reference condition for this gradient as 'moderately steep, cobble bed or mixed bedrock-cobble bed channel, with plain bed, pool-riffle or pool-rapid reach types. The length of pools and riffles are similar, and a narrow floodplain of sand, gravel or cobble often present'. The site fits this description well.

The site is located 200 m upstream of a bridge, with no clear effect on the depositional features at the site. The river appears to be incised with terraces along both banks and narrow flood benches (Figure 4 17). A steady sand supply is evident from the thick sand deposits on the flood benches. Small inset benches form along the margins, with dense sedge growth and provide good marginal cover. Sand is the dominant sediment type, with the banks consisting of fine sand, the benches of medium sand and the bed of coarse sand and fine gravel along pool sections and large gravel and cobble along riffle sections. Cobble and gravel voids are filled with coarse sand along the riffle.

The river level was high and turbid with sand actively moving on the bed during the sampling trip in February 2019. Cultivation extends down to the river banks and sand mining is taking place along sand

FIGURE 4 16: AERIAL VIEW OF THE TOBORA RIVER SHOWING THE LOCATION OF THE CROSS SECTION, POOLS AND RIFFLES (GOOGLE EARTH IMAGE 24 SEPTEMBER 2010).

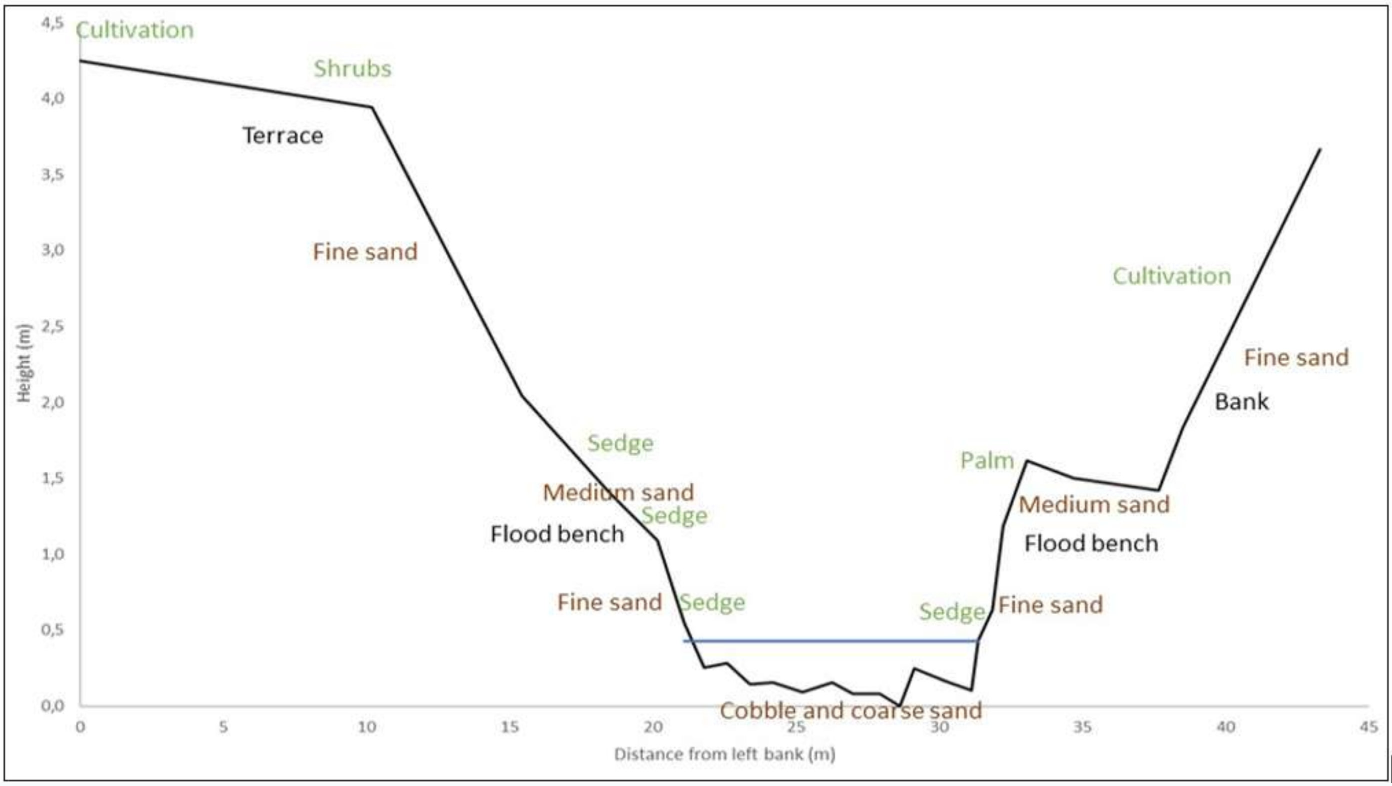


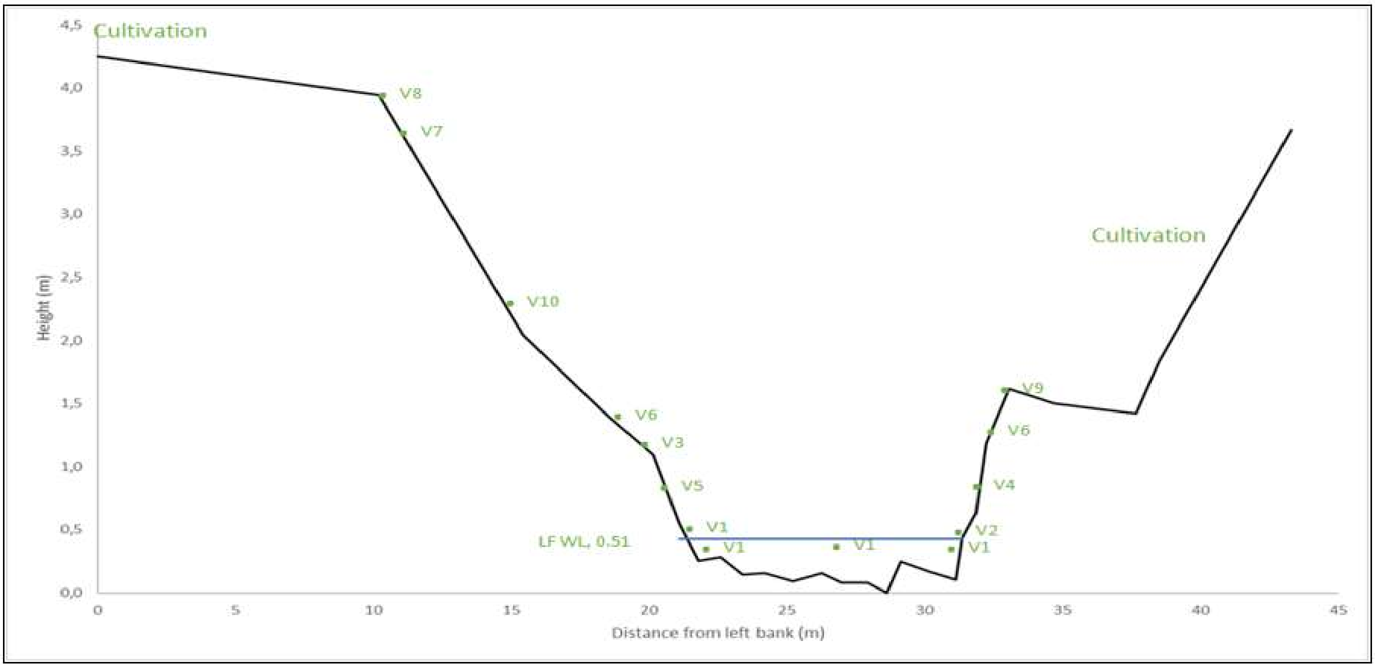
FIGURE 4 17: A CROSS SECTIONAL VIEW OF THE TOBORA RIVER INDICATING GEOMORPHOLOGICAL FEATURES, SEDIMENT COMPOSITION AND VEGETATION TYPES

bars and benches. Sand is harvested with buckets from sand bars without much impact on the instream habitat.

4.2.2.4 Riparian Vegetation

Both the left and right banks of the Tobora River were vegetated with different plant species. Reference condition of this site would be the same as PES but with less influence from human activities. Consequently, less or no invasive and exotic species on lower and upper sub-zones was to be expected. The banks and macro-channel bank should be more covered with vegetation and especially trees, as opposed to the current situation. Several human activities were observed during field surveys including sand mining and crop farming/vegetable gardening close to the river about 6 m. In addition to banks being covered with herbaceous vegetation, trees (e.g., Ficus sur and Grewia similis) were observed on both banks which provide support to stabilize banks. Marginal sub-zone was dominated by papyrus plants Cyperus involutus and Cyperus distans while lower part was occupied by species like Dactyloctenium aegyptium, Panicum maximum and Eragrostis ciliaris. The left bank had more shrub species dominated by Lantana camara which appear to be grazed by goats and sheep, and Tithonia diversifolia. Cynodon nlemfuensis was present on the sand bars on the left side of the river. At this site devil's plant which is an invasive species was also observed on the MACRO-CHANNEL BANK. Banks were covered by vegetation by 70 percent. Sand which likely was coming from the river and farms was deposited at the upper right bank. Distribution

FIGURE 4 18: CROSS SECTION OF THE TOBORA RIVER SHOWING INDICATOR PLANT SPECIES



Indicator Species	Number	Range	Remarks
Cyperus involutus	V1	marginal	thick dense stands
Cyperus distans	V2	marginal	forb
Dactyloctenium aegyptium	V3	lower	
Panicum maximum	V4	lower	
Eragrostis ciliaris	V5	lower	
Cynodon nlemfuensis	V6	flood bench	grazing resilient and dominant
L. camara	V7	upper	start of dense shrub cover
Tithonia diversifolia	V8	upper	young and adults
Palm trees	V9	upper	adults
Fig trees	V10	upper	adult large trees

of plant species along the cross section is indicated in Figure 4 18.

4.2.2.5 Fish

Tobora River meanders with the flow in a westerly, north-westerly direction. Three primary GHUs were identified and delineated for the site, namely a pool, riffle and a run. A total of four pools, two riffles and two runs were sampled with an electro-fisher, all with a shallow depth (Figure 4 19). The velocity depth classes associated with the pool was SS, with the velocity depth classes associated with the riffle and run GHUs all being classed as FS. Substrate in the pools is dominated by sand and gravel, with the substrate associated with the riffles and runs characterized by rocks, cobbles and boulders. Turbidity was considered to be high. Limited aquatic vegetation was present at the site, with marginal and overhanging vegetation present for almost the entire

FIGURE 4 19: AERIAL VIEW OF THE TOBORA RIVER SHOWING THE DELINEATED GHUS FOR THE SITE (GOOGLE EARTH)

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	25 – 75%	Leaves & stems	Roots	Sand & gravel	-	-
SD	-	-	-	-	-	-
FD	-	-	-	-	-	-
FS	25 – 75%	Leaves & stems	Undercut bank	Rocks, cobbles and boulders	-	-

TABLE 4 12: A SUMMARY OF THE HCR FOR THE REACH WITH ASSOCIATED VELOCITY DEPTH CLASS RATINGS AND CORRESPONDING DETAILS.

FIGURE 4 20: A PHOTOGRAPH DEPICTING HABITAT CHARACTERISTICS FOR THE TOBORA RIVER REACH (FEBRUARY 2019)

extent of the reach. Root wads and undercut banks were also recorded. An overview of the HCR ratings is presented in Table 4 12 and Figure 4 20.
A total of four fish species were sampled from the site, with a total of 22 individuals recorded for the site. No indicator species were recorded for the site. The species composition was dominated by Labeo sp and Enteromius sp.

Substrate was variable and consisted of sand, gravel, cobbles, boulders and bedrock. Habitat cover was dominated by undercut banks and overhanging vegetation, with marginal vegetation and root wads also present. Habitat diversity was considered to be relatively high, with two dominant velocity-depth classes, namely SS and FS. Excessive sediment (gravel and sand) is present in the channel.

4.2.2.6 Macroinvertebrates

Although there are clear signs of flow alteration in the system, likely linked to land use change and livestock activity and watering, some species of Baetidae and Heptageniidae were among the sensitive taxa recorded at the site. Signs of flow modifications include low abundances of flow sensitive taxa (Tricorythidae, Simuliidae and Hydropsychidae) which form 27 percent of all individuals at the site. The site is impacted by sand harvesting and cultivation of the riparian zone. Small –scale irrigation is also done at the site and along the river. Table 4 13 and Table 4

Table 4-13: Macroinvertebrate community metrics for Tobora site

Community Metrics	Score
Total abundance	1747
No. of taxa	38
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	1074
% EPT	61.48
Number rheophilic taxa	5
Abundance of rheophilic taxa	485
Relative abundance of rheophilic taxa	27.76
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	475
% STH	27.19

Table 4-14: Results of the SASS5 and TARISS on processed samples at Tobora

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	Number of taxa	ASPT	TARISS Score	Number of taxa	ASPT
167	29	5.8	167	29	5.8

Laboratory analysis for the SASS5 Protocol		
Total SASS Score	No. of taxa	ASPT
184	38	4.8

14 below indicate the field processed and laboratory processed score results for the site.

4.2.2.7 Water Quality

Turbidity was the highest at this site during the 1st survey attributed to increased sediments as a result of the rains that had been received the previous day. The levels were much higher than the recommended Tanzanian drinking water standards of 25 NTU. High turbidity reduce the amount of light that can penetrate the water surface which affects photosynthesis of aquatic plants therefore reduces the amount of dissolved oxygen in the water. It also leads to loss of vision for fish hence affecting its ability to catch prey and clogging of fish gills resulting in death. However, due to the flowing water, dissolved oxygen was within acceptable limits. This was also the case for electrical conductivity with low values in the 1st survey due to dilution effect and high values on the 2nd survey. Generally, the pH at this site is slightly higher than any other site probably influenced by geological factors such as the rock/soil type in the area. Contribution of groundwater during the 2nd survey could be the reason for the high pH compared to the 1st survey when the pH of the river was influenced by pH of the rain recorded the previous day. Groundwater normally has more contact time with the bedrock hence affecting the quality of the water based on the bedrock characteristics. Therefore during base flow conditions, the pH of the river will most likely reflect that of groundwater than periods of increased

Table 4-15: Results of water quality analysis at Tobora

Parameter	Unit	1st survey	2nd survey
pH	(-)	8.3	8.7
Electrical conductivity (EC)	µs/cm	544	695
Temperature (T)	deg C	28.1	28.5
Dissolved oxygen (DO)	mg/L	6.3	6.41
Oxygen saturation	%	93	96.5
Turbidity	T.U	1,000	75
Nitrate (NO_3^-)	mg/L	0	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	305	ns
Ammonium (NH_4^+)	mg/L	0.08	0.07
Non purgeable organic carbon (NPOC)	mg/L	12.5	8.31
Total nitrogen (TN)	mg/L	1.6	0.94

ns: not sampled

rainfall. Table 4 15 shows the field measurements and

4.2.3 Site Metrics

Table 4-16: Site metrics for Tobora

Metric	Social	Geomorph.	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	B/C	B	B	B	C	B/C
ToC	Declining	Stable/ declining	Declining	Stable	Declining	Declining
EIS	Medium	Medium	High	Very high	High	Low
SIS	High	-	-	High	Medium	Medium
EMC	B	B	B	A/B	B	B

4.2.4 *Indicators and Management Objectives*

Table 4-17: Indicators and management objectives for Tobora

EFA Component	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including subsistence crop farming, livestock keeping, vegetables & fruits collection/cultivation for the local communities residing along the Tobora River
	Target species	The following species should be abundant enough to suffice the needs of the population residing along Tobora River: Fish: Mumi Vegetables: Chinderema, Chinsaga, and Isebeso Trees: Chinsere, Chinseke, and Ebinyabutati Other resources: Ukindu
Geomorphology	Pool depth	Maintain pools of at least 0.5 m deep

Table 4-17: Indicators and management objectives for Tobora

EFA Component	Indicator	Management Objective(s)
	Available gravel and cobble habitat	Maintain flow variability and moderate sediment supply to maintain this habitat in good condition (e.g., not embedded with fine sediment)
Riparian Vegetation	Sedge, forb and grass communities	Continue maintaining abundances of flow sensitive sedge species (e.g., *Cyperus involutus*, *Cyperus distans* and forb *Commelina benghalensis*) at the site Continue to maintain abundances of moderately flow sensitive plant species (e.g., *Panicum maximum*). If depth of water for flow sensitive plant species is met then it should suffice this group too.
	C. involutus, *C. distans*, *and P. maximum*	Continued presence and occurrence of seedlings and adults of *C. involutus*, *C. distans and P. maximum* and the three should together be present at abundance of ≥20 percent
	Riparian tree communities	Continued presence and occurrence of seedlings, saplings and adults of *Ficus sur* with at least 10 percent abundance
Fish	Recruitment of indicator cyprinids spp.	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophilic species. This includes *Labeo victorianus* and *Labeobarbus altianalis.*
	Occurrence of indicator species	Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site
	Fish community wellbeing assessment	If either of the two previous indicators are not observed, a fish community wellbeing assessment should be undertaken
Invertebrates	SASS5 or TARISS Index	SASS5 or TARISS Index score >150 and Avg. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
	Ephemeroptera, *Plecoptera*, and *Trichoptera* orders	The following orders should be present in abundances >50 percent of the invertebrate community during the wet season when the river is flowing
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the WQ within acceptable standards to support growth and development of fish, macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic and agricultural purposes

laboratory results for water quality samples taken at

Table 4-18: Required flow conditions for Tobora

	Hydrological Component	Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Depth (m): 0.33 Velocity (m/s): 0.5	**Freshets** Depth (m): 0.5 Inundation: 1 day average 4 events during wet season Flow (m³/s): 1.8	Month: August Depth (m): 0.4 Velocity (m/s): 0.43 Flow (m³/s):1.04	Month: Feb, Jun-Aug, Dec Depth (m): 0.22 (0.1 avg) Velocity (m/s): 0.2 Inundation: >10 days Flow (m³/s):0.15	Month: Feb, Oct Depth (m): 0.22 Velocity (m/s): avg 0.1, max 0.98 Flow (m³/s): 0.1
	Low flows, wettest month	Depth (m): 0.76 Velocity (m/s): 0.91 Flow (m³/s): 8.2	**High Flows** Depth (m): 1.6 Velocity (m/s): Inundation: peak over 2 days 1 event per year during wet season Flow (m³/s): 24	Month: July Depth (m): 0.5 Velocity (m/s): 0.5 Flow (m³/s):1.72	Depth (m): 0.36 (0.21 avg) Velocity (m/s): 0.4 Inundation: >30 days Flow (m³/s): 0.8	Month: April Depth (m): 0.42 Velocity (m/s): avg 0.44, max 1.38 Flow (m³/s): 1.2
	High flows, freshets and/or floods	Depth (m): 1.13 Velocity (m/s): 1.48 Flow (m³/s): 39	**Floods** Depth (m): 1.6 Inundation: peak over 2 days, 1 event per year during wet season Flow (m³/s): 24	**Floods** Month: May Depth (m): 2 Velocity (m/s): 1.48 Flow (m³/s): 39 (once in 3 yrs. for 1-2 days)	Depth (m): 0.5 (0.3 avg) Velocity (m/s): 1.3 Inundation: >14 days Flow (m³/s): 1.7	**Freshets** Month: Apr-May, Nov-Dec Depth (m): 0.5 Flow (m³/s): 1.7 **Annual Flood** Flow (m³/s): 3
Drought Year	Low flows, driest month	Depth (m): 0.15 Velocity (m/s): 0.3 Flow (m³/s): 0.4	None	Month: July Any flow to allow water in pools be maintained while vegetation will be maintained by ground water.	Flow (m³/s): 0	Month: August Flow (m³/s): 0
	Low flows, wettest month	None	**Freshets** Depth (m): 0.5 Inundation: 1 day average, 3 events spread over the wet seasons Flow (m³/s): 1.8	Any flow to allow water in pools be maintained while vegetation will be maintained by ground water.	Flow (m³/s): 0	Month: April Flow (m³/s): 0
	High flows, freshets and/or floods	None	**High Flows** Depth (m): 1.6 Inundation: peak over 1 day 1 event per year Flow (m³/s): 24	Month: Apr- May Depth (m): 1.6 Velocity (m/s): 1.34 Flow (m³/s): 23.6 Freshest for at least 1 day	Depth (m): 0.36 (0.21 avg) Velocity (m/s): 0.4 Inundation: >21 days Flow (m³/s): 0.8	Month: Apr-May, Sept, Nov-Dec Depth (m): 0.36 Velocity (m/s): avg 0.4, max 1.23 Flow (m³/s): 0.8

the site.

Table 4-19: Confidence level for flow recommendations for Tobora

Site Name	Rating	Rationale
Social	4	The findings were matching with those of biophysical scientists
Hydraulics	3.5	Straight channel with pool riffle/rapid habitat. Two observations at relatively low flows used for calibration
Geomorphology	3.5	Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5	The site had relatively good representation of anticipated plant species in such a small river. It would be interesting to conduct the survey during wet season and compare the results to increase the level of confidence.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecology of species and social relationships.
Macroinvertebrates	2	No previous studies on macroinvertebrates exist in this river and the discharge values on which I based my recommendations on have been modeled. This gives low confidence to the flow values proposed.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.2.3 Site Metrics

4.2.5 Required Conditions

4.2.6 Confidence Ratings

4.3 Somoche

The EFA biophysical field site at Somoche is located at the downstream end of the Somoche River, about 0.35 km upstream from where it joins the mainstem Mara River. It has a mostly rocky substrate with areas of cobbles and sand. The Somoche Sub-basin is larger than the Tobora Sub-Basin but it is drier, resulting in higher discharges but a less flashy system. More fish species were found, indicating that this tributary is important for maintaining biodiversity within

FIGURE 4 21: SITE PHOTOS OF SOMOCHE

the mainstem Mara River. The surrounding area is dominated by rainfed agriculture and barren areas.

4.3.1 Social Survey – Kwitete, Nyamitita

Somoche River does not flow throughout the year but some of its tributaries are perennial. The river floods twice a year in April and December, during the wet seasons and can last from one to seven days extending up to a width of about 100 meters. Somoche River was identified to have more fish species (Mumi, Kamongo, Gogogo, Perege and Ebikoro) when compared to Tobora which had only two. There are natural vegetables (nine species), tree species which are important for fruits (17 species), timber and poles (39 species). The locals depend on the river for crop farming as well as livestock keeping which are the key livelihood activities in the site. Table 4 20 summarizes the wetland resources that are important to communities in Somoche. Water is the most important resource accounting for 77.7 percent followed by building poles and roofing

No.	Wetland Resources	Relative Importance (%) per sample village		Average
		Nyamitita	Kwitete	
1	Water	82.8	72.5	77.7
2	Building Poles	8.3	3.6	6.0
3	Roofing grasses	8.3	3.6	6.0
4	Livestock Pastures		7.3	3.7

TABLE 4 20: WETLAND RESOURCES AND THEIR RELATIVE IMPORTANCE TO THE LIVELIHOOD OF COMMUNITIES IN SOMOCHE RU

Table 4-20: Wetland resources and their relative importance to the livelihood of communities in Somoche RU

No.	Wetland Resources	Relative Importance (%) per sample village		Average
		Nyamitita	Kwitete	
5	Firewood/Charcoal		7.3	3.7
6	Building Sands	0	3.6	1.8
7	Natural fruits	0	1.2	0.6
8	Natural vegetables	0.3	0.6	0.5
9	Cultivation Land	0.3	0	0.2
10	Honey		0.2	0.1
11	Wildlife (animals and birds)		0.1	0.1
12	Fish	0	0	0.0
13	Building Stones	0		0.0

mm/yr, resulting in an evaporation value of 909 mm/yr, and a runoff value of 48 mm/yr.

The three main economic activities in the villages include agriculture involving about 60 percent of the population, following by livestock keeping at 20 percent and a small percentage of the people run small businesses. Table 4 21 below indicates the status of these activities.

Similarly to Tobora RU, the trend of resource utilization and the condition of the wetland in the

Table 4-21: Economic activities in Somoche RU

Activity		Performer	Location/Why	Time/Why
Agriculture	Maize			Twice Sept- Jan,
	Millet	Household	Flat areas	Feb- June
	Ulezi	Household	Flat areas	Feb- March
	Cassava	Household	Flat areas	Throughout the year
	Sweet potatoes	Household	Lowland	Year round
	Beans	Household	Lowland	Year round
	Cottons	Household	Lowland	Nov - Jan
	Paddy/Rice	Household	Lowland	Feb-June
	Cotton	Household	Valley	Year round
	Tobacco	Household	Lowland	Nov –Jan
	Peanuts	Household	Lowland	
	Fruits(Mangoes and Oranges)	Household	Lowland	
	Vegetables			Throughout the year
Animal husbandry		Around household - Rivers - Ponds - Mountains		
Small business		Settlements/business centres		

Table 4-22: Trend of resource utilization and condition of the wetland in Somoche RU

Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Fish	1000	100	7.5	Environmental degradation Increase in fish demand due to population increase Decrease in fish productivity and therefore to its population Decrease in water flows
Wild vegetables	1500	100	12.5	Effect of climate change Natural land has been converted to other use.
Wild fruits	1600	100	15	Effect of climate change Increased in population Cutting down of trees for different use.
Weaving materials	3000	100	252.5	The plant had so many different uses such as capes, bed, baskets etc.) In future, people will shift to alternatives
Building poles	10000	100	27.5	Increase in tree cutting for charcoal making Consumption had increased due to high population. Alternative building materials are very expensive.
Thatching materials	10500	100	04	Increased in consumption due to an increase in population Alternative materials are very expensive Effect of climate change Expansion of agriculture activities. Competition with increasing livestock
Degradation of wetland/river ecosystem	3.5	100	750	Uncontrolled crop farming and livestock keeping in the wetlands Drought Increase in population Expansion of charcoal business Dependency on wetland resources is increasing
Dependency of community to rivers and other wetland resources for their livelihood	7.5	100	700	Charcoal business expansion Requirement of land for agricultural activities had increased as a result of population growth. Easily available resources for our livelihood Limited substitutes and when available are too expensive. No options for cultural activities
Size (width) of the river	15	100	750	Cutting of trees Erosion due to agricultural activities. River bank destruction by livestock.
Quality of wetland/river	500	100	7.5	Defecation along the rivers Contamination from livestock grazing Cutting down of trees.

past (1960 to 1985) to the present and future time (2030) was assessed and responses given in Table 4 22

4.3.2 Biophysical – Somoche River at Somoche

4.3.2.1 Hydrology

The EFA site Somoche has a contributing upstream catchment area of 690 km2 with a dominated land use of agriculture, savanna, and grassland (Figure 4 22). Precipitation in the catchment sums up to 957 mm/yr, resulting in an evaporation value of 909 mm/yr, and a runoff value of 48 mm/yr.

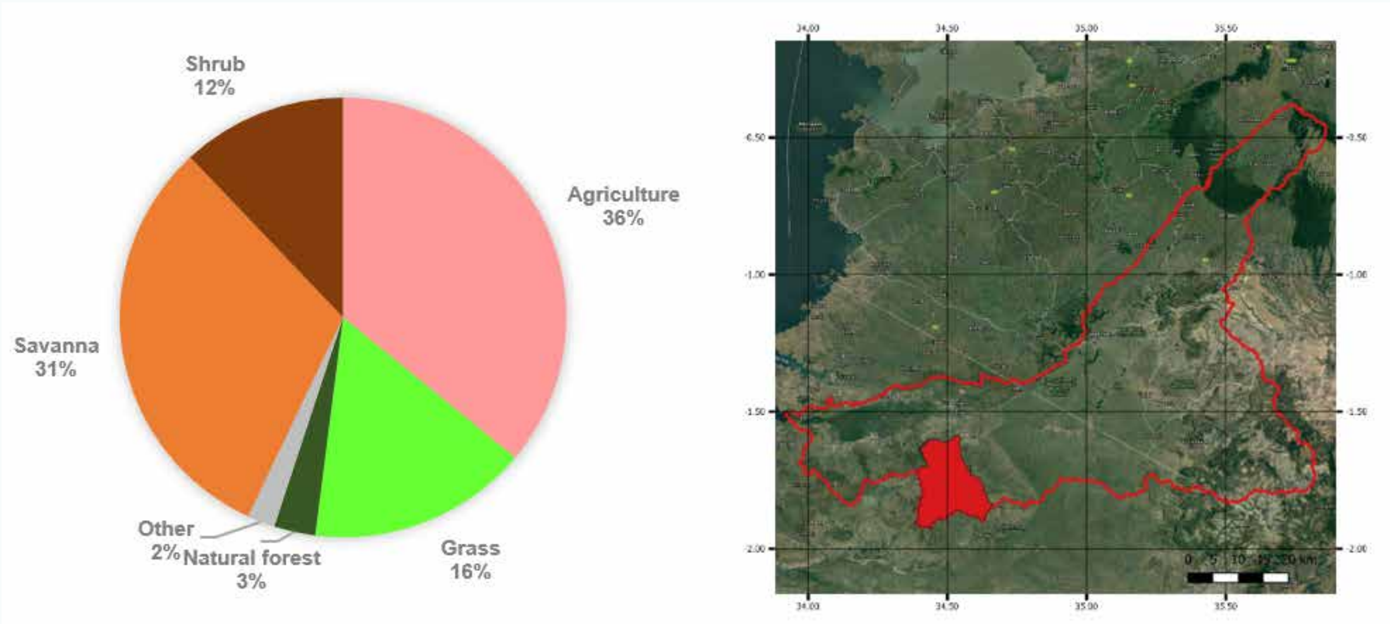


Figure 4 22: Land use within the Somoche sub-catchment (left) and catchment area (right)

Average monthly, minimum and maximum discharge values for Somoche EFA site are presented in Figure

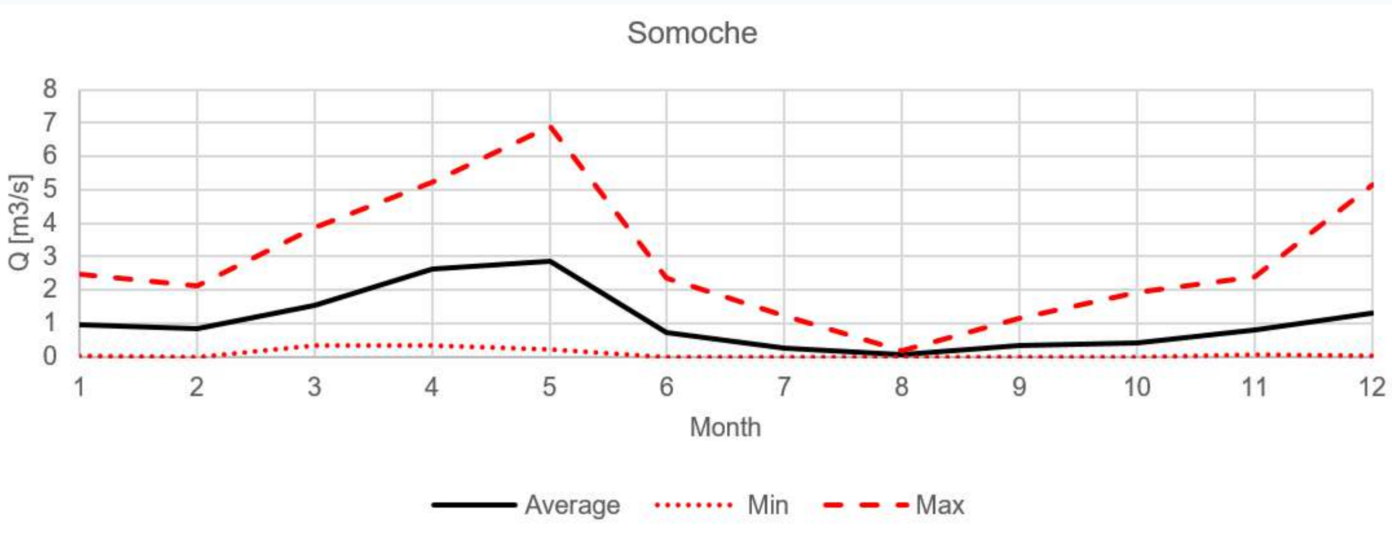


FIGURE 4 23: AVERAGE MONTHLY, MINIMUM AND MAXIMUM DISCHARGE VALUES FOR SOMOCHE

4 23. On average, the wettest month is May and the driest month is August, regularly going to almost zero during the dry season.

4.3.2.2 Hydraulics

The lower Somoche River is a steep fast-flowing bedrock channel with slower flowing deep pools. Large cobbles are present on the bed with small pockets where gravel is deposited. Sand and finer material are deposited on the well vegetated inset benches. Turbulent fast flowing rapids, riffles and runs and slower flowing less turbulent pools alternate along this reach. The channel cross section shows the observed and modelled flow levels (Figure 4 24). Observed velocity-depth data show a very weak relationship (R2 = <0.1), indicating a partial agreement between depth and expected velocity. Velocity tends to increase with depth, but the variability is very high, showing that there are areas along transects where deeper water is slow flowing or very shallow water is fast flowing. This shows high variability of hydraulic habitat along the transect. The frequency distribution for the various velocity-depth classes is shown in Figure 4 25.

4.3.2.3 Geomorphology

The Somoche EFA site is located along a straight reach with a pool-riffle sequence and strong bedrock influence (Figure 4 26). The site has a local gradient of 0,011 and can be classified as the upper foothill zone (Rowntree and Wadeson, 1999). Rowntree and Wadeson describe the reference condition for this gradient class as 'moderately steep, cobble bed or mixed bedrock-cobble bed channel, with plain bed, pool-riffle or pool-rapid reach types. The length of pools and riffles are similar, and a narrow floodplain of sand, gravel or cobble often present'. The site fits the reference description moderately due to the high terrace and strong bedrock influence.

The channel is incised with a high terrace along the right bank and consists of silt (Figure 4 27). The left bank is sloping and has no clear fluvial features (consists of fine sand). A vegetated core bar forms a large island along the left side of the channel. Small medium sand inset benches form along the margins and are not vegetated. The channel bed consists of bedrock, blocky boulders and slabby cobbles and gravels along riffles and rapids (Figure 4 27). Pools are long with overhanging vegetation. Sand deposits (medium and coarse sand) form on cobble islands with dense sedges and forbs. Very little evidence of high silt and clay loads on flood features such as sand bars. Limited bank erosion was observed despite grazing that is taking place along the banks. Agriculture takes place up to a meter of the right

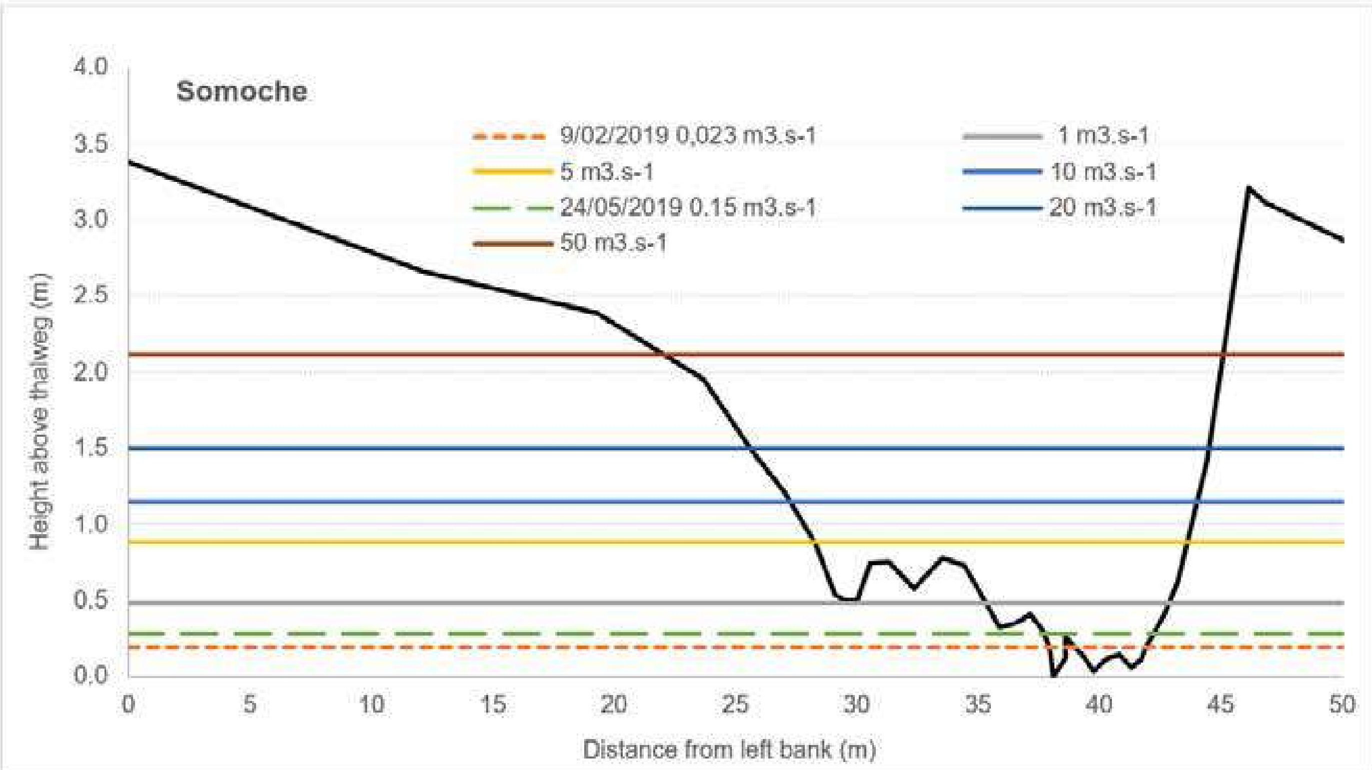


FIGURE 4 24: CROSS SECTION SHOWING OBSERVED (DOTTED LINES) AND MODELLED (SOLID LINES) WATER LEVELS FOR SOMOCHE

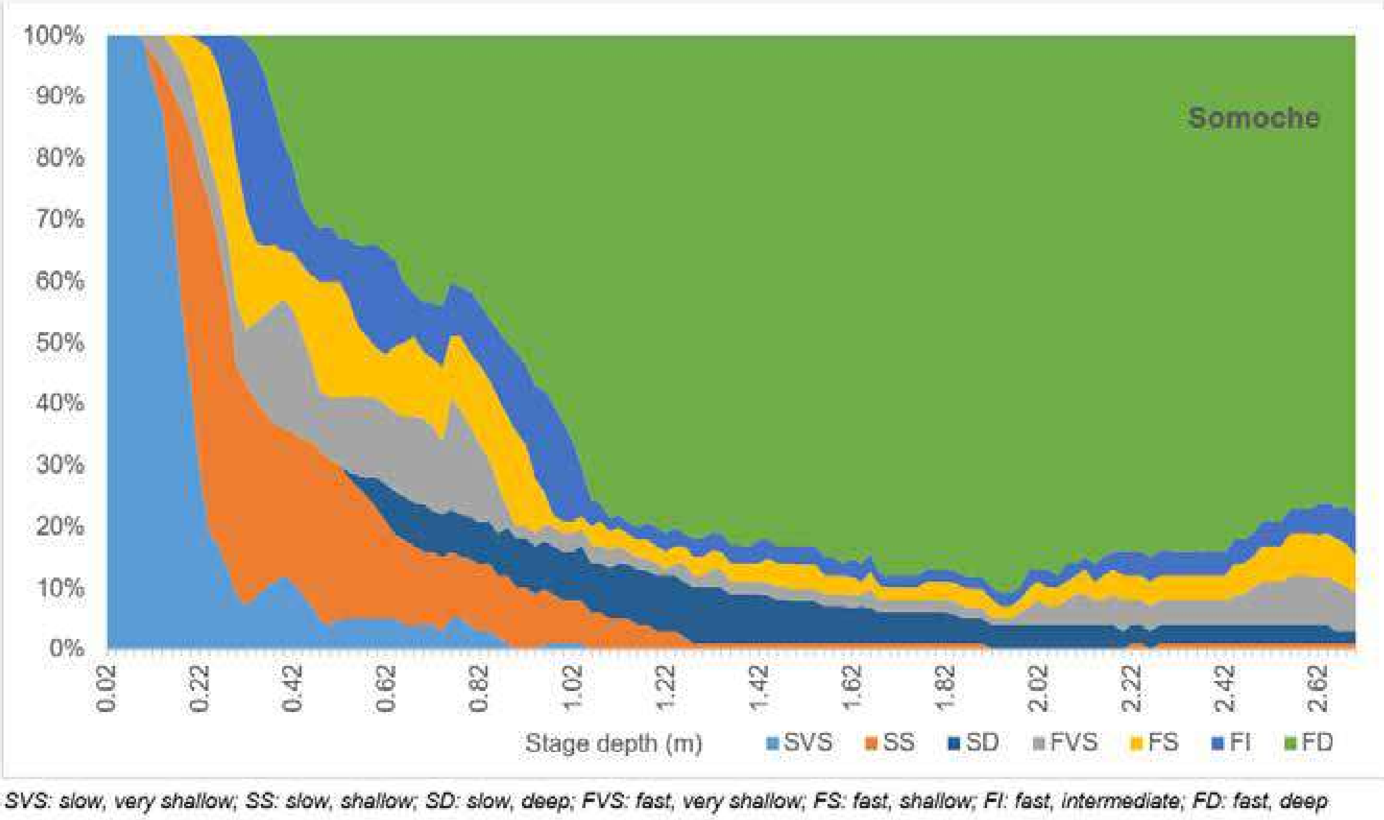


FIGURE 4 25: FREQUENCY DISTRIBUTION OF VELOCITY-DEPTH CLASSES FOR THE WETTED SOMOCHE RIVER CHANNE

FIGURE 4 26: A SATELLITE IMAGE OF THE SOMOCHE RIVER CHANNEL INDICATING THE LOCATION OF TRANSECT ACROSS A RIFFLE (GOOGLE EARTH IMAGE 21 JULY 2017).

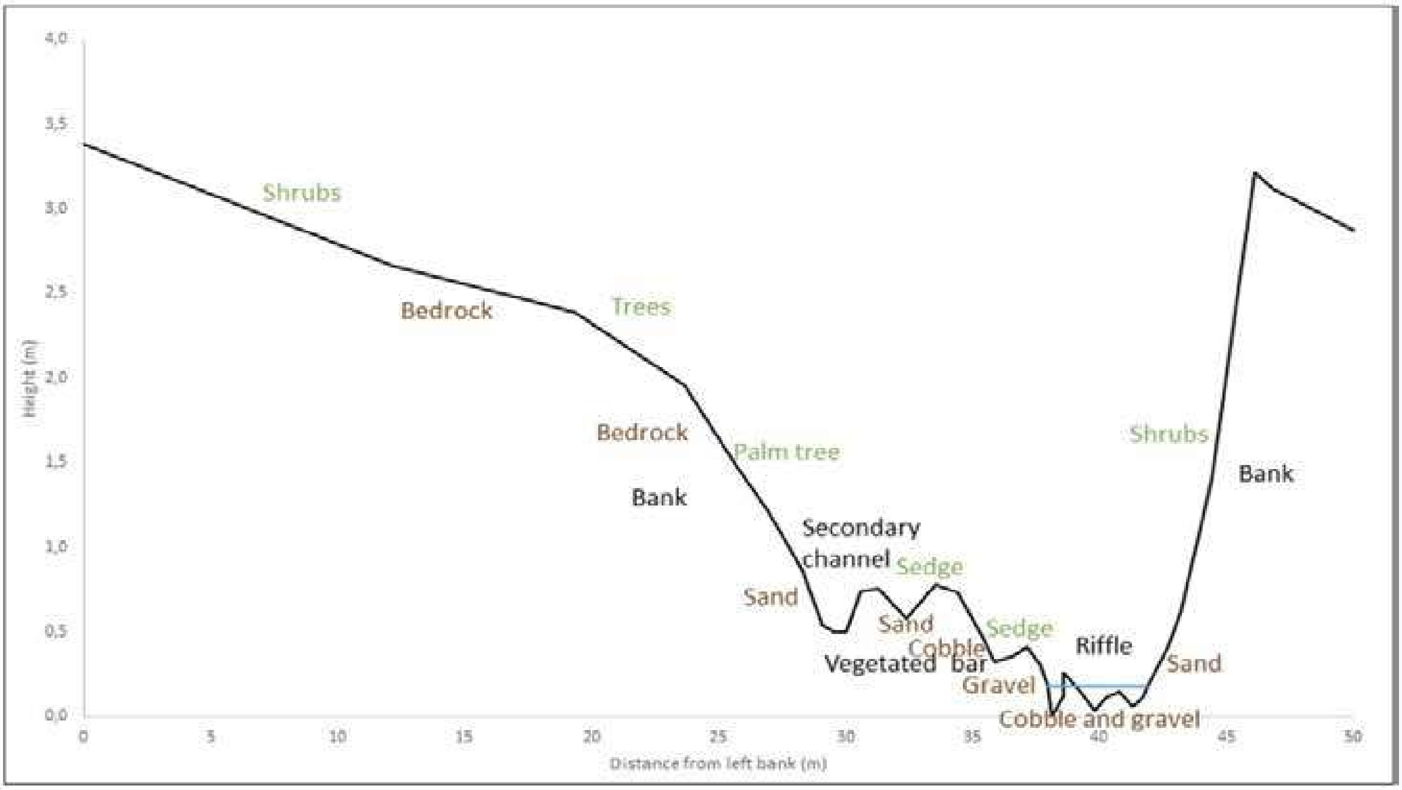
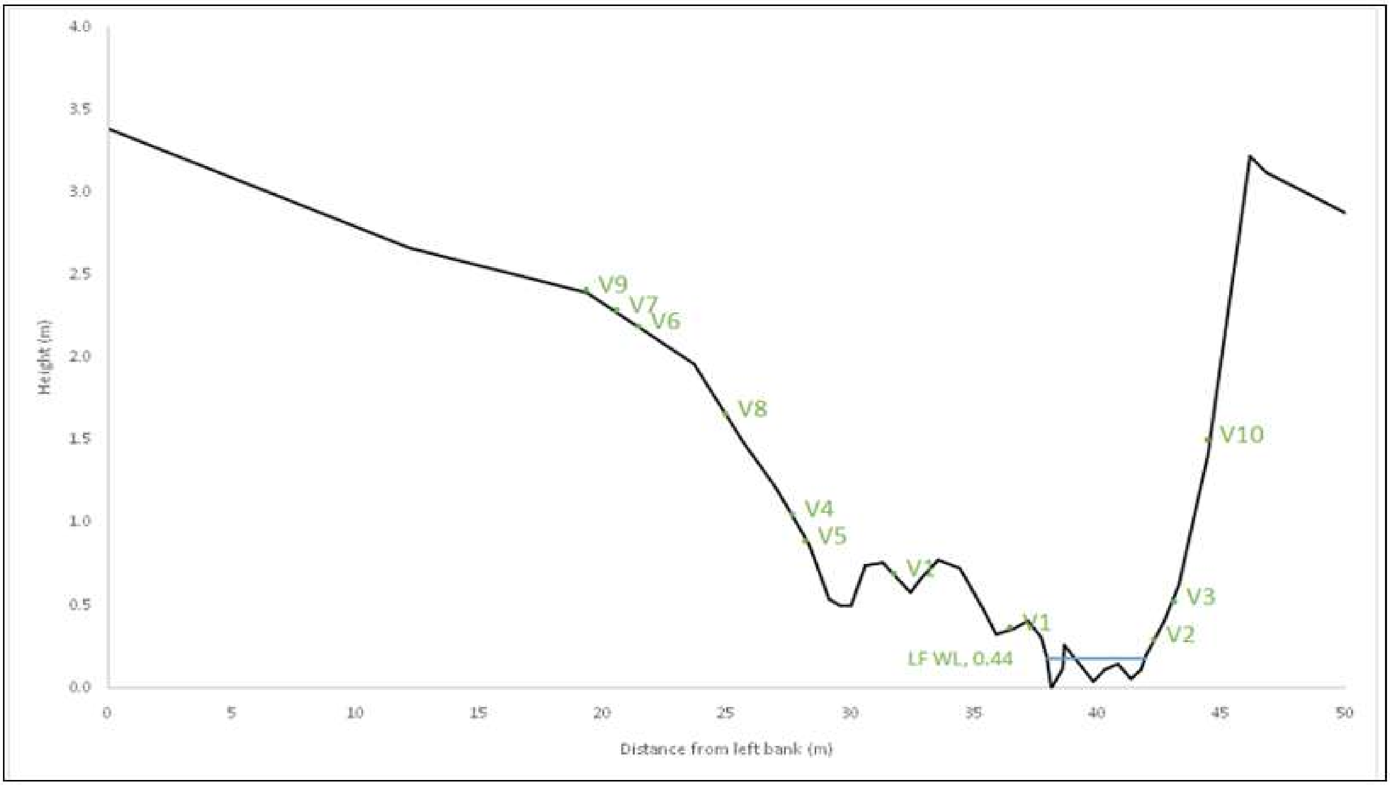


FIGURE 4 27: A CROSS SECTION ACROSS THE SOMOCHE RIVER SHOWING GEOMORPHIC FEATURES, DOMINANT SEDIMENT COMPOSITION AND VEGETATION TYPES.

bank, not allowing much lateral buffering.

4.3.2.4 Riparian Vegetation

The Somoche site was surveyed on both sides of the banks and the riparian zone was well covered with vegetation. Ideally the site would have a wider strip of riparian vegetation with more cover of grasses and sedges at the marginal and lower sub-zones and trees on upper sub-zones, at its reference conditions. Invasive and exotic species expected were expected to be absent at its reference condition. The river flows over a bedrock and large stones and there are also “island” made up of sand bars with several plant species dominated by notably papyrus Cyperus involutus and Cyperus distans. The left side of the river is used for grazing while the right is used for crop farming. Riparian indigenous species were found to be abundant i.e. around 65 percent of all the species. The site was used as watering point for cattle during the field survey. The left bank was more covered with vegetation as compared to right bank. Overall, the riparian zone was narrow likely due small size of the river itself and human pressure from grazing and agriculture. Marginal sub-zone had species like Paspalum scrobiculatum in addition to Cyperus species. Lower subzone had grass species Brachiaria scalaris, Echinochloa pyramidalis and Commelina benghalensis. At the upper sub-zone fig trees Ficus sur and F. exasperata and Acacia sp. were present. Sesbania macrantha and Mimosa pigra (an



Indicator Species	Number	Range	Remarks
Cyperus involutus	V1	marginal	thick dense stands
Paspalum scrobiculatum	V2	marginal	
Brachiaria scaralis	V3	lower	grass
Echinochloa pyramidalis	V4	lower	
Commelina benghalensis	V5	lower	forb
Ficus sur, F. exasperate	V6, V7	upper	young and adult trees
Palm trees	V8	upper	young and adults
Acacia sp.	V9	upper	large adult
Sesbania micrantha	V10	upper	small tree/shrub

FIGURE 4 28: CROSS SECTION OF THE SOMOCHE RIVER SHOWING INDICATOR PLANT SPECIES

invasive species) occupied benches of the Somoche River. Figure 4 28 shows the cross section with indicator species.

4.3.2.5 Fish

The Somoche site is located in the tributary of the Mara River, with northerly flow direction. The reach is considered to be straight. One primary GHU was identified and delineated for the site, namely a riffle with limited rapid characteristics (Figure 4 29). Sampling was undertaken by means of an electro-fisher. The velocity depth class associated with the GHU was FS. Substrate is dominated by gravel and cobbles, with boulders and bedrock also intermittently present across the reach. Aquatic vegetation was present at the site, with marginal and overhanging vegetation present. Root wads and undercut banks were also recorded but limited.

FIGURE 4 29: AERIAL VIEW OF THE SOMOCHE REACH SHOWING THE DELINEATED GHU FOR THE SITE (GOOGLE EARTH)

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	-	-	-	-	-	-
SD	-	-	-	-	-	-
FD	-	-	-	-	-	-
FS	> 75%	Leaves & stems	Roots & undercut banks	Rocks & cobbles	Tree debris	Sedges & bulrush

TABLE 4 23: A SUMMARY OF THE HCR FOR THE REACH WITH ASSOCIATED VELOCITY DEPTH CLASS RATINGS AND CORRESPONDING DETAILS.

Turbidity was considered to be high. An overview of the HCR ratings is presented in Table 4 23 and Figure 4 30.

A total of 14 fish species were sampled from the site, with a total of 108 individuals recorded for the site. Two indicator species were recorded for the site, namely Labeo victorianus and Oreochromis variabilis, both classified as critically endangered. The species composition was dominated by Labeo sp, comprising three genus.

Substrate was variable and consisted of numerous substrate types, with gravel and cobbles being dominant. Habitat cover was dominated by undercut

FIGURE 4 30: A PHOTOGRAPH DEPICTING HABITAT CHARACTERISTICS FOR THE SOMOCHE REACH (FEBRUARY 2019)

banks and also aquatic and overhanging vegetation. Habitat diversity was considered to be high, with one dominant velocity-depth class, namely FS.

4.3.2.6 Macroinvertebrates

Although there are clear signs of flow alteration in the system, likely linked to land use change and livestock activity and drinking, > 3 species of baetidae and Heptageniidae and Oligoneuridae were recorded at the site. This is also the only site that recorded freshwater crabs (Potamonautidae). The site recorded six rheophilic families which form 51 percent of all

Table 4-24: Macroinvertebrate community metrics for Somoche

Community Metrics	Score
Total abundance	1601
No. of taxa	44
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	1083
% EPT	67.65
Number rheophilic taxa	6
Abundance of rheophilic taxa	806
Relative abundance of rheophilic taxa	50.34
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	789
% STH	49.28

Table 4-25: Results of the SASS5 and TARISS on processed samples at Somoche

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	Number of taxa	ASPT	TARISS Score	Number of taxa	ASPT
191	29	6.6	193	29	6.7

Laboratory analysis for the SASS5 Protocol		
Total SASS Score	No. of taxa	ASPT
227	44	5.2

individuals at the site. Table 4 24 and Table 4 25 below indicate the field and laboratory processed score results for the site.

4.3.2.7 Water Quality

EC, pH, DO of the site within acceptable limits for both drinking water standards and fish requirements.

Turbidity was much higher during the 2nd round of survey than the 1st due to increased rainfall therefore increased sediments in the river. Small levels of total nitrogen measured but also within acceptable

Table 4-26: Results of water quality analysis at Somoche

Parameter	Unit	1st survey	2nd survey
pH	(-)	7.7	7.5
Electrical conductivity (EC)	µs/cm	309	160.2
Temperature (T)	deg C	25.1	24.6
Dissolved oxygen (DO)	mg/L	6.6	6.2
Oxygen saturation	%	93.2	85.9
Turbidity	T.U	200	1,000
Nitrate (NO_3^-)	mg/L	0	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	195.2	ns
Ammonium (NH_4^+)	mg/L	0.11	0.05
Non purgeable organic carbon (NPOC)	mg/L	8.9	6.98
Total nitrogen (TN)	mg/L	1.6	1.01

ns: not sampled

limits. Table 4 26 shows the field measurements and laboratory results for water quality samples taken at

Table 4-27: Site metrics for Somoche

Metric	Social	Geomorph	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	B/C	B	B	B	B	B
ToC	Declining	Stable/ declining	Declining	Declining	Declining	Stable
EIS	Medium	Medium	High	High	High	High
SIS	High	-	-	Moderate	Medium	Low
EMC	B	B	B	A/B	B	B

the site.

4.3.3 Site Metrics

Table 4-28: Indicators and management objectives for Somoche

EFA Component	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including recession agriculture depended by 60 percent of the population, vegetables & fruits collection/cultivation and subsistence fishing for the local communities residing along the Somoche river
	Target species	The following species should be abundant enough to suffice the needs of the population residing along Somoche River: Fish: Mumi and Kamongo Vegetables: Chinderema and Chinsaga Trees:Chinsere, Chinseke, and Ebinyabutati Other resources: Ukindu
Geomorphology	Pool depth	Maintain pools of at least 0.5 m deep
	Available gravel and cobble habitat	Maintain flow variability and moderate sediment supply to maintain this habitat in good condition (e.g. not embedded with fine sediment)
Riparian Vegetation	Sedge and grass communities	Continue to maintain abundances of flow sensitive sedge species (e.g., *Cyperus involutus and Cyperus distans*) at the site Continue to maintain abundances of moderately flow sensitive plant species (e.g., *Paspalum scrobiculatum* and *Echinochloa pyramidalis*). If depth of water for flow sensitive plant species is met then it should suffice this group too.
	C. involutus, *C. distans*, and *P. maximum*	Continued presence and occurrence of seedlings and adults of *C. involutus, C. distans and P. maximum* and the three should together be present at abundance of ≥20 percent
	Riparian tree communities	Continued presence and occurrence of seedlings, saplings and adults of *Ficus sur* with at least 10 percent abundance

Table 4-28: Indicators and management objectives for Somoche

EFA Component	Indicator	Management Objective(s)
Fish	Recruitment of indicator cyprinids spp.	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
	Fish community wellbeing assessment	If the previous indicator is not observed a fish community wellbeing assessment should be undertaken
Invertebrates	SASS5 or TARISS Index	South African Scoring System (SASS5) or TARISS Index score >150 and Av. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
	Ephemeroptera, *Plecoptera*, and *Trichoptera* orders	The following orders should be present in abundances >50 percent of the invertebrate community
	Hydropsychidae, *Simuliidae*, and *Tricorythidae* families	The following flow sensitive families should be present in abundances >30 percent of the invertebrate community during the wet season when the river is flowing
	Target species: Oligoneuridae sp. and *Potamonautes sp.*	*Oligoneuridae* is among the most sensitive family of macroinvertebrates to both water quality and quantity, and hence should be present at the site as a sign of good water and habitat conditions (no sedimentation). *Potamonautes* (freshwater crabs) depend on a well maintained riparian forest for food (leaf litter) and reproduction. Their presence means maintaining the riparian zone along the river and flow permanence throughout the year since they are long-lived species.
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish/macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic and livestock watering purposes

4.3.4 Indicators and Management Objectives

Table 4-29: Required flow conditions for Somoche

	Hydrological Component	Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Depth (m): 0.5 Inundation: 0 days Flow (m^3/s): 0.15	**Freshets** Depth (m): 0.7 Inundation: average over 2 days, 4 events during wet season Flow (m^3/s): 2.7	Month: August Depth (m): 0.4 Velocity (m/s): 0.62 Flow (m^3/s): 0.2	Month: Feb, Jun, Jul, Aug, Dec Depth (m): 0.3 (0.18 avg) Velocity (m/s): 0.237 Inundation: >10 days Flow (m^3/s): 0.3	Month: Feb, Oct Depth (m): 0. 08 Velocity (m/s): Av. Vel. 0.06, Max vel. 0.21 Flow (m^3/s): 0.03
	Low flows, wettest month	Depth (m): 0.5 Inundation: 0 days Flow (m^3/s) : 0.8	**High Flows** Depth (m): 1.1 Velocity (m/s): Inundation: 2 day peak Flow (m^3/s): 9	Depth (m): 0.5 Velocity (m/s): 1.1 Flow (m^3/s): 0.3	Month: Apr, May Depth (m): 0.46 (0.24 Avg) Velocity (m/s): 0.5 Inundation: >30 days Flow (m^3/s): 0.9	Month: April Depth (m): 0. 32 Velocity (m/s): avg 0.4, max. 1.2 Flow (m^3/s): 0.34
	High flows, freshets and/or floods	Depth (m): 1.13 Velocity (m/s): 1.48 Inundation:14 days Flow (m^3/s): 39	**Floods** Depth (m): 2.4 Inundation: peak over 2 days Wet season, 1 in 3/5 year event Flow (m^3/s): 70	Month: Apr- May Depth (m): 1.5 Velocity (m/s): 1.2 Flow (m^3/s): 20.2 1 in 3 years for at least 2 days. **Floods** Depth (m): 2.4 Velocity (m/s): 1.89 Flow (m3/s): 69.9 once in 5 yrs.	Depth (m): 0.62 (0.31 avg) Velocity (m/s): 0.62 Inundation: >14 days Flow (m^3/s): 1.9	Month: Apr-May, Nov- Dec Depth (m): 0. 38 Velocity (m/s): avg 0.44, max 1.34 Flow (m^3/s): 0.54 **Annual Flood** Depth (m): 0.5 Velocity (m/s): avg 0.52, max 1.58 Flow (m^3/s): 1
Drought Year	Low flows, driest month	None	None	Month: August Depth (m): 0.36 Velocity (m/s): 0.5 Flow (m^3/s): 0.2	Flow (m^3/s): 0	Month: August Depth (m): 0 Flow (m^3/s): >0
	Low flows, wettest month	None	**Freshets** Depth (m): 0.7 Inundation: average over 2 days 3 events during wet season Flow (m^3/s): 2.7	Depth (m): 0.42 Velocity (m/s): 0.6 Flow (m^3/s): 0.2	Flow (m^3/s): 0	Month: May Depth (m): 0. 32 Velocity (m/s): avg 0.33, max 1.05 Flow (m^3/s): >0
	High flows, freshets and/or floods	None	**High Flows** Depth (m): 1.1 Inundation: 2 day peak Annually during the wet season Flow (m^3/s): 9	Month: Apr-May Depth (m): 0.5 Velocity (m/s): 0.53 Flow (m^3/s): 1.11 Floods at least 1 in 3 yrs. for 2 days	Depth (m): 0.46 (0.24 avg) Velocity (m/s): 0.5 Inundation: >21 days Flow (m^3/s): 0.9	Month: Apr-May, Nov- Dec Depth (m): 0. 36 Velocity (m/s): avg 0.4, max 1.23 Flow (m^3/s): 0.5

Table 4-30: Confidence level for flow recommendations for Somoche

Site Name	Rating	Rationale
Social	4	The findings were matching with those of biophysical scientists
Hydraulics	3.5	Straight channel with pool riffle/rapid habitat. Two observations at relatively low flows used for calibration
Geomorphology	3.5	Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5	The river had several habitats covered with plants of different species including sedges, grasses, forbs and trees. Most of the species score were native species.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecolo of species and social relationships.
Macroinvertebrates	2	No previous studies on macroinvertebrates exist in this river and the discharge values on which I based my recommendations on have be modeled. This gives low confidence to the flow values proposed.
Water Quality	-	Water quality was not linked to discharge levels during this assessme and there was no historical data with which to compare the study resu

4.3.5 Required Conditions

4.3.6 Confidence Ratings

4.4 Tigithe

The EFA biophysical site at Tigithe is located about 5 km upstream from where it flows into the upper Mara Wetland. It flows parallel to the Mara River and flows directly into the Mara Wetland, near to where the Mara River enters the wetland. The area has higher rainfall than other areas of the Mara River Basin, although it is still considered a seasonal system by local residents. The Tigithe River is dominated by a riffle-pool system, with fine gravels, silty clays, and large cobbles present. There are high terraces on both banks and slight evidence of incision. There is commercial and artisanal mining in this catchment and there is concern over pollution in the river, although this is not related to alterations in flow. The fish here seem highly connected with the wetland species, indicating migration between the two

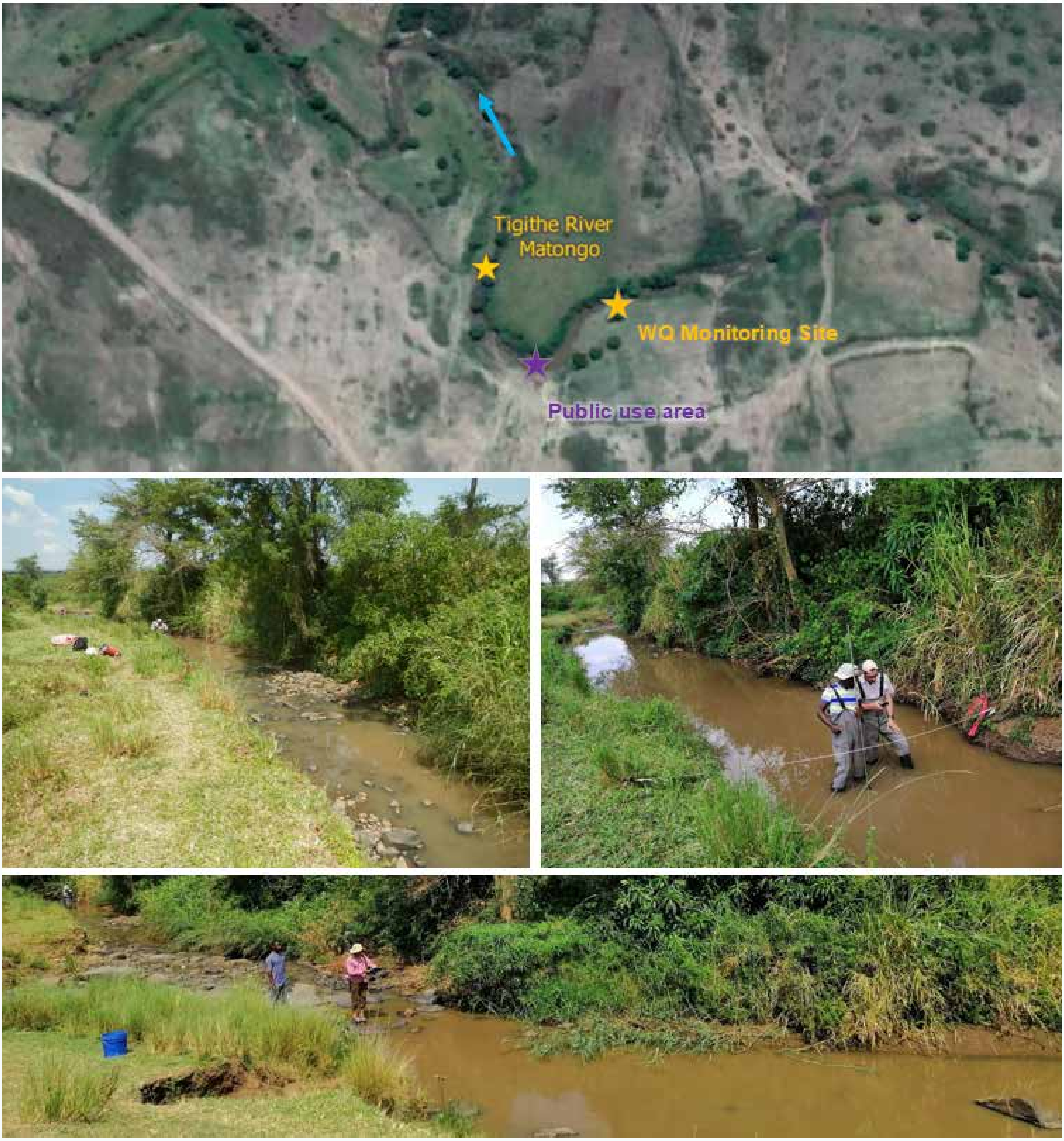


FIGURE 4 31: SITE PHOTOS OF TIGITHE

areas. Flows during drought conditions are needed to maintain good water quality in pools for aquatic species.

4.4.1 Social Survey

The Tigithe sub-basin consists of two RUs: the Lower Tigithe RU and the Upper Tigithe RU. Tigithe River is seasonal and dries up three times yearly from July to August. However, it is fed by many tributaries which are either permanent or seasonal. Flooding in the Lower Tigithe RU mostly occurs in the lower and middle reaches of the rivers due to confluence of various tributaries. The inundation lasts for a day and extends up to three kilometers while the depth of water goes up to one meter. This has formed a wetland which its extension has been increasing over the years.

4.4.1.1 Lower Tigithe

Lower Tigithe has about 10 species of fish that were identified by the community, 17 species of natural vegetables, 17 species of fruit trees, 50 tree species for building poles, five species of weaving reeds and seven species of thatching grass. Fourteen ecosystem services derived from wetland and rivers were identified to be useful for livelihood of communities in Lower Tigithe RU. Table 4 31 shows the wetland

Table 4-31: Wetland resources and their relative importance to the livelihood of communities in Lower Tigithe

No.	Wetland Resources	Relative Importance (%) per Sample Villages		Average
		Matongo	Nyakunguru	
1	Water	61.9	55.6	58.8
2	Cultivation Land	30.9	27.8	29.4
3	Livestock Pastures	1.5	9.3	5.4
4	Building Poles	0	4.3	2.2
5	Roofing grasses	1.5	2.2	1.9
6	Natural vegetables	1.5	0.7	1.1
7	Firewood/Charcoal	1.5		0.8
8	Weaving grasses	0.8		0.4
9	Medicinal Plants	0.2		0.1
10	Fish	0.1	0	0.1
11	Building Sands	0	0	0
12	Burned Bricks		0	0
13	Natural fruits	0	0	0
14	Wildlife (animals and birds)	0		0

resources/ecosystem services obtained in this RU and their relative importance to the two villages.

Four main economic activities are practiced in this RU i.e. Agriculture, livestock keeping (cows, sheep, chicken and donkey), petty trade, and mining in Matongo village (Table 4 32). Agricultural activities involve cultivation of crops such as maize, millet, bullrush millet, cassava, sweet potatoes, vegetables,

Table 4-32: Economic activities in Lower Tigithe RU

Activity		Performer	Location/Why	Time/Why
Agriculture	Maize Bullrush millet/Millet Paddy/rice Cassava Sweet potatoes Tobacco Fruits Bananas	Household Household Household Household Household Household Household Household	Scattered in the house Around the house Around the house Tigithe Mara valley because of its fertility and moisture Small irrigation	Jan – June Sep - Jan
Livestock keeping (cattle)		No specific place Famous during dry season		Jul - Aug
Mining			Near river banks	
Small business				

Table 4-33: Trend of resources and condition of the wetland in Lower Tigithe

Resource	Nyerere's Regime (1960 - 1985)	Current Situation	Future Expectations (2030)	Reasons
Fish	510	100	10	Encroachment of wetland areas by crop farmers
Wild vegetables	515	100	2.5	Expansion of crop farming to wetland areas Tree distorts the growth of vegetables through shading Polluted water from the Nyamongo mine impair vegetable growth Soil fertility has decreased
Wild fruits	530	100	2.5	Cutting down fruits trees for crop farming, charcoal and firewood.
Weaving materials	50	100	200	High production capacity Spread as the river expands. In most places the river-width has increased.
Building poles	1750	100	4.5	Cutting down of trees for crops cultivation, charcoal and firewood. Population increases.
Thatching materials	1250	100	03	Increase in population Expansion of crop cultivation Increased in livestock which poses competition with limited pastures
Degradation of wetland/river ecosystem	15	100	200	Little knowledge on environmental education Increase in population Extensive and uncontrolled farming in the wetlands Increasing plantation of eucalyptus which consumes much water

Table 4-33: Trend of resources and condition of the wetland in Lower Tigithe

Resource	Nyerere's Regime (1960 - 1985)	Current Situation	Future Expectations (2030)	Reasons
Dependency of community to rivers and other wetland resources for their livelihood	45	100	1100	Land uses have increased as a result of population growth Limited substitute and when available are too expensive to afford. No resource options for cultural activities
Size (width) of the river	50	100	200	Soil erosion
Quality of wetland/river	900	100	10	Expansion of the crop framings to the river banks Chemicals depositions in the wetlands from Nyamongo mines.

paddy/rice and bananas. The trend of resource utilization and condition of the wetland from the past to the future is shown in Table 4 33 below.

4.4.1.2 Upper Tigithe

The number of resources reported to be available in Upper Tigithe is much less compared to the number in Lower Tigithe. This include two fish species (Mumi and Furu), 12 species of natural vegetables, 12 species of fruit trees, 10 species of timber and building poles, one weaving material and four types of thatching

Table 4-34: Wetland resources and their relative importance to the livelihood of communities in Upper Tigithe

No.	Wetland Resources	Relative Importance (%) per sample villages		Average
		Kitawasi	Bungurere	
1	Water	88.9	65.3	77.1
2	Livestock Pastures	8.9	3.3	6.1
3	Cultivation Land	2.2	6.5	4.4
4	Firewood/Charcoal		6.5	3.3
5	Building Poles		3.3	1.7
6	Roofing grasses		3.3	1.7
7	Building Stones		3.3	1.7
8	Burned Bricks		3.3	1.7
9	Natural vegetables		1.6	0.8
10	Medicinal Plants		1.6	0.8
11	Natural fruits		0.8	0.4
12	Good air		0.8	0.4
13	Fish		0.4	0.2

grass. The number of wetland resources and their importance to the community is outlined in Table 4 34 below.

In terms of economic activities, only three were identified in the village: agriculture, livestock keeping and petty trade (Table 4 35).

Table 4-35: Economic activities in Kitawasi village in Upper Tigithe

Activity		Performer	Location/Why	Time/Why
Agriculture	Maize Millet Cassava Sweet potatoes Vegetables Bananas Coffee		Around household	Twice a year
Livestock keeping			In farms, privately	
Small business				

Table 4 36 below shows trend of resources utilization and condition of the wetland resources over the years. A hypothetical value of 100 was set as a current benchmark and perceived values of these

Table 4-36: Trend of resources utilization and condition of the wetland in Upper Tigithe

Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Fish	1000	100	30	Increased in population Illegal fishing Environmental degradation
Wild vegetables	1150	100	22.5	Water pollution Decrease in fertility of riparian land Destruction of vegetables by livestock during grazing Destruction of wetland areas by planting exotic plants
Wild fruits	1750	100	12.5	Increase in population Cutting of trees for crop cultivation Cutting of natural trees and replacement with exotic plants
Weaving materials	150	100	140	High rate of reproduction The rate of consumption is limited compared to regeneration
Building poles	5025	100	20.5	High exploitation of trees for multiple uses such as charcoal and firewood. Cutting of natural trees and replacement with exotic plants
Thatching materials	260	100	37.5	Increase in population Expansion of agricultural activities

Table 4-36: Trend of resources utilization and condition of the wetland in Upper Tigithe

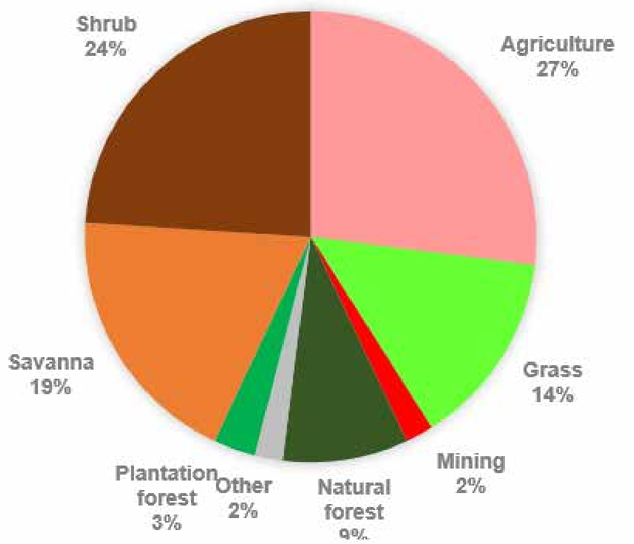
Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Degradation of wetland/river ecosystem	15	100	600	Little environmental education Increase in cutting of trees Population increase.
Dependency of community to rivers and other wetland resources for their livelihood	1750	100	50	Decrease in wetland resources and therefore limited resources to depend on Presence of substitutes, though are expensive
Size (width) of the river	40	100	175	Cutting down of trees. Extensive agricultural activities near water sources. Water flow increases hence distort river bank.
Quality of wetland/river	900	100	10	Destruction of water point Chemicals depositions in the wetlands from Nyamongo mines.

resources in the past and future with reference to the set benchmark indicated. The possible reasons for change have also highlighted.

4.4.2 Biophysical – Tigithe River at Matongo

4.4.2.1 Hydrology

The Tigithe EFA site has a contributing upstream catchment area of 183 km2 with a dominated land use of agriculture, shrub land, and savanna (Figure 4



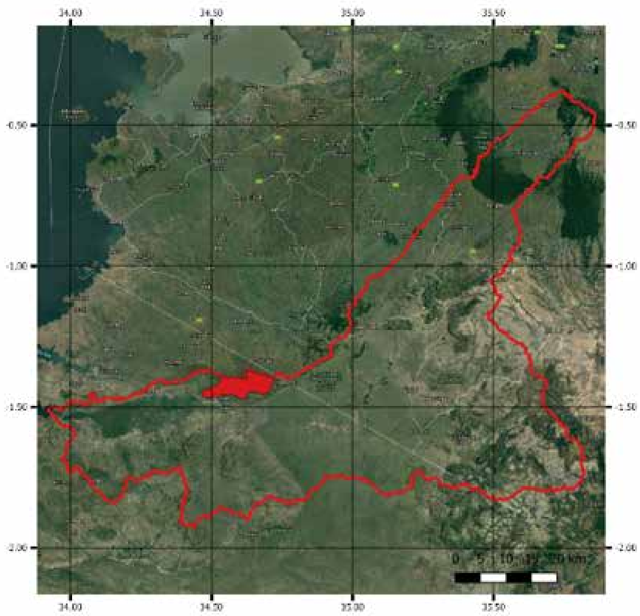


FIGURE 4 32: LAND USE WITHIN THE TIGITHE SUB-CATCHMENT (LEFT) AND CATCHMENT AREA (RIGHT)

32). Precipitation in the catchment sums up to 1,100 mm/yr, resulting in an evaporation value of 1,018 mm/yr, and a runoff value of 82 mm/yr.
Average monthly, minimum and maximum discharge

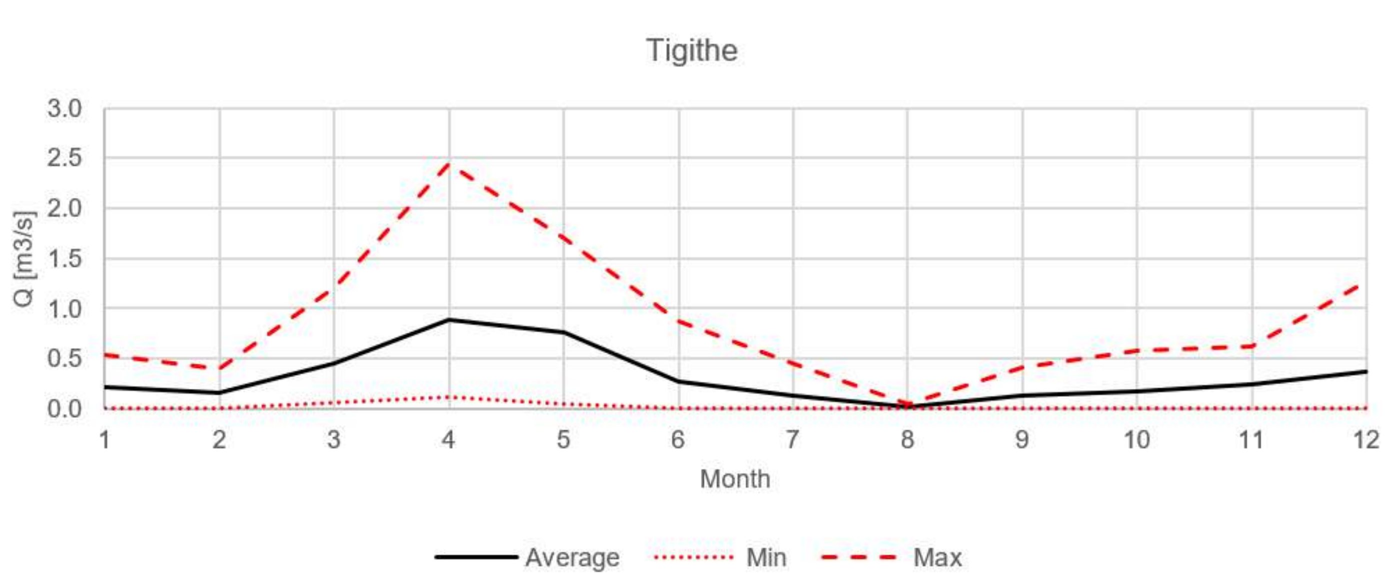


FIGURE 4 33: AVERAGE MONTHLY, MINIMUM AND MAXIMUM DISCHARGE VALUES FOR THE TIGITHE EFA SITE

values for Tigithe EFA site are presented in Figure 4 33. Typically, April is the wettest month and August is the driest month, going almost to zero m3/s.

4.4.2.2 Hydraulics

The Tigithe River follows a pool riffle sequence with slow-flowing pools and steeper faster turbulent flow along riffle sections. The hydraulic transect is shown in Figure 4 34 with the observed and modelled flow levels indicated. There was a weak relationship between depth and velocity (R2 < 0.36), showing high variability in the velocity–depth association

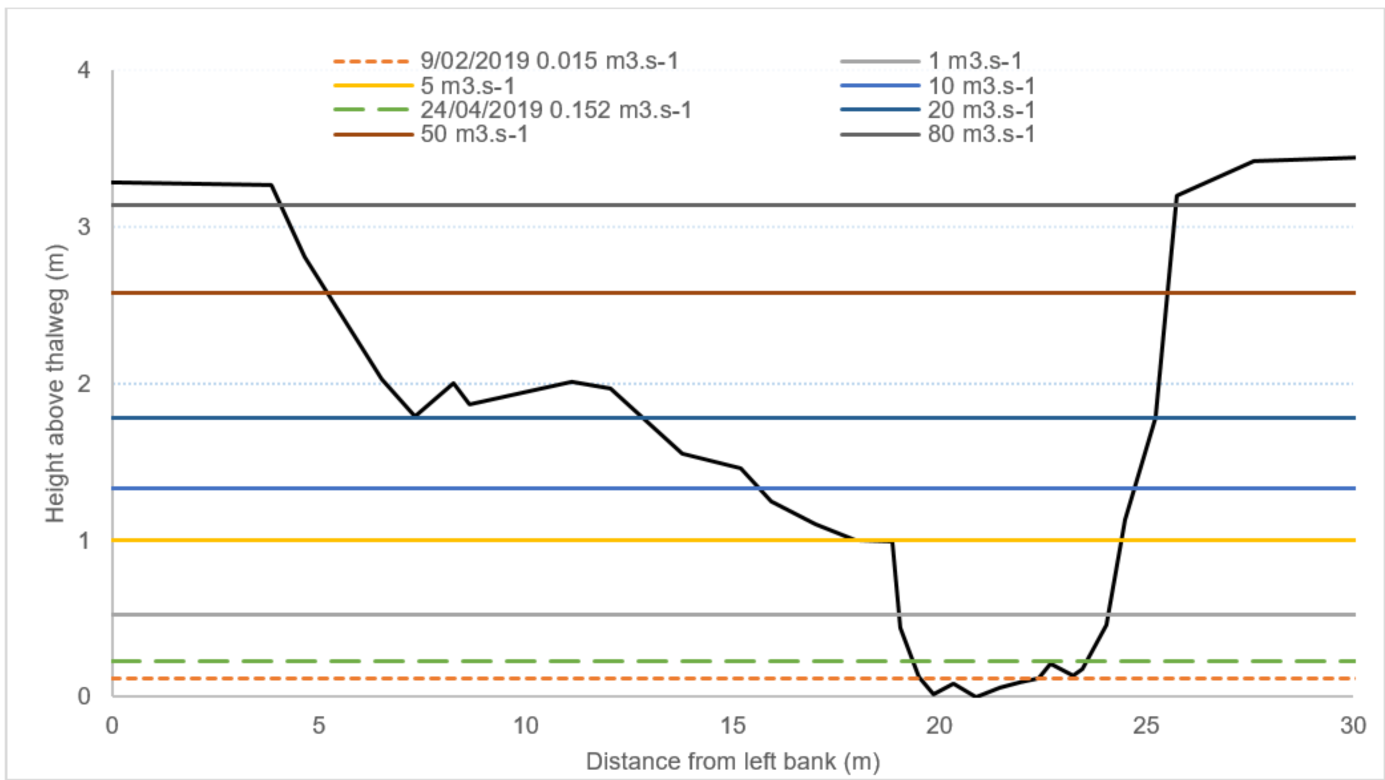
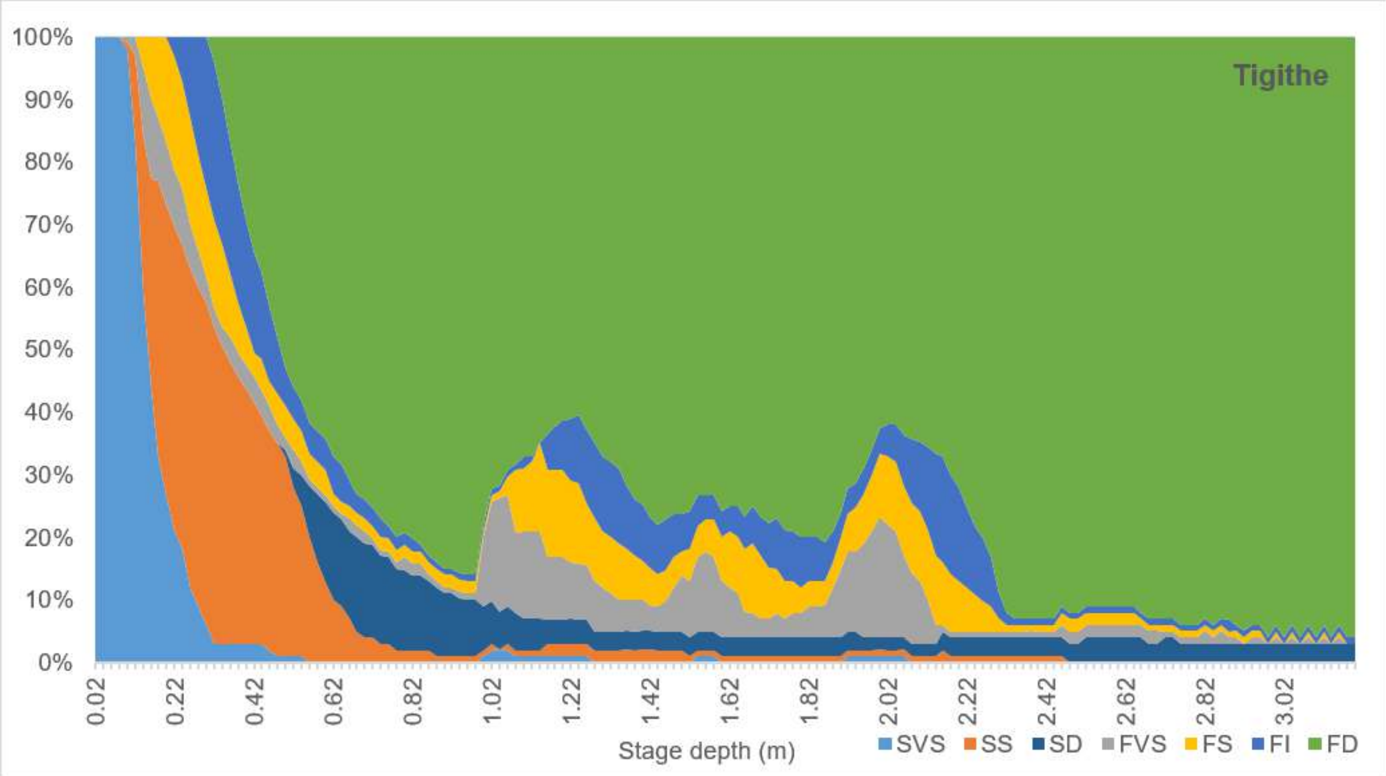


FIGURE 4 34: CROSS SECTION FOR TIGITHE RIVER SHOWING OBSERVED FLOW LEVELS (DOTTED LINES) AND MODELLED FLOW LEVELS (SOLID LINES)



SVS: slow, very shallow; SS: slow, shallow; SD: slow, deep; FVS: fast, very shallow; FS: fast, shallow; FI: fast, intermediate; FD: fast, deep

FIGURE 4 35: FREQUENCY DISTRIBUTION FOR VELOCITY-DEPTH CLASSES FOR THE WETTED CHANNEL OF THE TIGITHE RIVER

across the channel. The frequency distribution of the flow velocity-depth classes for the wetted channel are presented in Figure 4 35.

4.4.2.3 Geomorphology

Tigithe channel is a straight to sinuous channel with a pool-rapid sequence (Figure 4 36). The channel slope is 0.007808 and can be classified as a channel of the upper foothill zone (Rowntree and Wadeson, 1999). Rowntree and Wadeson define the reference condition as "moderately steep, cobble bed or mixed bedrock-cobble bed channel with plain bed, pool riffle, or pool rapid reach types. The length of pools and riffles /rapids are similar. Narrow flood plain of sand, gravel or cobble often present". The site fits this description well.

The channel is bedrock controlled and incised into the landscape as is evident by the narrow floodplain and terrace along the right bank (Figure 4 37). The terrace consists of silt and the floodplain/bench of layers of small gravel and sand. Recent flood deposited sand is present on the floodplain/bench. The banks are near vertical with active erosion along short sections of bank. A narrow inset bench lines the right bank composed of medium sand. The riffles consist of armored cobble with voids filled with coarse sand and fine gravel. A silt drape is present on bed features where the flow velocities are lower. The bed of the pools consist of fine gravel and silt.

The Tigithe River plays an important role in maintaining a large back swamp area to the North of the Mara channel (Figure 4 38). The back swamp forms on the Mara floodplain as a result of the alluvial ridge that forms due to sediment deposition along the Mara River. The Mara spills into this back swamp during flood conditions, but the Tigithe permanently

FIGURE 4 36: A SATELLITE IMAGE SHOWING THE TRANSECT POSITION (WHITE LINE) AND THE POOL-RIFFLE SEQUENCE ALONG THE TIGITHE RIVER (GOOGLE EARTH IMAGE DATE 17 JAN 2010).

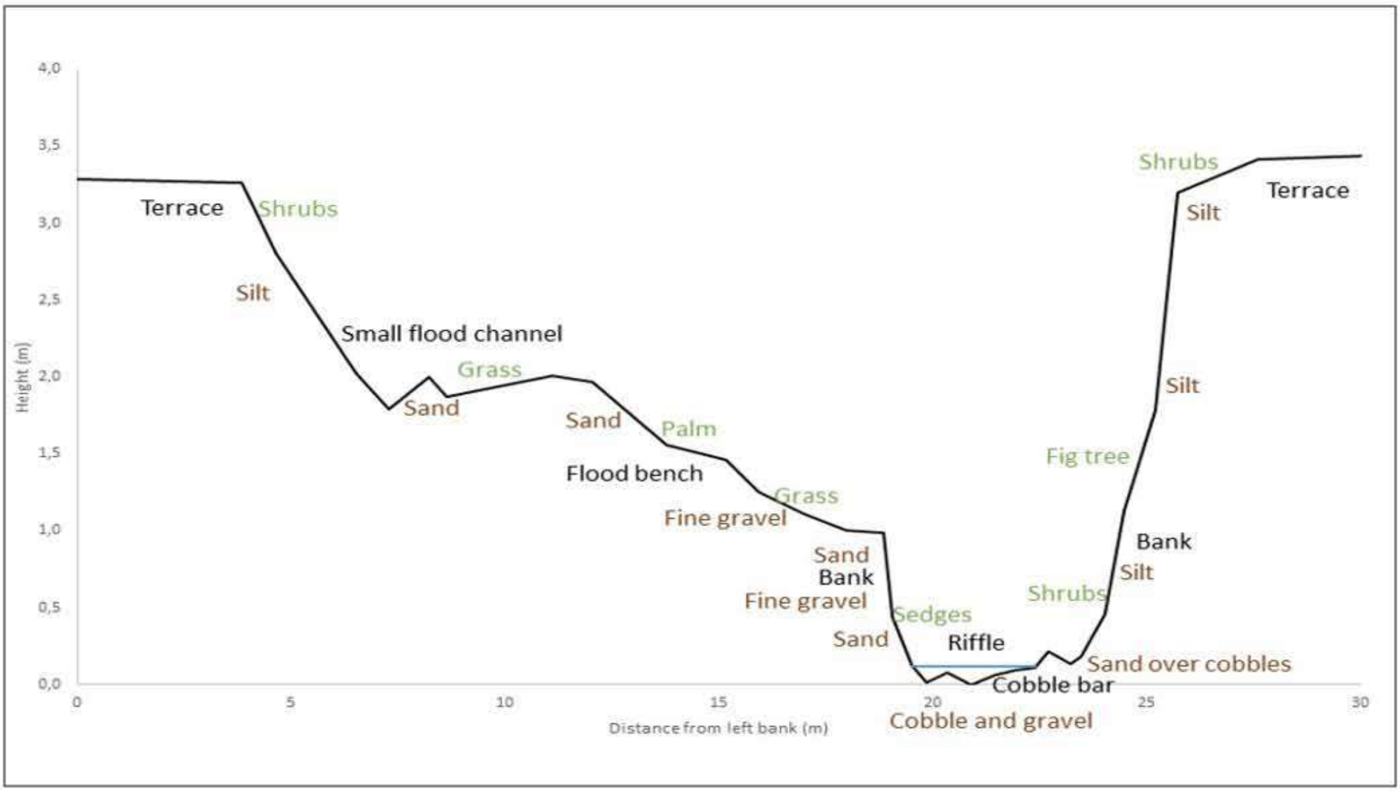


Figure 4 37: Channel cross section for the Tigithe River indicating the geomorphic features (black text), sediment type (brown text) and vegetation type (green text).

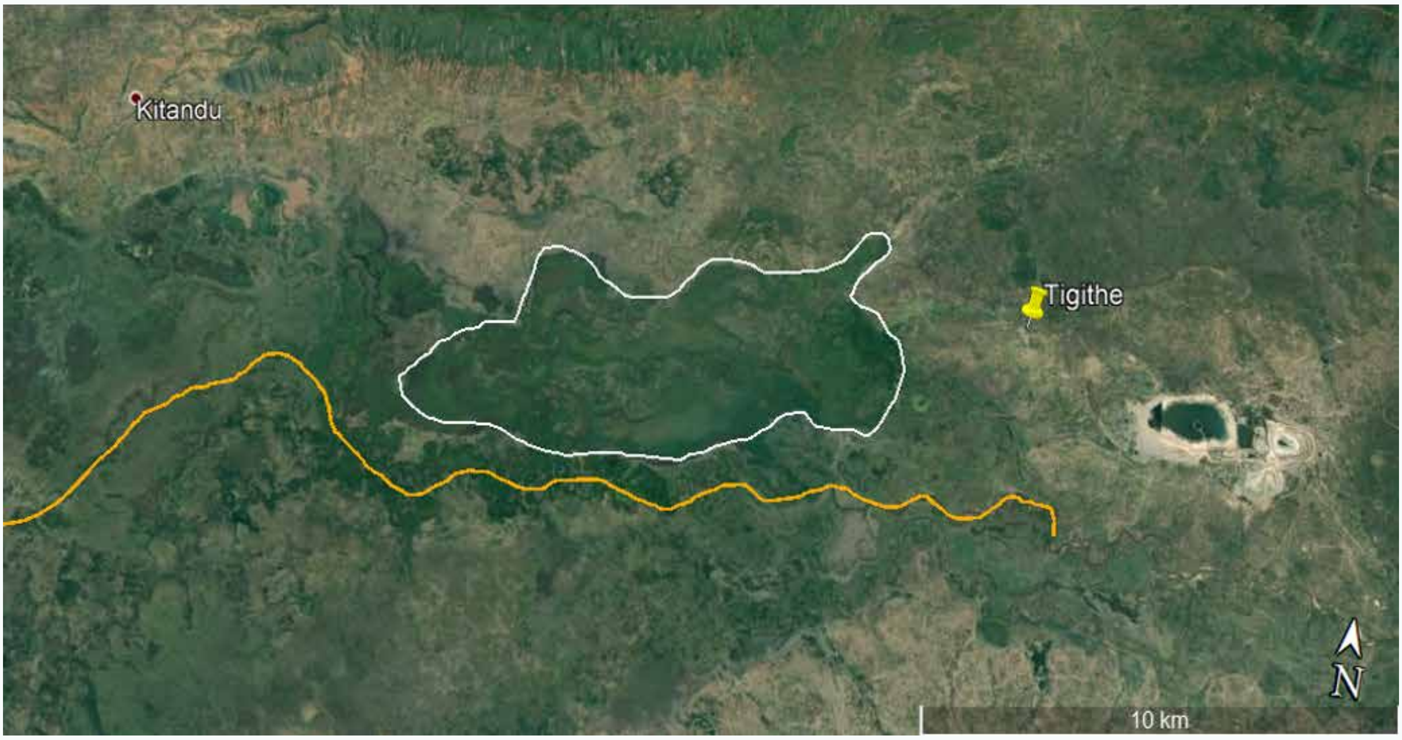


FIGURE 4 38: A GOOGLE EARTH IMAGE SHOWING THE BACK SWAMP (ENCIRCLED BY THE WHITE LINE) FORMED BY THE ALLUVIAL RIDGE/LEVEE (BROWN LINE) ALONG MARA RIVER. THE TIGITHE RIVER DRAINS INTO THE BACK SWAMP PERMANENTLY AND THE MARA RIVER ONLY DURING FLOOD FLOWS. FLOW DIRECTION IS FROM EAST TO WEST.

contributes to its water balance, making it a crucial source of surface water during low flow conditions.

4.4.2.4 Riparian Vegetation

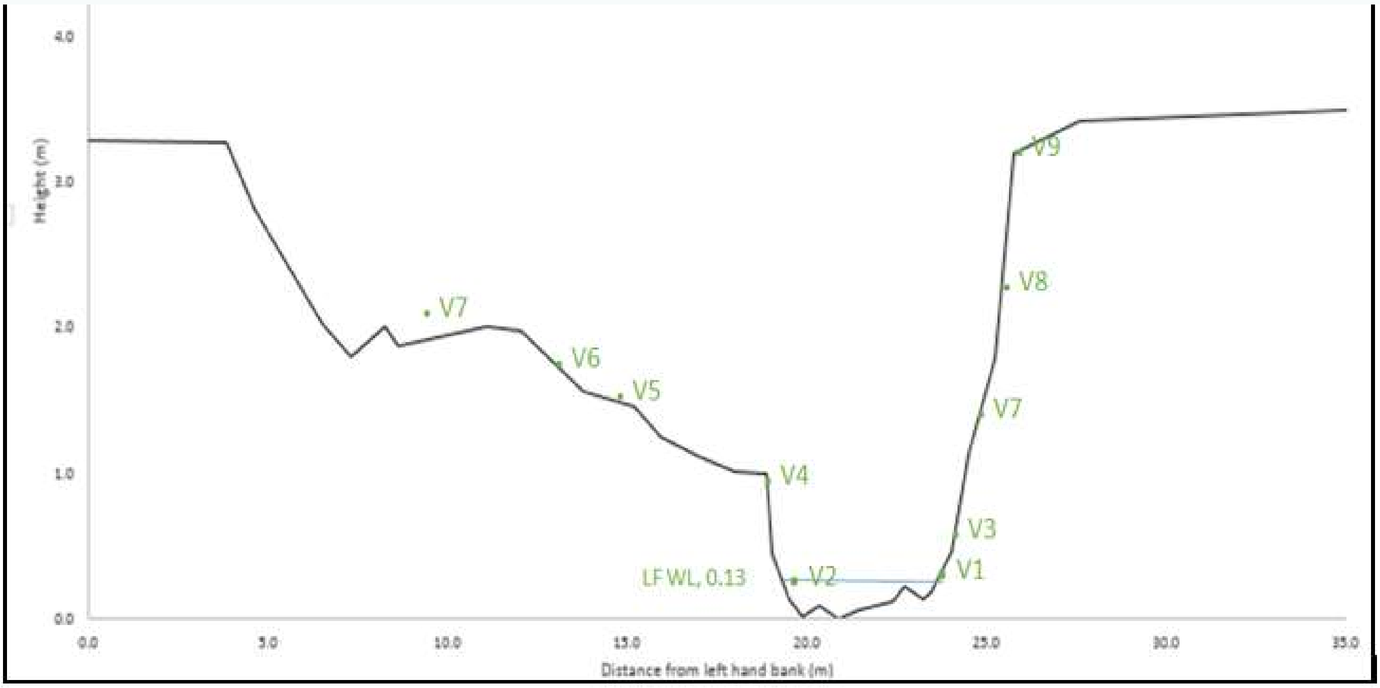
The bed of Tigithe River is made up of cobbles stones and sand and both left and right banks appear to be stable. At its natural state the site would have more vegetation cover in riparian area and at both banks. Herbaceous vegetation would have been tall on the floodplain which is on left side of the river. There would also be more riparian trees on both river banks. Absence of terrestrial tree species like Leucacena leucocephala and Lantana camara on the macro-channel bank would be expected. A strip of around 100 m was selected to study riparian vegetation in Tigithe.

Members of Poacea and Cyperaceae families dominated the marginal sub-zone including Cyperus cyperoides, Coix lacryma and Eriochloa macclounii. Lower sub-zone was occupied by Commelina carsonii, C. benghalensis, Cyperus cyperoides and Cynodon dactylon. Among the studied sites this was the site with more species richness in the Mara basin. Floodplain area was present on the left side and was dominated by grasses including Cynodon nlemfuensis (around 60 percent), Setaria sphacelata, Echinochloa sp., Hyparrhenia rufa and Brachiaria brizantha. Grazing and browsing by livestock appear to be high resulting in to lawns on the floodplain and pruned shrubs on terrestrial part of the system. Lantana camara was present in macro-channel bank. Overall, the vegetation cover was about 70 percent. Figure 4 39 shows cross section and plant species distribution at the site.

4.4.2.5 Fish

Tigithe River meanders with the flow in a westerly and northerly direction for the reach surveyed. Two primary GHUs were identified and delineated for the site, namely a pool and rapids (Figure 4 40). A total of four shallow pools and one deep pool were sampled with an electro-fisher and fyke net for the study, with all pools characterized by slow velocity. Four rapid areas were sampled, with all these areas characterized by a FS velocity-depth class. Substrate in the pools is dominated by sand and cobbles, with the substrate associated with the rapids characterized by rocks, cobbles and bedrock.

Turbidity was considered to be high. No aquatic vegetation was present at the site, with marginal and overhanging vegetation present for almost the entire extent of the reach. Root wads and undercut banks were also recorded for the majority of the pool units.



Indicator species	Number	Range	Remarks
Cyperus cyperoides	V1	marginal	
Coix lacryma	V2	marginal	
Forbs	V3	lower	
Cynodon dactylon	V4	lower	
Cynodon nlemfuensis	V5	upper	start of flood bench
Grasses**	V6	flood bench	dominated flood bench
Shrubs***	V7	upper	
Fig sp.	V8	upper	
Leucaena leucocephala	V9	upper/macro-channel bank	adult trees ~ 2 individuals, terrestrial

**Includes Commelina carsonii and C. benghalensis*

***Includes Setaria sphaceleta, Echinochloa sp., Hyparrhenia rufa and Brachiaria brizantha*

****Includes L. camara and Tithonia diversifolia*

FIGURE 4 39: CROSS SECTION OF THE TIGITHE RIVER SHOWING INDICATOR PLANT SPECIES

Table 4-37: A summary of the HCR for the reach with associated velocity depth class ratings and corresponding details.

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	25 – 75%	Leaves & stems	Roots & undercut banks	Sand & cobbles	Tree debris	Sedges
SD	5 – 25%	Leaves & stems	Roots & undercut banks	Sand & cobbles	Tree debris	Sedges
FD	-	-	-	-	-	-
FS	5 – 25%	Leaves & stems	Undercut banks	Rocks & cobbles	-	-

FIGURE 4 40: AERIAL VIEW OF THE TIGITHE RIVER SHOWING THE DELINEATED GHUS FOR THE SITE (GOOGLE EARTH)

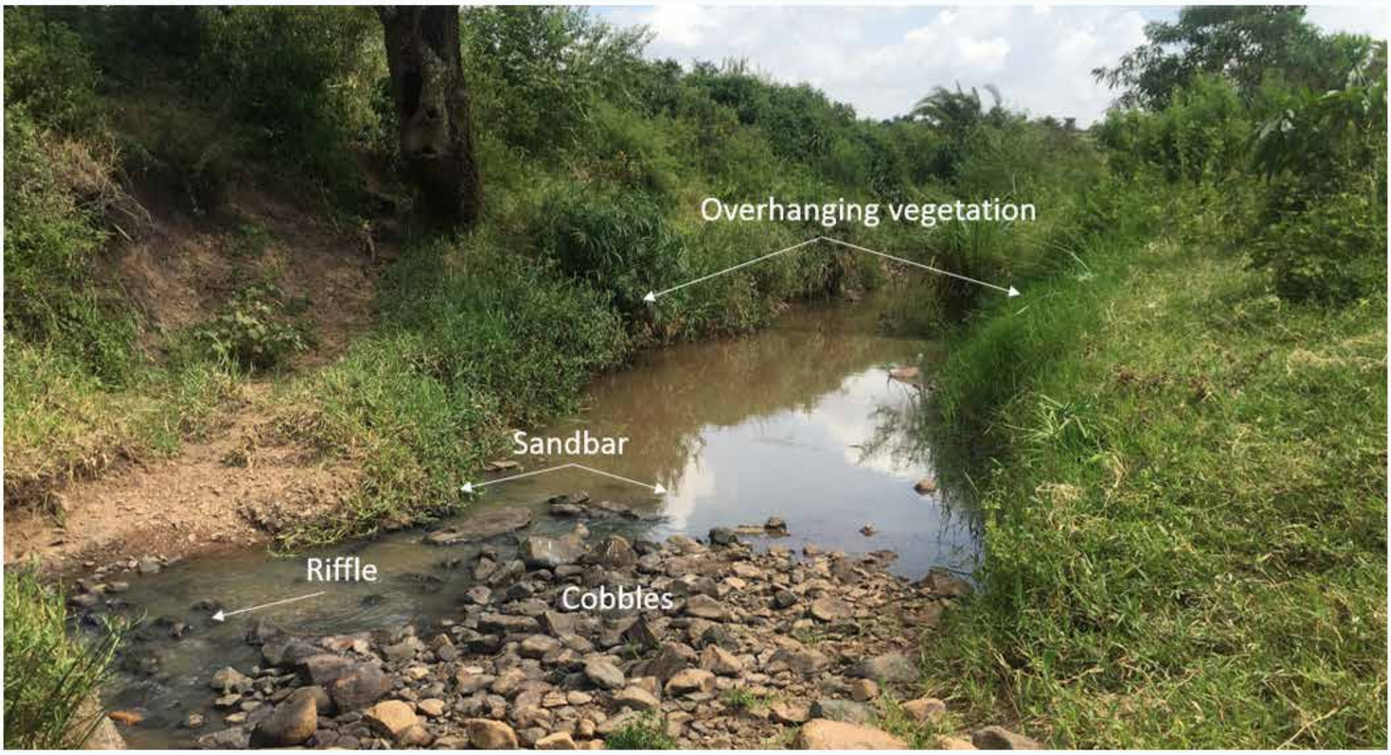


FIGURE 4 41: A PHOTOGRAPH DEPICTING HABITAT CHARACTERISTICS FOR THE TIGITHE RIVER REACH (FEBRUARY 2019)

Table 4 37 and Figure 4 41 show an overview of the HCR ratings.

A total of 15 fish species were sampled from the site, with a total of 124 individuals recorded for the site. Two indicator species were recorded for the site, namely Labeo victorianus and Clarias gariepinus, with only Labeo victorianus classified as critically endangered. There was no clear dominance by a genus or species for the composition. Substrate was variable and consisted of numerous substrate types, with gravel and cobbles being dominant. Habitat cover was generally dominated by aquatic vegetation. Habitat diversity was considered to be high, with three dominant velocity-depth class, namely FS, SD and SS.

4.4.2.6 Macroinvertebrates

Some of sensitive macroinvertebrate taxa were collected at this site (i.e. > 2 species of Baetidae, Tricorythidae and Hydropsychidae), and some that are very sensitive to poor water quality (Heptageniidae, Leptophlebiidae). The site is affected by mining and discharge of wastewater from mining, erosion and sedimentation from farmlands, unpaved roads and footpaths. The site is also impacted by watering livestock, bathing and laundry by residents from the nearby Matongo town. Habitat conditions look good, but there is potential for compromised water quality

Table 4-38: Macroinvertebrate community metrics for Tigithe

Community Metrics	Score
Total abundance	3208
No. of taxa	40
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	1770
% EPT	55.17
Number rheophilic taxa	6
Abundance of rheophilic taxa	1212
Relative abundance of rheophilic taxa	37.78
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	1178
% STH	36.72

Table 4-39: Results of the SASS5 and TARISS on processed samples at Tigithe

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	**Number of taxa**	**ASPT**	**TARISS Score**	**Number of taxa**	**ASPT**
152	26	5.8	150	26	5.8

Laboratory analysis for the SASS5 Protocol		
Total SASS Score	**No. of taxa**	**ASPT**
242	40	6.1

because of mining. Table 4 38 and Table 4 39 below indicate the field processed and laboratory processed score results for the site.

4.4.2.7 Water Quality

High nitrate levels during the 1st survey possibly from livestock manure when they water directly from the river. This level is just at the threshold recommended for safe drinking water. Increased conductivity from the initial to the 2nd survey contrary to expectations.

The increase in salinity during this period of slight rainfall increase could be due to salts which are washed into the river channel from the nearby agricultural areas. Runoff from these agricultural areas could also be the reason for the increased pH level. Slightly elevated levels of total nitrogen during the 2nd survey when there was slightly increased rainfall compared to the initial survey. Table 4 40 shows the field measurements and laboratory results for water quality samples taken at the site.

Table 4-26: Results of water quality analysis at Somoche

Parameter	Unit	1st survey	2nd survey
pH	(-)	7.7	7.5
Electrical conductivity (EC)	µs/cm	309	160.2
Temperature (T)	deg C	25.1	24.6
Dissolved oxygen (DO)	mg/L	6.6	6.2
Oxygen saturation	%	93.2	85.9
Turbidity	T.U	200	1,000
Nitrate (NO_3^-)	mg/L	0	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	195.2	ns
Ammonium (NH_4^+)	mg/L	0.11	0.05
Non purgeable organic carbon (NPOC)	mg/L	8.9	6.98
Total nitrogen (TN)	mg/L	1.6	1.01

ns: not sampled

Table 4-27: Site metrics for Somoche

Metric	Social	Geomorph	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	B/C	B	B	B	B	B
ToC	Declining	Stable/ declining	Declining	Declining	Declining	Stable
EIS	Medium	Medium	High	High	High	High
SIS	High	-	-	Moderate	Medium	Low
EMC	B	B	B	A/B	B	B

Table 4-28: Indicators and management objectives for Somoche

EFA Component	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including recession agriculture depended by 60 percent of the population, vegetables & fruits collection/cultivation and subsistence fishing for the local communities residing along the Somoche river
	Target species	The following species should be abundant enough to suffice the needs of the population residing along Somoche River: Fish: Mumi and Kamongo Vegetables: Chinderema and Chinsaga Trees:Chinsere, Chinseke, and Ebinyabutati Other resources: Ukindu
Geomorphology	Pool depth	Maintain pools of at least 0.5 m deep
	Available gravel and cobble habitat	Maintain flow variability and moderate sediment supply to maintain this habitat in good condition (e.g. not embedded with fine sediment)
Riparian Vegetation	Sedge and grass communities	Continue to maintain abundances of flow sensitive sedge species (e.g., *Cyperus involutus and Cyperus distans*) at the site Continue to maintain abundances of moderately flow sensitive plant species (e.g., *Paspalum scrobiculatum* and *Echinochloa pyramidalis*). If depth of water for flow sensitive plant species is met then it should suffice this group too.
	C. involutus, *C. distans*, and *P. maximum*	Continued presence and occurrence of seedlings and adults of *C. involutus, C. distans and P. maximum* and the three should together be present at abundance of ≥20 percent
	Riparian tree communities	Continued presence and occurrence of seedlings, saplings and adults of *Ficus sur* with at least 10 percent abundance
Fish	Recruitment of indicator cyprinids spp.	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
	Fish community wellbeing assessment	If the previous indicator is not observed a fish community wellbeing assessment should be undertaken
Invertebrates	SASS5 or TARISS Index	South African Scoring System (SASS5) or TARISS Index
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
	Ephemeroptera, *Plecoptera*, and *Trichoptera* orders	The following orders should be present in abundances >50 percent of the invertebrate community
	Hydropsychidae, *Simuliidae*, and *Tricorythidae* families	The following flow sensitive families should be present in abundances >30 percent of the invertebrate community during the wet season when the river is flowing
	Target species: Oligoneuridae sp. and *Potamonautes sp.*	*Oligoneuridae* is among the most sensitive family of macroinvertebrates to both water quality and quantity, and hence should be present at the site as a sign of good water and habitat conditions (no sedimentation). *Potamonautes* (freshwater crabs) depend on a well maintained riparian forest for food (leaf litter) and reproduction. Their presence means maintaining the riparian zone along the river and flow permanence throughout the year since they are long-lived species.
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish/macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic and livestock watering purposes

4.3.3 Site Metrics

Table 4-29: Required flow conditions for Somoche

	Hydrological Component	Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Depth (m): 0.5 Inundation: 0 days Flow (m³/s): 0.15	**Freshets** Depth (m): 0.7 Inundation: average over 2 days, 4 events during wet season Flow (m³/s): 2.7	Month: August Depth (m): 0.4 Velocity (m/s): 0.62 Flow (m³/s): 0.2	Month: Feb, Jun, Jul, Aug, Dec Depth (m): 0.3 (0.18 avg) Velocity (m/s): 0.237 Inundation: >10 days Flow (m³/s): 0.3	Month: Feb, Oct Depth (m): 0. 08 Velocity (m/s): Av. Vel. 0.06, Max vel. 0.21 Flow (m³/s): 0.03
Maintenance Year	Low flows, wettest month	Depth (m): 0.5 Inundation: 0 days Flow (m³/s) : 0.8	**High Flows** Depth (m): 1.1 Velocity (m/s): Inundation: 2 day peak Flow (m³/s): 9	Depth (m): 0.5 Velocity (m/s): 1.1 Flow (m³/s): 0.3	Month: Apr, May Depth (m): 0.46 (0.24 Avg) Velocity (m/s): 0.5 Inundation: >30 days Flow (m³/s): 0.9	Month: April Depth (m): 0. 32 Velocity (m/s): avg 0.4, max. 1.2 Flow (m³/s): 0.34
Maintenance Year	High flows, freshets and/or floods	Depth (m): 1.13 Velocity (m/s): 1.48 Inundation:14 days Flow (m³/s): 39	**Floods** Depth (m): 2.4 Inundation: peak over 2 days Wet season, 1 in 3/5 year event Flow (m³/s): 70	Month: Apr- May Depth (m): 1.5 Velocity (m/s): 1.2 Flow (m³/s): 20.2 1 in 3 years for at least 2 days. **Floods** Depth (m): 2.4 Velocity (m/s): 1.89 Flow (m3/s): 69.9 once in 5 yrs.	Depth (m): 0.62 (0.31 avg) Velocity (m/s): 0.62 Inundation: >14 days Flow (m³/s): 1.9	Month: Apr-May, Nov- Dec Depth (m): 0. 38 Velocity (m/s): avg 0.44, max 1.34 Flow (m³/s): 0.54 **Annual Flood** Depth (m): 0.5 Velocity (m/s): avg 0.52, max 1.58 Flow (m³/s): 1
Drought Year	Low flows, driest month	None	None	Month: August Depth (m): 0.36 Velocity (m/s): 0.5 Flow (m³/s): 0.2	Flow (m³/s): 0	Month: August Depth (m): 0 Flow (m³/s): >0
Drought Year	Low flows, wettest month	None	**Freshets** Depth (m): 0.7 Inundation: average over 2 days 3 events during wet season Flow (m³/s): 2.7	Depth (m): 0.42 Velocity (m/s): 0.6 Flow (m³/s): 0.2	Flow (m³/s): 0	Month: May Depth (m): 0. 32 Velocity (m/s): avg 0.33, max 1.05 Flow (m³/s): >0
Drought Year	High flows, freshets and/or floods	None	**High Flows** Depth (m): 1.1 Inundation: 2 day peak Annually during the wet season Flow (m³/s): 9	Month: Apr-May Depth (m): 0.5 Velocity (m/s): 0.53 Flow (m³/s): 1.11 Floods at least 1 in 3 yrs. for 2 days	Depth (m): 0.46 (0.24 avg) Velocity (m/s): 0.5 Inundation: >21 days Flow (m³/s): 0.9	Month: Apr-May, Nov- Dec Depth (m): 0. 36 Velocity (m/s): avg 0.4, max 1.23 Flow (m³/s): 0.5

4.3.4 Indicators and Management Objectives

Table 4-30: Confidence level for flow recommendations for Somoche

Site Name	Rating	Rationale
Social	4	The findings were matching with those of biophysical scientists
Hydraulics	3.5	Straight channel with pool riffle/rapid habitat. Two observations at relatively low flows used for calibration
Geomorphology	3.5	Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5	The river had several habitats covered with plants of different species including sedges, grasses, forbs and trees. Most of the species scored were native species.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecology of species and social relationships.
Macroinvertebrates	2	No previous studies on macroinvertebrates exist in this river and the discharge values on which I based my recommendations on have been modeled. This gives low confidence to the flow values proposed.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.3.5 Required Conditions

4.3.6 Confidence Ratings

4.4 Tigithe

The EFA biophysical site at Tigithe is located about 5 km upstream from where it flows into the upper Mara Wetland. It flows parallel to the Mara River and flows directly into the Mara Wetland, near to where the Mara River enters the wetland. The area has higher rainfall than other areas of the Mara River Basin, although it is still considered a seasonal system by local residents. The Tigithe River is dominated by a riffle-pool system, with fine gravels, silty clays, and large cobbles present. There are high terraces on both banks and slight evidence of incision. There is commercial and artisanal mining in this catchment and there is concern over pollution in the river, although this is not related to alterations in flow. The fish here seem highly connected with the wetland species, indicating migration between the two

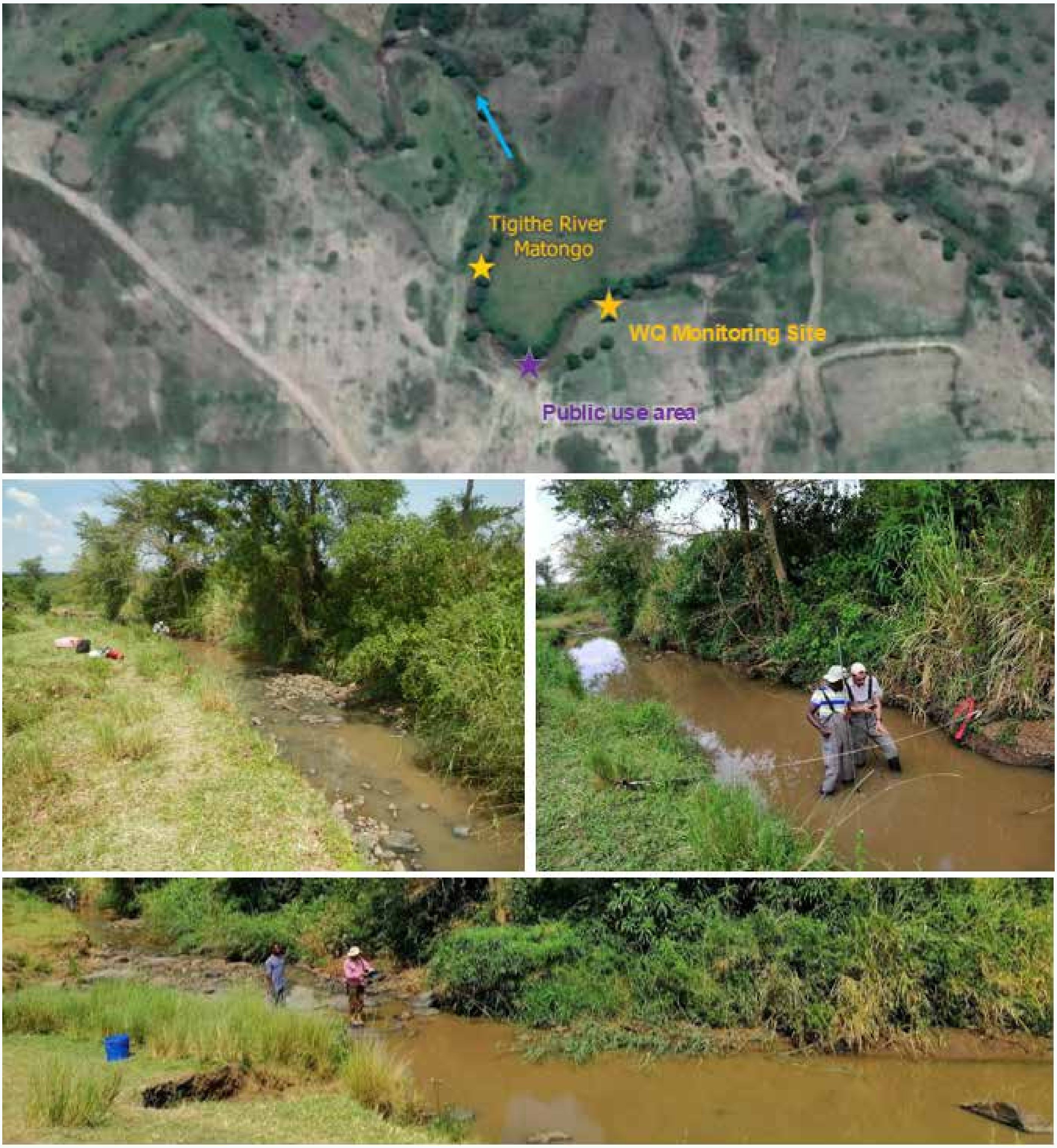


FIGURE 4 31: SITE PHOTOS OF TIGITHE

areas. Flows during drought conditions are needed to maintain good water quality in pools for aquatic species.

4.4.1 Social Survey

The Tigithe sub-basin consists of two RUs: the Lower Tigithe RU and the Upper Tigithe RU. Tigithe River is seasonal and dries up three times yearly from July to August. However, it is fed by many tributaries which are either permanent or seasonal. Flooding in the Lower Tigithe RU mostly occurs in the lower and middle reaches of the rivers due to confluence of various tributaries. The inundation lasts for a day and extends up to three kilometers while the depth of water goes up to one meter. This has formed a wetland which its extension has been increasing over the years.

4.4.1.1 Lower Tigithe

Lower Tigithe has about 10 species of fish that were identified by the community, 17 species of natural vegetables, 17 species of fruit trees, 50 tree species for building poles, five species of weaving reeds and seven species of thatching grass. Fourteen ecosystem services derived from wetland and rivers were identified to be useful for livelihood of communities

Table 4-31: Wetland resources and their relative importance to the livelihood of communities in Lower Tigithe

No.	Wetland Resources	Relative Importance (%) per Sample Villages		Average
		Matongo	Nyakunguru	
1	Water	61.9	55.6	58.8
2	Cultivation Land	30.9	27.8	29.4
3	Livestock Pastures	1.5	9.3	5.4
4	Building Poles	0	4.3	2.2
5	Roofing grasses	1.5	2.2	1.9
6	Natural vegetables	1.5	0.7	1.1
7	Firewood/Charcoal	1.5		0.8
8	Weaving grasses	0.8		0.4
9	Medicinal Plants	0.2		0.1
10	Fish	0.1	0	0.1
11	Building Sands	0	0	0
12	Burned Bricks		0	0
13	Natural fruits	0	0	0
14	Wildlife (animals and birds)	0		0

in Lower Tigithe RU. Table 4 31 shows the wetland resources/ecosystem services obtained in this RU and their relative importance to the two villages.

Four main economic activities are practiced in this RU i.e. Agriculture, livestock keeping (cows, sheep, chicken and donkey), petty trade, and mining in Matongo village (Table 4 32). Agricultural activities involve cultivation of crops such as maize, millet, bullrush millet, cassava, sweet potatoes, vegetables, paddy/rice and bananas. The trend of resource utilization and condition of the wetland from the past to the future is shown in Table 4 33 below.

Table 4-32: Economic activities in Lower Tigithe RU

Activity		Performer	Location/Why	Time/Why
Agriculture	Maize Bullrush millet/Millet Paddy/rice Cassava Sweet potatoes Tobacco Fruits Bananas	Household Household Household Household Household Household Household Household	Scattered in the house Around the house Around the house Tigithe Mara valley because of its fertility and moisture Small irrigation	Jan – June Sep - Jan
Livestock keeping (cattle)		No specific place Famous during dry season		Jul - Aug
Mining			Near river banks	
Small business				

Table 4-33: Trend of resources and condition of the wetland in Lower Tigithe

Resource	Nyerere's Regime (1960 - 1985)	Current Situation	Future Expectations (2030)	Reasons
Fish	510	100	10	Encroachment of wetland areas by crop farmers
Wild vegetables	515	100	2.5	Expansion of crop farming to wetland areas Tree distorts the growth of vegetables through shading Polluted water from the Nyamongo mine impair vegetable growth Soil fertility has decreased
Wild fruits	530	100	2.5	Cutting down fruits trees for crop farming, charcoal and firewood.
Weaving materials	50	100	200	High production capacity Spread as the river expands. In most places the river-width has increased.
Building poles	1750	100	4.5	Cutting down of trees for crops cultivation, charcoal and firewood. Population increases.
Thatching materials	1250	100	03	Increase in population Expansion of crop cultivation Increased in livestock which poses competition with limited pastures
Degradation of wetland/river ecosystem	15	100	200	Little knowledge on environmental education Increase in population Extensive and uncontrolled farming in the wetlands Increasing plantation of eucalyptus which consumes much water

Table 4-33: Trend of resources and condition of the wetland in Lower Tigithe

Resource	Nyerere's Regime (1960 - 1985)	Current Situation	Future Expectations (2030)	Reasons
Dependency of community to rivers and other wetland resources for their livelihood	45	100	1100	Land uses have increased as a result of population growth Limited substitute and when available are too expensive to afford. No resource options for cultural activities
Size (width) of the river	50	100	200	Soil erosion
Quality of wetland/river	900	100	10	Expansion of the crop framings to the river banks Chemicals depositions in the wetlands from Nyamongo mines.

4.4.1.2 Upper Tigithe

The number of resources reported to be available in Upper Tigithe is much less compared to the number in Lower Tigithe. This include two fish species (Mumi and Furu), 12 species of natural vegetables, 12 species of fruit trees, 10 species of timber and building poles, one weaving material and four types of thatching grass. The number of wetland resources and their

Table 4-34: Wetland resources and their relative importance to the livelihood of communities in Upper Tigithe

No.	Wetland Resources	Relative Importance (%) per sample villages		Average
		Kitawasi	Bungurere	
1	Water	88.9	65.3	77.1
2	Livestock Pastures	8.9	3.3	6.1
3	Cultivation Land	2.2	6.5	4.4
4	Firewood/Charcoal		6.5	3.3
5	Building Poles		3.3	1.7
6	Roofing grasses		3.3	1.7
7	Building Stones		3.3	1.7
8	Burned Bricks		3.3	1.7
9	Natural vegetables		1.6	0.8
10	Medicinal Plants		1.6	0.8
11	Natural fruits		0.8	0.4
12	Good air		0.8	0.4
13	Fish		0.4	0.2

importance to the community is outlined in Table 4 34 below.

Table 4-35: Economic activities in Kitawasi village in Upper Tigithe

Activity		Performer	Location/Why	Time/Why
Agriculture	Maize Millet Cassava Sweet potatoes Vegetables Bananas Coffee		Around household	Twice a year
Livestock keeping			In farms, privately	
Small business				

In terms of economic activities, only three were identified in the village: agriculture, livestock keeping and petty trade (Table 4 35).

Table 4 36 below shows trend of resources utilization and condition of the wetland resources over the years. A hypothetical value of 100 was set as a current benchmark and perceived values of these

Table 4-36: Trend of resources utilization and condition of the wetland in Upper Tigithe

Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Fish	1000	100	30	Increased in population Illegal fishing Environmental degradation
Wild vegetables	1150	100	22.5	Water pollution Decrease in fertility of riparian land Destruction of vegetables by livestock during grazing Destruction of wetland areas by planting exotic plants
Wild fruits	1750	100	12.5	Increase in population Cutting of trees for crop cultivation Cutting of natural trees and replacement with exotic plants
Weaving materials	150	100	140	High rate of reproduction The rate of consumption is limited compared to regeneration
Building poles	5025	100	20.5	High exploitation of trees for multiple uses such as charcoal and firewood. Cutting of natural trees and replacement with exotic plants
Thatching materials	260	100	37.5	Increase in population Expansion of agricultural activities

Table 4-36: Trend of resources utilization and condition of the wetland in Upper Tigithe

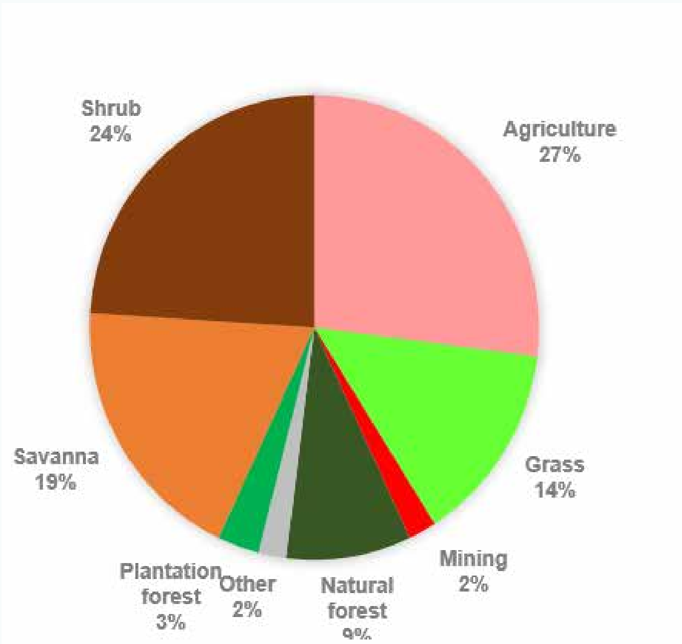
Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Degradation of wetland/river ecosystem	15	100	600	Little environmental education Increase in cutting of trees Population increase.
Dependency of community to rivers and other wetland resources for their livelihood	1750	100	50	Decrease in wetland resources and therefore limited resources to depend on Presence of substitutes, though are expensive
Size (width) of the river	40	100	175	Cutting down of trees. Extensive agricultural activities near water sources. Water flow increases hence distort river bank.
Quality of wetland/river	900	100	10	Destruction of water point Chemicals depositions in the wetlands from Nyamongo mines.

resources in the past and future with reference to the set benchmark indicated. The possible reasons for change have also highlighted.

4.4.2 Biophysical – Tigithe River at Matongo

4.4.2.1 Hydrology

The Tigithe EFA site has a contributing upstream catchment area of 183 km2 with a dominated land use of agriculture, shrub land, and savanna (Figure 4



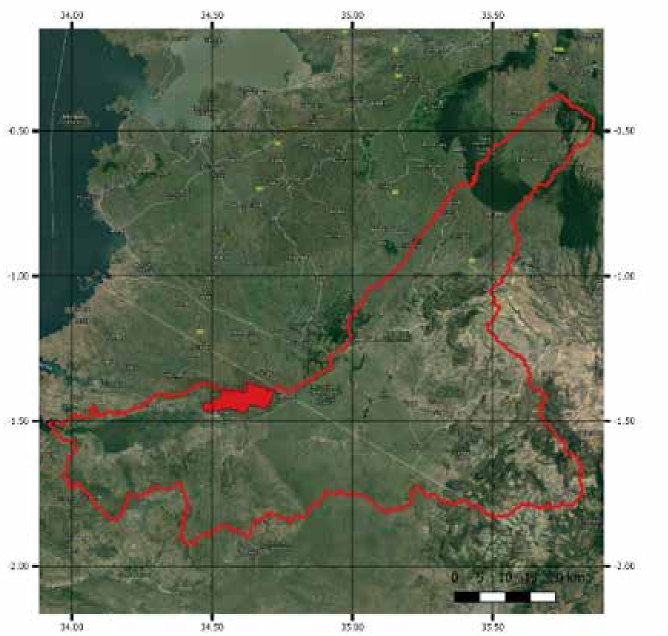


FIGURE 4 32: LAND USE WITHIN THE TIGITHE SUB-CATCHMENT (LEFT) AND CATCHMENT AREA (RIGHT)

32). Precipitation in the catchment sums up to 1,100 mm/yr, resulting in an evaporation value of 1,018 mm/yr, and a runoff value of 82 mm/yr.
Average monthly, minimum and maximum discharge

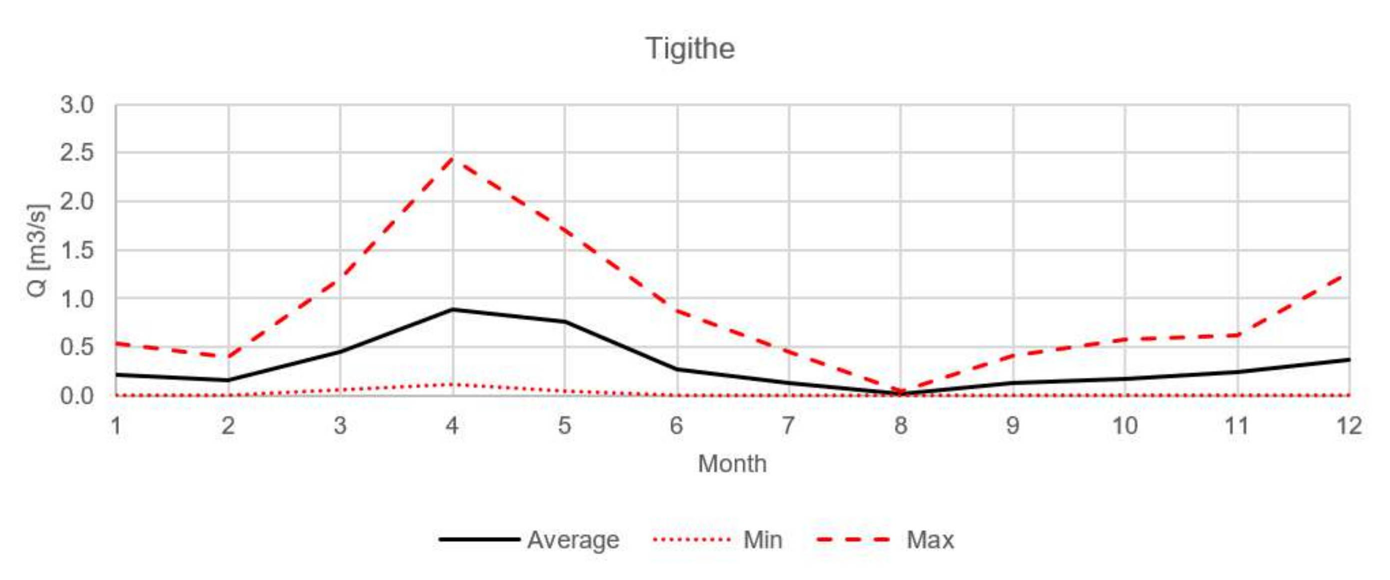


FIGURE 4 33: AVERAGE MONTHLY, MINIMUM AND MAXIMUM DISCHARGE VALUES FOR THE TIGITHE EFA SITE

values for Tigithe EFA site are presented in Figure 4 33. Typically, April is the wettest month and August is the driest month, going almost to zero m3/s.

4.4.2.2 Hydraulics

The Tigithe River follows a pool riffle sequence with slow-flowing pools and steeper faster turbulent flow along riffle sections. The hydraulic transect is shown in Figure 4 34 with the observed and modelled flow levels indicated. There was a weak relationship between depth and velocity ($R2 < 0.36$), showing high variability in the velocity–depth association

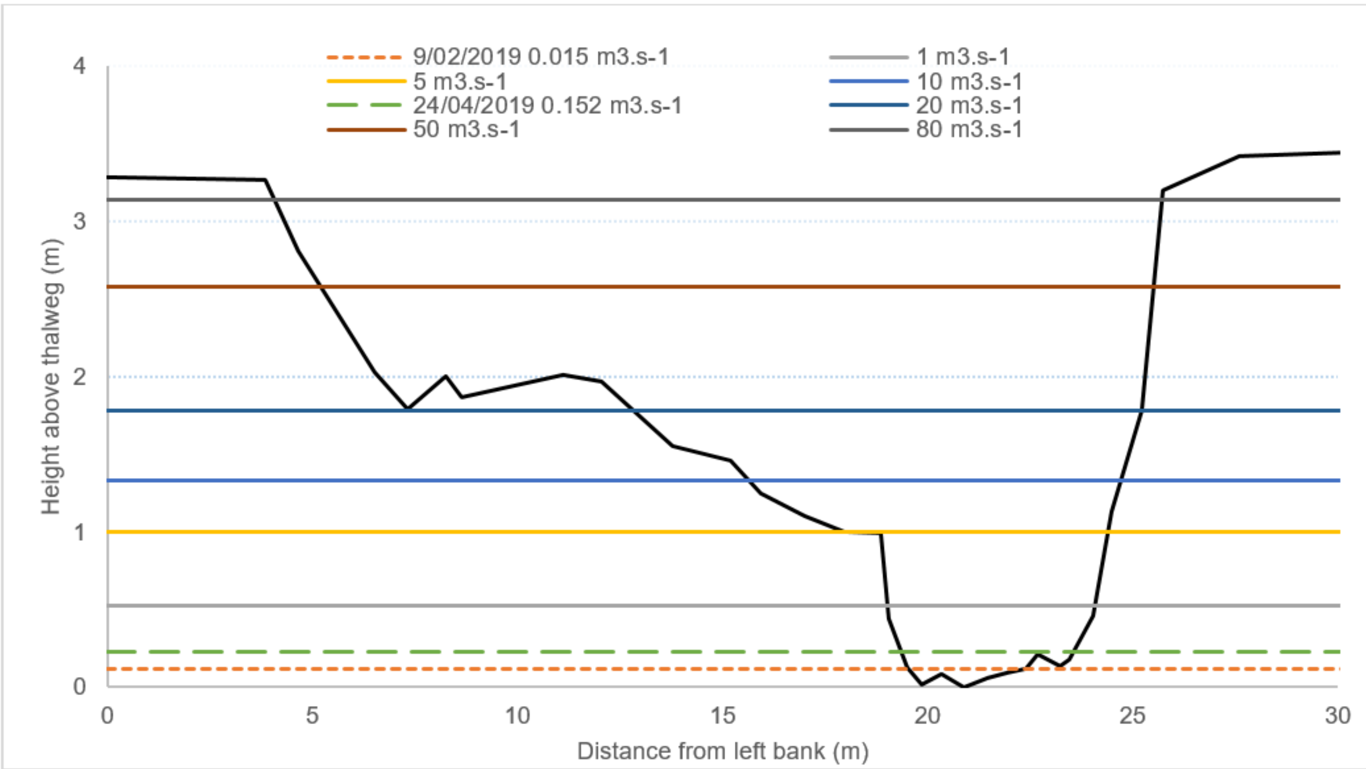


Figure 4-34: Cross section for Tigithe River showing observed flow levels (dotted lines) and modelled flow levels (solid lines)

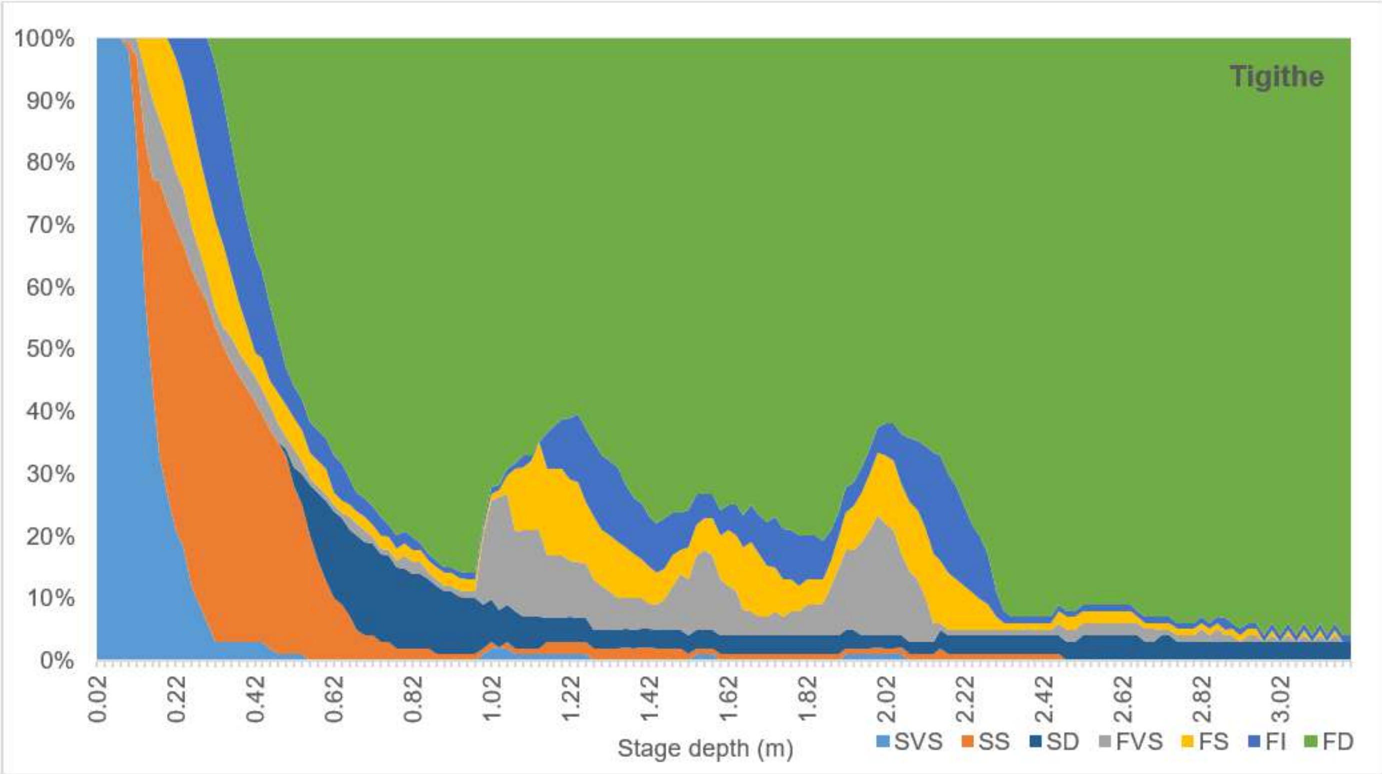


FIGURE 4 35: FREQUENCY DISTRIBUTION FOR VELOCITY-DEPTH CLASSES FOR THE WETTED CHANNEL OF THE TIGITHE RIVER

across the channel. The frequency distribution of the flow velocity-depth classes for the wetted channel are presented in Figure 4 35.

4.4.2.3 Geomorphology

Tigithe channel is a straight to sinuous channel with a pool-rapid sequence (Figure 4 36). The channel slope is 0.007808 and can be classified as a channel of the upper foothill zone (Rowntree and Wadeson, 1999). Rowntree and Wadeson define the reference condition as "moderately steep, cobble bed or mixed bedrock-cobble bed channel with plain bed, pool riffle, or pool rapid reach types. The length of pools and riffles /rapids are similar. Narrow flood plain of sand, gravel or cobble often present". The site fits this description well.

The channel is bedrock controlled and incised into the landscape as is evident by the narrow floodplain and terrace along the right bank (Figure 4 37). The terrace consists of silt and the floodplain/bench of layers of small gravel and sand. Recent flood deposited sand is present on the floodplain/bench. The banks are near vertical with active erosion along short sections of bank. A narrow inset bench lines the right bank composed of medium sand. The riffles consist of armored cobble with voids filled with coarse sand and fine gravel. A silt drape is present on bed features where the flow velocities are lower. The bed of the pools consist of fine gravel and silt.

The Tigithe River plays an important role in maintaining a large back swamp area to the North of the Mara channel (Figure 4 38). The back swamp forms on the Mara floodplain as a result of the alluvial ridge that forms due to sediment deposition along the Mara River. The Mara spills into this back swamp

Figure 4 36: A satellite image showing the transect position (white line) and the pool-riffle sequence along the Tigithe River (Google Earth Image date 17 Jan 2010).

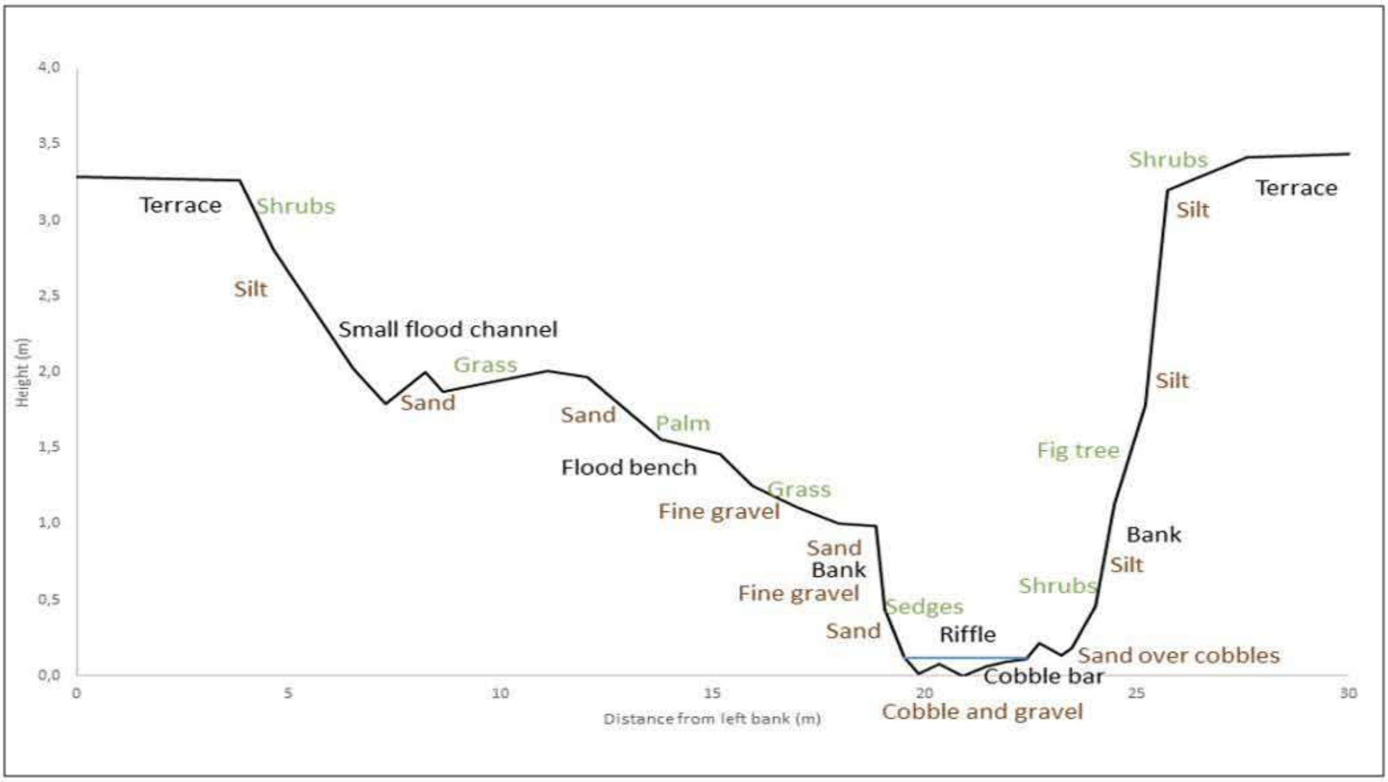


FIGURE 4 37: CHANNEL CROSS SECTION FOR THE TIGITHE RIVER INDICATING THE GEOMORPHIC FEATURES (BLACK TEXT), SEDIMENT TYPE (BROWN TEXT) AND VEGETATION TYPE (GREEN TEXT).

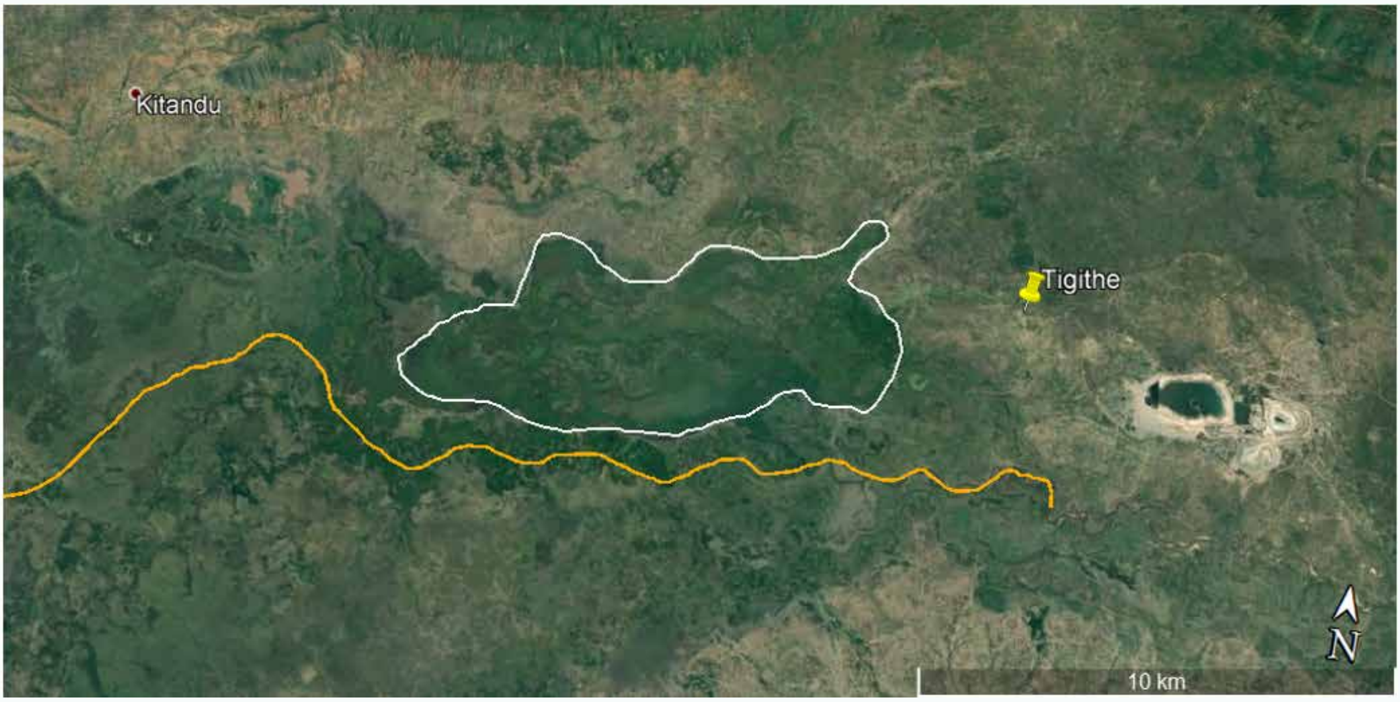


FIGURE 4 38: A GOOGLE EARTH IMAGE SHOWING THE BACK SWAMP (ENCIRCLED BY THE WHITE LINE) FORMED BY THE ALLUVIAL RIDGE/LEVEE (BROWN LINE) ALONG MARA RIVER. THE TIGITHE RIVER DRAINS INTO THE BACK SWAMP PERMANENTLY AND THE MARA RIVER ONLY DURING FLOOD FLOWS. FLOW DIRECTION IS FROM EAST TO WEST.

during flood conditions, but the Tigithe permanently contributes to its water balance, making it a crucial source of surface water during low flow conditions.

4.4.2.4 Riparian Vegetation

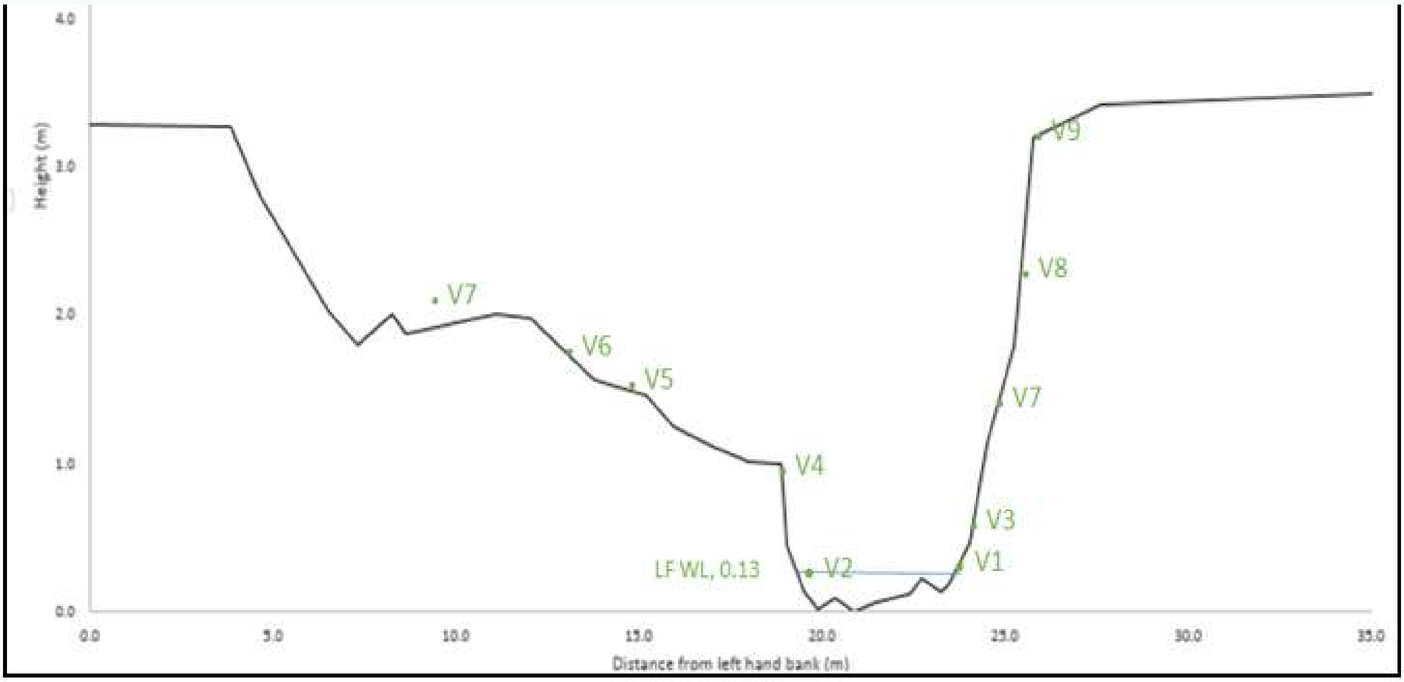
The bed of Tigithe River is made up of cobbles stones and sand and both left and right banks appear to be stable. At its natural state the site would have more vegetation cover in riparian area and at both banks. Herbaceous vegetation would have been tall on the floodplain which is on left side of the river. There would also be more riparian trees on both river banks. Absence of terrestrial tree species like Leucacena leucocephala and Lantana camara on the macro-channel bank would be expected. A strip of around 100 m was selected to study riparian vegetation in Tigithe.

Members of Poacea and Cyperaceae families dominated the marginal sub-zone including Cyperus cyperoides, Coix lacryma and Eriochloa macclounii. Lower sub-zone was occupied by Commelina carsonii, C. benghalensis, Cyperus cyperoides and Cynodon dactylon. Among the studied sites this was the site with more species richness in the Mara basin. Floodplain area was present on the left side and was dominated by grasses including Cynodon nlemfuensis (around 60 percent), Setaria sphacelata, Echinochloa sp., Hyparrhenia rufa and Brachiaria brizantha. Grazing and browsing by livestock appear to be high resulting in to lawns on the floodplain and pruned shrubs on terrestrial part of the system. Lantana camara was present in macro-channel bank. Overall, the vegetation cover was about 70 percent. Figure 4 39 shows cross section and plant species distribution at the site.

4.4.2.5 Fish

Tigithe River meanders with the flow in a westerly and northerly direction for the reach surveyed. Two primary GHUs were identified and delineated for the site, namely a pool and rapids (Figure 4 40). A total of four shallow pools and one deep pool were sampled with an electro-fisher and fyke net for the study, with all pools characterized by slow velocity. Four rapid areas were sampled, with all these areas characterized by a FS velocity-depth class. Substrate in the pools is dominated by sand and cobbles, with the substrate associated with the rapids characterized by rocks, cobbles and bedrock.

Turbidity was considered to be high. No aquatic vegetation was present at the site, with marginal and overhanging vegetation present for almost the entire extent of the reach. Root wads and undercut banks were also recorded for the majority of the pool units. Table 4 37 and Figure 4 41 show an overview of the



Indicator species	Number	Range	Remarks
Cyperus cyperoides	V1	marginal	
Coix lacryma	V2	marginal	
Forbs	V3	lower	
Cynodon dactylon	V4	lower	
Cynodon nlemfuensis	V5	upper	start of flood bench
Grasses**	V6	flood bench	dominated flood bench
Shrubs***	V7	upper	
Fig sp.	V8	upper	
Leucaena leucocephala	V9	upper/macro-channel bank	adult trees ~ 2 individuals, terrestrial

**Includes Commelina carsonii and C. benghalensis*

***Includes Setaria sphaceleta, Echinochloa sp., Hyparrhenia rufa and Brachiaria brizantha*

****Includes L. camara and Tithonia diversifolia*

Figure 4-39: Cross section of the Tigithe River showing indicator plant species

Table 4-37: A summary of the HCR for the reach with associated velocity depth class ratings and corresponding details.

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	25 – 75%	Leaves & stems	Roots & undercut banks	Sand & cobbles	Tree debris	Sedges
SD	5 – 25%	Leaves & stems	Roots & undercut banks	Sand & cobbles	Tree debris	Sedges
FD	-	-	-	-	-	-
FS	5 – 25%	Leaves & stems	Undercut banks	Rocks & cobbles	-	-

Figure 4-40: Aerial view of the Tigithe River showing the delineated GHUs for the site (Google Earth)

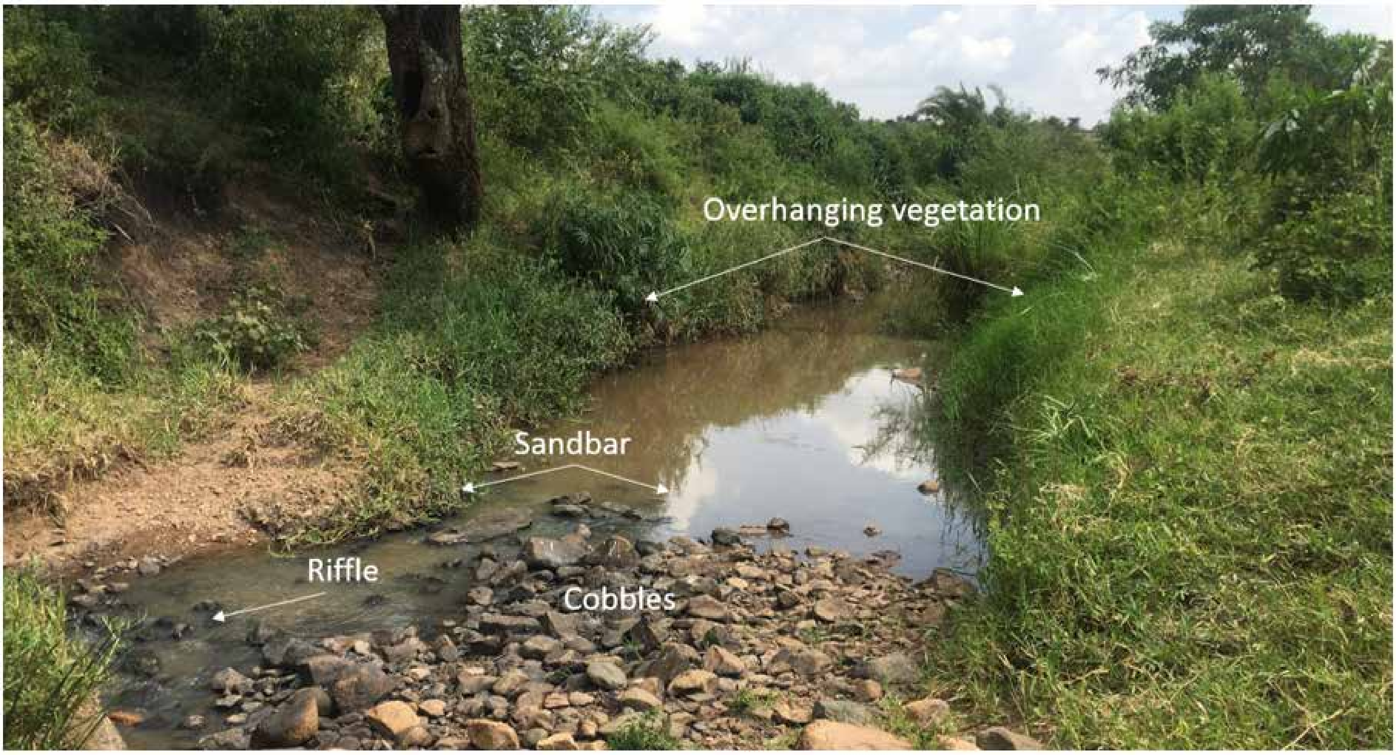


Figure 4-41: A photograph depicting habitat characteristics for the Tigithe River reach (February 2019)

HCR ratings.

A total of 15 fish species were sampled from the site, with a total of 124 individuals recorded for the site. Two indicator species were recorded for the site, namely Labeo victorianus and Clarias gariepinus, with only Labeo victorianus classified as critically endangered. There was no clear dominance by a genus or species for the composition.

Substrate was variable and consisted of numerous substrate types, with gravel and cobbles being dominant. Habitat cover was generally dominated by aquatic vegetation. Habitat diversity was considered to be high, with three dominant velocity-depth class, namely FS, SD and SS.

4.4.2.6 Macroinvertebrates

Some of sensitive macroinvertebrate taxa were collected at this site (i.e. > 2 species of Baetidae, Tricorythidae and Hydropsychidae), and some that are very sensitive to poor water quality (Heptageniidae, Leptophlebiidae). The site is affected by mining and discharge of wastewater from mining, erosion and sedimentation from farmlands, unpaved roads and footpaths. The site is also impacted by watering livestock, bathing and laundry by residents from the nearby Matongo town. Habitat conditions look good, but there is potential for compromised water quality

Table 4-38: Macroinvertebrate community metrics for Tigithe

Community Metrics	Score
Total abundance	3208
No. of taxa	40
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	1770
% EPT	55.17
Number rheophilic taxa	6
Abundance of rheophilic taxa	1212
Relative abundance of rheophilic taxa	37.78
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	1178
% STH	36.72

Table 4-39: Results of the SASS5 and TARISS on processed samples at Tigithe

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	Number of taxa	ASPT	TARISS Score	Number of taxa	ASPT
152	26	5.8	150	26	5.8

Laboratory analysis for the SASS5 Protocol		
Total SASS Score	No. of taxa	ASPT
242	40	6.1

because of mining. Table 4 38 and Table 4 39 below indicate the field processed and laboratory processed score results for the site.

4.4.2.7 Water Quality

High nitrate levels during the 1st survey possibly from livestock manure when they water directly from the river. This level is just at the threshold recommended for safe drinking water. Increased conductivity from the initial to the 2nd survey contrary to expectations. The increase in salinity during this period of slight rainfall increase could be due to salts which are washed into the river channel from the nearby agricultural areas. Runoff from these agricultural areas could also be the reason for the increased pH level. Slightly elevated levels of total nitrogen during the 2nd survey when there was slightly increased

Table 4-40: Results of water quality analysis at Tigithe

Parameter	Unit	1st survey	2nd survey
pH	(-)	7.9	8.2
Electrical conductivity (EC)	µs/cm	480	581
Temperature (T)	deg C	26.1	22.9
Dissolved oxygen (DO)	mg/L	5.7	6.92
Oxygen saturation	%	81	91.9
Turbidity	T.U	50	35
Nitrate (NO_3^-)	mg/L	10	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	191.5	ns
Ammonium (NH_4^+)	mg/L	0.16	0.07
Non purgeable organic carbon (NPOC)	mg/L	6.0	5.46
Total nitrogen (TN)	mg/L	1.6	5.70

ns: not sampled

rainfall compared to the initial survey. Table 4 40

Table 4-41: Site metrics at Tigithe

Metric	Social	Geomorph.	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	C	B/C	B	B	B/C	B/C
ToC	Declining	Stable/ declining	Declining	Declining	Declining	Declining
EIS	Medium	Medium	Medium	High	High	High
SIS	High	-	-	High	Medium	High
EMC	B	B	B	A/B	B	B

shows the field measurements and laboratory results

Table 4-42: Indicators and management objectives for Tigithe

EFA Component	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including subsistence crop farming, livestock keeping, vegetables and fruits collection/cultivation and subsistence fishing for the local communities residing along the Tigithe river
	Target species	The following species should be abundant enough to suffice the needs of the population residing along Tigithe River: Fish: Mumi, Sato, and Ibemea Vegetables: Chinderema, Inkurwa, and Isebeso Trees: Murama, Mategete, Chinsere, and Chinseke Other species: Ibitende/Matende, Itutu, and Ekibabe
Geomorphology	Pool depth	Maintain pools of at least 0.5 m deep
	Available gravel and cobble habitat	Maintain flow variability and a moderate sediment supply to maintain this habitat in good condition (e.g. not embedded with fine sediment)
Riparian Vegetation	Sedge and grass communities	Continue to maintain abundances of flow sensitive sedge and grass species (e.g., *Cyperus cyperoides*, *Coix lacryma* and *Eriochloa macclounii*) at the site Continue to maintain abundances of moderately flow sensitive plant species, including *Commelina carsonii*, *C. benghalensis* and *Cynodon dactylon*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
	C. cyperoides, *Eriochloa macclounii*, and Ficus spp.	Continued presence and occurrence of seedlings and adults of *Cyperus cyperoides* and *Eriochloa macclounii* and the two should together be present at abundance of ≥10 percent Continued presence and occurrence of seedlings, saplings and adults of Fig species e.g. *Ficus sur* and *F. sycomorus* with at least 10 percent abundance
Fish	Recruitment of indicator cyprinids spp.	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
	Occurrence of indicator species	Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site
	Fish community wellbeing assessment	If either of the two previous indicators are not observed a fish community wellbeing assessment should be undertaken
Macro-invertebrates	SASS5 or TARISS Index	South African Scoring System (SASS5) or TARISS Index score >150 and Av. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more baetid species, three or more species of *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*.
	Ephemeroptera, *Plecoptera*, and *Trichoptera* orders	The following orders should be maintained >50 percent of the invertebrate community.
	Hydropsychidae, *Simuliidae*, and *Tricorythidae* families	The following flow sensitive families should be present in abundances >40 percent of the invertebrate community during the wet season.

Table 4-42: Indicators and management objectives for Tigithe

EFA Component	Indicator	Management Objective(s)
	Target species: *Oligoneuridae sp.*	This family is among the most sensitive taxa of macroinvertebrates that should be present at the site as a sign of good water and habitat conditions (no sedimentation)
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish/macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic, livestock and agricultural purposes
		Ensure water is devoid of toxins/contaminants which can cause disease outbreaks

Table 4-43: Required flow conditions for Tigithe

Hydrological Component		Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Depth (m): 0.1 (0.05 avg) Velocity (m/s): 0.07 Inundation: 0 days Flow (m³/s): 0.009	**Freshets** Depth (m): 0.8 Inundation: 1 day average 4 events per year During wet season Flow (m³/s): 2.9	Month: August Depth (m): 0.14 Velocity (m/s): 0.18 Flow (m³/s):0.04	Depth (m): 0.2 (0.11 avg) Velocity (m/s): 0.22 Inundation: Not less than 10 days Flow (m³/s): 0.1	Month: Feb, Oct Depth (m): 0.12 Velocity (m/s): avg 0.09, max 0.31 Flow (m³/s): 0.012
Maintenance Year	Low flows, wettest month	Depth (m): 0.5 (0.36) Velocity (m/s): 0.5 Inundation:0 days Flow (m³/s): 0.9	**High Flows** Depth (m): 1.9 Velocity (m/s): Inundation: 2 days peak during the wet season Flow (m³/s): 24	Depth (m): 0.2 Velocity (m/s): 0.18 Flow (m³/s): 0.06	Depth (m): 0.3 (0.2 avg) Velocity (m/s): 0.3 Inundation: >30 days Flow (m³/s): 0.25	Month: April Depth (m): 0.24 Velocity (m/s): avg 0.25, max 0.82 Flow (m³/s): 0.15
Maintenance Year	High flows, freshets and/or floods	Depth (m): 2 (0.83) Velocity (m/s): 1.77 Inundation: 1 day	**Floods** Depth (m): 2.4 Inundation: peak over 3 days during wet season Every 1:3 to 1:5 years Flow (m³/s): 42	Month: May Depth (m): 1.5 Velocity (m/s): 1.19 Flow (m³/s): 20.9 Freshet at least 1 in 2 yrs for 2 days to refresh the system **Floods** Depth (m): 2 Velocity (m/s): 1.58 Flow (m³/s): 43.2, at least 1 in 3 yrs. for 1 day	Depth (m): 0.56 (0.42 avg) Velocity (m/s): 0.57 Inundation: >14 days Flow (m³/s): 1.2	**Freshets** Month: Apr-May, Nov-Dec Depth (m): 0.52 Flow (m³/s): 1 **Annual Flood** Depth (m): 1.02 Flow (m³/s): 5
Drought Year	Low flows, driest month	Depth (m): 2 (0.83) Velocity (m/s): 1.77 Inundation: 1 day	None	Month: August Flow (m³/s): > 0.0	Flow (m³/s): 0	Month: August Depth (m): 0.2 Velocity (m/s): avg 0.22, max 0.72 Flow (m³/s): 0

Table 4-43: Required flow conditions for Tigithe

Hydrological Component	Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Low flows, wettest month	Depth (m): 0.1 Velocity (m/s): Low Inundation: 0 days	**Freshets** Depth (m): 0.8 Velocity (m/s): Inundation: 1 day average 4 events per year Flow (m^3/s): 2.9	Flow (m^3/s): >0.05	Depth (m): 0.1 (0.05 avg) Velocity (m/s): 0.07 Inundation: >30 days Flow (m^3/s): 0.05	Month: April Depth (m): 0.12 Velocity (m/s): avg 0.09, max 0.31 Flow (m^3/s): >0
High flows, freshets and/or floods	Depth (m): 1 Velocity (m/s): medium Inundation: 1 day	**High Flows** Depth (m): 1.9 Inundation: 2 days peak during wet season Flow (m^3/s): 24	Month: May Depth (m): 1.2 Velocity (m/s):1.3 Flow (m^3/s): 7.8 Freshet at least once in a year	Depth (m): 0.3 (0.2 avg) Velocity (m/s): 0.3 Inundation: >14 days Flow (m^3/s): 0.25	Month: Apr-May, Sept, Nov- Dec Depth (m): 0.42 Velocity (m/s): avg 0.42, max 1.33 Flow (m^3/s): 0.6

for water quality samples taken at the site

4.4.3 Site Metrics

Table 4-44: Confidence level for flow recommendations for Tigithe

Site Name	Rating	Rationale
Social	4	The findings were matching with those of biophysical scientists
Hydraulics	3.5	Straight channel with pool riffle/rapid habitat. Two observations at relatively low flows used for calibration
Geomorphology	3.5	Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5	This site had a small river compared to other sites, and faces anthropogenic pressure. However, it still retains a good number of plant species including indicator sedge and grass species. Floodplain had a good number of forb and herb species. It had the highest species richness among all the sites but would be nice if wet season survey would have been done to get a picture of species composition and diversity for the site. Wet season allows recruitment of annual species.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecology of species and social relationships.
Macroinvertebrates	3	Some studies on fish exist on this river, which gives an indication on the flow stability of this river. Even without any previous macroinvertebrates studies exist in this river, and the discharge values on which I based my recommendations on have been modeled, there is some confidence on the values I propose.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.4.4 Indicators and Management Objectives

4.4.6 Confidence Ratings

4.5 Mara Mines

The Mara Mines EFA biophysical site is located about 8.5 km downstream of the confluence with the Somoche River and 30 km upstream from where the Mara River flows into the upper Mara Wetland. It is also located about 2.5 km downstream from the LVBWB river gauging station at Mara Mines. The river is very wide at this location, with predominantly sandy substrate (which becomes braided at low flows) and there is evidence of incision. The banks are very steep with a variety of terraces, making it

FIGURE 4.4.2: SITE PHOTOS OF MARA MINES

difficult for the river to overbank at this location. The surrounding area is dominated by rainfed agriculture and livestock grazing.

4.5.1 Social Survey – Borenga, Gantamome

Two rivers are found in this RU, the Mara River and the Somoche River, which are fed by seasonal tributaries. The area has large wetlands at the confluence of the two rivers. These wetlands are important for locals' livelihood as most of the area is dry and mountainous hence not suitable for crop farming. Flooding occurs twice a year in April and December. The extent of flood is about 50 metres for the tributaries and up to two km for the Mara River with a flooding duration of 1 to 14 days and two months, respectively. The depth of the water is about one half of a meeting in inundated areas. A very diverse species of riparian vegetation and fishes (10 species) were identified in the site. These provide the local communities with natural vegetables (23 species), weaving materials,

Table 4-45: Wetland resources and their relative importance to livelihoods in Mara Mines RU

No.	Wetland Resources	Relative Importance (%) per sample villages		Average
		Gantamome	Borenga	
1	Water	93	89.9	91.5
2	Cultivation Land	0.7	9	4.9
3	Livestock Pastures	4.7	0.9	2.8
4	Firewood/Charcoal	1.4	0	0.7
5	Natural vegetables	0	0.1	0.1
6	Building Sands	0.1	0	0.1
7	Roofing grasses	0	0	0
8	Natural fruits	0	0	0
9	Honey	0	0	0
10	Fish	0	0	0
11	Burned Bricks		0	0
12	Building Stones	0		0
13	Building Poles	0	0	0

poles and thatching materials. The wetlands are important areas for crop farming and livestock keeping. Table 4 45 below shows the resources available and their relative importance in Mara Mines RU.

Table 4-46: Economic activities in Mara Mines RU

Activity	Performers	Location	When	Why in that place	Why in that time
Crop farming	All members of the household	Banks of river Mara	Twice annually	Borenga-Allocated by land use plan. Gantamome- Fertile land	Enough rainfall
Livestock keeping	All members of the household	Banks of river Mara	Year round	Borenga-Allocated by land use plan. Gantamome- Availability of pastures	Livestock need food
Petty trade	Not specified	Mobile	Year round	Customer hotspot	To compensate losses in farming and livestock

The two major economic activities performed in the villages are farming and livestock keeping, with

Table 4-47: Trend of resources and condition of the wetland in Mara Mines RU

Resource	Nyerere's Regime (1960 - 1985)	Current situation	Future Expectations (2030)	Reasons
Fish	6000	100	15	Population increase Illegal fishing Increased number of fisherman
Wild vegetables	2500	100	20	Increase in crop farming and residents as a result of population increase
Wild fruits	1000	100	12.5	Limited knowledge on the value of edible fruits by new generations. This facilitate more cutting of trees for building and charcoal making
Weaving materials	1000	100	05	Encroachments of river banks by crop farmers The uses of weaving materials are many and it is likely to increase in future Environmental degradation
Building poles	2000	100	04	Effect of climate change Illegal cutting of trees
Thatching materials	1000	100	05	Population increase fuel more use of thatching grass for roofing Increase in livestock which competes with limited pastures Effect of climate change Expansion of agriculture which limits the areas for grass growth
Degradation of wetland/river ecosystem	10	100	300	Population increase Uncontrolled grazing of livestock in the wetlands Cutting of trees
Dependency of community to rivers and other wetland resources for their livelihood	35	100	1900	Population growth Wetland resources constitute the main source of livelihood
Size (width) of the river	17.5	100	600	Extensive agriculture activities Clearing of trees and other riparian vegetation
Quality of wetland/river	250	100	26.5	Contaminations from livestock Defecation along the water streams

an addition of petty trading in Gantamome village (Table 4 46).
Past and future trend of the wetland utilization and condition is indicated in Table 4 47 below.

4.5.2 Biophysical – Mara River at Mara Mines

4.5.2.1 Hydrology

The EFA site Mara Mines has a contributing upstream catchment area of 11,283 km2 with a dominated land use of grass- and shrub land (Figure 4 43). Precipitation in the catchment sums up to 954 mm/yr, resulting in an evaporation value of 884 mm/yr, and a runoff value of 71 mm/yr.

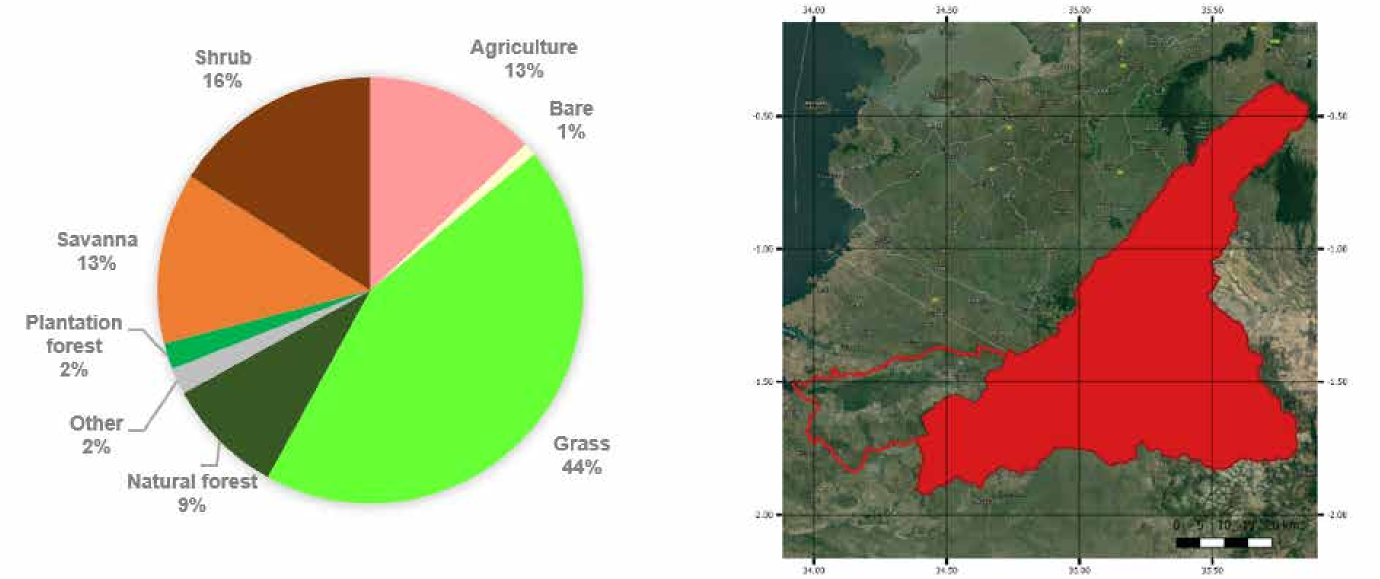


Figure 4-43: Land use within the Mara Mines sub-catchment (left) and catchment area (right)

Average monthly, minimum and maximum discharge values for Mara Mines EFA site are presented in Figure 4 44. On average, the wettest month is May

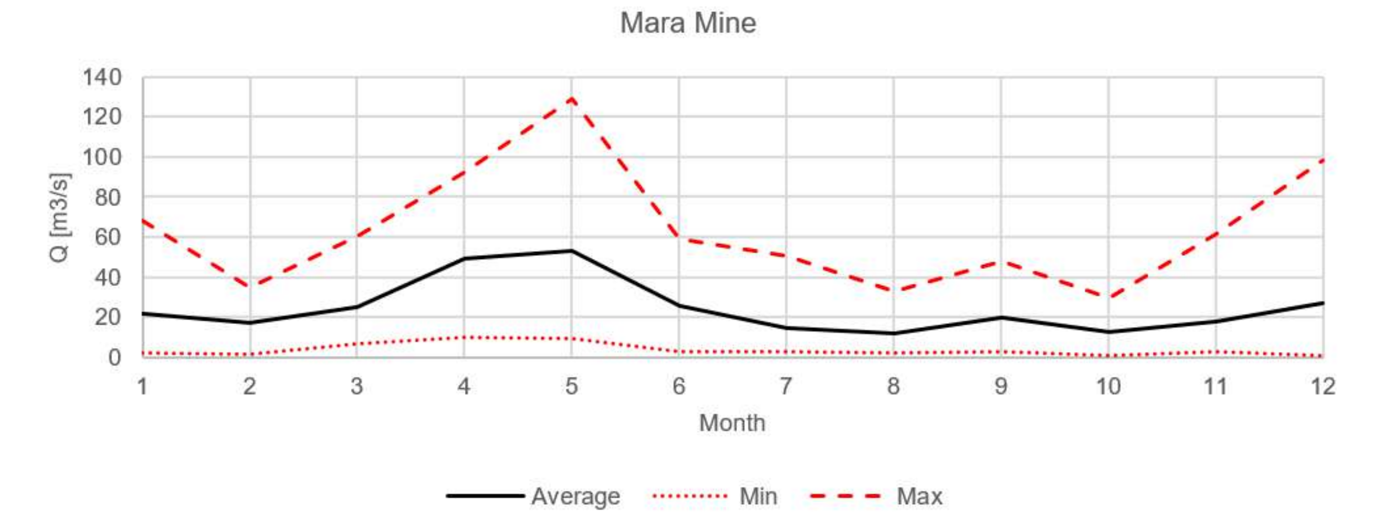


Figure 4-44: Average monthly, minimum and maximum discharge values for the Mara Mines EFA site

and the driest month is August. The Mara River at Mara Mines typically does not stop flowing, but can reach very low flow levels depending on the rain patters in the MRB.

4.5.2.2 Hydraulics

This section of the Mara River is characterized by a low gradient sand bed river with low bed roughness and a relatively square channel shape, creating relatively little hydraulic diversity. The hydraulic habitat is dominated by shallow slow flow during low flows and fast deep flows during high flows. During low flows pool sections do exist along the outer bends, creating deeper slower flow. In Figure 4 39 the channel cross section is presented with the observed and modelled flow levels indicated.

During the low flow there was a weak relationship ($R2 < 0.24$) between depth and velocity, possibly due to multiple channels of which some had very little flow. The modelled rating curve matches the observed low discharge and depth data closely, showing that the hydraulic model performed well for the lower end of

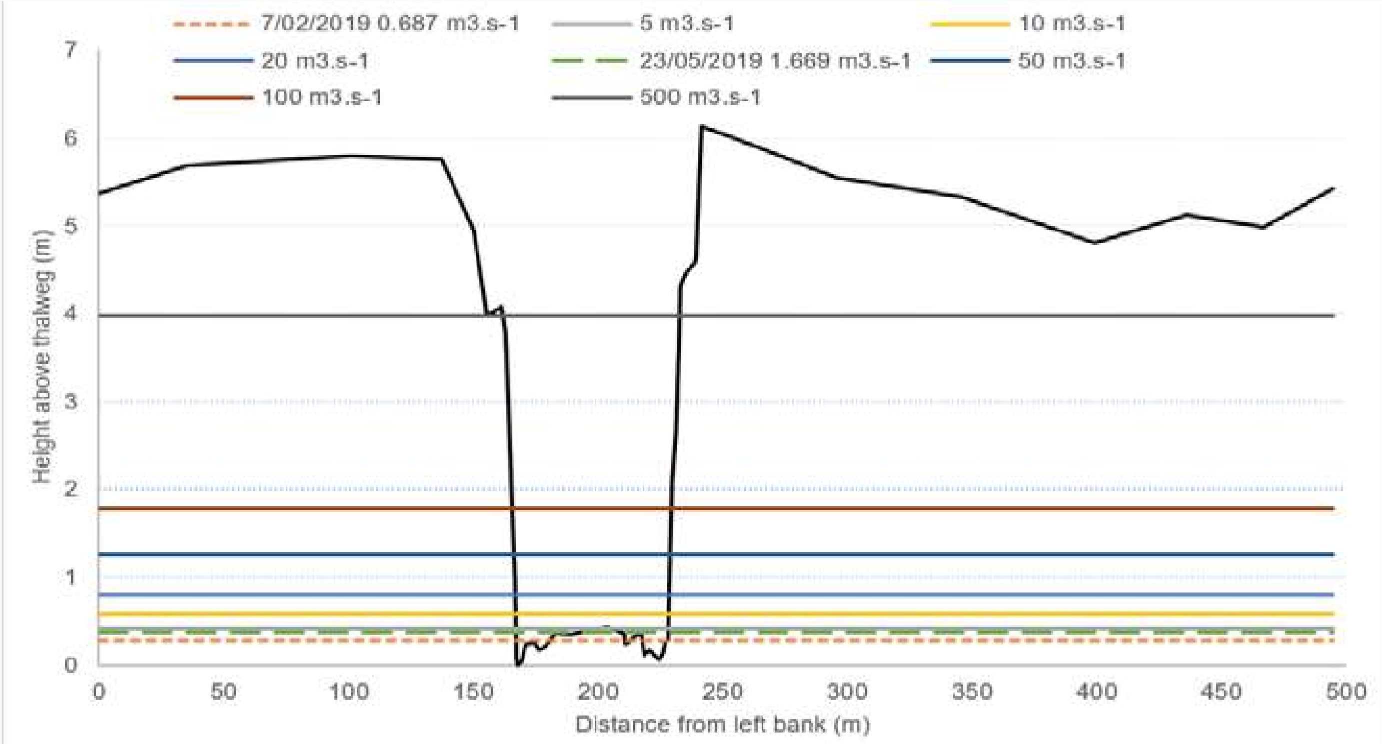


FIGURE 4 45: CROSS SECTION FOR THE MARA RIVER AT MARA MINES FOR OBSERVED (DOTTED LINES) AND MODELLED (SOLID LINES) FLOW LEVELS

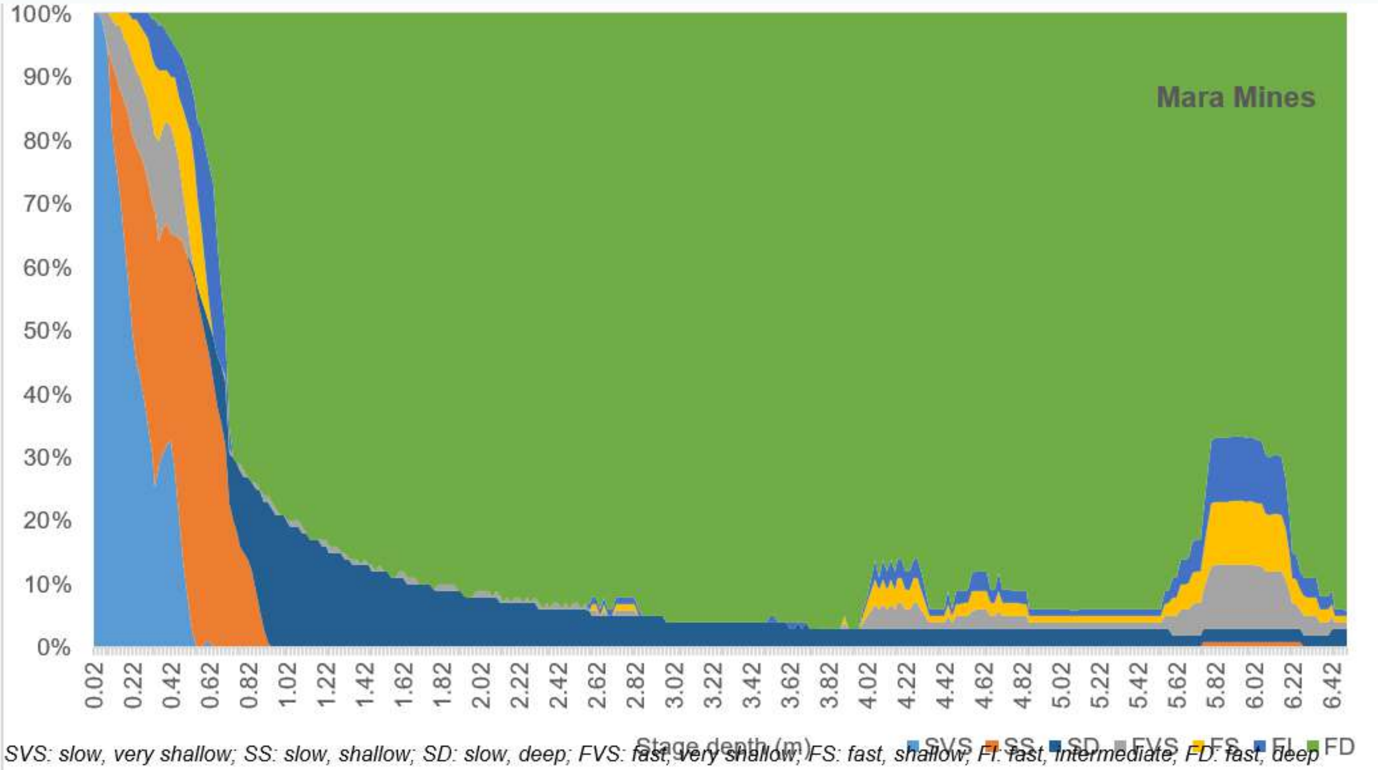


FIGURE 4 46: FREQUENCY DISTRIBUTION OF DEPTH-VELOCITY CLASSES FOR THE WETTED CHANNEL OF THE MARA RIVER FLOODPLAIN SITE NEAR MARA MINES the rating curve (see Annex D for the rating curve). Modelled velocity depth frequency distribution classes are presented in Figure 4 46.

4.5.2.3 Geomorphology

The Mara River at Mara Mines enters the floodplain and follows a meandering style with outer cut banks and inner scroll bars (Figure 4 47). The river slope is 0.0018 and is classified as a lower foothill river (Rowntree and Wadeson, 1999). This classification is described as a 'lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool –rapid/riffle with sand bars common in pools. Pools significantly longer than rapid/riffle habitats. Floodplain often present'. The site does not fit the description well due to the lack of rapid and riffle habitats, and long pools along the reach.

The river appears to be incised and is lined by levees (Figure 4 48). The levees prevent overbank flooding at the site, limiting spills onto the floodplain to low points along the banks and flood channels. This is evident by the narrow flood benches along both banks with fig trees and shrubs lining it. Mature terrestrial species are found on the flood plain, indicating infrequent flooding. A cut-off meander depression can be seen on the floodplain (top right of Figure 4 47; ~1.5 m lower than floodplain surface), indicating that the floodplain processes are still active. Outer bank erosion and scroll bar formation supports this finding.

The banks are steep and composed of silt and fine sand. The channel bed is dominated by coarse sand with small superficial gravel patches. The bed material is loose with very little fine sediment trapped in the interstitial spaces. The inset benches are very narrow along both banks and composed of fine sand and

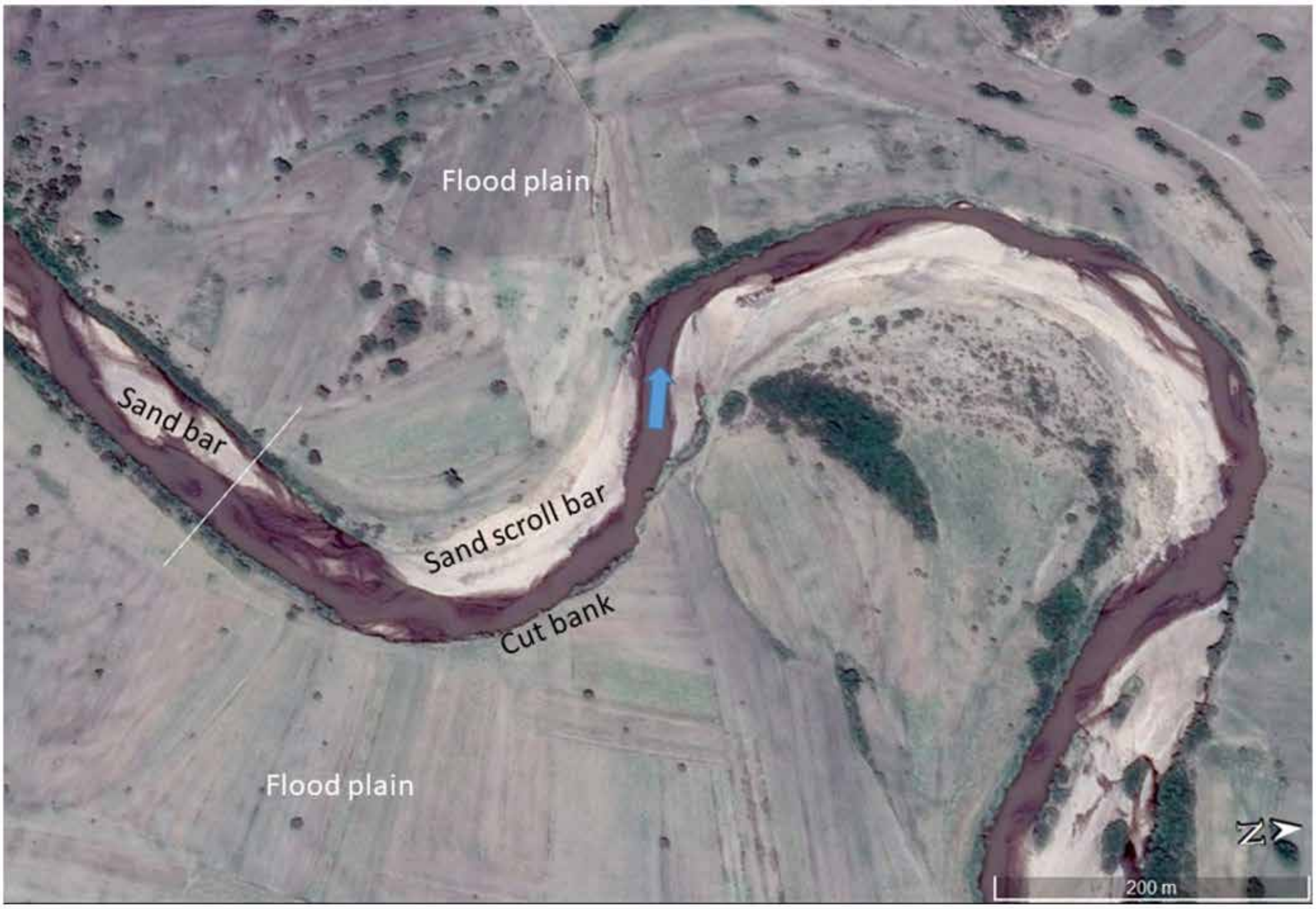


FIGURE 4 47: AERIAL VIEW OF THE MARA RIVER AT MARA MINES SHOWING THE LOCATION OF THE CROSS SECTION, THE MEANDERING PLANFORM AND SANDY BED (GOOGLE EARTH IMAGE DATE 14 APRIL 2017).

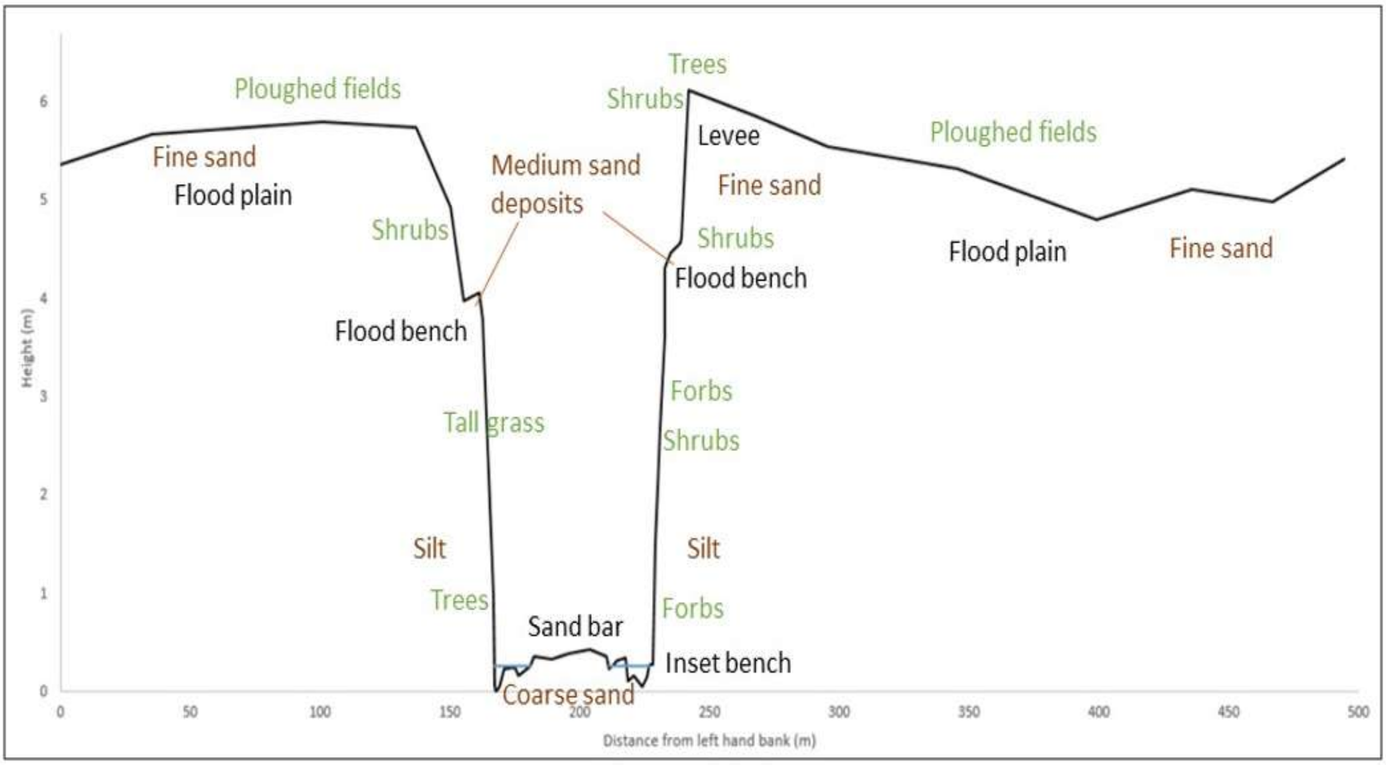


Figure 4-48: Cross section of the Mara River channel at Mara Mines showing sediment composition, vegetation type and geomorphic features.

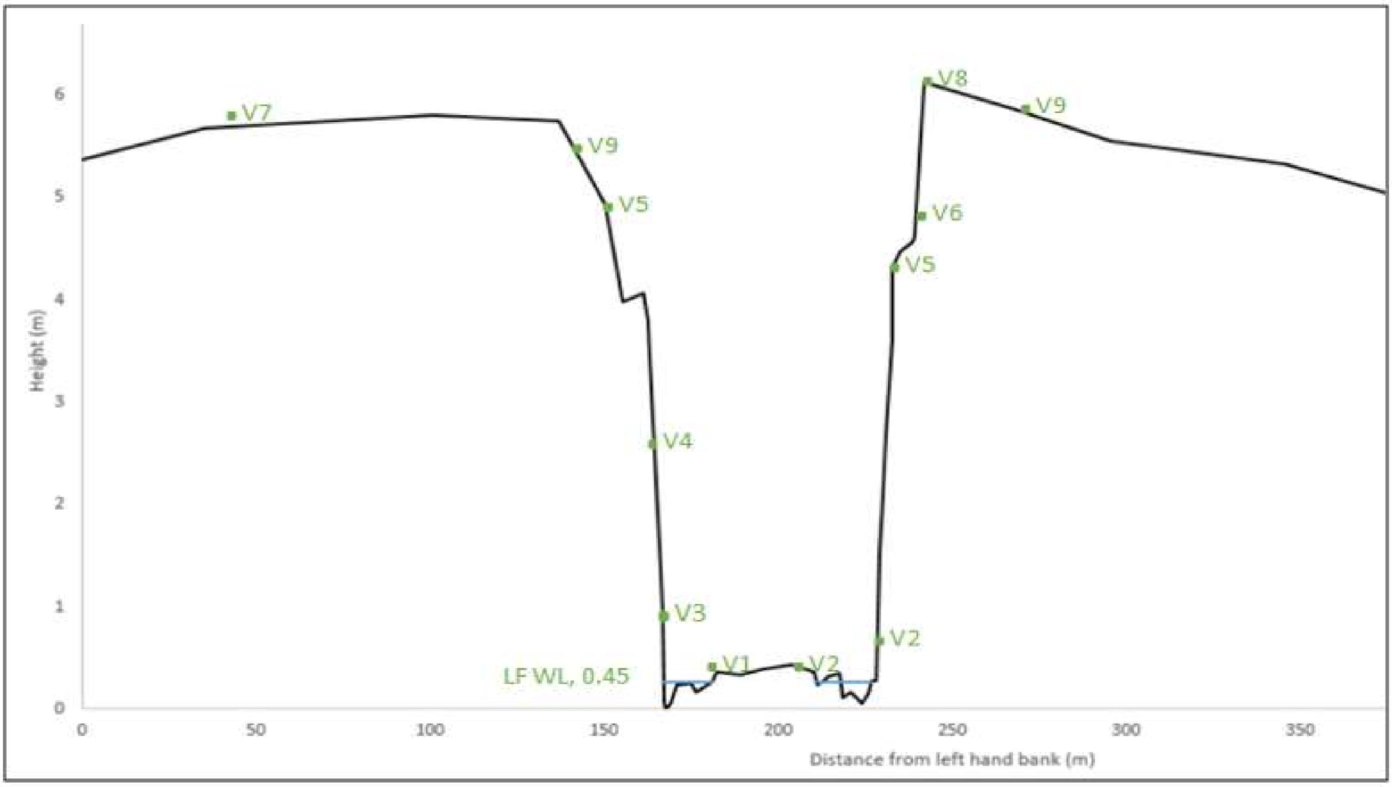
silt. The inset benches along the right banks shows signs of erosion near cattle watering site. Local elders remember a narrower tree lined channel from their youth.

4.5.2.1 Riparian Vegetation

The site is expected to be dominated by more grasses and sedges at marginal and lower sub-zones which are typical for riparian areas at its reference condition. Alien plant species are not expected at the two zones at reference. It expected that the vegetation in the upper sub-zone would be taller with more shade resulting in less non-woody vegetation cover. There would be large fig trees with intermediate class sizes suppressing establishment of alien plant species such as Lantana camara and Mimosa pigra.

The macro-channel bank is expected to be densely wooded and the proportion of terrestrial species is expected to be high due to infrequent flooding at reference condition. It was observed that the site had several sand bars and the river tended to meander through the sand bars. There are also flooding benches which are dominated by grazing tolerant grass Cynodon nlemfuensis by almost 90 percent. The riparian zone was covered with woody trees, shrubs and tall grasses especially the left side. Remarkably Ficus exasperate dominated the left bank at lower sub-zone.

There was a large flooding area on the right side of the river which is used for crop farming and grazing. Bank incision and slumping was also observed during the survey. Crop fields were also present on both sides of the river and grazing pressure was high on both sides of the river as well. A shrub like Lantana camara was present and provided refugia to many



Indicator Species	Number	Range	Remarks
Urochloa brachyuran	V1	marginal	
Commelina benghalensis	V2	marginal	forb
Ficus exasperata	V3	lower	start and dominated left bank
Leersia hexandra	V4	lower	tall dense grass
Cynodon nlemfuensis	V5	upper	start of flood bench
L. camara	V6	flood bench	refugia to forb species
Fig tree	V7	floodplain	adult large tree
Floodplain	V8	upper	start of floodplain
Dactylotenium aegyptium	V9	upper/macro-channel bank	

Figure 4-49: Cross section of the Mara River at Mara Mines showing indicator plant species

forb species. There were few species at marginal sub-zone i.e. Urochloa brachyuran (grass) and Commelina benghalensis (forb). Figure 4 49 shows distribution of plant species along the cross section of the river.

4.5.2.5 Fish

The Mara River at Mara Mine consists of two survey reaches. The first reach is located at the gauging station and the second reach is further downstream; presents the delineated GHUs for the two reaches. The upstream reach was sampled with an electrofisher, and the downstream reach was sampled with a combination of an electrofisher, cast net and seine net.

The first reach consists of two dominant GHUs, namely a rapid unit which is associated with the primary channel, and three runs (Figure 4 50). The water flow for these units is in a northerly direction, with all units characterized by a FS velocity-depth class. The substrate for this reach of the system

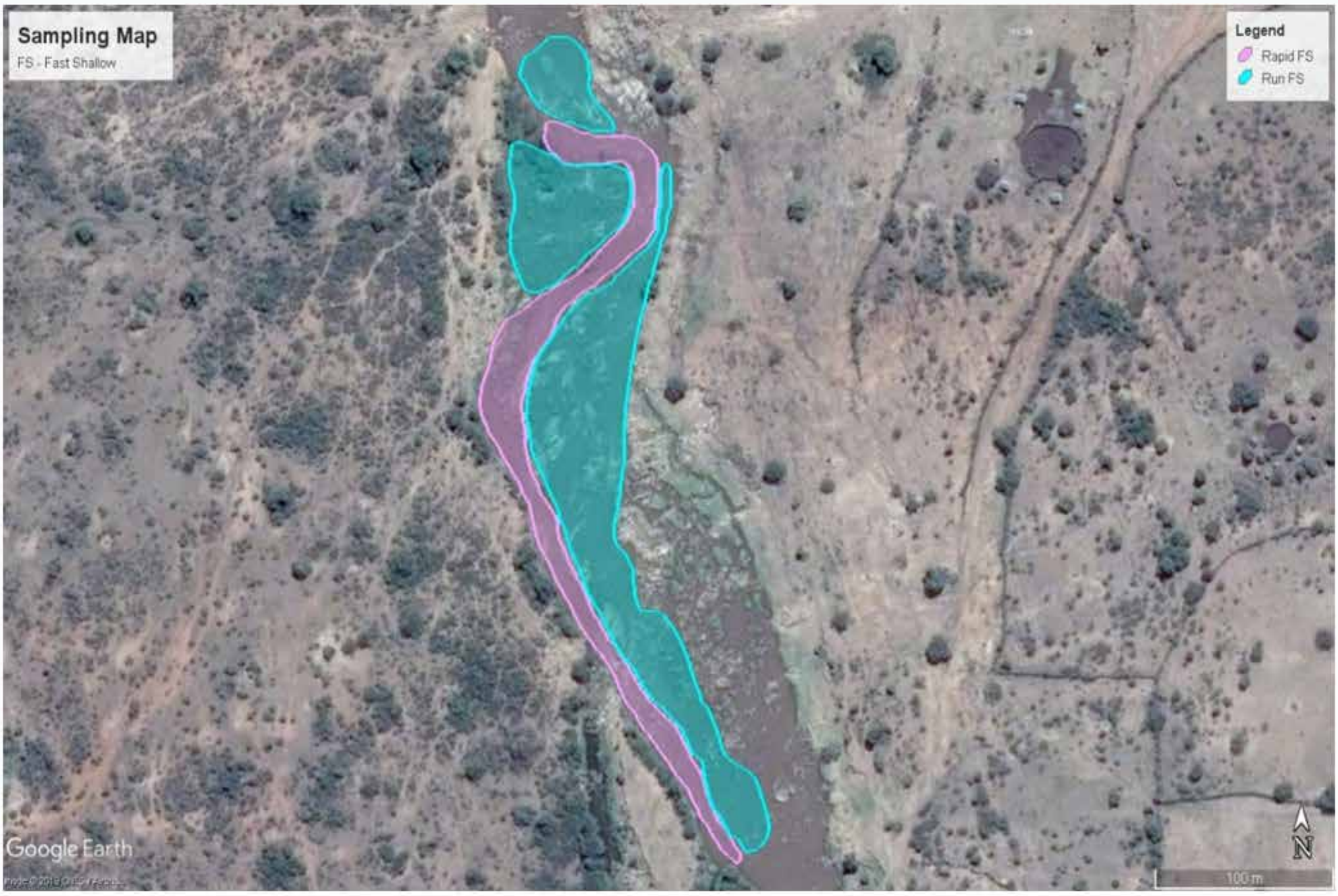


Figure 4-50: Aerial view of the Mara River showing the delineated GHUs for the site (Google Earth) for the Mara Mine upstream

Table 4-48: A summary of the HCR for the reach with associated velocity depth class ratings and corresponding details for the upstream reach.

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	-	-	-	-	-	-
SD	-	-	-	-	-	-
FD	25 – 75%	-	-	Bedrock & boulders	-	-
FS	> 75%	-	-	Bedrock & boulders	-	-

was characterized by cobbles, rocks, boulders and bedrock. Aquatic and marginal vegetation, root wads or overhanging vegetation were present. HCR ratings for the upstream reach is presented in Table 4 48.

The downstream reach is classified as a shallow run with relatively fast flow (Figure 4 51). The reach is located in a meandering portion of the system, with sandbars present in the channel. The substrate within the channel was dominated by stones and gravel, with root wads and overhanging vegetation present

Figure 4-51: Aerial view of the Mara River showing the delineated GHUs for the site (Google Earth) for the Mara Mine downstream

Table 4-49: A summary of the HCR for the reach with associated velocity depth class ratings and corresponding details for the downstream reach.

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	-	-	-	-	-	-
SD	-	-	-	-	-	-
FD	-	-	-	-	-	-
FS	> 75%	Leaves	Roots and undercut banks	Stones & gravel	Tree debris	-

although limited. Turbidity was considered high for both the upstream and the downstream reaches. An overview of the HCR ratings is presented in Table 4 49 and Figure 4 52.

A total of 20 fish species were sampled from the site, with a total of 99 individuals recorded for the site. Two indicator species were recorded for the site, namely Oreochromis niloticus and Clarias gariepinus. There was a dominance by Labeo sp for the composition.

Substrate for the upstream reach was dominated by cobbles, rocks and bedrock.

Habitat cover also consisted of a variety of types, with vegetation being dominant. The substrate for the downstream reach was dominated by sand and gravel, with mud located on the channel edges. The dominant cover was provided my marginal

FIGURE 4 52: A PHOTOGRAPH DEPICTING HABITAT CHARACTERISTICS FOR THE DOWNSTREAM REACH FOR THE MARA MINE SITE (FEBRUARY 2019)

vegetation, with areas of root wads. Habitat diversity was considered to be high for the upstream reach and low for the downstream reach, with two dominant velocity-depth class, namely FS and FS.

4.5.2.6 Macroinvertebrates

Most of the macroinvertebrate taxa are moderately to highly sensitive to river flow and habitat availability (i.e., Naucoridae, Gomphidae, Lestidae, Baetidae, Simuliidae, Elmidae, Tricorythidae and Hydropsychidae), and some that are very sensitive

Table 4-50: Macroinvertebrate community metrics for Mara Mines

Community Metrics	Score
Total abundance	2683
No. of taxa	38
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	1449
% EPT	54.01
Number rheophilic taxa	6
Abundance of rheophilic taxa	1905
Relative abundance of rheophilic taxa	71.00
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	1765
% STH	65.78

Table 4-51: Results of the SASS5 and TARISS on processed samples at Mara Mines

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	**Number of taxa**	**ASPT**	**TARISS Score**	**Number of taxa**	**ASPT**
219	35	6.3	221	35	6.3

Laboratory analysis for the SASS5 Protocol		
Total SASS Score	**No. of taxa**	**ASPT**
245	37	6.6

to poor water quality (Heptageniidae, Oligoneuridae and Perlidae). Table 4 50 and Table 4 51 below indicate the field processed and laboratory processed score results for the site.

4.5.2.7 Water Quality

The pH, conductivity and turbidity are all within the same range during the high and low flows. The slightly high pH could be an effect of geology much like the case in Tobora. The sandy channel could be playing a big role in terms of cleaning/filtering the water hence the no change in turbidity observed during the two surveys. Presence of nitrate was also measured

Table 4-52: Results of the water quality analysis for Mara Mines

Parameter	Unit	1st survey	2nd survey
pH	(-)	8.0	8.4
Electrical conductivity (EC)	µs/cm	485	433
Temperature (T)	deg C	32.6	27.4
Dissolved oxygen (DO)	mg/L	5.7	7.97
Oxygen saturation	%	91.4	116.4
Turbidity	T.U	400	400
Nitrate (NO_3^-)	mg/L	10	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	231.8	ns
Ammonium (NH_4^+)	mg/L	0.02	0.09
Non purgeable organic carbon (NPOC)	mg/L	11.1	12.5
Total nitrogen (TN)	mg/L	3.2	1.43

ns: not sampled

at this site possibly from the numerous number of

Table 4-53: Site metrics for Mara Mines

Metric	Social	Geomorph.	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	A/B	B/C	B	B	B	B
ToC	Stable	Stable/ declining	Declining	Declining	Declining	Declining
EIS	Medium	High	Medium	Medium	High	Medium
SIS	High	-	-	Medium	Medium	High
EMC	B	B	B	B	B	B

livestock that water directly from the river. Table 4 52

Table 4-54: Indicators and management objectives for Mara Mines

EFA Components	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including subsistence crop farming, livestock keeping, vegetables and fruits collection/cultivation for the local communities residing along the Mara River at Mara Mines
	Target species	The following species should be abundant enough to suffice the needs of the population residing along Mara River at Mara Mines: Fish: Mumi, Sato, and Ningu Vegetables: Chinsaga, Nyakanwa, and Chenkunyenyi Trees: Chinseke, Amasisi/Ukwaju, Omongoro/Mninga pori, and Egysamiti Other species i.e. grasses: Ukindu, Amabanche and Itutu
Geomorphology	Pool depth	Maintain pools of at least 0.5 m deep
	Inset benches	Maintain flow variability and moderate sediment supply to maintain this lower bank habitat
Riparian Vegetation	Riparian tree and grass and communities	Continue to maintain abundances of flow sensitive grass species e.g. *Urochloa brachyuran* at the site
		Continue to maintain abundances of moderately flow sensitive plant species, including *Ficus exasperata* and *Echinochloa pyramidalis*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
	F. exasperata and *E. pyramidalis*	Continued presence and occurrence of seedlings and adults of *F. exasperata, E. pyramidalis and Urochloa brachyuran* and the three should together be present at abundance of ≥20 percent of the riparian plant community as in natural setting
Fish	Recruitment of indicator cyprinids spp.	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
	Occurrence of indicator species	Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site
	Fish community wellbeing assessment	If either of the two previous indicators are not observed a fish community wellbeing assessment should be undertaken

Table 4-54: Indicators and management objectives for Mara Mines

EFA Components	Indicator	Management Objective(s)
Invertebrates	SASS5 or TARISS Index	South African Scoring System (SASS5) or TARISS Index score >200 and Av. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more baetid species, *Hydropsychidae, Tricorythidae, Leptophlebiidae, Elmidae, Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
	Ephemeroptera, Plecoptera, and Trichoptera orders	The following orders should be present in abundances >50 percent of the invertebrate community.
	Hydropsychidae, Simuliidae, Tricorythidae, and *Lestidae* families	The following flow sensitive and marginal vegetation dependent families should be present in abundances >40 percent of the invertebrate community.
	Target species: Oligoneuridae sp. and Perlidae sp.	*Oligoneuridae* is among the most sensitive family of macroinvertebrates to both water quality and quantity, and hence should be present at the site as a sign of good water and habitat conditions (no sedimentation). *Perlidae* (stoneflies) are very sensitive to flows because they prefer fast velocities. Their presence means maintaining good water quality and stable substrate for attachment.
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish/macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic (washing, drinking) and livestock purposes
		Ensure water is devoid of toxins/contaminants which can cause disease outbreaks.

shows the field measurements and laboratory results

Table 4-55: Required flow conditions for Mara Mines

Hydrological Component		Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Month: Feb, Aug Depth (m): 0.21 Velocity (m/s):0.27 Inundation: 0 days Flow (m^3/s): 3.5	None	Month: October Depth (m): 0.4 Velocity (m/s): 0.25 Flow (m^3/s): 1.8	Month: Feb, Aug, Oct Depth (m): 1.08 (0.53 avg) Velocity (m/s): 0.11 Inundation: >10 days Flow (m^3/s): 3.5	Month: Feb, Oct Depth (m): 0.42 Velocity (m/s): 0.25 (98% velocity 0.81) Flow (m^3/s): 2.1
	Low flows, wettest month	Month: March Depth (m): 0.71 Velocity (m/s): 0.7 Inundation: 0 days Flow (m^3/s): 30.7	None	Month: July Depth (m): 0.6 Velocity (m/s): 0.33 Flow (m^3/s): 6.2	Month: Jan, Mar, Apr-Jul, Sep, Nov, Dec Depth (m): > 0.75 (0.45 avg) Velocity (m/s): 0.54 Inundation: >30 days Flow (m^3/s): 15	Month: May Depth (m): 0.7 Velocity (m/s): 0.4 (98% velocity 1.27 m/s) Flow (m^3/s): 10
	High flows, freshets and/or floods	Month: Apr, May, Nov, Dec Depth (m): 2.11 Velocity (m/s): 1.5	**High Flows** Depth (m): 3 (2.4-3.5) Inundation: 2days peak, 1 in 3 years.	**Freshets** Month: September Depth (m): 1.4 Velocity (m/s): 0.94	Month: Apr, May Depth (m): >1.2 (0.9 avg) Velocity (m/s): 0.8	**Freshets** Month: Apr-May, Nov-Dec Depth (m): 1.26

Table 4-55: Required flow conditions for Mara Mines

Hydrological Component		Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
		Inundation (days): 7 days Flow (m^3/s): 210	Flow (m^3/s): 300 **Freshets** Depth (m): 0.5-0.7 Inundation: 2 day average, 2 per wet season (2 wet seasons, 4 freshets per year) Flow (m^3/s): 10 **Flood** Depth (m): 5 (4.5-5.6) Inundation: 3 days peak (1 in 10 years) Flow (m^3/s): 800	Flow (m^3/s): 64.3 **Floods** Month: Apr-May Depth (m): 3.4 Velocity (m/s): 1.91 Inundation: 1-2 days Flow (m^3/s): 382 (once in 3 years)	Inundation: >21 days Flow (m^3/s): 46	Velocity (m/s): 0.86 (98% velocity 2.03) Flow (m^3/s): 25 **Annual Flood** 2 weeks in May and Nov Flow (m^3/s): 50 (Annual flood)
Drought Year	Low flows, driest month	Depth (m): 0.12 Velocity (m/s): 0.22 Inundation (days):0 Flow (m^3/s): 0.7	None	Month: Oct Depth (m): 0.3 Velocity (m/s): 0.22 Flow (m^3/s): 0.71	Month: Feb, Aug, Oct Depth (m): 0.13 (0.4 avg) Velocity (m/s): 0.25 Inundation: Not less than 10 days Flow (m^3/s): 1.8	Month: Feb-Mar Depth (m): 0.36 Velocity (m/s): 0.24 (98% velocity 0.79) Flow (m^3/s): 1.1
	Low flows, wettest month	Depth (m): 0.21 Velocity (m/s): 0.27 Inundation: 0 days Flow (m^3/s): 3.5	None	Month: July Depth (m): 0.5 Velocity (m/s): 0.3 Flow (m^3/s): 3.5	Month: Jan, Mar-Jul, Sep, Nov, Dec Depth (m): >0.64 (0.35 avg) Velocity (m/s): 0.36 Inundation: >30 days Flow (m^3/s): 7.6	Month: Apr-June Depth (m): 0.48 Velocity (m/s): 0.26 (98% velocity 0.86) Flow (m^3/s): 3.1
	High flows, freshets and/or floods	Depth (m): 1.19 Velocity (m/s):0.99 Inundation: 7 days Flow (m^3/s): 74.4	**High Flows** Depth (m): 2.4 (2.4-3.5) Inundation: 2 day peak 1 in 3 years Flow (m^3/s): 194 **Freshets** Depth (m): 0.5-0.7 Inundation: 2 day average 3 events during wet season Flow (m^3/s): 10	Month: Apr-May Depth (m): 1.9 Velocity (m/s): 1.21 Inundation:1-3 days Flow (m^3/s): 121.5 (once in 3 yrs.)	Month: Apr, May Depth (m): >0.88 (0.59 avg) Velocity (m/s): 0.6 Inundation: >21 days Flow (m^3/s): 22	Month: Apr-May, Nov- Dec Depth (m): 0.7 Velocity (m/s): 0.4 (98% velocity 1.27) Flow (m^3/s): 10

for water quality samples taken at the site.

Table 4-56: Confidence level for flow recommendations for Mara Mines

Site Name	Rating	Rationale
Social	4	The findings were matching with those of biophysical scientists
Hydraulics	3.5	Straight channel with pool riffle/rapid habitat. Two observations at relatively low flows used for calibration
Geomorphology	3.5	Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5	This site had a good cover of plant species mostly native ones especially on river banks. All vegetation zones had good representation of native species. Survey of more transects especially further down the river would have increased the confidence level. The river appear to have variable habitats compared to what was captured in regard to vegetation.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecology of species and social relationships.
Macroinvertebrates	4	The hydraulic cross-section had clear boundaries, and the flow measurements had high confidence. Given the previous studies at the site, an understanding of flow requirements for invertebrate taxa has been gained, and this gives a lot of confidence to the flows values I have proposed.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.5.3 Site Metrics

4.5.4 Indicators and Management Objectives

4.5.5 Required Conditions

4.5.6 Confidence Ratings

4.6 Bisarwi

The Bisarwi EFA biophysical study site is located in the upper Mara Wetland along one of the main flow channels on the northern side of the wetland. It is downstream of both the Tigithe River and the mainstem Mara River. There is little habitat diversity inside the channel since it is uniform in shape and dominated by fine materials. There is a slight levee on the banks, making them higher than the surrounding floodplain area. There is little vegetation on the banks and evidence of active erosion. The surrounding area

FIGURE 4 53: SITE PHOTOS OF BISARWI

is predominantly flood-recession agriculture, with fields going right up to the banks.

4.6.1 Social Survey – Kembwi, Marasibora

Initially, the area had no wetlands. These started to appear in 1997 during El Niño in which the water overflowed to inundate areas where there were native vegetation and trees. This suppressed the growth of native vegetation and trees causing the appearance of wetland vegetation i.e. papyrus. Since then, papyrus occupied the area causing the formation of Irirabo wetland. The wetlands have diverse species of fishes. The area is fairly in its natural state where fishing is done by approximately 60 percent of the locals, forming an important livelihood activity. Riparian vegetation are also in good condition as compared

Table 4-57: Wetland resources and their relative importance in North Mara RU

No.	Wetland Resources	Relative Importance (%) per sample villages		Average
		Kembwi	Marasibora	
1	Water	96.1	78.2	87.2
2	Fish	0	9.8	4.9
3	Cultivation Land	1.9	7.8	4.9
4	Weaving grasses	0	3.9	2.0
5	Livestock Pastures	1.9	0.1	1
6	Roofing grasses	0	0.2	0.1
7	Building Poles	0	0	0
8	Firewood/Charcoal		0	0
9	Natural vegetables	0	0	0
10	Building Sands	0		0
11	Natural fruits	0		0
12	Medicinal Plants	0		0
13	Wildlife (animals and birds)		0	0

to other sites. They provide locals with natural vegetables, trees for fruits, poles and timber; weaving and thatching materials for subsistence use (Table 4 57).

There are five main economic activities in the RU which include agriculture, livestock keeping, fishing,

Table 4-58: Economic activities in North Mara RU

Activity		Performer	Location/Why	Time/Why
Agriculture	Maize Millet Finger millet Cassava Sweet potatoes	Family	Valleys	Because of the rain pattern (twice a year)
Livestock keeping	Cows, Goats, Sheep Chickens and ducks	Family	Valleys	
Ulowaji (swimming)		Men	Valleys/Rivers	April, Dec and Nov
Small business		Women	Business centers	
Fishing		Men		April (high season) Oct (low season)

Table 4-59: Trend of resources and condition of the wetland in North Mara RU

Resource	Nyerere's Regime (1960 - 1985)	Current Situation	Future Expectations (2030)	Reasons
Fish	1000	100	50	Population increase hence high consumption rate.
Wild Vegetables	200	100	50	Agricultural expansion Cutting down of trees Increase inundation distance since 1998 when we had El Niño
Wild Fruits	250	100	45	Expansion of agriculture activities Un-prescribed burning of the natural land for agriculture purposes.
Weaving materials	10	100	225	Flooding facilitate seed dispersal Increase in inundation distance widen the spread
Building poles	600	100	40	Increasing in the use of poles for building activities Felling of trees for agriculture purposes Unplanned burning/fire.
Thatching materials	650	100	17.5	Increase in number of cattle keepers and number of livestock hence high grazing of the plant materials.
Degradation of wetland/river ecosystem	10	100	160	Cultivation near water sources High deforestation than forestation Increased in population Livestock grazing near water sources.
Dependency of community to rivers and other wetland resources for their livelihood	80	100	120	Increased in population around the wetland High cost for substitute resources.
Size (width) of the river	50	100	175	Increased in siltation Livestock distort river bank Decreased in water depth hence water spread due to increase in width.
Quality of wetland/river	600	100	50	Mining activities from Nyamongo Pollution from the livestock

small business and ulowaji (swimming) in Kembwi Village (Table 4 58). The trend of resource utilization and wetland condition is given in Table 4 59.

4.6.2 Biophysical – Mara Wetland at Bisarwi

4.6.2.1 Hydrology

The EFA site Bisarwi has a contributing upstream catchment area of 11,903 km2 with a dominated

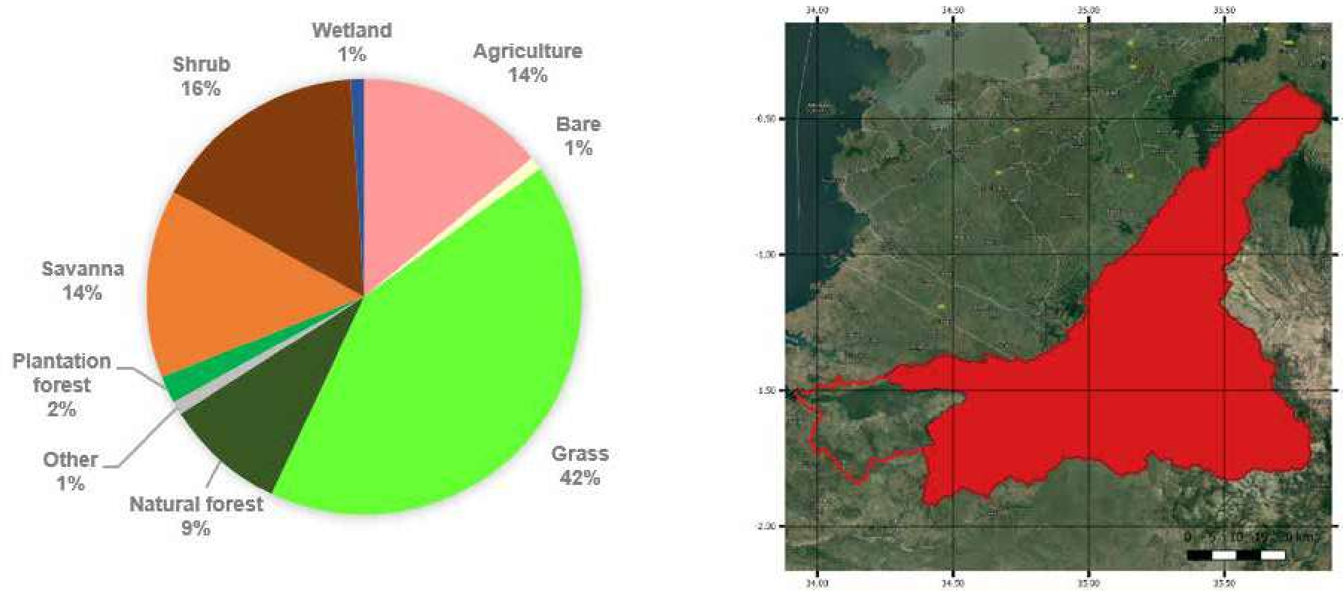


Figure 4-54: Land use within the Bisarwi sub-catchment (left) and catchment area (right)

land use of grass- and shrub land (Figure 4 54). Precipitation in the catchment sums up to 960 mm/yr, resulting in an evaporation value of 889 mm/yr, and a runoff value of 71 mm/yr.

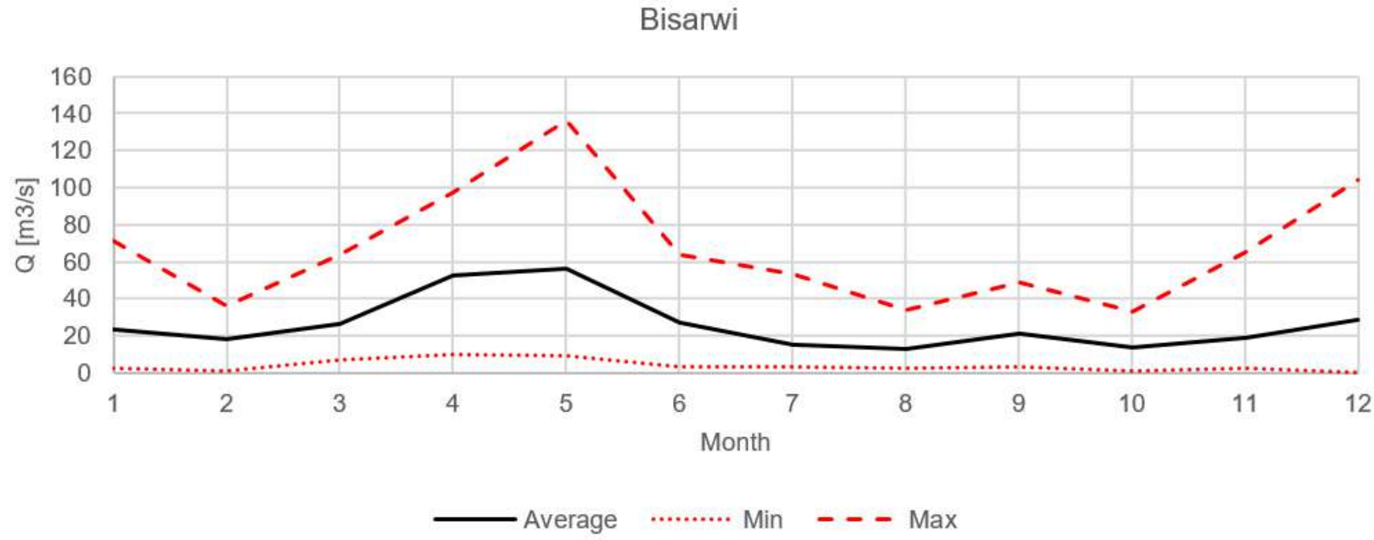


Figure 4-55: Average monthly, minimum and maximum discharge values for the Bisarwi EFA site

Average monthly, minimum and maximum discharge values for Bisarwi EFA site are presented in Figure 4 55. On average, the wettest month is May and the driest month is August.

4.6.2.2 Hydraulics

The Mara River at Bisarwi is typical of a low energy system transporting fine sediment through slow deep flows. The channel is narrow and deep with a limited range of shallow flow habitats. This changes dramatically once the river bursts its banks, flooding extensive floodplain areas that have shallow to deep flow that could range from slow to fast. Figure 4 56 shows the transect with observed and modelled flow levels indicated. Note that the channel fills first before the water spills onto the floodplain. There

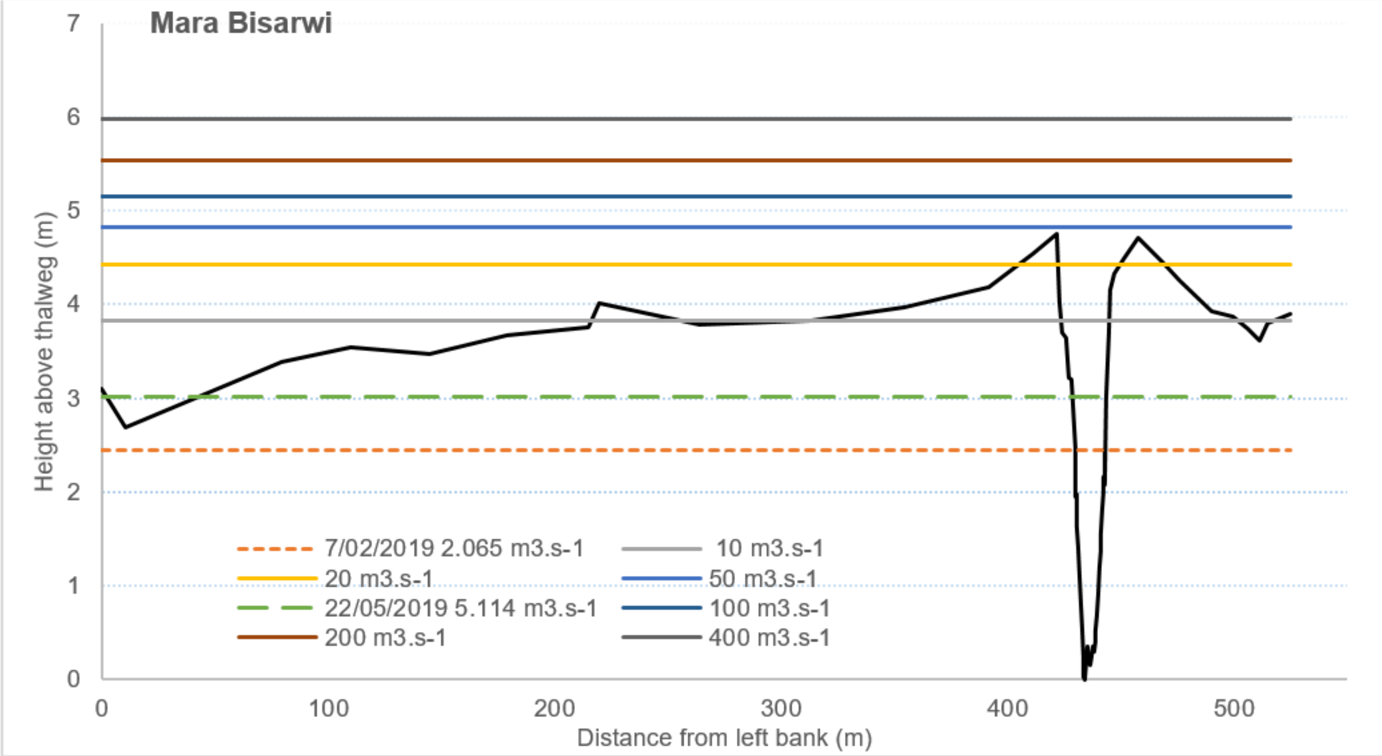
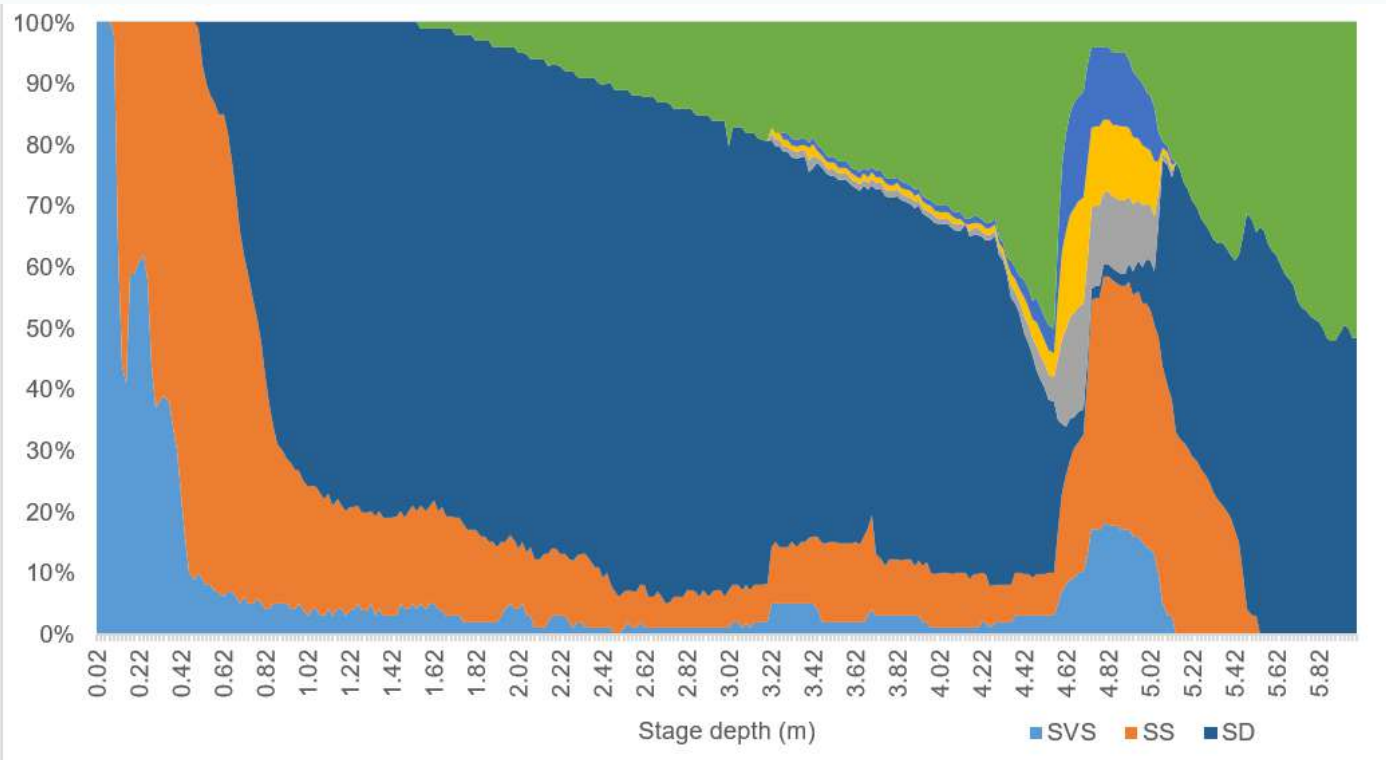


FIGURE 4 56: CROSS SECTION INDICATING OBSERVED (DOTTED LINES) AND MODELLED (SOLID LINES) FLOW LEVELS AT THE BISARWI EFA SITE



SVS: slow, very shallow; SS: slow, shallow; SD: slow, deep

FIGURE 4 57: FREQUENCY DISTRIBUTION OF DEPTH-VELOCITY CLASSES FOR THE MARA RIVER AT BISARWI was a moderate relationship between flow depth and velocity ($R2 < 0.78$). The velocity-depth frequency distribution for the incremental increase in wetted channel in Figure 4 57.

4.6.2.3 Geomorphology

The Mara River at Bisarwi has a sinuous channel pattern and is located one kilometer upstream of the main avulsion that took place in ~1989 (Figure 4 58). The river channel slope is 0.000102 and is classified as a lowland river (Rowntree and Wadeson, 1999). They define the reference condition as a "low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content of the bed or banks". The site fits the description to a moderate level due to the cohesive nature of the banks that resist lateral movement of classic meandering channels.

Local elders ascribe the avulsion to woody debris that caused a channel blockage during the 1989 floods. A smaller channel has developed since, linking the main channel just downstream of the site to the main channel that formed during the avulsion. It is anticipated that this new channel will increase in size and become the new Mara River channel for the near future.

The channel at the site is flanked by levees and is deep and narrow (Figure 4 59). The upper banks are steep and poorly vegetated, with active bank erosion and bank slumping and no signs of sediment deposition. Cattle accessing the river for drinking adds to the trampling and degradation of the banks. The banks, bed and floodplain are composed of silt. The floodplain slopes away from the levees and backwaters and flood channels are present leading floodwater away from the main channel (Figure 4

FIGURE 4 58: AERIAL VIEW OF THE MARA RIVER (BLUE ARROWS) AT BISARWI INDICATING THE LOCATION OF THE TRANSECT AND THE BIFURCATION OF THE MARA RIVER UPSTREAM OF THE AVULSION THAT TOOK PLACE IN 1989 (GOOGLE EARTH IMAGE 21 JULY 2017). THE BLACK ARROW INDICATES THE NEW CHANNEL AND THE WHITE ARROWS INDICATE FLOOD CHANNELS.

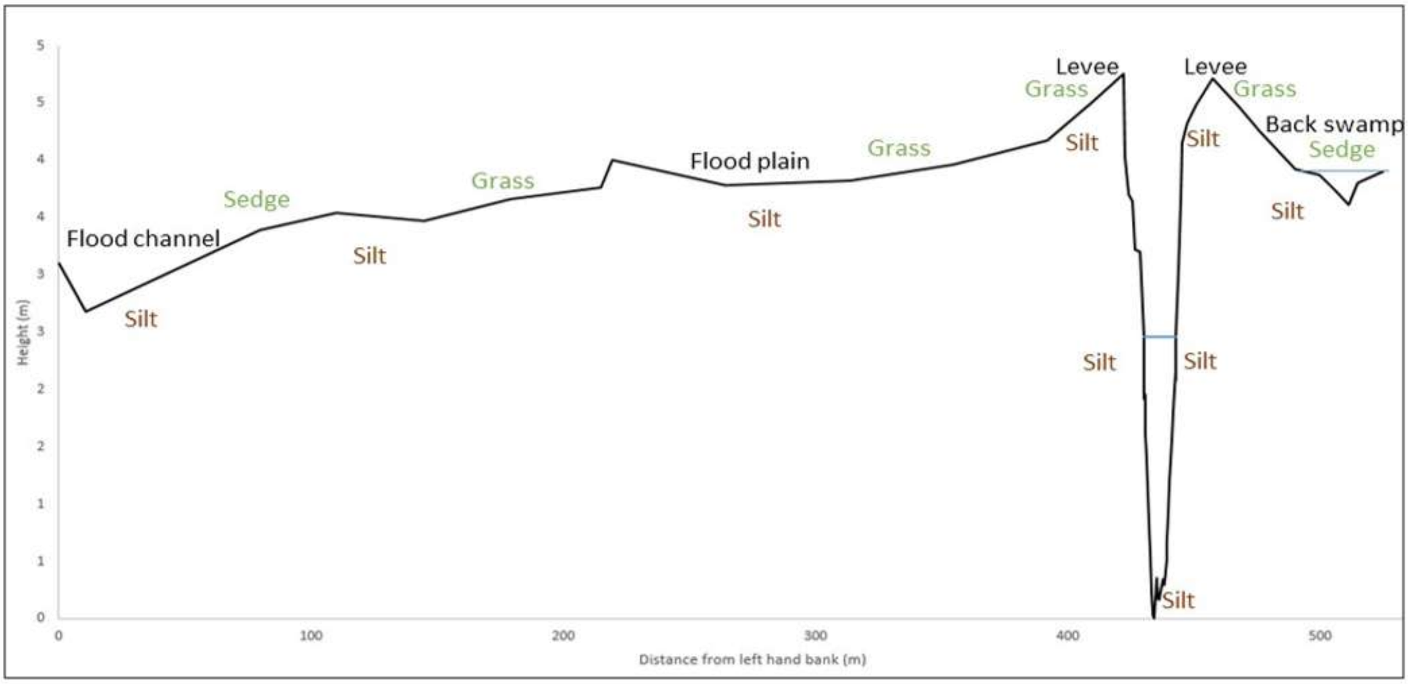


Figure 4-59: Cross section of the Mara River near Bisarwi showing the morphological features, sediment composition and vegetation composition.

59). Higher ground on the floodplain has grass and shrubs growing, whereas the lower areas vegetated with grasses and sedges. Floating water plants and rushes are present in the back waters.

4.6.2.4 Riparian Vegetation

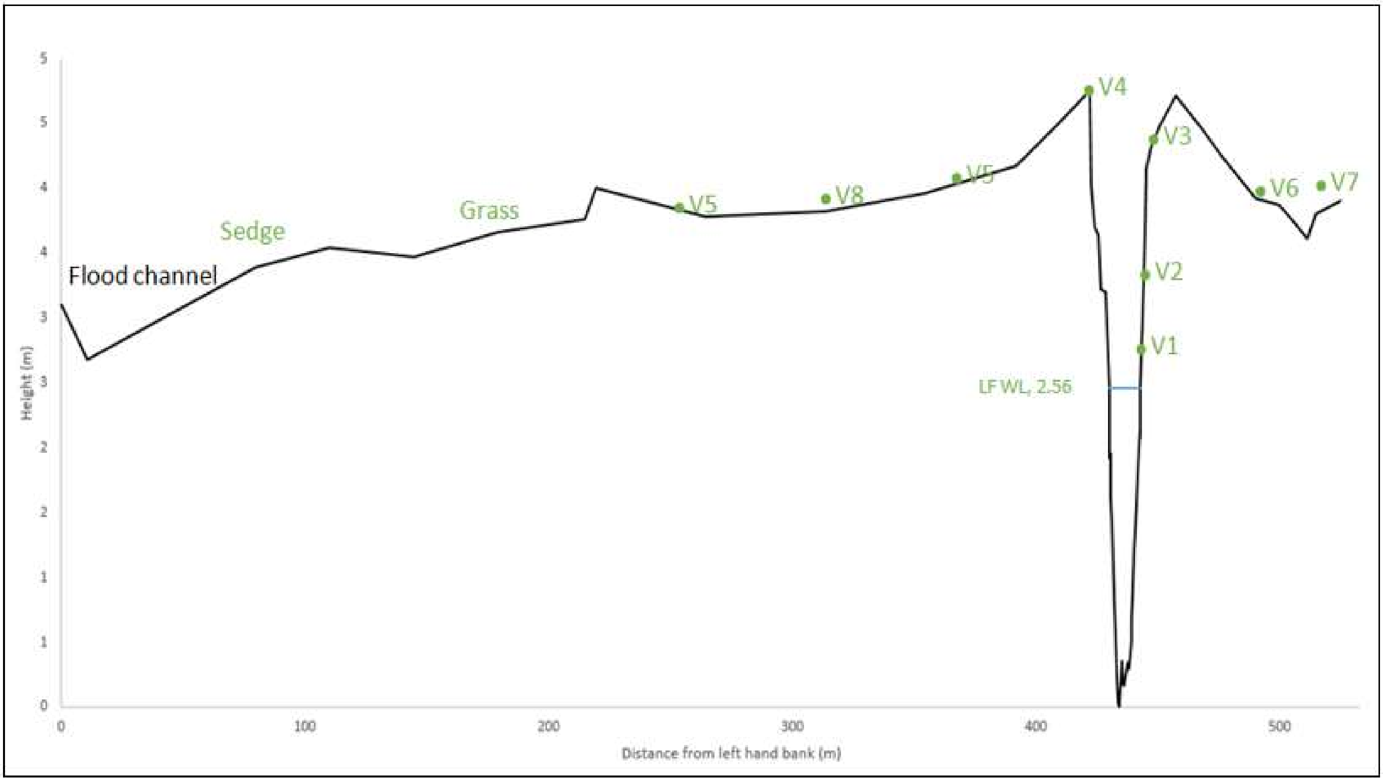
The site is expected to be dominated by more grasses and sedges at marginal and lower sub-zones at its reference condition including a good cover of wetland plant species including hydrophilic grasses and sedges. It is also expected to have in-stream vegetation which includes macrophytes and fringing submerged aquatic plants that provide in-stream cover and food for aquatic fauna. Only a few wetland/ riparian woody plants are expected during high flows due to inundation.

During the survey it was observed that the site experience high human disturbance through cattle grazing and banks were unstable and slumping. Water was very turbid indicating that clay soil erosion and diverse human activities are taking place on the site and up the river. There were papyrus stands about 50 m away from the river on right hand side. There were virtually no plants on the marginal sub-zone except some dead grass species at the lower sub-zone which could be a result of prolonged inundation, denied moisture and/or effect of trampling.

A large part of the marginal and lower sub-zones were bare. At the upper part there was 1 stand of Mimosa pigra on the right bank. The floodplain on the left side of the river was dominated by intensively grazed grass Cynodon nlemfuensis (60 percent). Other common species within floodplain were Sida acuta (invasive), Sida alba, Rorippa micrantha and Conyza bonariensis (all forbs). Water hyacinth Eichhornia crassipes was also present but at low numbers. Hippo grass, Vossia cuspidate, was present but only in few places on the lower sub-zone. Figure 4 60 shows the distribution of plant species along the cross section of the river.

4.6.2.5 Fish

The Bisarwi reach of the Mara River has a sinuous channel pattern, flowing in a westerly to north-westerly direction. A total of three GHUs were identified and sampled for this reach (Figure 4 61). Sampling included a combination of electrofishing, cast net and seine net efforts. These included a pool associated with the Mara River itself, and a run flowing in a southerly direction from the Mara River. The pool and the run were characterized with SD and FS velocity-depth classes. A total of three pools, all isolated from the Mara River were also sampled, but yielded no fish species. These pools were shallow with no flow (NF) presented. The substrate of the



Indicator Species	Number	Range	Remarks
Vossia cuspidata	V1	lower	
Mimosa pigra	V2	lower	
*Cynodon species**	V3	lower	intensively grazed
*Cyperus species***	V4	lower	start of floodplain
Sida species***	V5	upper	
Nymphaea nouchali	V6	back waters	
Typha domingensis	V7	back waters	
Annual shrubs	V8	from levees	*Conyza bonariensis* and *Ageratum conyzoides*

**Includes Cynodon nlemfuensis and C. dactylon*

***Includes Cyperus cyperoides and C. distans*

****Includes Sida acuta and S. alba*

Figure 4-60: Cross section of the Mara River at Bisarwi showing indicator plant species

Table 4-60: A summary of the HCR for the reach with associated velocity depth class ratings and corresponding details.

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	-	-	-	-	-	-
SD	> 75%	-	-	Silt & clay	Tree debris	Grasses
FD	25 – 75%	-	-	Silt & clay	-	-
FS	-	-	-	-	-	-

FIGURE 4 61: AERIAL VIEW OF THE MARA RIVER SHOWING THE DELINEATED GHUS FOR THE SITE (GOOGLE EARTH)

Mara River and the tributary (run) was dominated by silt and clay. Aquatic and overhanging vegetation was recorded for the Mara River. Table 4 60 and Figure 4 62 show an overview of the HCR ratings.

A total of 17 fish species were sampled from the site, with a total of 164 individuals recorded for the site. Two indicator species were recorded for the site, namely Oreochromis niloticus and Clarias gariepinus. There was a dominance by Schilbe depressirostris for the composition.

Substrate for the reach was dominated silt, mud and

FIGURE 4 62: A PHOTOGRAPH DEPICTING HABITAT CHARACTERISTICS FOR THE MARA RIVER REACH AT BISARWI (FEB 2019) sand. Habitat cover also considered to be generally limited, with aquatic and marginal vegetation the dominant types. The reach of the Mara River was characterized by a SD velocity-depth class.

4.6.2.6 Macroinvertebrates

This is a floodplain site where flooding occurs during the rainy season, but during the dry season water in confined to the main channel. Instream habitat is reduced and most of the taxa are those that prefer slow moving water/wetlands. Only Baetidae, among the Ephemeroptera, Plecoptera, and Tricoptera taxa, were collected at the site, and none of the rheophilic taxa. The site is highly impacted by grazing and fishing. The floods have cleared all the vegetation

Table 4-61: Macroinvertebrate community metrics for Bisarwi site

Community Metrics	Score
Total abundance	624
No. of taxa	27
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	29
% EPT	4.65
Number rheophilic taxa	1
Abundance of rheophilic taxa	2
Relative abundance of rheophilic taxa	0.32
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	2
% STH	0.32

Table 4-62: Results of the SASS5 and TARISS on processed samples at Bisarwi site

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	Number of taxa	ASPT	TARISS Score	Number of taxa	ASPT
91	19	4.8	93	19	4.9

Laboratory analysis for the SASS5 Protocol		
Total SASS Score	No. of taxa	ASPT
119	27	4.4

along the river, a sign of high sediment loads coming from upstream. Table 4 61 and Table 4 62 below indicate the field processed and laboratory processed score results for the site.

4.6.2.7 Water Quality

The major difference in the parameter measured during the two surveys was turbidity with high values during the 2nd survey; but values having exceeded the drinking water standards in both periods of survey. This may be brought about by the presence of very fine sediments in the river channel which result in turbid waters. Increase in sediment loading in the river channel and overland flow as a result of high rains was attributed to the high turbidity observed then. Table 4 63 shows the field measurements and

Table 4-63: Results of the water quality analysis at Bisarwi

Parameter	Unit	1st survey	2nd survey
pH	(-)	7.3	7.1
Electrical conductivity (EC)	µs/cm	437	447
Temperature (T)	deg C	29	27
Dissolved oxygen (DO)	mg/L	3.1	3.3
Oxygen saturation	%	46.4	47.3
Turbidity	T.U	300	800
Nitrate (NO_3^-)	mg/L	8	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	244	ns
Ammonium (NH_4^+)	mg/L	0.16	0.11
Non purgeable organic carbon (NPOC)	mg/L	8.5	11.8
Total nitrogen (TN)	mg/L	1.7	2.02

ns: not sampled

Table 4-64: Site metrics for Bisarwi

Metric	Social	Geomorph.	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	B/C	B/C	B	B	B/C	C
ToC	Declining	Declining	Declining	Stable	Declining	Declining
EIS	Low	High	Medium	High	High	Medium
SIS	High	-	-	High	Medium	High
EMC	B/C	B	B	B/C	B	B

laboratory results for water quality samples taken at

Table 4-65: Indicators and management objectives for Bisarwi

EFA Component	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including fishing, recession agriculture, livestock keeping, vegetables and fruits collection/cultivation for the local communities residing along the Mara Wetland at Bisarwi
	Target species	The following species should be abundant enough to suffice the needs of the population residing along the Mara Wetland at Bisarwi: Fish: Mumi, Kamongo, and Perege Vegetables: Chinsaga, Chinderema, and Isibeso/Mchicha Trees: Chinseke, Nyatunglo, Omisabisabi, and Omuka Other species i.e. grasses: Matende, Itutu, and Engeri
Geomorphology	Overbank flooding	Maintain flood flows to ensure channel-floodplain sediment connectivity
Riparian Vegetation	Grass and sedges communities	Continue to maintain abundances of moderately flow sensitive plant species, including *Vossia cuspidata and Cyperus distans*
		Improve recruitment conditions and connectivity of riparian and floodplain sedges, grasses and forbs, including *Echinochloa haploclada, Cynodon dactylon* and *Cyperus cyperoides* on greater parts of the wetland
	Vossia cuspidata and *Cyperus distans*	Continued presence and occurrence of seedlings and adults of *Vossia cuspidata* and *Cyperus distans* and the two should together be present at abundance of ≥10 percent
Fish	Indicator spp. recruitment	Maintain recruitment of indicator species based on observations of including fry/fingerlings of at least three of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
	Populations of indicator species	Maintain populations of indicator species including observations of each of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
	Fish community assessment	Failure to achieve either of the two indicators above should trigger a fish community wellbeing assessment
Invertebrates	SASS5 or TARISS Index	The SASS5/TARISS is not applicable at this site because the indices have only been tested in rivers
	Coleoptera, Hemiptera, and *Odonata*	Most taxa in these orders prefer marginal vegetation and macrophytes as attachment/habitat sites. The also prefer slow and deep waters as refuges and feeding sites.
	Target species: *Baetidae spp.*	This family is moderately tolerant to poor water quality, so should be maintained as an indicator species for this. *Baetidae* prefer moderate velocities and moderate water quality that is characteristic of floodplain rivers.
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish/macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic (washing, drinking) and livestock purposes

the site.

Table 4-66: Required flow conditions for Bisarwi

Hydrological Component		Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Depth (m): 1 (0.63 avg) Velocity (m/s): 0.04 Inundation: 0 days Flow (m^3/s): 0.19	None	Month: Feb, Oct Depth (m): 2.5 Velocity (m/s): 0.13 Flow (m^3/s): 2.85	Depth (m): 2.56 (1.67 avg) Velocity (m/s): 0.14 Inundation: >30 days Flow (m^3/s): 3	Month: Feb, Oct Depth (m): 1.76 Velocity (m/s): avg 0.08, max 0.28 Flow (m^3/s): 1
	Low flows, wettest month	Depth (m): 2 (1.25 avg) Velocity (m/s): 0.1 Inundation: 0 days Flow (m^3/s): 1.5	**Freshets** Depth (m): 4.4 Inundation: average over 2 days, 3 times a year during the wet season Flow (m^3/s): 20	Depth (m): 2.7 Velocity (m/s): 0.15 Flow (m^3/s): 3.59	Depth (m): 4 (2.1 Avg) Velocity (m/s): 0.25 Inundation: >30 days Flow (m^3/s): 12	Month: April Depth (m): 0.24 Velocity (m/s): avg 0.25, max 0.82 Flow (m^3/s): 3
	High flows, freshets and/or floods	Depth (m): 5 (0.37) Velocity (m/s): 0.25 Inundation: 2 days Flow (m^3/s): 75.2	**Floods** Depth (m): 5.15 Inundation: average over 3 days, every 2nd year Flow (m^3/s): 100	**Floods** Months: Apr-May Depth (m): 4.84 Velocity (m/s): 0.3 Flow (m^3/s): 58.8 at least for 3 days once in every 2 yrs	Depth (m): 4.8 (0.17 avg) Velocity (m/s): 0.36 Inundation: >10 days Flow (m^3/s): 50	Month: Apr-May, Nov-Dec Depth (m): 4.8 Flow (m^3/s): 50
Drought Year	Low flows, driest month	Depth (m): 0.5 Velocity (m/s): Low Inundation: 0 days	None	Month: Feb, Oct Depth (m): 2.3 Velocity (m/s): 0.12 Flow (m^3/s): 2.23	Depth (m): 1.74 (1.1 avg) Velocity (m/s): 0.08 Inundation: > 30 days Flow (m^3/s): 1	Month: August Depth (m): 1.4 Velocity (m/s): avg 0.06, max 0.21 Flow (m^3/s): 0.5
	Low flows, wettest month	Depth (m): 1 Velocity (m/s): Low Inundation: 0 days	**Freshets** Depth (m): 4.4 Inundation: average over 2 days 2 times a year During the wet season Flow (m^3/s): 20	Depth (m): 2.4 Velocity (m/s): 0.12 Flow (m^3/s): 2.53	Depth (m): 3 (1.9 avg) Velocity (m/s): 0.2 Inundation: >30 days Flow (m^3/s): 6.5	Month: April Depth (m): 1.76 Velocity (m/s): avg 0.08, max 0.28 Flow (m^3/s): 1
	High flows, freshets and/or floods	Depth (m): 3 Velocity (m/s): medium Inundation: 2 days Flow (m^3/s): 4.9	**Floods** Depth (m): 5.15 Inundation: average over 2 days every 2nd year Flow (m^3/s): 100	**Freshets** Months: Apr-May Depth (m): 3.82 Flow (m^3/s): 10.1 Once in 2 years for 2 days	Depth (m): 4 (2.1 avg) Velocity (m/s): 0.25 Inundation: >14 days Flow (m^3/s): 12	Month: April-May Depth (m): 4.58 Flow (m^3/s): 12

4.6.3 Site Metrics

Table 4-67: Confidence level for flow recommendations for Bisarwi

Site Name	Rating	Rationale
Social	3.5	Because of wetlands and many water bodies confluency, the locals were a little bit vague in their discussion because of a lot of references concerning available water bodies
Hydraulics	Channel 3.5	Straight and simple/uniform channel
	Floodplain 2	The cross section was constrained to the observed extent of 500m of a 14 km wide floodplain. Uncertainty around hydraulic behavior of lateral spillage over levees. This requires 2D modelling across the entire floodplain surface. Disaggregation of velocity depth frequency distribution from 1D modelling is designed for river channels, thus its accuracy on floodplains is uncertain.
Geomorphology	3	Observations limited to a small portion of the wider floodplain Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	3.5	Riparian zone had only very few plant species. At the upper side of the banks most areas were bare due to livestock grazing pressure and in areas where there were some vegetation it was mainly forbs and grazing resilient grass species like *Cynodon*. Far into the floodplain there were relatively good vegetation cover but it appears as if connectivity was somehow constrained during the survey. Repeated survey during wet season would increase the confidence.
Fish	3	Moderate – data has been collected from the study area and in combination with data from region moderate confident assessment is available. We still have a poor understanding of the biology and ecology of species and social relationships.
Macroinvertebrates	2	The confidence level on the hydraulics was low. Given lack of clear understanding of the seasonal variability in habitat and flow conditions at the site, the confidence if the flow levels I have proposed is low.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.6.4 Indicators and Management Objectives
4.6.5 Required Conditions
4.6.6 Confidence Ratings

4.7 Mara Wetland

The Mara Wetland EFA site is located in the most downstream end of the wetland and is the most downstream EFA study site. It is about 15 km upstream from the outlet of the Mara River into Lake Victoria. The inside of the wetland is dominated by floating papyrus, while the land on the edges of the wetland are predominantly raid-fed and flood recession agriculture.

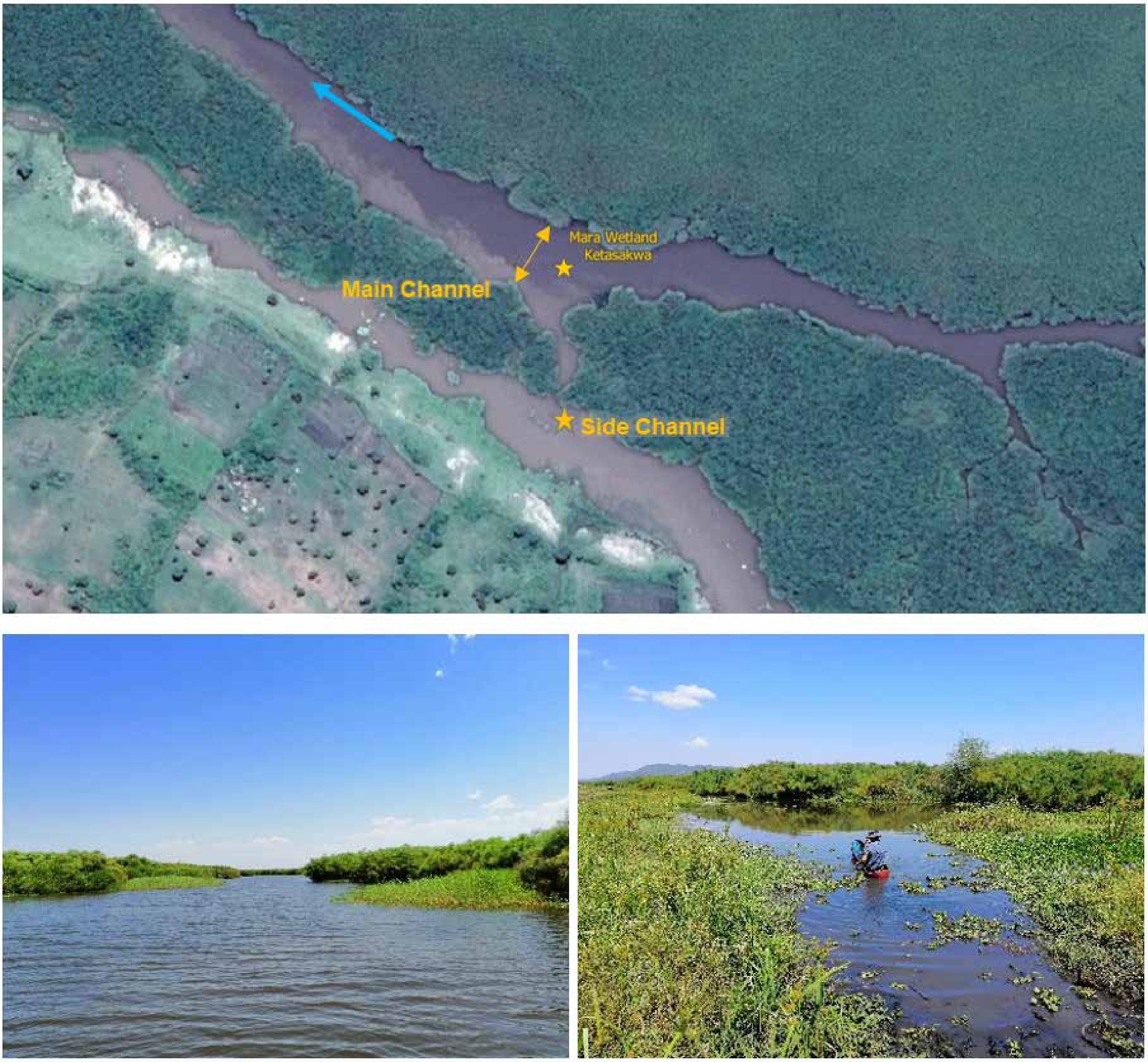


FIGURE 4 63: SITE PHOTOS OF MARA WETLAND

4.7.1 Social Survey – Ryamisanga, Wegero

The Mara River, which flows throughout the area, inundates the greater extent of the wetlands in South Mara RU. The wetlands experience the greatest inundation twice a year in April and December. The maximum inundation reaches a distance of about 18 kilometers in Wegero Village which is the largest inundation coverage among all the studied RUs.

The wetlands are richest in terms of fish species (9 species) when compared to other sites. Fishing is done throughout a year and forms part of key livelihood activities in the area. Other resources present include natural vegetables (10 species), natural fruit trees (12 species), trees for building poles (15 species), weaving materials and thatching grass.

Of all the resources available for livelihood, water was reported to be the most relative important and accounts for an average of 80 percent. Livestock pastures were the second important (7.5 percent)

Table 4-68: Wetland resources and their relative importance to the livelihood of communities in South Mara RU

No.	Wetland Resources	Relative Importance (%) per sample villages		Average
		Wegero	Ryamisanga	
1	Water	71.6	89	80.3
2	Livestock Pastures	14.3	0.6	7.5
3	Fish	4.8	8.9	6.9
4	Cultivation Land	4.8	1.1	3.0
5	Building Poles	1.2	0.1	0.7
6	Roofing grasses	1.2	0	0.6
7	Firewood/Charcoal	1.2	0	0.6
8	Weaving grasses	0.4	0.3	0.4
9	Natural vegetables	0.4	0	0.2
10	Natural fruits	0.1	0	0.1
11	Wildlife (animals and birds)	0		0

followed by fish (6.9 percent) and wetland areas for farming (3 percent). Other resources accounted for less than one percent of relative importance (Table

Table 4-69: Economic activities in South Mara RU

Activity	Performer	Location/Why	Time/Why
Agriculture	All	Mountains Valley	Rain season
Livestock keeping	All		
Fishing	Male	River Mara	
Small business	All	Premises/Home	

4 68).
The main economic activities include agriculture,

Table 4-70: Trend of resources and condition of the wetland in South Mara RU

Resource	Nyerere's Regime (1960 - 1985)	Current Situation	Future Expectations (2030)	Reasons
Fish	1000	100	44	High consumption rate
Wild vegetables	1000	100	50	Increase in users/consumers Effect of climate change Expansion of agricultural activities
Wild fruits	600	100	35	Cutting down of trees for poles, fire wood and building materials. Effect of climate change Expansion of crop cultivation
Weaving materials	30	100	225	The plant have high and easily seed dispersal High reproduction rate lead to covering of the big part of the wetland.
Building poles	550	100	29.5	Cutting of trees for cultivation Floods often erode the top soil and the plant Increase in population and therefore uses too
Thatching materials	580	100	77.5	Increased in crop cultivation and livestock keeping Floods erode the soil and hence vegetation Population has increased hence high exploitation.
Degradation of wetland/river ecosystem	12.5	100	175	Population has increased, hence high exploitation
Dependency of community to rivers and other wetland resources for their livelihood	12.5	100	190	Increase in population Alternative sources are expensive (unaffordable)
Size (width) of the river	20	100	180	Increasing in flooding rate that facilitate high soil erosion and therefore width Hippos also contribute to alter the river bank hence increasing its width
Quality of wetland/river	580	100	27	Chemicals depositions in the wetlands from Nyamongo mines. Change in the direction of the river. Extensive weeds Uncontrolled crop cultivation and livestock keeping.

livestock keeping, fishing and small-scale businesses (Table 4 69).
The trend of resource utilization and wetland conditions is given in Table 4 70 below.

4.7.2 Biophysical – Mara Wetland at Ketasakwa

4.7.2.1 Hydrology

The EFA site Mara Wetland has a contributing upstream catchment area of 13,272 km2 with a dominated land use of grass- and shrub land (Figure 4 64). Precipitation in the catchment sums up to 985 mm/yr,

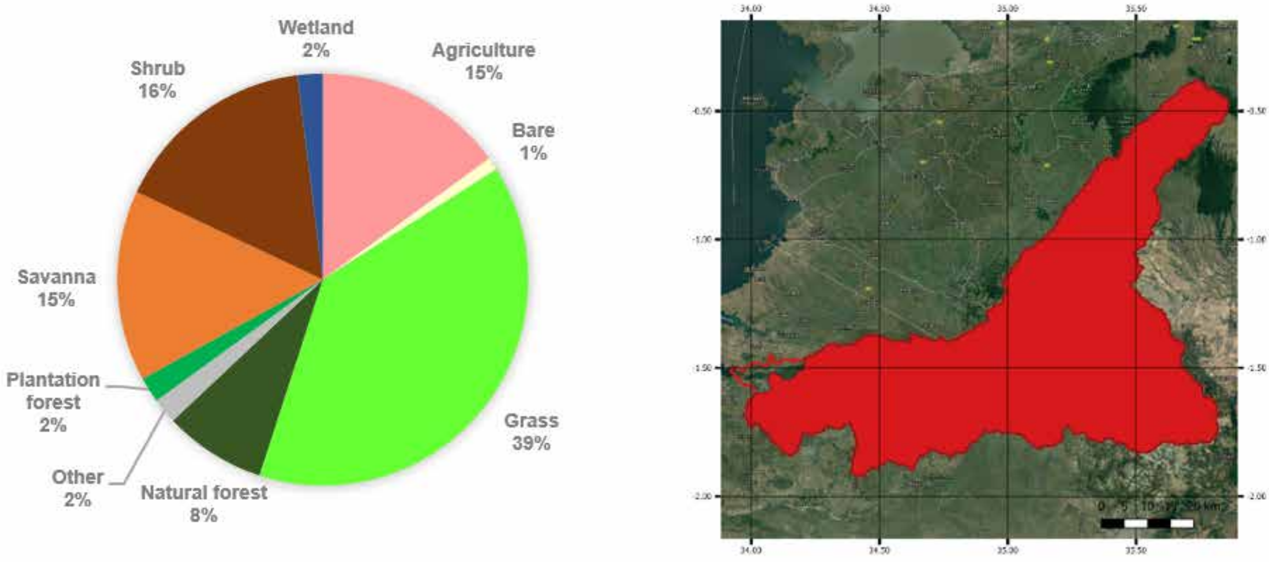


Figure 4-64: Land use within the Mara Wetland sub-catchment (left) and catchment area (right)

resulting in an evaporation value of 912 mm/yr, and a runoff value of 73 mm/yr.

Average monthly, minimum and maximum discharge values for Bisarwi EFA site are presented in Figure 4 65. At this location in the wetland, the flow from rainfall runoff can vary widely, with May being the wettest month and August being the driest month. However, there are large influences from Lake Victoria and potentially inputs from groundwater, which ensures that there is water available year-round. The influence from these other sources have

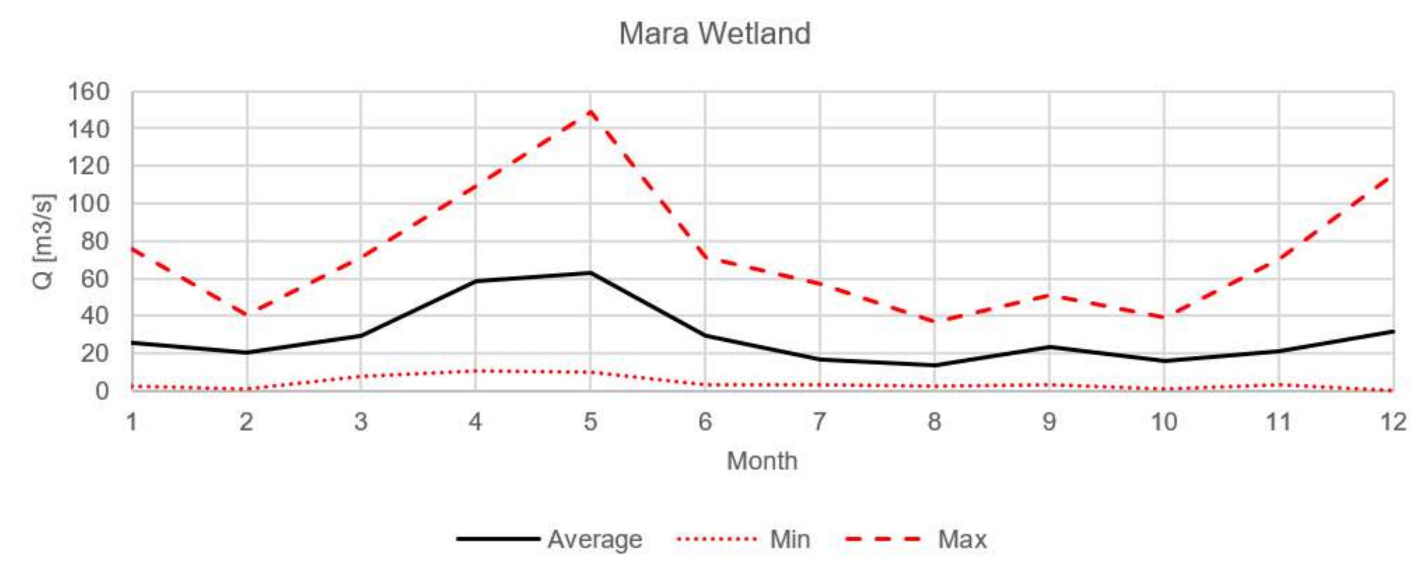


FIGURE 4 65: AVERAGE MONTHLY, MINIMUM AND MAXIMUM DISCHARGE VALUES FOR THE MARA WETLAND EFA SITE not been quantified so it is unsure how much of the Mara River influences the hydrological conditions at the site.

4.7.2.2 Hydraulics

The Mara wetland is dominated by floating papyrus over very slow flowing to stagnant water with a depth of 1 to 1.5 meters during the dry season. The open channel has deep slow flow. The edges of the wetland has shallow to deep stagnant water that could become faster flowing during higher flows as there is low roughness provided by the sparse vegetation. Observed and modelled flow levels are indicated in Figure 4 66. Observed flow velocity and depth had a weak relationship in the wetland channel ($R2 < 0.24$). This is due to the relatively slow flow velocities across

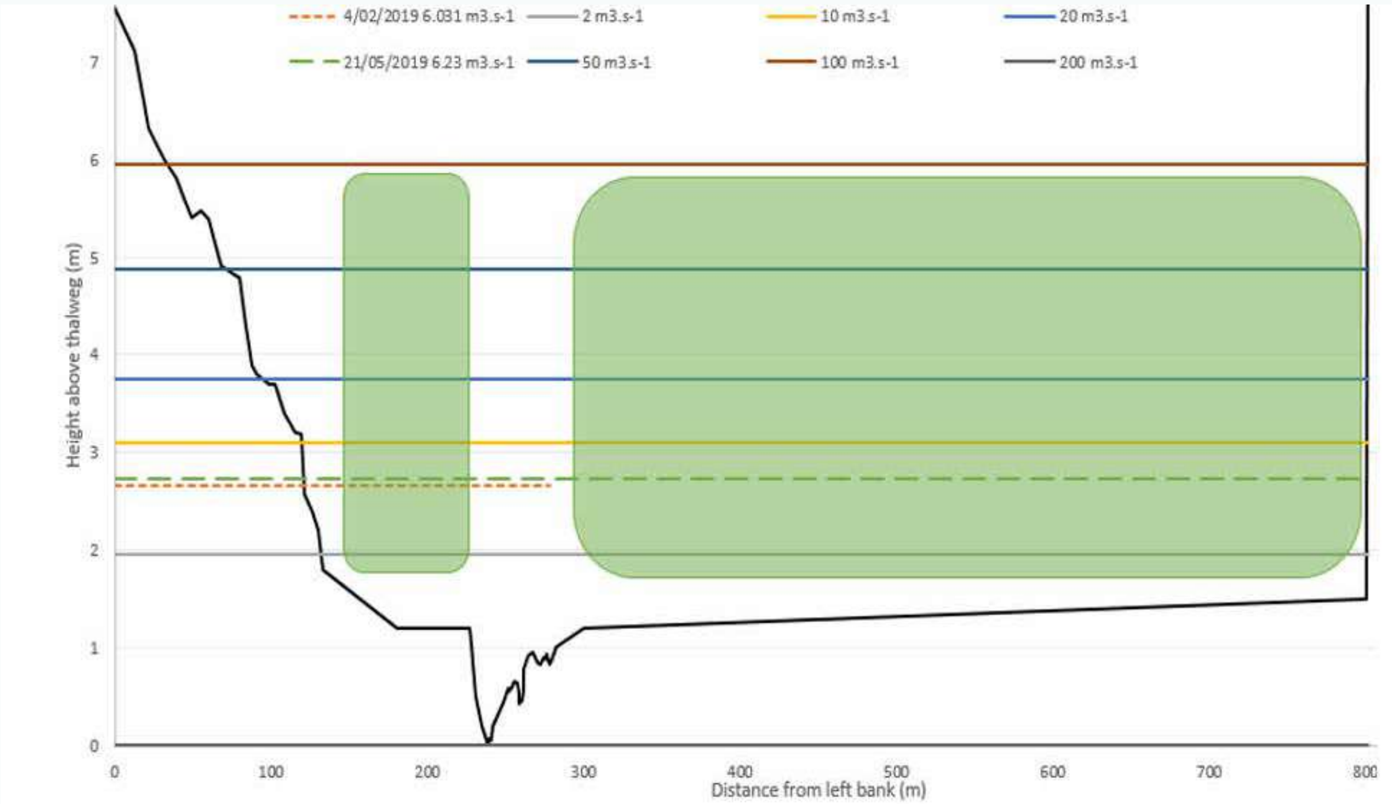


FIGURE 4 66: CROSS SECTION FOR THE SOUTHERN EXTENT OF THE MARA WETLAND. DOTTED LINES INDICATE OBSERVED FLOW LEVELS AND SOLID LINES MODELLED FLOW LEVELS. THE GREEN RECTANGLES INDICATE THE EXTENT OF THE DENSE PAPYRUS PLANTS.

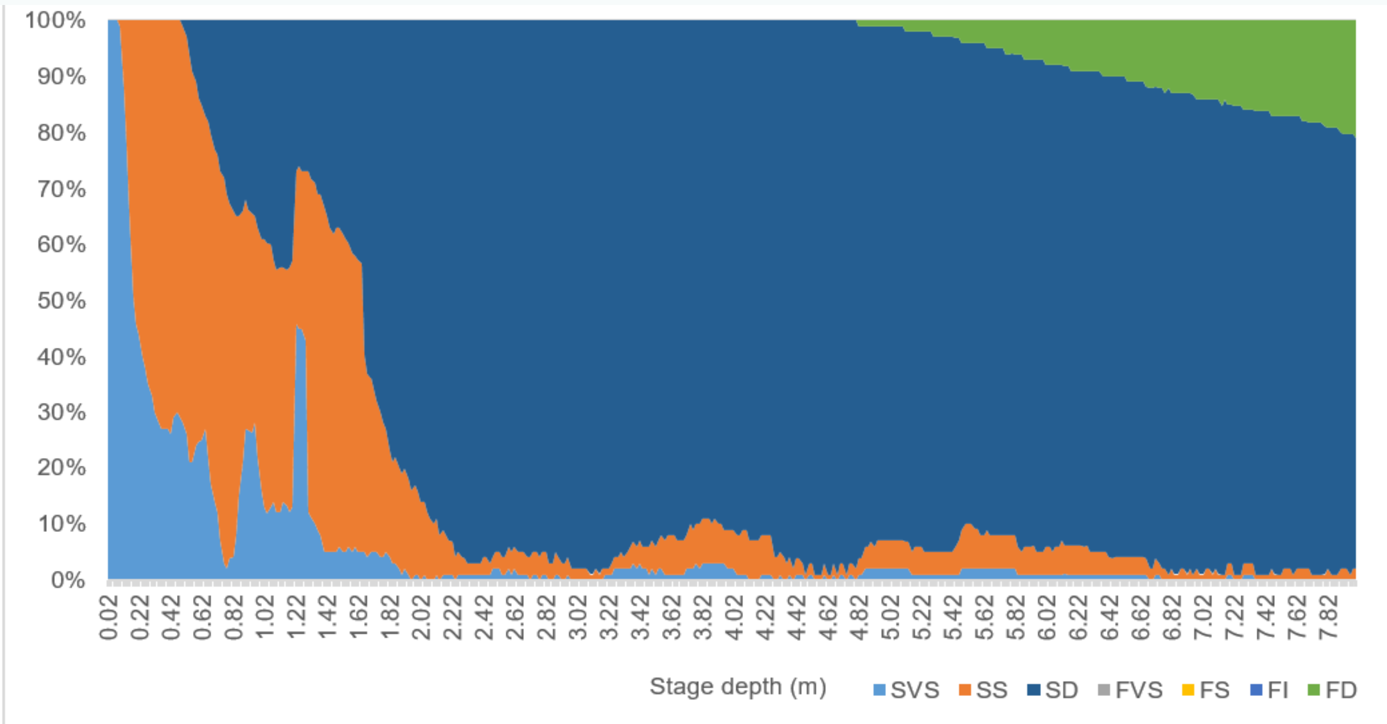


FIGURE 4 67: FREQUENCY DISTRIBUTION FOR VELOCITY-DEPTH CLASSES FOR THE MARA WETLAND a range of depths. Figure 4 67 the modelled frequency distribution of the flow velocity-depth classes for the wetted channel at a range of inundation levels.

4.7.2.3 Geomorphology

The Mara River forms a wide wetland (2 – 12 km wide) with an active channel along the southern margin. The channel is less pronounced in areas where papyrus forms a thick mat across the channel. The study site is located along a narrower part of the wetland before entering Lake Victoria. The channel at the site is ~ 60 m wide and the bed and flooded plain under the papyrus consists of silt (Figure 4 68 and Figure 4 69). The silt is compacted in the channel, compared to less compacted material along the edges of the vegetation/papyrus. Shallow to deep backwaters exist closer to the left bank, with bedrock cropping out in-between the silty bottom.

The hillslope forms a flood-prone area with grassy vegetation that extends 2 m vertically above low flow water levels (Figure 4 69). Large areas of papyrus is burnt, but the burning seems to affect the above water stems only, leaving the rhizomes largely unaffected. The flow velocity in the main channel is < 0.05m/s and measuring flow under the floating vegetation was not possible due to the thickness and density of the vegetative matter. Small areas of coarse sand are available where tributaries form alluvial fans along the margin of the wetland.

The water slope at the site is 0.0000255. If we extend this slope to the edge of the lake (roughly 16 km away) we can estimate an elevation difference of 40 cm. If we extend this slope across the entire papyrus section

FIGURE 4 68: PLAN VIEW OF THE MARA WETLAND TRANSECT AND FLOW DIRECTION (GOOGLE EARTH IMAGE DATED 28 DECEMBER 2018).

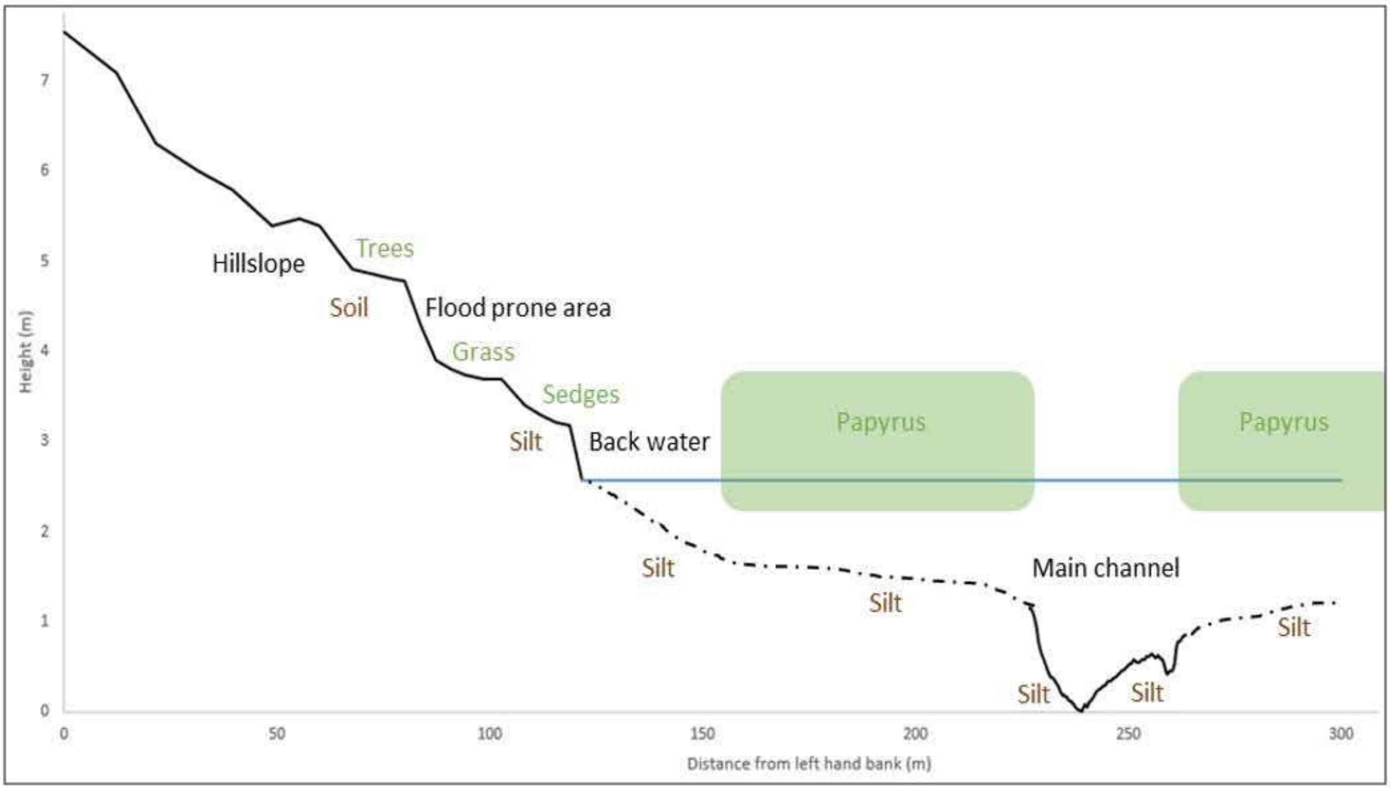


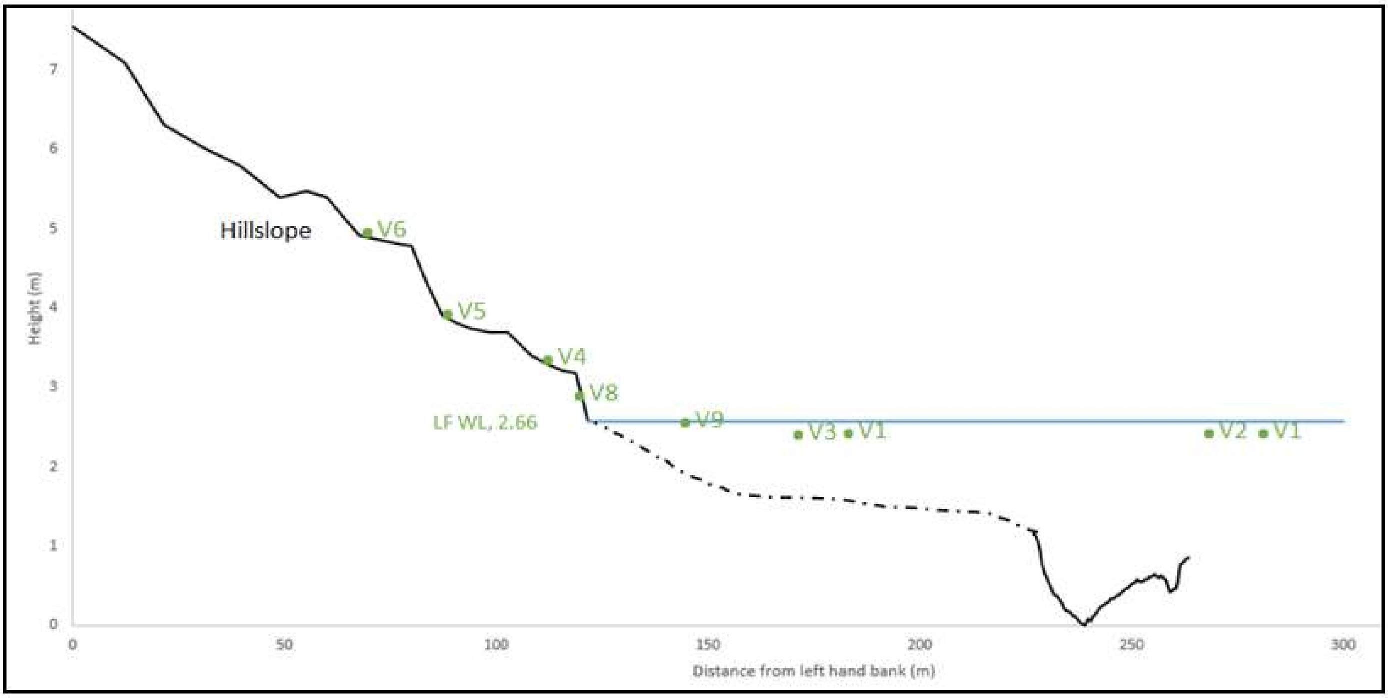
FIGURE 4 69: CROSS SECTION OF THE LEFT BANK SIDE OF THE MARA WETLAND INDICATING THE MAIN GEOMORPHOLOGICAL FEATURES, SEDIMENT COMPOSITION AND VEGETATION TYPES. NOTE THE WETLAND EXTENDS FOR ANOTHER 2 KM TO THE RIGHT BANK. THE DASHED LINE INDICATE THE LIKELY BATHOMETRY OF THE CROSS SECTION THAT WAS NOT SURVEYED.

of the wetland (35 km length), we can estimate an elevation difference of 86 cm. This would suggest that the Lake level has a significant influence at this site.

4.7.2.4 Riparian Vegetation

The site is expected to be free of alien and invasive plant species and be dominated with typical wetland plant species including hydrophilic grass, sedges and macrophytes at reference condition. Often times plant distribution and composition follows mosaic pattern but with majority (dominant) being wetland plants particularly papyrus stands.

Woody plant species might be present at off-shore of the wetlands but not dominant. Annual herbs and forbs are present. Many times species richness at core wetland is not as high as in the floodplain and the composition between the two differs. During the field survey it was observed that the site experience minimal human activities. Water hyacinth was present in large numbers and the genus cyperus (Cyperus glaucophyllus, Cyperus laxus and Cyperus papyrus) dominated the area by 95 percent. Of the three, Cyperus papyrus was the most dominant (70 percent). Sesbania sesban a perennial legume tree was also present together with Nymphaea nouchali (fern) and Polygonum senegalense (herb). Floodplain formed part of the system on the south east side and it was dominated by intensively grazed short grass Cynodon nlemfuensis which covered almost 60 percent of the floodplain. Beyond the floodplain there is a clear line of trees which indicate that flooding is



Indicator Species	Number	Range	Remarks
Cyperus papyrus	V1	marginal	dominant by over 80%, giant papyrus
Sesbania sesban	V2	marginal	
Vossia cuspidata	V3	marginal	
Cyperus laxus, C. glaucophyllux	V4	lower	
Cynodon nlemfuensis	V5	floodplain	dominated the floodplain
Faidherbia albida	V6	floodplain	large tree, 2 individuals
Nymphaea nouchali	V7	back waters	
Urochloa trichopus	V8	upper	
Eichhornia crassipes	V9	Back waters	high density at this site

Figure 4-70: Cross section of the Mara wetland at Ketasakwa showing indicator plant species

active and restrict encroachment of woody species particularly trees. Figure 4 70 shows the distribution of plant species along the cross section of the river.

4.7.2.5 Fish

The Mara Wetlands are located in the lower portion of the Mara River Basin. The reach of the system considered for the study is associated with an active channel along the southern margin of the system, flowing in a westerly direction. For the purposes of the study, GHUs have been delineated for areas of the system which could be accessed and sampled. As a result of this, areas of the system characterized by dense stands of Papyrus (predominantly) could not be access and sampled. One GHU was identified and delineated for the study, but with varying velocity-depth classes (Figure 4 71). A SD pool was delineated for the main channel, with SS pools delineated on the periphery of the wetland system. Sampling included a combination of electrofishing, cast net and seine net efforts. The substrate for these units is dominated by silt. Aquatic and overhanging vegetation was in

Figure 4-71: Aerial view of the Mara River showing the delineated GHUs for the site (Google Earth)

Table 4-71: A summary of the HCR for the reach with associated velocity depth class ratings and corresponding details.

Class	Rating	Overhanging vegetation	Undercut banks and root wads	Stream substrate	Submerged logs	Aquatic macrophytes
SS	5 – 25%	Papyrus	Roots	Silt	Tree debris	Papyrus
SD	> 75%	Papyrus	Roots and undercut banks	Silt	Tree debris	Papyrus
FD	-	-	-	-	-	-
FS	-	-	-	-	-	-

abundance for the habitat units. An overview of the HCR ratings is presented in Table 4 71 and Figure 4 72 below.

A total of 18 fish species were sampled from the site, with a total of 244 individuals recorded for the site. Two indicator species were recorded for the site, namely Protopterus aethiopicus and Clarias gariepinus. The fish diversity and abundances are generally considered to be good.

Substrate for the reach was dominated silt, mud and sand. Habitat cover also considered to be generally limited, with aquatic and marginal vegetation the

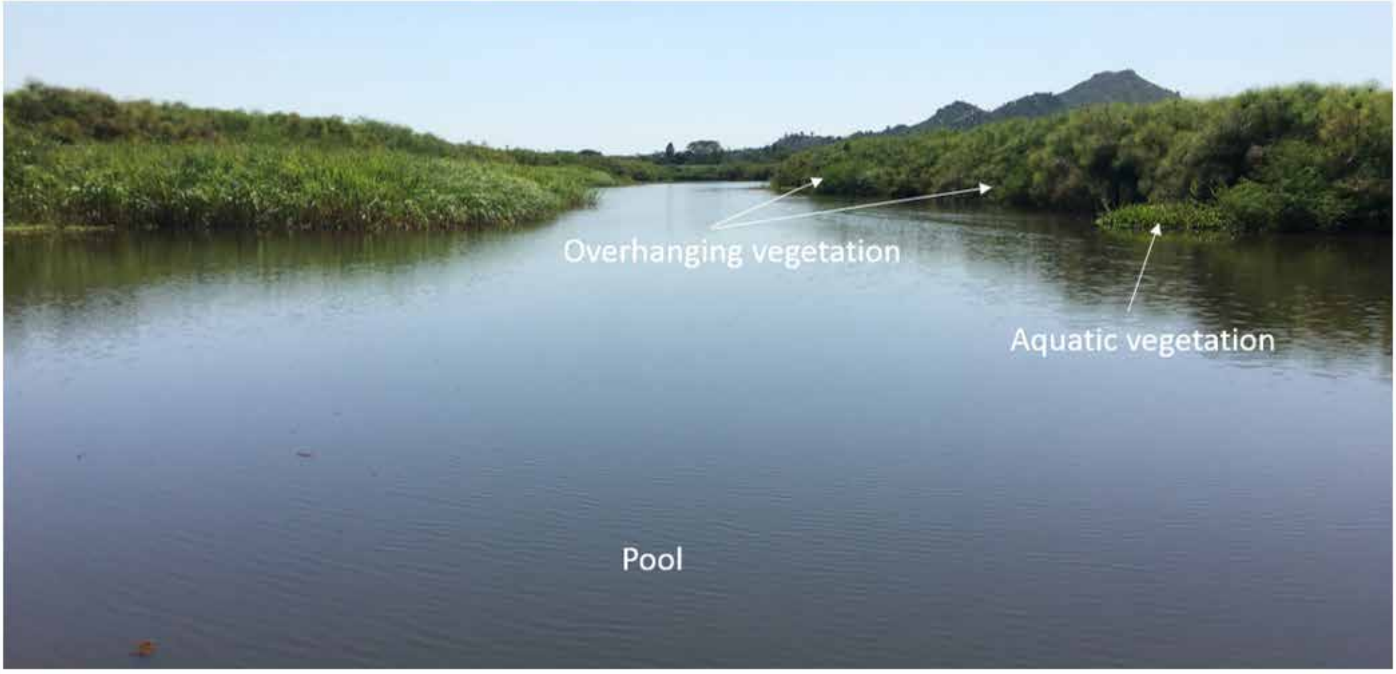


Figure 4-72: A photograph depicting habitat characteristics for the Mara River wetland reach

dominant types. The reach of the Mara River was characterized by a SD, and with the side water areas characterized by SS velocity-depth class.

4.7.2.6 Macroinvertebrates

This is a wetland site that is flooded during the rainy season, with large areas of rooted macrophytes which are inundated. The main channel has flowing water which provides riverine habitats for some sensitive taxa such as Baetidae, but no rheophilic taxa occur at the site because of the slow water flow (low velocity

Table 4-72: Macroinvertebrate community metrics for the Mara Wetland

Community Metrics	Score
Total abundance	428
No. of taxa	32
Abundance of *Ephemeroptera*, *Plecoptera*, and *Tricoptera* (EPT)	52
% EPT	12.15
Number rheophilic taxa	1
Abundance of rheophilic taxa	2
Relative abundance of rheophilic taxa	0.50
Abundance of *Simuliidae*, *Tricorythidae* and *Hydropsychidae* (STH)	0
% STH	0

Table 4-73: Results of the SASS5 and TARISS on processed samples for the Mara Wetland

Field analysis of the SASS5 and TARISS protocol					
SASS5 Score	Number of taxa	ASPT	TARISS Score	Number of taxa	ASPT
110	23	4.8	112	23	4.9
Laboratory analysis for the SASS5 Protocol					
Total SASS Score		No. of taxa		ASPT	
169		32		5.3	

< 0.3m/s). Table 4 72 and Table 4 73 below indicate the field processed and laboratory processed score results for the site.

4.7.2.7 Water Quality

Very low oxygen levels measured at the site during both sampling events. This could be as a result of the slow flowing (almost still) water and presence of organic matter from decaying papyrus which consumes most of the oxygen. Acceptable levels of turbidity in the water during the 1st and 2nd survey. In as much as the turbidity was low, the water had a light-brownish/tea color, possibly from high organic load in the water resulting from the charred

Table 4-74: Results of the water quality analysis at the Mara Wetland

Parameter	Unit	1st survey	2nd survey
pH	(-)	6.6	7.0
Electrical conductivity (EC)	µs/cm	261	252
Temperature (T)	deg C	23.5	24
Dissolved oxygen (DO)	mg/L	0.3	0.27
Oxygen saturation	%	3.2	1.5
Turbidity	T.U	10	25
Nitrate (NO_3^-)	mg/L	0	ns
Nitrite (NO_2^-)	mg/L	0	ns
Alkalinity (HCO_3^-)	mg/L	131.8	ns
Ammonium (NH_4^+)	mg/L	0.27	0.11
Non purgeable organic carbon (NPOC)	mg/L	14.4	23.3
Total nitrogen (TN)	mg/L	0.7	1

ns: not sampled

remains of burnt papyrus. Table 4 74 shows the

Table 4-75: Site metrics for the Mara Wetland

Metric	Social	Geomorph.	Riparian Vegetation	Fish	Macro-invertebrates	Water Quality
PES	B/C	B	A	B	B	B
ToC	Declining	Stable	Stable	Stable	Stable	Stable
EIS	Low	High	High	High	High	High
SIS	High	-	-	High	Medium	High
EMC	B	B	A	A/B	B	B

field measurements and laboratory results for water

Table 4-76: Indicators and management objectives for the Mara Wetland

EFA Component	Indicator	Management Objective(s)
Social	Livelihood	Maintain a river condition that will enhance the livelihoods including fishing, recession agriculture, livestock keeping, vegetables and fruits collection/cultivation for the local communities residing along the Mara wetland at Kitasakwa
	Target species	The following species should be abundant enough to suffice the needs of the population residing along the Mara Wetland at Kitasakwa: Fish: Mumi, Kamongo, and Sato Vegetables: Isebeso, Chinsaga, and Inkuruwa Trees: Chinseke, Chinsondobiro, Ekerera, and Egetobekere Other species (i.e., grasses): Matende, Amahohi, Engeri, and Ekigara
Geomorphology	High roughness vegetation	Maintain suitable water depth and substrate to support dense Papyrus vegetation (for ideal sedimentation environment)
Riparian Vegetation	Sedge, grass, forb and fern communities	Continue to maintain abundances of flow sensitive sedge and fern species (e.g., *Cyperus papyrus* and *Azolla filiculoides*) at moderately modified natural conditions
		Continue to maintain abundances of moderately flow sensitive grass and forb species, including *Vossia cuspidata, Urochloa trichopus* and *Commelina benghalensis*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
	Cyperus papyrus and *Vossia cuspidata*	Continued presence and occurrence of seedlings and adults of *Cyperus papyrus* and *Vossia cuspidata* and the two should together be present at abundance of ≥30 percent of the riparian plant community
	Nymphaea nouchali and *Azolla filiculoides*	Continued presence and occurrence of seedlings and adults of *Nymphaea nouchali* and *Azolla filiculoides* and the two should together be present at abundance of ≥1 percent of the riparian plant community
Fish	Indicator spp. recruitment	Maintain recruitment of indicator species based on observations of including fry/fingerlings of at least three of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*

Table 4-76: Indicators and management objectives for the Mara Wetland

EFA Component	Indicator	Management Objective(s)
	Populations of indicator species	Maintain populations of indicator species including observations of each of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
	Fish community assessment	Failure to achieve either of the two indicators above should trigger a fish community wellbeing assessment
Macro-invertebrates	SASS5 or TARISS Index	The SASS5/TARISS is not applicable at this site because the indices have only been tested in rivers
	Coleoptera, *Hemiptera*, and *Odonata*	Most taxa in these orders prefer marginal vegetation and macrophytes as attachment/habitat sites. The also prefer slow and deep waters as refuges and feeding sites.
	Target species: *Baetidae, Caenidae,* and *Leptophlebiidae* spp.	These families are moderately tolerant to poor water quality, so should be maintained as indicators. They also prefer low to medium velocities, so maintaining them will require having constantly flowing water in the main channel to maintain flow velocities, dissolved oxygen and temperature.
Water Quality	pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish/macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic (washing, drinking) and livestock purposes

quality samples taken at the site.

Table 4-77: Required flow conditions for the Mara Wetland

Hydrological Component		Social	Geomorphology	Riparian Vegetation	Fish	Macro-invertebrates
Maintenance Year	Low flows, driest month	Depth (m): 1 (0.63 avg) Velocity (m/s): 0.04 Inundation: 0 days Flow (m^3/s) : 0.18	None	Month: Feb, Oct Depth (m): 2.7 Velocity (m/s): 0.02 Flow (m^3/s): 6.3	Depth (m): 1.8 (0.72 avg) Velocity (m/s): 0 Inundation: >30 days Flow (m^3/s): 1.5	Month: Feb, Oct Depth (m): 2.54 Velocity (m/s): avg 0.02, max 0.08 Flow (m^3/s): 5
	Low flows, wettest month	Depth (m): 2 (1.25 avg) Velocity (m/s): 0.1 Inundation: 0 days Flow (m^3/s): 1.5	None	Depth (m): 3.3 Velocity (m/s): 0.03 Flow (m^3/s): 12.7	Depth (m): 2.5 (1.4 avg) Velocity (m/s): 0 Inundation: >30 days Flow (m^3/s): 4.8	Month: April Depth (m): 3.1 Velocity (m/s): avg 0.03, max 0.11 Flow (m^3/s): 10
	High flows, freshets and/or floods	Depth (m): 5 (0.37) Velocity (m/s): 0.25 Inundation: 2 days	**Floods** Depth (m): 5 Velocity (m/s): Inundation: 10 day average Flow (m^3/s): 54	**Floods** Months: Apr-May Depth (m): 4.8 Velocity (m/s): 0.06 Flow (m^3/s): 47.3 once every 2 years for at least 2 weeks	Depth (m): 4 (2.5 avg) Velocity (m/s): 0.05 Inundation: >30 days Flow (m^3/s): 26	Month: Apr-May, Nov-Dec Depth (m): 4.9 Velocity (m/s): avg 0.07, max 0.25 Flow (m^3/s): 50
Drought Year	Low flows, driest month	Depth (m): 0.5 Velocity (m/s): Low Inundation: 0 days	None	Month: Oct Depth (m): 2.4 Velocity (m/s): 0.02 Flow (m^3/s): 4.2	Depth (m): 1.6 (0.59 avg) Inundation: >10 days Flow (m^3/s): 1	Month: August Depth (m): 1.96 Velocity (m/s): avg 0.01, max 0.05 Flow (m^3/s): 2

4.7.3 Site Metrics

Table 4-78: Confidence level for flow recommendations for Mara Wetland

Site Name	Rating	Rationale
Social	3	The water depth and floods were not well determined because the interviewees use their experiences, and when the water levels were very high the errors become large
Hydraulics	2	The cross section was constrained to the observed extent of 800m of a 2.5 km wide floodplain. We assume that the papyrus has a high roughness which constrain flow, but the flow velocities under the papyrus during high flow is unknown. The extent to which the papyrus remains anchored and is inundated during high flows is unknown. The influence of the lake on the energy slope is very uncertain for high flows. Disaggregation of velocity depth frequency distribution from 1D modelling is designed for river channels, thus its accuracy on floodplains is uncertain.
Geomorphology	3	Observations based on a short section of the wider wetland Observations during relatively low flows only Lack of historical images to describe the variability of the geomorphic template of the channel
Riparian Vegetation	2.5	The hydraulics of this site on broad scale was not so clear, did not know with certainty what was happening on the right side of the bank. So this lowered the confidence level. The relationship of this site with inflows, outflows and Lake Victoria was not so obvious. Little knowledge of how this site interacts with the lake lowered the confidence.
Fish	2	Very low confidence in uncertainty that modelled flows and depths are not accurate. Knowledge of the fishes and their habitat preferences (depth and cover preferences) is moderate but the use of this information in the wetland is limited.
Macroinvertebrates	2	The confidence level on the hydraulics very low since the entire cross-section of the wetland was not modeled. Given lack of clear understanding of the seasonal variability in habitat and flow conditions at the site, the confidence if the flow levels I have proposed is very low.
Water Quality	-	Water quality was not linked to discharge levels during this assessment, and there was no historical data with which to compare the study results.

4.7.4 Indicators and Management Objectives
4.7.5 Required Conditions
4.7.6 Confidence Ratings
4.8 Data Gaps
Some of the knowledge gaps identified by the experts are outlined below:

- Where and at what discharge does flood water spill onto the floodplain and how does this affect velocity-depth habitat types across the surface?

- How does the floating papyrus influence the hydrodynamics of the wetland?

- What is the bed topography across the floodplain and permanent wetland? Are there preferential pathways across the floodplain and wetland? How dynamic are these preferential flow pathways and what is maintaining/threatening them?

- How variable is the geomorphic template under natural and present day conditions?

- To what extent is the river incision and avulsion linked to tectonic activity, catchment land use and climate change?

- To what extent do hippos maintain pool and riffle habitats?

- How does river avulsion influence the physical habitat across the floodplain?

- How will the extent and the character of the floodplain and permanent wetland change if the Lake Victoria water level drops by 2-5 meters?

- How will the extent and the character of the floodplain and permanent wetland change if a large dam is constructed on the lower Mara River?

- More information on the biology, ecology and fisheries of the study area is required. Emphasis should be placed on drivers of fisheries and dependence and determination of conservation plan for species.

- Historical diversity of the streams feeding into the lower Mara River need to be investigated. This should include taxonomic lists of major groups of taxa, especially the most threatened (crabs) and flow and habitat sensitive taxa (Oligoneuriidae, Odonata, and other Ephemeroptera, Plecoptera, and Tricoptera taxa).

- There is a need to investigate historical water levels (hydrology) and permanence of the streams feeding into the lower Mara River. All the three tributaries (Tobora, Somoche and Tigithe) are currently seasonal, but it is possible that before the extensive land use and land cover changes and intensification of human activities, including mining, in the catchments, these streams were permanent. This will have implications on the recommendations being made for the conservation of the streams.

- There is lack of historical data making it impossible to check the trend of water quality in comparison to the present state. The available information is quite limited and inconsistent in terms of dates of monitoring from one station to the other hence not possible to make a longitudinal comparison.

- How does flow levels/discharge vary with water quality?

- To what extent/rate does the riparian vegetation cover change in different parts (or RUs) of the Mara basin?

- How does denial/decrease/changing of flooding influence the wetland/floodplain plant biodiversity?

In other words flooding dynamics and plant biodiversity relationships need further research.

Presented below are the results of the Lower Mara EFA, which include the final RQOs and the calculations for the reserve, which include basic human needs and environmental flows. The RQO statements are intended to be a guide as to how resources should be managed now and into the future, which are then accompanied by targets on how to meet those management conditions and numerical indicators that should be met. The RQO statements were reviewed by the EFA technical team and their site metrics, indicator species (or indicator functions), and management objectives for each site were incorporated into the process. The basic human needs and environmental flow values are calculated in m3/second and m3/day to align with both hydrological calculations and the on-going WAP process.

The environmental flow values are also accompanied by descriptions of indicator functions for both low flows dry season, low flow wet season, and high flows, freshets, and floods, as well as potential consequences if those flows are not met.

Results of this assessment apply to conditions in the basin today. As the basin continues to grow in population, conditions on the ground change, and more information becomes available, these values should be updated. Ideally, this should occur every five to ten years to align with the schedule of updating the WAP. To help inform the updating of these numbers, monitoring activities and an adaptive management cycle are recommended for inclusion as part of implementing the reserve.

5.1 Final Resource Quality Objectives

5.1.1 Kogatende

The Kogatende EFA site lies within the Serengeti RU, and the majority of this land is inside SENAPA. The largest stakeholder in this RU is SENAPA and local tour operators. As such, the largest concerns at this site involve the wildlife and associated ecotourism in the area. In general, the pressure on the ecosystem from human activities were considered low by stakeholders, with the biggest concern coming from infrastructure construction or improvements inside the park. There are impacts from the annual migration but the impacts are considered natural. Maintaining a high level of resource quality is important as it supports various macrofauna (hippopotamuses, crocodiles, elephants, ungulates, etc.) which is the main driver of tourism and the local economy. The current resource quality conditions were determined to be high for all categories (the exception being poor conditions for fish), indicating that the ecosystem was in an almost natural condition. Stakeholders and the EFA technical team indicated there was a slight degradation in conditions, particularly for low flows and water quality. They would like to see the area slightly improved to return to natural conditions. All of these considerations resulted in a management class of A, or a near natural conditions where the natural flow regime is to be maintained. This is reflected in the RQO statements for the Serengeti RU (Table 5 1). The indicators and management objectives

Table 5-1: Final RQO statements for Kogatende

Resource Quality Element	RQO Statement
Kogatende – Serengeti RU – Management Class: A	
Low Flows	Low flows should maintain pools and riffle habitats for flow sensitive macroinvertebrates and fish and for crocodiles and hippopotamuses to survive and remain in their normal situation
High Flows	High flows should support the growth and reproduction of aquatic animals (invertebrates and fish) and riparian vegetation for dependent animals (wildebeest, zebra) and birds (ducks, weavers)
Water Quality	Water quality parameters should be in a natural condition so that they will support aquatic species, vegetation, and wildlife
Instream Habitat	Should support refuge habitat for aquatic animals (fish, crocodile, hippopotamuses, etc.) and maintain biodiversity
Riparian Habitat	Should be able to maintain carrying capacity of biodiversity (wild animals)
Biota	Water quality and flow levels in the river should allow for a natural abundance of fish and macroinvertebrates, while crocodiles, hippopotamuses, and weavers should be maintained in number that support tourism

Table 5-2: RQO targets and indicators for Kogatende

Resource Quality Element	Target	Indicator
Low Flows	Comply with environmental flows	See monthly environmental flow values for Kogatende
High Flows		
Water Quality	Natural conditions of system parameters: pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates and riparian vegetation
		Ensure the water quality is within acceptable limits for use by wildlife
Instream Habitat	Adequate pool depth for refuge habitat	Maintain deep (>1 m) pools
	Available gravel and cobble habitat	Scour sand and hippo dung from gravel habitat
Riparian Habitat	Healthy grass and sedge communities	Continue to maintain abundances of flow sensitive grass and sedge species (e.g., *Echinochloa haploclada,* and *Cyperus distans*) at slightly modified conditions
		Continue to maintain abundances of moderately flow sensitive plant species, including *Commelina benghalensis* and *Sphaeranthus steetzii*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
		Continued presence and occurrence of seedlings and adults of *E. haploclada*, *C. distans,* and *C. benghalensis* and the three should together be present at abundance of ≥15 percent as in natural conditions
Biota	Presence of indicator fish species	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
		Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site
	Fish community wellbeing	If either of the two previous indicators are not observed a fish community wellbeing assessment should be undertaken
	Presence of indicator macroinvertebrate species	SASS5 or TARISS Index score >200 and Avg. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more baetid species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
		Ephemeroptera, *Plecoptera* and *Trichoptera* orders should be present in abundances >50 percent of the invertebrate community
		The flow sensitive families *Hydropsychidae*, *Simuliidae,* and *Tricorythidae* should be present in abundances >30 percent of the invertebrate community
		Oligoneuridae sp. is among the most sensitive taxa of macroinvertebrates that should be present at the site as a sign of good water and habitat conditions (no sedimentation)

from the EFA technical team (Table 4 6) were adapted to develop the RQO targets and numerical indicators (Table 5 2).

5.1.2 Tobora

The Tobora EFA site lies at the outlet of the Tobora RU, which is managed by the Tobora WUA. The primary land use in the sub-basin is rainfed and flood recession agriculture, livestock grazing, and a small amount of fishing. The pressure on the system from human activities was considered moderate by stakeholders, with the activities with the greatest impact being livestock grazing, invasive species, sewage/solid waste, and the development around towns. These degrade the conditions of the resource quality elements through the destruction of the riparian zone, increased erosion, pollution, and destruction of habitat.

The stakeholders considered the resource quality elements of low flows and water quality to be the most important since natural waterways are the main water sources for people and livestock. Overall, the stakeholders and EFA technical team considered the RU to be in a moderate condition and thought that all resource quality elements were degrading except for high flows. They would like to improve these conditions, but overall would like to balance human activities with environmental protection in a way which supports the sustainable use of natural resources. These considerations were combined for a management class of B, which is a somewhat altered hydrological condition but with relatively small impacts to the ecosystem. The RQO statements were developed to reflect the desire for sustainable use, allowing all resource quality element to be managed in a somewhat altered condition (Table 5 3). The

Table 5-3: Final RQO statements for Tobora

Resource Quality Element	RQO Statement
Tobora – Tobora RU – Management Class: B	
Low Flows	Low flow should be sufficient to meet the needs of livestock, domestic use, and small-scale irrigation while maintaining the river ecosystem in a somewhat altered condition
High Flows	High flows should be sufficient to support the current extent of flood recession agriculture and maintain the riparian ecosystem in a somewhat altered condition
Water Quality	Nutrients and turbidity should not present health risks to human beings, livestock, or cause instream and riparian ecosystems to drop below a somewhat altered condition
Instream Habitat	Instream habitat should be sufficient to meet small-scale fishing and maintain instream biodiversity in a somewhat altered condition
Riparian Habitat	Riparian habitat should be sufficient to support biomass energy provision (charcoal), bees for pollination, and maintain riparian vegetation in a somewhat altered condition
Biota	Fish (for sustainable fisheries), birds (for pollination), bees (pollination and honey production), trees (for sustainable harvesting), and riparian grasses (for livestock forage) should be maintained at appropriate levels to meet the needs of local communities while maintaining the ecosystem in a somewhat altered condition

Table 5-4: RQO targets and indicators for Tobora

Resource Quality Element	Target	Indicator
Low Flows	Comply with environmental flows, which includes important ecosystem services for local communities	See environmental flow values for Tobora
High Flows		
Water Quality	Acceptable conditions for system parameters: pH, DO, EC, turbidity, nutrients	Maintain the WQ within acceptable standards to support growth and development of fish, macroinvertebrates and riparian vegetation
		Maintain acceptable standards for domestic and agricultural purposes
Instream Habitat	Adequate pool depth for refuge habitat	Maintain pools of at least 0.5 m deep
	Available gravel and cobble habitat	Maintain flow variability and moderate sediment supply to maintain this habitat in good condition (e.g., not embedded with fine sediment).
Riparian Habitat	Healthy sedge, forb and grass communities	Continue maintaining abundances of flow sensitive sedge species (e.g., *Cyperus involutus, Cyperus distans,* and forb *Commelina benghalensis)* at the site
		Continue to maintain abundances of moderately flow sensitive plant species (e.g., *Panicum maximum*). If depth of water for flow sensitive plant species is met then it should suffice this group too.
		Continued presence and occurrence of seedlings and adults of *C. involutus, C. distans, and P. maximum* and the three should together be present at abundance of ≥20 percent
	Healthy riparian tree communities	Continued presence and occurrence of seedlings, saplings and adults of *Ficus sur* with at least 10 percent abundance
Biota	Presence of indicator fish species	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophilic species. This includes *Labeo victorianus* and *Labeobarbus altianalis.*
		Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site
	Fish community wellbeing	If either of the two previous indicators are not observed, a fish community wellbeing assessment should be undertaken
	Presence of indicator macroinvertebrate species	SASS5 or TARISS Index score >150 and Avg. Score Per Taxon >6.
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae,* and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
		Ephemeroptera, Plecoptera, and *Trichoptera* orders should be present in abundances >50 percent of the invertebrate community during the wet season when the river is flowing
	Maintain important species for subsistence activities	The following species should be abundant enough to suffice the needs of the population residing along Tobora River: Fish: Mumi Vegetables: Chinderema, Chinsaga, and Isebeso Trees:Chinsere, Chinseke, and Ebinyabutati Other resources: Ukindu

indicators and management objectives from the EFA technical team (Table 4 17) were adapted to develop the RQO targets and numerical indicators (Table 5 4).

5.1.3 Somoche

The Somoche EFA site lies at the outlet of the Somoche RU and is managed by the Somoche WUA. The primary land use is similar to the Tobora sub-basin, where rainfed and flood recession agriculture, livestock grazing, and aquaculture are the major economic activities. According to stakeholders, the pressure on the system was considered to be moderate, with the largest concerns coming from deforestation of the riparian zone, pollutants from small-scale gold mining activities, and degradation of the ecosystem from livestock. Low flows and water quality were ranked as the most important resource quality elements due to the reliance on these water sources for domestic, agricultural, and fishing purposes. Overall, the current conditions were considered to be moderate, but there was a range of conditions when separated out by resource quality element (low flows were considered to be in poor condition, but high flows, water quality, and riparian habitat were considered to be in good condition). The stakeholders and EFA technical team considered most resource quality elements to be degrading (except for instream habitat). Overall, they wanted to see the condition of the resource quality objective improve. These considerations were combined for a management class of B, which is a somewhat altered hydrological condition but with relatively small impacts to the ecosystem. The RQO statements were developed to reflect the desire for sustainable use, allowing all resource quality element to be managed in a somewhat altered condition (Table 5 5). The

Table 5-5: Final RQO statements for Somoche

Resource Quality Element	RQO Statement
Somoche – Somoche RU – Management Class: B	
Low Flows	Low flows should be adequate to meet water demand for domestic uses, livestock needs, and irrigated agriculture and maintain the aquatic ecosystem in a somewhat altered condition
High Flows	High flows should be adequate to meet the reserve requirement for use in the low flow
Water Quality	Controlling the level of nutrients and sediments in the stream to within levels that cannot cause harm to humans and aquatic organisms
Instream Habitat	Instream habitat should be sufficient to support fishing, aquaculture, and maintain the ecosystem in a somewhat altered condition
Riparian Habitat	Riparian habitat should be sufficient to support fishing and aquaculture and maintain the ecosystem in a somewhat altered condition
Biota	Biota should be sufficient to support fishing, aquaculture, and instream biodiversity of macroinvertebrates while maintaining the ecosystem in a somewhat altered condition

Table 5-6: RQO targets and indicators for Somoche

Resource Quality Element	Target	Indicator
Low Flows	Comply with environmental flows, which includes important ecosystem services for local communities	See environmental flow values for Somoche
High Flows		
Water Quality	Acceptable conditions for system parameters: pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates, and riparian vegetation
		Maintain acceptable standards for domestic and livestock watering purposes
Instream Habitat	Adequate pool depth for refuge habitat	Maintain pools of at least 0.5 m deep
	Available gravel and cobble habitat	Maintain flow variability and moderate sediment supply to maintain this habitat in good condition (e.g. not embedded with fine sediment)
Riparian Habitat	Healthy sedge and grass communities	Continue to maintain abundances of flow sensitive sedge species (e.g., *Cyperus involutus and Cyperus distans*) at the site.
		Continue to maintain abundances of moderately flow sensitive plant species (e.g., *Paspalum scrobiculatum* and *Echinochloa pyramidalis*). If depth of water for flow sensitive plant species is met then it should suffice this group too.
		Continued presence and occurrence of seedlings and adults of *C. involutus, C. distans and P. maximum* and the three should together be present at abundance of ≥20 percent
	Healthy riparian tree communities	Continued presence and occurrence of seedlings, saplings and adults of *Ficus sur* with at least 10 percent abundance
Biota	Presence of indicator fish species	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.

Table 5-6: RQO targets and indicators for Somoche

Resource Quality Element	Target	Indicator
	Fish community wellbeing	If the previous indicator is not observed a fish community wellbeing assessment should be undertaken
	Presence of indicator macroinvertebrate species	SASS5 or TARISS Index score >150 and Av. Score Per Taxon >6.
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae*, *Leptophlebiidae*, *Elmidae*, *Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
		Ephemeroptera, Plecoptera and *Trichoptera* orders should be present in abundances >50 percent of the invertebrate community
		The flow sensitive families *Hydropsychidae*, *Simuliidae,* and *Tricorythidae* should be present in abundances >30 percent of the invertebrate community during the wet season when the river is flowing
		Oligoneuridae is among the most sensitive family of macroinvertebrates to both water quality and quantity, and hence should be present at the site as a sign of good water and habitat conditions (no sedimentation). *Potamonautes* (freshwater crabs) depend on a well maintained riparian forest for food (leaf litter) and reproduction. Their presence means maintaining the riparian zone along the river and flow permanence throughout the year since they are long-lived species.
	Maintain important species for subsistence activities	The following species should be abundant enough to suffice the needs of the population residing along Somoche River: Fish: Mumi and Kamongo Vegetables: Chinderema and Chinsaga Trees: Chinsere, Chinseke, and Ebinyabutati Other resources: Ukindu

indicators and management objectives from the EFA technical team (Table 4 28) were adapted to develop the RQO targets and numerical indicators (Table 5 6).

5.1.4 Tigithe

The Tigithe sub-basin is divided into two RUs: Upper Tigithe RU and Lower Tigithe RU. This was done to align with the existing management structure in this sub-basin, namely the boundaries of the Upper Tigithe WUA and the Lower Tigithe WUA. For the EFA, there was only one site (Tigithe River at Matongo) which is located within the Lower Tigithe RU. For the RQOs, there will be two sets of RQO statements; however, only one set of RQO targets and indicators as well as one set of environmental flow values will be presented since it is expected that the needs of both RUs will be met with these recommendations.

The Tigithe sub-basin contains many disperse human activities, with the main economic drivers being rainfed agriculture, livestock grazing, and small-scale gold mining. Overall, stakeholders considered the impacts from human activities to be moderate with the biggest pressures coming from mining, livestock grazing, deforestation, and the impacts from villages. Plantations of eucalyptus trees are also becoming more common and some stakeholders are concerned about the impact this is having on water resources and biodiversity. Again, low flows and water quality are considered to have the highest importance of all the resource quality elements since it is the only source of water for domestic and livestock use. Stakeholders are concerned about the impacts of mining activities and toxic material in the river as well as pathogens which may affect human health. Stakeholders in the Lower Tigithe RU considered the current conditions of the resource quality elements to be moderate, while the Upper Tigithe stakeholders considered their conditions to be poor. These conditions also match the findings of the EFA technical team. All stakeholders thought conditions were declining and wanted to see them improve so they could continue utilizing important ecosystem services in the future.

These considerations were combined for a management class of B in each of the RUs, which is a somewhat altered hydrological condition but with relatively small impacts to the ecosystem. The RQO statements were developed to reflect a desire for sustainable use, allowing all resource quality element to be managed in a somewhat altered condition (Table 5 7). The indicators and management objectives from

Table 5-7: Final RQO statements for Tigithe

Resource Quality Element	RQO Statement
Tigithe – Upper Tigithe RU – Management Class: B	
Low Flows	Low flows should be adequate to meet water demands for domestic uses, livestock needs, and irrigated agriculture and maintain the aquatic ecosystem in a somewhat altered condition
High Flows	Amount of water required during high flows should be increased through storage facilities to sufficiently meet domestic and livestock needs as well as replenishing other water sources to support low flow demands.
Water Quality	Water quality should be improved to sustain river health, biota (fish, birds, crabs) as well as community and livestock health through appropriate agricultural practices and livestock keeping with moderate alternations of the biodiversity
Instream Habitat	Instream habitat should be maintained to support aquatic life through appropriate catchment conservation efforts and enforcement mechanisms of the source buffer zones
Riparian Habitat	Riparian habitat should be maintained to support aquatic life through appropriate catchment conservation efforts and enforcement mechanisms of the source buffer zones and with awareness raising on the effects of invasive species
Biota	The diverse community of macroinvertebrates and algae (periphyton) should be maintained in order to provide food (fish) and maintain water quality with slight alterations to the ecosystem
Tigithe – Lower Tigithe RU – Management Class: B	
Low Flows	Low flow should be sufficient enough to meet legal mining activities and maintain water quality and healthy ecosystems in a somewhat altered condition
High Flows	Amount of water required during high flows should be increased through storage facilities to sufficiently meet domestic and livestock needs as well as replenishing other water sources to support low flow demands
Water Quality	Toxics, sediments, and nutrients should not affect the health of the community and livestock while not affecting the life of the aquatic ecosystem and maintaining the ecosystem in a somewhat altered condition
Instream Habitat	Instream habitats should be sufficient enough to support fish breeding and maintain ecosystems in a somewhat altered condition
Riparian Habitat	Riparian habitat should be maintained to support aquatic life through appropriate catchment conservation efforts and enforcement mechanisms of the source buffer zones and with awareness raising on the effects of invasive species
Biota	The diverse community of macroinvertebrates and algae (periphyton) should be maintained in order to provide food (fish) and maintain water quality with slight alterations to the ecosystem

Table 5-8: RQO targets and indicators for Tigithe

Resource Quality Element	Target	Indicator
Low Flows	Comply with environmental flows, which includes important ecosystem services for local communities	See environmental flow values for Tigithe
High Flows		
Water Quality	Acceptable conditions for system parameters: pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates, and riparian vegetation
		Maintain acceptable standards for domestic, livestock, and agricultural purposes
		Ensure water is devoid of toxins and contaminants which can cause disease outbreaks
Instream Habitat	Adequate pool depth for refuge habitat	Maintain pools of at least 0.5 m deep
	Available gravel and cobble habitat	Maintain flow variability and a moderate sediment supply to maintain this habitat in good condition (e.g. not embedded with fine sediment)
Riparian Habitat	Healthy sedge and grass communities .	Continue to maintain abundances of flow sensitive sedge and grass species (e.g., *Cyperus cyperoides, Coix lacryma* and *Eriochloa macclounii*) at the site.
		Continue to maintain abundances of moderately flow sensitive plant species including *Commelina carsonii, C. benghalensis* and *Cynodon dactylon*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
		Continued presence and occurrence of seedlings and adults of *Cyperus cyperoides* and *Eriochloa macclounii* and the two should together be present at abundance of ≥10 percent
	Healthy riparian tree community	Continued presence and occurrence of seedlings, saplings and adults of Fig species e.g. *Ficus sur* and *F. sycomorus* with at least 10 percent abundance
Biota	Presence of indicator fish species	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
		Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site
	Fish community wellbeing	If either of the two previous indicators are not observed a fish community wellbeing assessment should be undertaken
	Presence of indicator macroinvertebrate species	SASS5 or TARISS Index score >150 and Avg. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, three or more species of *Hydropsychidae, Tricorythidae, Leptophlebiidae, Elmidae, Heptageniidae* and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*
		Ephemeroptera, Plecoptera and Trichoptera orders should be maintained >50 percent of the invertebrate community
		The flow sensitive families *Hydropsychidae*, *Simuliidae* and *Tricorythidae* should be present in abundances >40 percent of the invertebrate community during the wet season

Table 5-8: RQO targets and indicators for Tigithe

Resource Quality Element	Target	Indicator
		*Oligoneuridae sp.*is among the most sensitive taxa of macroinvertebrates that should be present at the site as a sign of good water and habitat conditions (no sedimentation)
	Maintain important species for subsistence activities	The following species should be abundant enough to suffice the needs of the population residing along Tigithe River: Fish: Mumi, Sato, and Ibemea Vegetables: Chinderema, Inkurwa, and Isebeso Trees: Murama, Mategete, Chinsere, and Chinseke Other species: Ibitende/Matende, Itutu, and Ekibabe

the EFA technical team (Table 4 42) were adapted to develop the RQO targets and numerical indicators (Table 5 8).

5.1.5 Mara Mines

The Mara Mines EFA site is located within the Mara Mines RU. Currently, there is no WUA in this area and water is managed by the LVBWB directly and utilized at the village or individual level. There were no stakeholders present at the RQO workshop for this RU. The RQOs presented have been developed by the EFA technical team using the social and ecological information gathered at the site and have been reviewed by project partners. The primary land use is rainfed and flood recession agriculture, livestock grazing, and some subsistence fishing. The impacts on the system from human activities appear to be moderate with the biggest pressures being the removal of riparian vegetation (including riparian trees) due to farming and impacts on the ecosystem from livestock grazing and watering. Consistent with the other RUs, low flows and water quality appear to the be resource quality elements that are most important to the local communities as the Mara River is the largest local water source for domestic and livestock use and it supports local fish populations. Current conditions appear to be moderate but showing signs of degradation in almost every category, and it is expected that local communities would like to see the resource quality elements maintained for future use. These considerations were combined for a management class of B, which is a somewhat altered hydrological condition but with moderate impacts to the ecosystem. The RQO statements were developed to reflect the desire for sustainable use, allowing all resource quality element to be managed in a somewhat altered condition (Table 5 9). The indicators and management objectives from the EFA

Table 5-9: Final RQO statements for Mara Mines

Resource Quality Element	RQO Statement
Mara Mines – Mara Mines RU – Management Class: B	
Low Flows	Low flows should be adequate to meet water demand for domestic use, livestock grazing, and fishing, while providing enough water to maintain the ecosystem in a somewhat altered condition
High Flows	High flows should be adequate to refresh the river banks, riparian zone, and areas used for flood recession agriculture while maintaining the ecosystem in a somewhat altered condition
Water Quality	Water quality should support the growth of fish communities to support local fishermen and be safe for use by humans and livestock
Instream Habitat	Instream habitat should provide for different stages of fish life cycles (spawning, growth, migration, etc.) to support local fishing activities and maintain biodiversity of aquatic species in a somewhat altered condition
Riparian Habitat	Riparian habitat should support biodiversity of vegetation species as to support marginal habitats for aquatic species, maintain a community of riparian trees, and provide forage for livestock grazing while being maintained in a somewhat altered condition
Biota	Fish abundance and diversity should be maintained to support local communities and sustained diversity of species

Table 5-10: RQO targets and indicators for Mara Mines

EFA Components	Indicator	Management Objective(s)
Low Flows	Comply with environmental flows, which includes important ecosystem services for local communities	See environmental flow values for Mara Mines
High Flows		
Water Quality	Acceptable conditions for system parameters: pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates, and riparian vegetation
		Maintain acceptable standards for domestic (washing, drinking) and livestock purposes
		Ensure water is devoid of toxins and contaminants which can cause disease outbreaks.
Instream Habitat	Adequate pool depth for refuge habitat	Maintain pools of at least 0.5 m deep
	Development of inset benches	Maintain flow variability and moderate sediment supply to maintain this lower bank habitat
Riparian Habitat	Healthy riparian tree and grass communities	Continue to maintain abundances of flow sensitive grass species (e.g., *Urochloa brachyuran)* at the site.
		Continue to maintain abundances of moderately flow sensitive plant species, including *Ficus exasperata* and *Echinochloa pyramidalis*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
		Continued presence and occurrence of seedlings and adults of *F. exasperata, E. pyramidalis, and Urochloa brachyuran* and the three should together be present at abundance of ≥20 percent of the riparian plant community as in natural setting.
Biota	Presence of indicator fish species	Following floods ensure that there has been successful recruitment of large migratory cyprinids that are also semi-rheophillic species. This includes *Labeo victorianus* and *Labeobarbus altianalis*.
		Ensure that there are individuals of *Zaireichthys CF. rotundiceps* at the site.
	Fish community wellbeing	If either of the two previous indicators are not observed a fish community wellbeing assessment should be undertaken
	Presence of indicator macroinvertebrate species	SASS5 or TARISS Index score >200 and Avg. Score Per Taxon >6
		Community to include a large proportion of sensitive taxa such as: three or more *baetid* species, *Hydropsychidae*, *Tricorythidae, Leptophlebiidae, Elmidae, Heptageniidae*, and *Oligoneuridae* with lower relative abundances of *Chironimidae* and *Oligochaeta*.
		Ephemeroptera, Plecoptera, and Trichoptera orders should be present in abundances >50 percent of the invertebrate community.
		The flow sensitive and marginal vegetation dependent families *Hydropsychidae*, *Simuliidae*, *Tricorythidae*, and *Lestidae* should be present in abundances >40 percent of the invertebrate community.
		Oligoneuridae is among the most sensitive family of macroinvertebrates to both water quality and quantity, and hence should be present at the site as a sign of good water and habitat conditions (no sedimentation). *Perlidae*

Table 5-10: RQO targets and indicators for Mara Mines

EFA Components	Indicator	Management Objective(s)
		(stoneflies) are very sensitive to flows because they prefer fast velocities. Their presence means maintaining good water quality and stable substrate for attachment.
	Maintain important species for subsistence activities	The following species should be abundant enough to suffice the needs of the population residing along Mara River at Mara Mines: Fish: Mumi, Sato, and Ningu, Vegetables: Chinsaga, Nyakanwa, and Chenkunyenyi Trees: Chinseke, Amasisi/Ukwaju, Omongoro/Mninga pori, and Egysamiti Other species: Ukindu, Amabanche, and Itutu

technical team (Table 4 54) were adapted to develop the RQO targets and numerical indicators (Table 5 10).

Bisarwi

The Bisarwi EFA site is located within the North Mara RU and is managed by the North Mara WUA. The main activities in the area are rainfed and flood recession agriculture and livestock grazing. According to stakeholders, the impacts from human activities on the ecosystem are slightly above moderate with the greatest pressures being from invasive species (including water hyacinth and eucalyptus), deforestation of native trees, activities from villages, and livestock grazing. Again, low flows and water quality were ranked as the most important resource quality elements since the wetland is the most used water resource for domestic use, livestock grazing, and fishing, and it is also important to maintain local wildlife (hippopotamus). Stakeholders and the EFA technical team considered the current conditions of the resource quality elements to be moderate but with a declining trend in condition. Their desire is for conditions to improve so the system can continue to be utilized for future use. These considerations were combined for a management class of B, which is a somewhat altered hydrological condition but with relatively small impacts to the ecosystem. The RQO statements were developed to reflect the desire for sustainable use, allowing all resource quality element to be managed in a somewhat altered condition (Table 5 11). The indicators and management objectives from

Table 5-11: Final RQO statements for Bisarwi

Resource Quality Element	RQO Statement
Bisarwi – North Mara RU – Management Class: B	
Low Flows	Low flows should be sufficient to support macroinvertebrates, and local fisheries population (e.g., mofu, mumi, nembe, ningli, and gogogo) and livestock while maintaining the ecosystem in a somewhat altered condition
High Flows	High flows should be sufficient to support paddy-rice agriculture and papyrus for handcrafting while maintaining the ecosystem in a somewhat altered condition
Water Quality	Nutrients and pathogens should be low enough not to accelerate eutrophication, threats to fish and macroinvertebrates and human health risks (e.g., cholera, typhoid, etc.) while maintaining the ecosystem in a somewhat altered condition
Instream Habitat	Instream habitat should be sufficient to support the aquatic ecosystem in a somewhat altered condition.
Riparian Habitat	Riparian habitat should be sufficient to support wildlife in terms of grazing (hippopotamuses) and protect river banks against erosion while maintaining the ecosystem in a somewhat altered condition
Biota	Biota should be sufficient to support community health (e.g., protein intake) and maintain ecological functioning (e.g., nutrient retention) in a somewhat altered condition

Table 5-12: RQO targets and indicators for Bisarwi

EFA Component	Indicator	Management Objective(s)
Low Flows	Comply with environmental flows, which includes important ecosystem services for local communities	See environmental flow values for Bisarwi
High Flows		
Water Quality	Acceptable conditions for system parameters: pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates, and riparian vegetation
		Maintain acceptable standards for domestic (washing, drinking) and livestock purposes
Instream Habitat	Overbank flooding	Maintain flood flows to ensure channel-floodplain sediment connectivity
Riparian Habitat	Healthy grass and sedges communities	Continue to maintain abundances of moderately flow sensitive plant species, including *Vossia cuspidata and Cyperus distans*
		Improve recruitment conditions and connectivity of riparian and floodplain sedges, grasses and forbs, including *Echinochloa haploclada, Cynodon dactylon,* and *Cyperus cyperoides* on greater parts of the wetland
		Continued presence and occurrence of seedlings and adults of *Vossia cuspidata* and *Cyperus distans* and the two should together be present at abundance of ≥10 percent
Biota	Presence of indicator fish species	Maintain recruitment of indicator species based on observations of including fry/fingerlings of at least three of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
		Maintain populations of indicator species including observations of each of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
	Fish community wellbeing	Failure to achieve either of the two indicators above should trigger a fish community wellbeing assessment
	Presence of indicator macroinvertebrate species	Most taxa in the *Coleoptera, Hemiptera, and Odonata* orders prefer marginal vegetation and macrophytes as attachment/ habitat sites. The also prefer slow and deep waters as refuges and feeding sites.
		Baetidae spp. family is moderately tolerant to poor water quality, so should be maintained as an indicator species for this. *Baetidae* prefer moderate velocities and moderate water quality that is characteristic of floodplain rivers.
	Maintain important species for subsistence activities	The following species should be abundant enough to suffice the needs of the population residing along the Mara Wetland at Bisarwi: Fish: Mumi, Kamongo, and Perege Vegetables: Chinsaga, Chinderema, and Isibeso/Mchicha Trees: Chinseke, Nyatunglo, Omisabisabi, and Omuka Other species: Matende, Itutu, and Engeri

the EFA technical team (Table 4 65) were adapted to develop the RQO targets and numerical indicators (Table 5 12).

5.17 Mara Wetland

The Mara Wetland EFA site is located within the South Mara RU and is managed by the South Mara WUA. The main activities are rainfed and flood recession agriculture and livestock grazing, similar to the rest of the Lower MRB. The stakeholders find that there is little pressure on the system from human activities with only moderate concerns coming from invasive species, livestock grazing, and burning of wetland vegetation. All resource quality elements were ranked as having low impact from human activities, but almost all were ranked as having high importance to the communities due to a mix of ecosystem functions (such as breeding and refuge sites for fish and wildlife and nutrient regulation) and services to humans (for domestic use, livestock grazing, and fishing). Stakeholders and the EFA technical team considered the current conditions to be moderate and overall stable, but with a slight degradation in habitat in recent years. There is a desire to improve the resource quality elements in the area to allow for continued use of wetland resources. These considerations were combined for a management class of B, which is a somewhat altered hydrological condition but with relatively small impacts to the ecosystem. The RQO statements were developed to reflect the desire for sustainable use, allowing all resource quality element to be managed in a somewhat altered condition (Table 5 13). The indicators and management objectives from

Table 5-13: Final RQO statements for Mara Wetland

Resource Quality Element	RQO Statement
Mara Wetland – South Mara RU – Management Class: B	
Low Flows	Low flows should be sufficient to support macrophyte growth, survival of macroinvertebrates and fish and livestock through drinking water and forage while maintaining the ecosystem in a somewhat altered condition
High Flows	High flows should be sufficient to support the reproduction of macroinvertebrates and fish species (lungfish, tilapia species, etc.) and maintain aquatic breeding sites while maintaining the ecosystem in a somewhat altered condition
Water Quality	Toxics, nutrients, and infection microbes should not cause health risks to humans, livestock, and the wetland and riparian habitats to maintain ecosystem services
Instream Habitat	Instream habitat should be healthy enough to provide a conducive environment (habitat, refuge, and breeding sites) for wildlife (hippopotamuses, crocodiles), macroinvertebrates and fish (lungfish, tilapia species), and clean water for domestic use
Riparian Habitat	Riparian habitat should be healthy enough to buffer instream water from diffuse and point pollution and solid wastes and maintain provisioning ecosystem services (e.g., food, clean water, herbs/medicinal plants, firewood) to communities and support breeding sites and refuge for wildlife and fish
Biota	Aquatic macroinvertebrates, fish species (lungfish, tilapia species, mumi, etc.) and aquatic plant species (cyperus papyrus, phramite, and typha) should be sustained to support livelihoods (subsistence and business) and health ecosystems (nutrient uptake)

Table 5-14: Indicators and management objectives for the Mara Wetland

EFA Component	Indicator	Management Objective(s)
Low Flows	Comply with environmental flows, which includes important ecosystem services for local communities	See environmental flow values for Mara Wetland
High Flows		
Water Quality	Acceptable conditions for system parameters: pH, DO, EC, turbidity, nutrients	Maintain the water quality within acceptable standards to support growth and development of fish, macroinvertebrates, and riparian vegetation
		Maintain acceptable standards for domestic (washing, drinking) and livestock purposes
Instream Habitat	High roughness vegetation	Maintain suitable water depth and substrate to support dense Papyrus vegetation (for ideal sedimentation environment)
Riparian Habitat	Healthy sedge, grass, forb, and fern communities	Continue to maintain abundances of flow sensitive sedge and fern species (e.g. *Cyperus papyrus* and *Azolla filiculoides*) at moderately modified natural conditions
		Continue to maintain abundances of moderately flow sensitive grass and forb species including *Vossia cuspidata*, *Urochloa trichopus* and *Commelina benghalensis*. If depth of water for flow sensitive plant species is met then it should suffice this group too.
		Continued presence and occurrence of seedlings and adults of *Cyperus papyrus* and *Vossia cuspidata* and the two should together be present at abundance of ≥30 percent of the riparian plant community
		Continued presence and occurrence of seedlings and adults of *Nymphaea nouchali* and *Azolla filiculoides* and the two should together be present at abundance of ≥1 percent of the riparian plant community
Biota	Presence of indicator fish species	Maintain recruitment of indicator species based on observations of including fry/fingerlings of at least three of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
		Maintain populations of indicator species including observations of each of the following species: *Mastacembelus frenatus, Mormyrus kannume, Oreochromis leucostictus, Oreochromis variabilis,* and *Labeobarbus altianalis*
	Fish community wellbeing	Failure to achieve either of the two indicators above should trigger a fish community wellbeing assessment
	Presence of indicator macroinvertebrate species	Most taxa in the *Coleoptera*, *Hemiptera,* and *Odonata* orders prefer marginal vegetation and macrophytes as attachment/ habitat sites. The also prefer slow and deep waters as refuges and feeding sites.
		Baetidae Caenidae and *Leptophlebiidae spp.*families are moderately tolerant to poor water quality, so should be maintained as indicators. They also prefer low to medium velocities, so maintaining them will require having constantly flowing water in the main channel to maintain flow velocities, dissolved oxygen and temperature.
	Maintain important species for subsistence activities	The following species should be abundant enough to suffice the needs of the population residing along the Mara Wetland at Kitasakwa: Fish: Mumi, Kamongo, and Sato

Table 5-14: Indicators and management objectives for the Mara Wetland

EFA Component	Indicator	Management Objective(s)
		Vegetables: Isebeso, Chinsaga, and Inkuruwa Trees: Chinseke, Chinsondobiro, Ekerera, and Egetobekere Other species: Matende, Amahohi, Engeri, and Ekigara

the EFA technical team (Table 4 76) were adapted to develop the RQO targets and numerical indicators (Table 5 14).

5.2 Basic Human Needs

The final estimates for flow requirements for basic human needs were calculated in units of m3/day and also m3/s to align with the environmental flow values. The basic human needs values for 2018 ranged from 0.006 m3/s in North Mara RU to 0.018 m3/s in Mara Mines RU (Table 5 15). The values for BHNs are based on a daily requirement of 25 liters/person/day and are expected to remain constant throughout the year. The BHN values are based on the RUs to align with the planning units used in the water allocation planning effort. Estimates for BHN

Table 5-15: Basic human needs estimates for 2018 by resource unit

Resource Unit	Estimated Population (2012)*	Estimated Population (2018)	Water Demand for Basic Human Needs (m^3/day)	Water Demand for Basic Human Needs (m^3/s)
Serengeti	41,570	48,137	1,203.43	0.014
Tobora	32,930	38,133	953.33	0.011
Somoche	47,459	54,958	1,373.95	0.016
Upper Tigithe	25,641	29,692	742.30	0.009
Lower Tigithe	31,476	36,450	911.24	0.011
Mara Mines	54,517	63,130	1,578.25	0.018
North Mara	17,067	19,763	494.08	0.006
South Mara	88,560	102,552	2,563.80	0.030
Total	**339,219**	**392,815**	**9,820.37**	**0.114**

*NBS, 2012

Table 5-16: Future basic human needs estimates by resource unit

Resource Unit	Estimated Population (2012)*	Estimated Future Population	Water Demand for Basic Human Needs (m^3/day)	Water Demand for Basic Human Needs (m^3/s)
		2023		
Serengeti	41,570	54,397	1,359.92	0.016
Tobora	32,930	43,091	1,077.29	0.012
Somoche	47,459	62,104	1,552.60	0.018
Upper Tigithe	25,641	33,553	838.82	0.010
Lower Tigithe	31,476	41,189	1,029.73	0.012
Mara Mines	54,517	71,339	1,783.47	0.021
North Mara	17,067	22,333	558.33	0.006
South Mara	88,560	115,887	2,897.16	0.034

Table 5-16: Future basic human needs estimates by resource unit

Resource Unit	Estimated Population (2012)*	Estimated Future Population	Water Demand for Basic Human Needs (m^3/day)	Water Demand for Basic Human Needs (m^3/s)
Total	**339,219**	**443,892**	**11,097.31**	**0.128**
		2028		
Serengeti	41,570	61,470	1,536.74	0.018
Tobora	32,930	48,695	1,217.37	0.014
Somoche	47,459	70,179	1,754.48	0.020
Upper Tigithe	25,641	37,916	947.89	0.011
Lower Tigithe	31,476	46,545	1,163.62	0.013
Mara Mines	54,517	80,615	2,015.37	0.023
North Mara	17,067	25,237	630.92	0.007
South Mara	88,560	130,955	3,273.88	0.038
Total	**339,219**	**501,611**	**12,540.28**	**0.145**
		2038		
Serengeti	41,570	78,495	1,962.37	0.023
Tobora	32,930	62,181	1,554.53	0.018
Somoche	47,459	89,617	2,240.42	0.026
Upper Tigithe	25,641	48,417	1,210.42	0.014
Lower Tigithe	31,476	59,436	1,485.90	0.017
Mara Mines	54,517	102,943	2,573.56	0.030
North Mara	17,067	32,227	805.67	0.009
South Mara	88,560	167,225	4,180.63	0.048
Total	**339,219**	**640,540**	**16,013.51**	**0.185**

**NBS, 2012*

requirements were also calculated for the 5, 10, and 20 years to align with the water allocation planning process (Table 5 16).

5.3 Environmental Flows

Environmental flows are the amount of water at different times of the year needed to "protect aquatic ecosystems and to secure ecologically sustainable development" (per the definition of the reserve in Tanzania). For the Lower MRB, these values were determined through the RQO process (Section 3.2) and resulted in a management class of A (the highest level of protection) in Serengeti RU to protect wildlife resources and the related ecotourism, and a management class of B (a balance between resource protection and use) in the rest of the RUs where local residents rely heavily on the river for everyday needs. Using these management classes as a guide, the technical team determined the environmental flow requirements to meet these objectives.

Environmental flows are expressed as monthly low flow values (in m3/s) across one water year (October to September) as well as freshets and floods with specific durations and timing requirements. These building blocks of the environmental flow regime were set for each EFA study site for both maintenance years and a drought years. For the monthly low flows, the percent of average flow was calculated to provide context. For the monthly low flows, freshets, and floods, the magnitude (in cubic meters per day, m3/day, and million cubic meters, Mm3) for inclusion in the parallel WAP effort in the Lower MRB.

The values for the environmental flow were developed through group consensus with the technical team and project partners during the Flow Setting Technical Meeting. Typically, needs of the most sensitive indicator was selected as the environmental flow, ensuring that the other less sensitive ecological and social indicators would also be met. The values decided upon during this meeting were monthly low flows for the driest month, monthly low flows for the wettest month, and high flow events (such as freshets and floods) that are critical for ecological and/or social functions. The final values from the technical meeting are summarized in Table 5 17 and Table 5 18.

The two low flow monthly values were then used to develop the monthly low flow requirements of the other months. This was done by calculating the percent of the environmental flow compared to the average flow of the two known months, calculating the linear relationship between the two, and then applying this relationship to the other months. In this way, the environmental flows across the water year, mimic the natural shape of the hydrograph. After the preliminary values were determined at the Flow Setting Technical Meeting, they were reviewed to ensure the values aligned when looking at the entire river system.

Social requirements have been incorporated into the ecological motivations for each site and were not separated individually. In general, the local communities rely mostly on rainfed agriculture and livestock keeping for their livelihoods, and use fish, native fruits and vegetables, trees, and grasses from the river ecosystem to for their daily activities. Some also use the river water to meet domestic water needs, although shallow groundwater wells are more commonly used in the area.

During the low flow conditions throughout the year, local communities require enough water in the channel to support their domestic and livestock needs, but they prefer that the floodplain remain free of water as it is where they farm and graze their livestock. They also require enough water to maintain specific species of riparian plants for food or building materials. During floods, it is important the floodplain is inundated to replenish soil moisture and fertility for crops, maintain meadows for grazing livestock, and fill local water sources (including ponds, swamps, and seasonal tributaries).

High flows are also when many fish are caught, which are an important source of food. If the flow regime does not support these activities, it could greatly affect the ability of these communities to obtain their basic needs of water, food, and income. In drought years, it is particularly important to meet the flow values since the available water resources are reduced, increasing the pressure on the system by humans. These uses can be applied to all EFA study sites in the Lower MRB except Kogatende, which does not have any communities in the surrounding area.

The final environmental flow values set for each site are presented in the following sections, along with brief descriptions of their motivations and the

Table 5-17: Environmental flow values for a maintenance year

	Hydrological Component	Kogatende	Tobora	Somoche	Tigithe	Mara Mines	Bisarwi	Mara Wetland*
Maintenance Year	Low flow, driest month	Month: Feb Flow (m³/s): 2.4	Month: Aug Flow (m³/s): 0.15	Month: Aug Flow (m³/s): 0.3	Month: Aug Flow (m³/s): 0.1	Month: Oct Flow (m³/s): 3.5	Month: Feb Flow (m³/s): 3.0	*Month: Aug* *Depth (m): 2.7*
	Low flow, wettest month	Month: May Flow (m³/s): 12	Month: May Flow (m³/s): 0.8	Month: May Flow (m³/s): 0.9	Month: Apr Flow (m³/s): 0.25	Month: May Flow (m³/s): 15	Month: May Flow (m³/s): 12	*Month: May* *Depth (m): 3.3*
	High flow, freshets and/or floods	– 1 freshet of 52 m³/s for 21 days in Apr-May – 4 freshets of 30 m³/s for 4 days each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 160 m³/s for 3 days in May (annual) – 1 flood event of 490 m³/s flood for 1 day in May (1 in 5 years)	– 1 freshet of 1.7 m³/s for 14 days in Apr-May – 3 freshets of 1.7 m³/s for 7 days each (2 in Nov-Dec, 1 in Mar-May) – 1 flood event of 24 m³/s during 2 days in May (annual) – 1 flood event of 97 m³/s during 3 days in May (1 in 3 years)	– 1 freshet of 2 m³/s for 21 days in Apr-May – 4 freshets of 2.7 m³/s for 2 days each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 20 m³/s for 3 days in Apr-May (annual) – 1 flood event of 70 m³/s for 2 days in May (1 in 3 years)	– 1 freshet of 1.2 m³/s for 14 days in Apr-May – 3 freshets of 1 m³/s for 7 days each (2 in Nov-Dec, 1 in Mar-May) – 4 freshets of 2.9 m³/s for 1 day each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 26 m³/s for 2 days (annual) – 1 flood event of 43 m³/s for 2 days (1 in 3 years)	– 1 freshet of 46 m³/s for 21 days in Apr-May – 3 freshets of 25 m³/s for 7 days each (2 in Nov-Dec, 1 in Mar-May) – 4 freshets of 10 m³/s for 2 days each (2 in Mar-May, 2 in Nov-Dec) – 1 flood event of 74 m³/s for 1 day (annual) – 1 flood event of 334 m³/s for one day (1 in 3 years) – 1 flood event of 498 m³/s for 1 day (1 in 6 years)	– 1 freshet of 50 m³/s for 10 days in May – 1 freshet of 50 m³/s for 1-2 days in Dec – 2 freshets of 20 m³/s for 2 days each (1 in Nov-Dec, 1 in Mar-May) – 1 flood event at 75 m³/s for 2 days (annual) – 1 flood event at 100 m³/s for 3 days (1 in 2 years)	*– 1 freshet at 4 m for 14 days (annual)* *– 2 freshet at 5 m for 10 days each in May and Nov (annual)* *– 1 flood event at 4.8 m for 14 days (1 in 2 years)*

*Only depth requirements were provided at this site due to an incomplete hydraulic cross-section, low confidence in the hydraulic model, and potential effects from the level of Lake Victoria

Table 5-18: Environmental flow values for drought year

	Hydrological Component	Kogatende	Tobora	Somoche	Tigithe	Mara Mines	Bisarwi	Mara Wetland*
Drought Year	Low flow, driest month	Month: Feb Flow (m³/s): 1.6	None	None	Month: Aug Flow (m³/s): 0.0	Month: Oct Flow (m³/s): 1.8	Month: Feb Flow (m³/s): 1.0	*Month: Aug* *Depth (m): 2.4*
	Low flow, wettest month	Month: May Flow (m³/s): 8.0	None	None	Month: Apr Flow (m³/s): 0.05	Month: May Flow (m³/s): 7.6	Month: May Flow (m³/s): 6.5	*Month: May* *Depth (m): 2.8*
	High flow, freshets and/or floods	– 1 freshet of 20 m³/s for 21 days in Apr-May – 4 freshets of 10 m³/s for 7 days in Apr-May, Nov-Dec – 3 freshets of 30 m³/s for 2 days each in Apr-May (2 in Nov-Dec, 1 in Mar-May) – 1 flood event of 56 m³/s for 1 day in May (annual)	None	None	– 1 freshet of 0.25 m³/s for 14 days in Apr-May – 4 freshets of 0.6 m³/s for 7 days each (2 in Nov-Dec, 2 in Mar-May) – 3 freshets of 2.9 m³/s for 1 day each (2 in Nov-Dec, 1 in Mar-May) – 1 flood event of 26 m³/s for 2 days in May (annual)	– 1 freshet of 22 m³/s for 21 days in Apr-May – 4 freshets of 10 m³/s for 7 days each (2 in Nov-Dec, 2 in Mar-May) – 1 flood event of 122 m³/s peak for 2 days in May (1 in 3 years)	– 2 freshets of 12 m³/s for 10 days each in May and Dec	*– 1 freshet of 3.2 m for 14 days (annual)* *– 1 flood event of 4.4 m for 14 days (1 in 2 years)*

*Only depth requirements were provided at this site due to an incomplete hydraulic cross-section, low confidence in the hydraulic model, and potential effects from the level of Lake Victoria consequences if they are not met. Full motivations for each EFA component can be found in the starter documents in Annex B through Annex I.

5.3.1 Kogatende

At Kogatende, located on the mainstem of the Mara River, the dry season low flow requirements during a maintenance year are to ensure that the marginal zone vegetation has enough access to water during the dry months. The vegetation in this zone includes grass, sedge, and forb species. Dry season low flows provide important recruitment habitat for newly hatched fish individuals and rheophilic species, while also allowing movement between different habitats in the river channel and flowing tributaries. For macroinvertebrates, they are important for promoting suitable substrate and periphyton growth for scraper species, providing flow within riffles to support rheophilic species, maintaining good water quality in pools and backwater zones, as well as submerged marginal vegetation required for specific taxa.

If the flows are not met, this will likely decrease the abundance of the marginal zone plant species at the site as well as recruitment of newly hatched fish and vegetation-dependent macroinvertebrate taxa, threatening the survival of these species. The lack of proper in-channel habitats may cause a loss of specific fish and macroinvertebrate species, such as flow sensitive species that rely on highly oxygenated water in riffles.

The wet season low flows are important for inundating the lower zone vegetation and supporting seed germination and dispersal. They also provide conditions for rheophilic fish species to feed in riffle and rapid habitats, allowing them to recover from the low flow periods. Wet season low flows are also needed to provide habitats for spawning and recruitment of indicator fish species. The wet season low flows provide depths and velocities that will help flow sensitive macroinvertebrate taxa survive, while flushing out organic matter (including hippopotamus dung) and fine sediments from in-channel habitats, which will help sustain sensitive EPT taxa (Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies)).

If the wet season low flows are not met, then there will be a reduction in the germination and dispersal of the lower zone vegetation species. The flows also provide critical habitats for various life functions of fish species and may cause fish populations to become unsustainable. The lack of wet season low flows could also be detrimental to the recruitment and larval development of flow-sensitive macroinvertebrate taxa. And if the organic matter and fines are not removed, this could smother algae that is the main food source for scraper macroinvertebrates. In addition, the accumulation of organic matter in pools and backwaters (from the lack of flushing) could cause anoxic or hypoxic conditions for aquatic species.

Regular high flows are important from a geomorphological perspective because they maintain gravel bars (which are important for fish spawning habitat); freshets scour organic matter (including hippopotamus dung) from riffles, move gravels through the system, and inundate flood benches; and floods are important for scouring bars, flood benches, and inset benches while moving the bulk of the sediment through the system. Floods are important for vegetation because they prevent alien species from establishing, allow native species to recruit in the marginal and lower zones after flooding events, and stimulate growth and reproduction in established plant communities. The flooding also replenishes soil moisture and nutrients in the banks and flood benches. Freshets are particularly important for flushing organic matter and fine sediment, enhancing habitat suitability for annual and perennial plants. Higher flows are important for fish species because they allow for connection with tributaries and inundate gravel bars, increasing habitat diversity, species diversity, and migration between different habitats. They are important for flushing fines from stable substrate and maintaining good water quality conditions for sensitive macroinvertebrate taxa. They also reduce predation of macroinvertebrates from insectivorous fish since there are additional habitats for fish to access.

A lack of annual freshets and floods over a number of years prevents the maintenance of existing habitat and development of new habitats by preventing geomorphological scouring and deposition, which limits the growth of annual plant species and threatens the survival of moderately flow sensitive plant species. It also prevents the connections with tributaries, decreasing fish habitat diversity which could lead to a loss of critical fish communities. Lack of high flows also prevents the flushing of important macroinvertebrate habitat, which could be detrimental to rheophilic taxa and cause less sensitive taxa to dominate the system. Without access to additional habitats, insectivorous fish also predate heavily on macroinvertebrates in one area, changing the community structure in that habitat.

In general, drought requirements are about the survival of individuals during extreme dry periods. For fish and macroinvertebrates, it is critical that pools in the river channel are maintained and refreshed (either through constant low flow or through freshets) so that necessary water quality conditions are maintained. If these flows are not met, the abundance of many flow-sensitive species could decrease. The wet month low flows and freshet functions are similar to the maintenance year on a decreased magnitude, but are particularly important for the rejuvenation of aquatic species since many of individuals may be stressed from the dry month drought conditions. In addition, these higher flows maintain important marginal vegetation which is also critical habitat for many fish and macroinvertebrate indicator species. Floods are not particularly common in drought years but can provide critical refreshment and flushing of the system. When flows become too low, there is the possibility of extreme conditions in specific water quality parameters, including increased temperatures and low levels of dissolved oxygen.

One issue specific to Kogatende is the presence of large numbers of hippopotamuses in the river. They produce a large amount of dung, which impacts in-channel habitat by filling in riffles and covering stable substrates in organic material. At extreme low flows or in standing water (like disconnected pools and backwaters), the hippo dung can also cause anoxic conditions. This adds to the importance of maintaining proper flushing of the system through higher flows, freshets, and floods to scour out the dung from habitats, and maintaining low flows so they can replenish pools in times of low flows or drought conditions.

While the Serengeti macrofauna (including crocodiles and hippopotamuses) are not a specific indicator, it is expected that the ecological conditions provided by the environmental flows will provide adequate conditions for both habitat and food sources for the resident populations. In particular, ensuring the presence of pools during dry months that are deep enough to hold these animals have been considered during this process.

The full results of the environmental flow values

Table 5-19: Environmental flow values for Kogatende

	Index		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Avg.	Annual Total
	Average flow (m^3/s)		18.63	18.30	23.47	20.21	16.05	20.52	43.66	51.76	29.71	22.56	26.03	31.13	26.84	
Maintenance Year	**Monthly low flows**															
	Environmental flow (m^3/s)		3.09	3.00	4.40	3.52	**2.40**	3.60	9.82	**12.00**	6.07	4.15	5.08	6.45	5.30	
	% Average flow		17%	16%	19%	17%	15%	18%	22%	23%	20%	18%	20%	21%	20%	
	Magnitude (m^3/day)		267,172	259,519	379,728	303,948	207,360	311,193	848,692	1,036,800	524,546	358,439	439,077	557,511	457,832	
	Magnitude (Mm^3/month)		8.28	7.79	11.77	9.42	5.81	9.65	25.46	32.14	15.74	11.11	13.61	16.73		167.50
	Annual freshets and floods															
	Magnitude (m^3/day)		0	345,600	334,452	0	0	0	345,600	3,344,516	0	0	0	0	364,181	
	Magnitude (Mm^3/month)		0	10.37	10.37	0	0	0	10.37	103.68	0	0	0	0		134.78
	Total:	**m^3/day**	**267,172**	**605,119**	**714,180**	**303,948**	**207,360**	**311,193**	**1,194,292**	**4,381,316**	**524,546**	**358,439**	**439,077**	**557,511**	**822,013**	
	Total:	**Mm^3/month**	**8.28**	**18.15**	**22.14**	**9.42**	**5.81**	**9.65**	**35.83**	**135.82**	**15.74**	**11.11**	**13.61**	**16.73**		**302.29**
Drought Year	**Monthly low flows**															
	Environmental flow (m^3/s)		2.06	2.00	2.93	2.35	**1.60**	2.40	6.55	**8.00**	4.05	2.77	3.39	4.30	3.53	
	% Average flow		11%	11%	12%	12%	10%	12%	15%	15%	14%	12%	13%	14%	13%	
	Magnitude (m^3/day)		178,115	173,013	253,152	202,632	138,240	207,462	565,794	691,200	349,697	238,959	292,718	371,674	305,221	
	Magnitude (Mm^3/month)		5.52	5.19	7.85	6.28	3.87	6.43	16.97	21.43	10.49	7.41	9.07	11.15		111.67
	Annual freshets and floods															
	Magnitude (m^3/day)		0	374,400	362,323	0	0	195,097	201,600	1,354,529	0	0	0	0	207,329	
	Magnitude (Mm^3/month)		0	11.23	11.23	0	0	6.05	6.05	41.99	0	0	0	0		76.55
	Total:	**m^3/day**	**178,115**	**547,413**	**615,475**	**202,632**	**138,240**	**402,559**	**767,394**	**2,045,729**	**349,697**	**238,959**	**292,718**	**371,674**	**512,550**	
	Total:	**Mm^3/month**	**5.52**	**16.42**	**19.08**	**6.28**	**3.87**	**12.48**	**23.02**	**63.42**	**10.49**	**7.41**	**9.07**	**11.15**		**188.22**

Environmental flow values in bold indicate those determined during flow setting technical meeting

Mm^3 = million cubic meters

Table 5-20: Freshet and flood events for environmental flows for Kogatende

	Month	Type	Flow (m^3/s)	Duration (days)	Individual Magnitude (Mm^3)	Combined Magnitude* (Mm^3)
Maintenance Year	***Annual Events***					
	Nov	Freshet	30	4	10.37	10.37
	Dec	Freshet	30	4	10.37	10.37
	Apr	Freshet	30	4	10.37	10.37
	May	Freshet	30	4	10.37	103.68
		Freshet	52	21	94.35	
		Flood	160	1	13.82	
	Additional Events**					
	May	5-year Flood	490	1	42.34	42.34
Drought Year	***Annual Events***					
	Nov	Freshet	10	7	6.05	11.23
		Freshet	30	3	7.78	
	Dec	Freshet	10	7	6.05	11.23
		Freshet	30	3	7.78	
	Mar	Freshet	10	7	6.05	6.05
	Apr	Freshet	10	7	6.05	6.05
	May	Freshet	30	3	7.78	41.99
		Freshet	20	21	36.29	
		Flood	56	1	4.84	

** Combined magnitude values incorporate the magnitude of smaller events into the magnitude of the larger events to avoid double counting*

***Additional events are not included in the annual magnitude calculations for environmental flows*

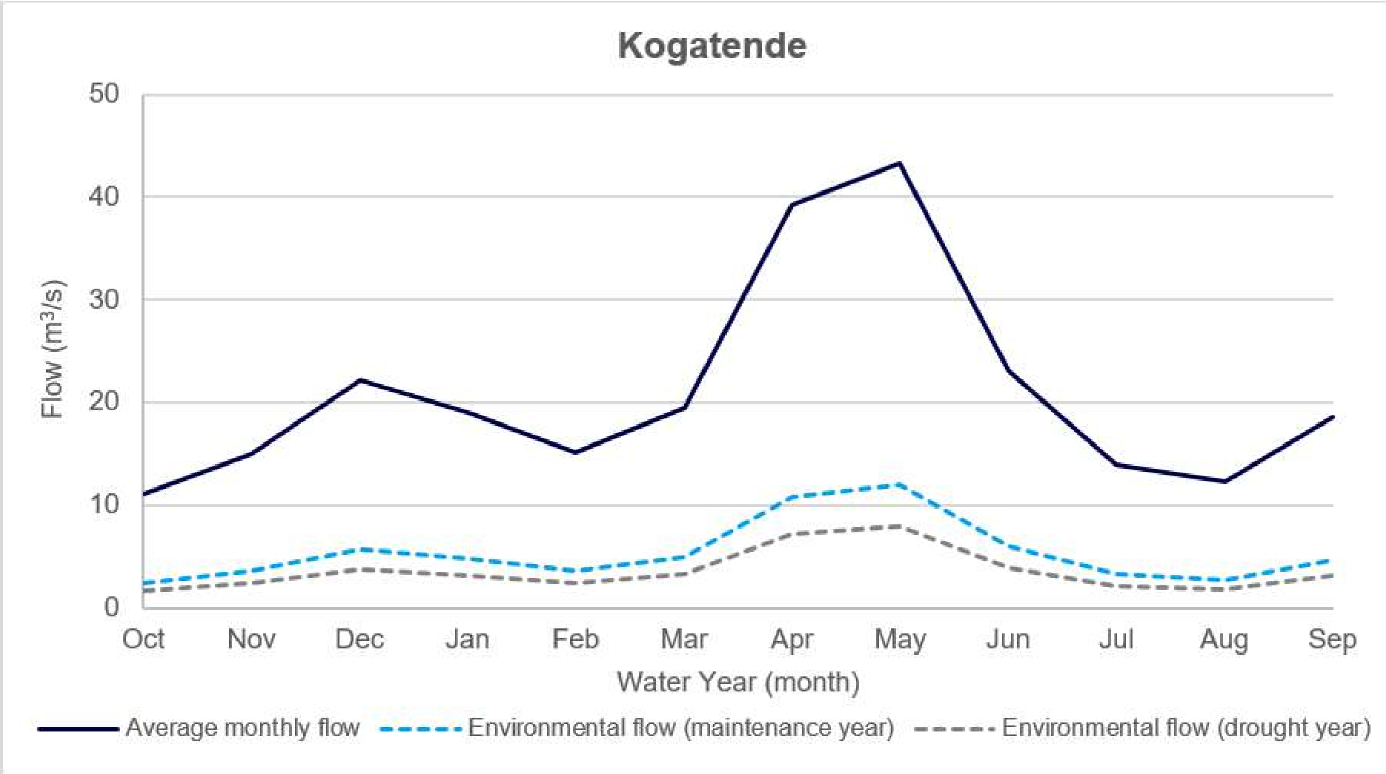


Figure 5-1: Environmental flow values for Kogatende

at Kogatende are presented in Table 5 19, details on freshets and flow values are in Table 5 20, and environmental flow values are graphed in Figure 5 1.

5.3.2 Tobora

For Tobora, dry season low flows are important to support the survival of marginal zone vegetation, including grass, sedge, and forb species. They also refresh pools, which are important refuge to migrating fish species, and provide habitat for flow-sensitive macroinvertebrate species. If the dry month low flows are not met, there will likely be a decrease in the abundance of the marginal zone vegetation, also decreasing the available habitat for vegetation-dependent macroinvertebrates. If the refreshed pools are not available as refuges for fish, it may decrease the biodiversity in the area and reduce populations of indicator fish species. The lack of proper habitat may reduce the abundance of flow-sensitive and water-quality sensitive macroinvertebrate species.

Wet season low flows are important to inundate lower zone vegetation and support seed germination and dispersal in the system. These inundated plants are important habitat for vegetation associated taxa, supporting larval stages of odonates and true bugs, and providing attachment sites for other taxa. Maintaining these flows are important for migrating species during wet periods to open up additional feeding habitats. If wet season low flows are not met, the seeds from the lower zone vegetation species may not disperse and germinate, reducing the abundance of these species. The lack of inundated plant habitat for macroinvertebrates may result in a lowering of biodiversity. For fish, the lack of habitat for conditioning and recruiting may reduce species abundance and potentially cause species losses.

For geomorphology, freshets help to move sand out of gravel and cobble beds and flush riffles, which creates important habitat for fish and macroinvertebrates; high flows inundate and transport sand into flood benches, and floods move gravels and turn cobbles (improving habitat diversity while also scouring vegetation and inset benches to form new habitat for recruitment and colonization). These higher flow events also trigger physiological changes in most annual plant species in the upper and lower zones and help disperse seeds on higher parts of the bank.

The floods often clear debris and promote germination of riparian tree species. Floods also provide ecological cues for fish spawning and increase connectivity between habitats (mainstem to tributary, tributary to floodplain, etc.). In addition, they are important for restructuring macroinvertebrate communities and reducing predation pressure from specific taxa and insectivorous fish. If higher flow events are not met (including freshets and floods), habitat diversity for fish and macroinvertebrates will decrease because sand will remain in gravel and cobble beds (increasing embeddedness) and fill in riffles, the flood benches will not be replenished and/or shifted, and the vegetation may encroach the system due to a lack of scouring. The lack of high flows will also prevent annual species from germinating and, over time, the system could change from being dominated by riparian trees to being dominated by shrubs. The lack of floods could prevent fish from accessing additional habitats and reduce abundance, while the lack of macroinvertebrate habitat will be a disadvantage to sensitive taxa.

For the local communities, the importance of maintaining proper fish populations (and their food sources) is high since 45 percent of the residents engage in fishing activities. In addition, the annual flood helps to bring back important moisture and nutrients to the agricultural lands close to the river and replenishes seasonal water bodies that, along with the Tobora River, are important sources of domestic water.

At this site, there are no environmental flow values for drought conditions. It is thought that the river frequently goes dry in drought years and the aquatic species present during those conditions often survive pools fed by springs or groundwater. However, from the ecological studies, it appears that most fish species do not use these tributaries in drought conditions and the resident populations of macroinvertebrates are less sensitive taxa which are able to survive in standing pools.

This suggests these tributaries are not critical for species survival and maintaining biodiversity in the Lower MRB. In addition, when pools stand for too long or become too small due to evaporation and lack of replenishment, there is the possibility of extreme conditions in specific water quality parameters, including increased temperatures and low levels of dissolved oxygen. There is also the chance of concentrating pollutants from humans (such as fertilizers, pesticides, and raw sewage) to unsafe levels for aquatic life. These conditions could become fatal for any aquatic organisms living in these pools. For these reasons, the EFA technical team decided that it is acceptable for this system to go dry in drought years and no environmental flow values have been set.

It is important to note that subsurface flow and/or groundwater are likely feeding these systems during dry periods, and there is evidence from the local communities that the river flows year round in a normal (or maintenance year), even during dry months. As such, groundwater management is very important in this catchment. If too much groundwater is abstracted that is hydrologically connected to the river, it could prevent low flows from occurring during maintenance years.

In the environmental flow recommendations below, there are some months where the environmental flow exceeds the average flow for that month. There are significant uncertainties associated with the average flow found using regionalization during the dry months since regionalization is based on rainfall-runoff relationships and cannot account for water that comes from groundwater or springs. It is likely that the Tobora River system is fed by groundwater (either shallow subsurface flow or deeper aquifers) but there have been no studies completed on this topic. In addition, there is no river gauging station at this site. As such, there is no historical data record to compare the regionalization results to see how closely they match actual conditions. This further stresses the need to establish a river gauging station at this site to begin collecting data on the hydrological conditions in the Tobora River. Once a substantial data record has been built (at least a few years of daily water level and flow data), then these EFA results should be revisited and revised as needed. See Section 6.3.1 for more details on the uncertainties related to basin hydrology.

The full results of the environmental flow values at

Table 5-21: Environmental flow values for Tobora

	Index	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Avg.	Annual Total
	Average flow (m³/s)	0.21	0.43	0.75	0.49	0.45	0.83	1.38	1.50	0.46	0.18	0.03	0.19	0.58	
Maintenance Year	**Monthly low flows**														
	Environmental flow (m³/s)	0.23	0.33	0.47	0.35	0.34	0.50	0.75	**0.80**	0.34	0.21	**0.15**	0.22	0.39	
	% Average flow	108%	76%	62%	72%	74%	61%	54%	53%	74%	121%	431%	116%	68%	
	Magnitude (m³/day)	19,717	28,206	40,594	30,508	29,082	43,542	64,604	69,120	29,338	18,378	12,960	18,887	33,745	
	Magnitude (Mm³/month)	0.61	0.85	1.26	0.95	0.81	1.35	1.94	2.14	0.88	0.57	0.40	0.57		12.32
	Annual freshets and floods														
	Magnitude (m³/day)	0	34,272	33,166	0	0	0	34,272	190,637	0	0	0	0	24,362	
	Magnitude (Mm³/month)	0	1.03	1.03	0	0	0	1.03	5.91	0	0	0	0		8.99
	Total: m³/day	**19,717**	**62,478**	**73,760**	**30,508**	**29,082**	**43,542**	**98,876**	**259,757**	**29,338**	**18,378**	**12,960**	**18,887**	**58,107**	
	Total: Mm³/month	**0.61**	**1.87**	**2.29**	**0.95**	**0.81**	**1.35**	**2.97**	**8.05**	**0.88**	**0.57**	**0.40**	**0.57**		**21.32**
Drought Year	**Monthly low flows**														
	Environmental flow (m³/s)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	% Average flow	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnitude (m³/day)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnitude (Mm³/month)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Annual freshets and floods														
	Magnitude (m³/day)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnitude (Mm³/month)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total: m³/day	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total: Mm³/month	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Environmental flow values in bold indicate those determined during flow setting technical meeting

Mm³ = million cubic meters

Table 5-22: Freshet and flood events for environmental flows for Tobora

	Month	Type	Flow (m^3/s)	Duration (days)	Individual Magnitude (Mm^3)	Combined Magnitude* (Mm^3)
Maintenance Year	***Annual Events***					
	Nov	Freshet	1.7	7	1.03	1.03
	Dec	Freshet	1.7	7	1.03	1.03
	Apr	Freshet	1.7	7	1.03	1.03
	May	Freshet	1.7	14	2.06	5.91
		Flood	24	2	4.15	
	Additional Events*					
	May	3-year flood	97	3	25.14	25.14

**Combined magnitude values incorporate the magnitude of smaller events into the magnitude of the larger events to avoid double counting*

***Additional events are not included in the annual magnitude calculations for environmental flows*

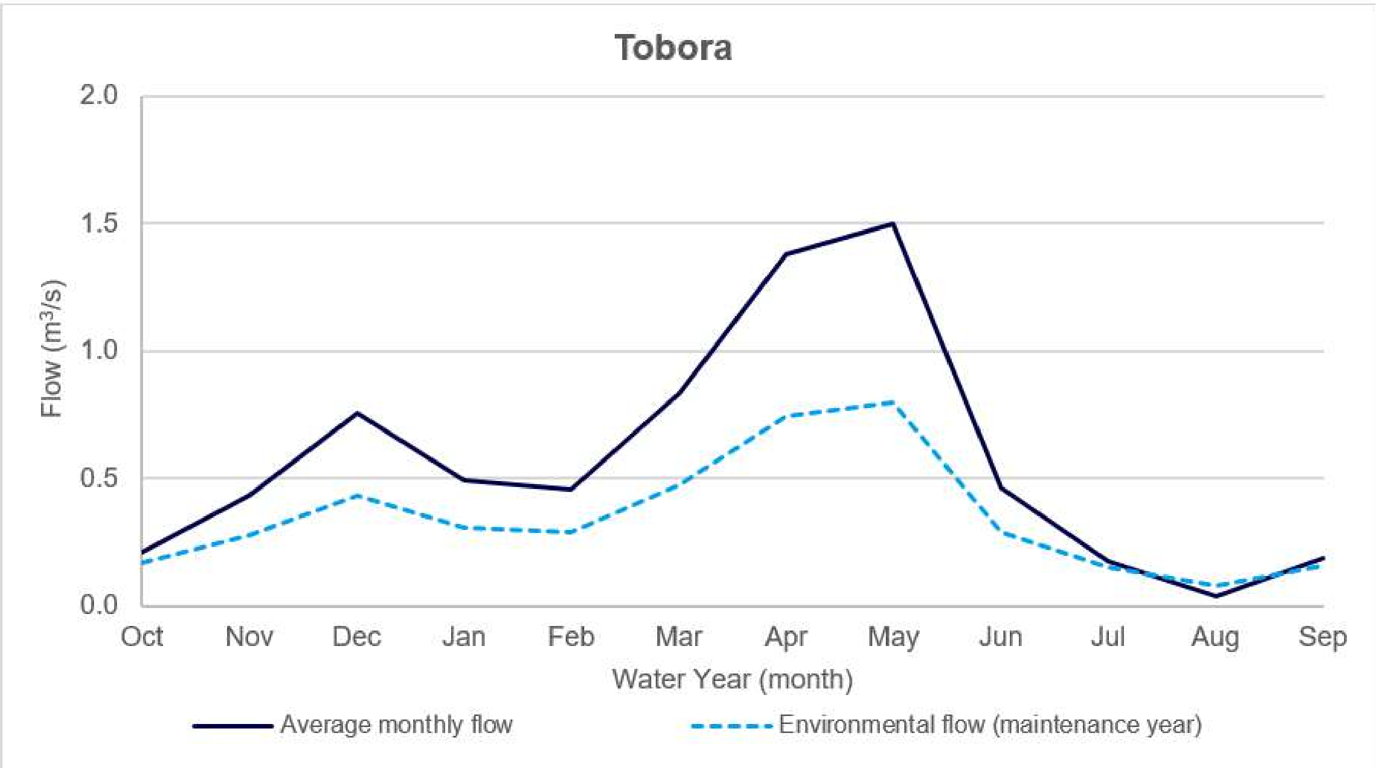


Figure 5-2: Environmental flow values for Tobora

Tobora are presented in Table 5 21, details on freshets and flow values are in Table 5 22 , and environmental flow values are graphed in Figure 5 2.

5.3.3 Somoche

The motivations and consequences for environmental flows at Somoche are similar to those found at Tobora. Something specific to Somoche is the presence of rare vulnerable fish species. Maintaining refreshed pools during the dry season low flows, access to riffles and other feeding areas during wet season low flows, and providing access to additional habitats during freshets and floods are all critical for the survival of these species. Not providing these conditions could result in a loss of abundance, or in cases of prolonged extreme drought, extinction of these species. Local communities use the Somoche River as an important source of domestic water and some flood recession agriculture.

Similar to Tobora, no environmental flow values are set for drought conditions at this site. The Somoche also is impacted by large uncertainties in the average flow values during dry months, causing the environmental flow values to be much larger than the average flow during these times. It is likely that the Somoche River system is also fed by groundwater (either shallow subsurface flow or deeper aquifers) but there have been no studies completed on this topic. In addition, there is no river gauging station at this site. As such, there is no historical data record to compare the regionalization results to see how closely they match actual conditions. This further stresses the need to establish a river gauging station at this site to begin collecting data on the hydrological conditions in the Somoche River. Once a substantial data record has been built (at least a few years of daily water level and flow data), then these EFA results should be revisited and revised as needed. See Section 6.3.1 for more details on the uncertainties related to basin hydrology.

The full results of the environmental flow values

Table 5-23: Environmental flow values for Somoche

	Index	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Avg.	Annual Total
	Average flow (m^3/s)	0.40	0.82	1.31	0.95	0.84	1.56	2.62	2.86	0.73	0.28	0.06	0.34	1.06	
Maintenance Year	**Monthly low flows**														
	Environmental flow (m^3/s)	0.37	0.46	0.57	0.49	0.47	0.62	0.85	**0.90**	0.44	0.35	**0.30**	0.36	0.52	
	% Average flow	93%	56%	43%	52%	56%	40%	32%	31%	61%	124%	500%	106%	48%	
	Magnitude (m^3/day)	32,215	39,991	49,063	42,398	40,361	53,691	73,317	77,760	38,325	29,993	25,920	31,104	44,511	
	Magnitude ($Mm^3/month$)	1.00	1.20	1.52	1.31	1.13	1.66	2.20	2.41	1.15	0.93	0.80	0.93		16.25
	Annual freshets and floods														
	Magnitude (m^3/day)	0	15,552	15,050	0	0	0	15,552	271,463	0	0	0	0	26,468	
	Magnitude ($Mm^3/month$)	0	0.47	0.47	0	0	0	0.47	8.42	0	0	0	0		9.82
	Total: m^3/day	**32,215**	**55,543**	**64,113**	**42,398**	**40,361**	**53,691**	**88,869**	**349,223**	**38,325**	**29,993**	**25,920**	**31,104**	**70,980**	
	Total: $Mm^3/month$	**1.00**	**1.67**	**1.99**	**1.31**	**1.13**	**1.66**	**2.67**	**10.83**	**1.15**	**0.93**	**0.80**	**0.93**		**26.07**
Drought Year	**Monthly low flows**														
	Environmental flow (m^3/s)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	% Average flow	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnitude (m^3/day)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnitude ($Mm^3/month$)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Annual freshets and floods														
	Magnitude (m^3/day)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnitude ($Mm^3/month$)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total: m^3/day	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total: $Mm^3/month$	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Environmental flow values in bold indicate those determined during flow setting technical meeting

Mm^3 = million cubic meters

Table 5-24: Freshet and flood events for environmental flows for Somoche

	Month	Type	Flow (m^3/s)	Duration (days)	Individual Magnitude (Mm^3)	Combined Magnitude* (Mm^3)
Maintenance Year	***Annual Events***					
	Nov	Freshet	2.7	2	0.47	0.47
	Dec	Freshet	2.7	2	0.47	0.47
	Apr	Freshet	2.7	2	0.47	0.47
	May	Freshet	2	21	3.63	8.42
		Freshet	3	2	0.47	
		Flood	20	3	5.18	
	Additional Events*					
	May	3-year flood	70	2	12.10	12.10

**Combined magnitude values incorporate the magnitude of smaller events into the magnitude of the larger events to avoid double counting*

***Additional events are not included in the annual magnitude calculations for environmental flows*

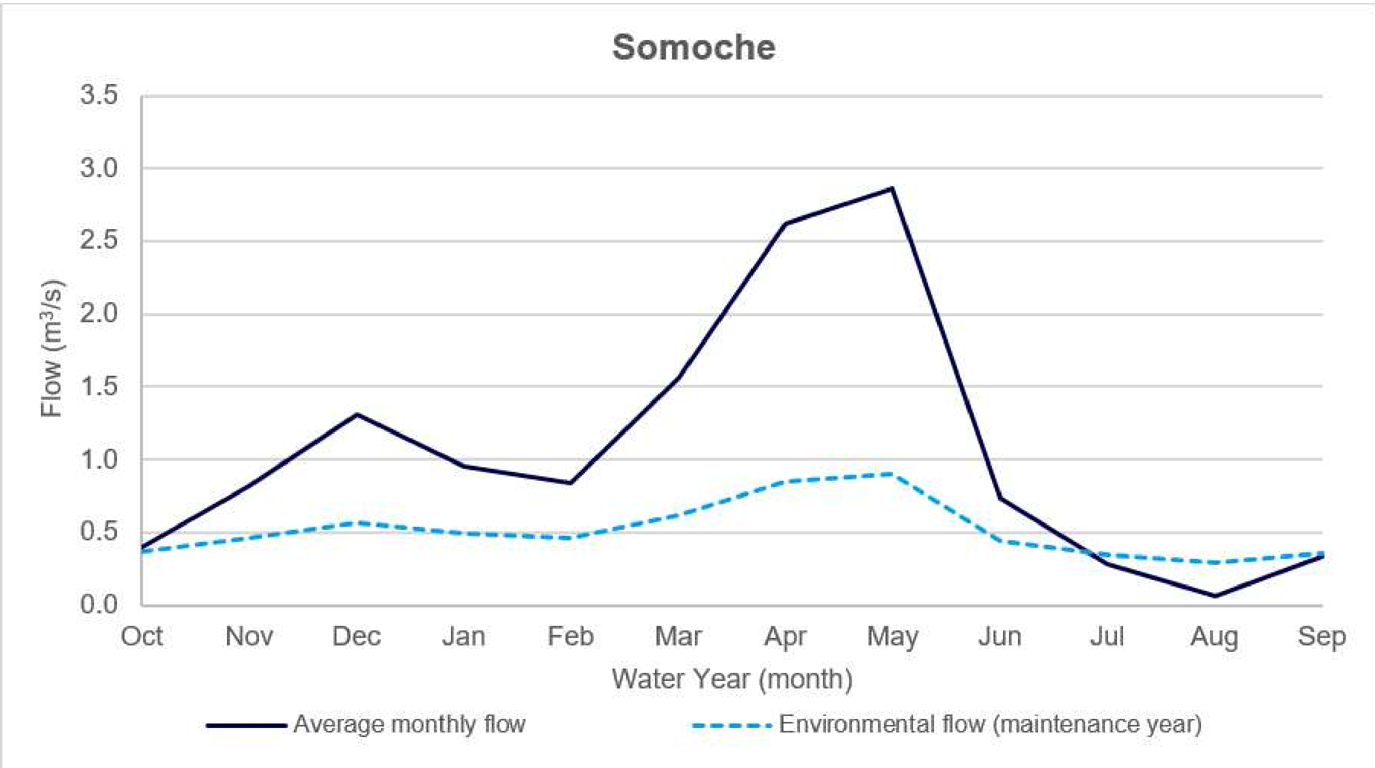


Figure 5-3: Environmental flow values for Somoche

at Somoche can be found in Table 5 23, details on freshets and flow values in Table 5 24, and graph of the environmental flow values in Figure 5 3.

5.3.4 Tigithe

There are many similarities between Tobora, Somoche, and Tigithe as they are tributaries with similar topography and geomorphology. As such, the motivations and consequences for geomorphology, riparian vegetation, macroinvertebrates, and water quality are the same as described for Tobora. However, since it is connected directly to the Mara Wetland and not the mainstem of the Mara River, there are important differences in the fish communities present at the site. During the dry season low flows, it is important that pools are regularly refreshed, and shallow riffles are maintained for resident fish. If dry season low flows are not met, the available habitat for resident species can impact biodiversity in the fish community. The wet season low flows are important for providing feeding and refuge habitats for resident and sensitive species of fish, as well as deep pools and other habitats suitable for wetland species of fish. If the wet season low flows are not met, this could impact species' ability to condition and recruit, potentially having a long-term impact on abundance and species viability. Freshets are required to allow the movement of migratory fish between habitats, in particular between the wetland and river. Freshets are important for cueing fish breeding, especially moving wetland species up into the river. Riffle and rapid habitats are also needed for rheophilic fish species. If these conditions are not met, critical habitats for fish species may not be available and abundance and biodiversity may be reduced. For the local communities, it is important to maintain proper fish populations (and their food sources) since 20 percent of the residents engage in fishing activities. In addition, the annual flood helps to bring back important moisture and nutrients to the agricultural lands close to the river and replenishes seasonal water bodies that, along with the Tigithe River, are important sources of domestic water.

Motivations and consequences are similar between maintenance years and drought years. If drought conditions last too long, there is a chance of extinction of local endemic fish species. Due to water pollution concerns in the Tigithe system from nearby mining activities, it is also important to have regular freshets to flush any pollutants from standing pools, which are critical refuge during a drought. While the hydrology is uncertain in the system, it is hypothesized that low flows come from subsurface and/or groundwater. As such, it is important to properly manage groundwater resources to ensure these flows continue to contribute to the river system. Similar to Tobora and Somoche, there are some months where the environmental flow exceeds (sometimes by a large amount) the average flow for that month. There are significant uncertainties associated with the average flow found using regionalization during the dry months since regionalization is based on rainfall-runoff relationships and cannot account for water that comes from groundwater or springs. It is unknown how groundwater is contributing to the system as there have been no studies conducted on this topic. There is also no historical flow record in the Tigithe, so the actual hydrological regime is unknown. This further stresses the need to establish a river gauging station at this site to begin collecting data on the hydrological conditions. Once a substantial data record has been built (at least a few years of daily water level and flow data), then these EFA results should be revisited and revised as needed. See Section 6.3.1 for more details on the uncertainties related to basin hydrology. The full results of the environmental flow

Table 5-25: Environmental flow values for Tigithe

	Index		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Avg.	Annual Total
	Average flow (m^3/s)		0.17	0.24	0.37	0.22	0.16	0.45	0.89	0.77	0.27	0.13	0.02	0.13	0.32	
Maintenance Year	**Monthly low flows**															
	Environmental flow (m^3/s)		0.13	0.14	0.16	0.13	0.12	0.18	**0.25**	0.23	0.14	0.12	**0.10**	0.12	0.15	
	% Average flow		74%	57%	44%	62%	78%	39%	28%	30%	54%	93%	615%	93%	48%	
	Magnitude (m^3/day)		10,939	12,029	13,897	11,622	10,763	15,135	21,600	19,803	12,355	10,310	8,640	10,312	13,117	
	Magnitude ($Mm^3/month$)		0.34	0.36	0.43	0.36	0.30	0.47	0.65	0.61	0.37	0.32	0.27	0.31		4.79
	Annual freshets and floods															
	Magnitude (m^3/day)		0	25,632	24,805	0	0	0	25,632	189,801	0	0	0	0	22,156	
	Magnitude ($Mm^3/month$)		0	0.77	0.77	0	0	0	0.77	5.88	0	0	0	0		8.19
	Total:	**m^3/day**	**10,939**	**37,661**	**38,703**	**11,622**	**10,763**	**15,135**	**47,232**	**209,604**	**12,355**	**10,310**	**8,640**	**10,312**	**35,273**	
	Total:	**$Mm^3/month$**	**0.34**	**1.13**	**1.20**	**0.36**	**0.30**	**0.47**	**1.42**	**6.50**	**0.37**	**0.32**	**0.27**	**0.31**		**12.98**
Drought Year	**Monthly low flows**															
	Environmental flow (m^3/s)		0.01	0.01	0.02	0.01	0.01	0.03	**0.05**	0.04	0.01	0.01	**0.00**	0.01	0.02	
	% Average flow		5%	5%	5%	5%	5%	6%	6%	6%	5%	5%	0%	5%	5%	
	Magnitude (m^3/day)		766	1,130	1,752	994	708	2,165	4,320	3,721	1,238	557	0	557	1,492	
	Magnitude ($Mm^3/month$)		0.02	0.03	0.05	0.03	0.02	0.07	0.13	0.12	0.04	0.02	0.00	0.02		0.55
	Annual freshets and floods															
	Magnitude (m^3/day)		0	12,096	19,788	0	0	0	20,448	102,008	0	0	0	0	12,862	
	Magnitude ($Mm^3/month$)		0	0.36	0.61	0	0	0	0.61	3.16	0	0	0	0		4.75
	Total:	**m^3/day**	**766**	**13,226**	**21,541**	**994**	**708**	**2,165**	**24,768**	**105,729**	**1,238**	**557**	**0**	**557**	**14,354**	
	Total:	**$Mm^3/month$**	**0.02**	**0.40**	**0.67**	**0.03**	**0.02**	**0.07**	**0.74**	**3.28**	**0.04**	**0.02**	**0.00**	**0.02**		**5.30**

Environmental flow values in bold indicate those determined during flow setting technical meeting

Mm^3 = million cubic meters

Table 5-26: Freshet and flood events for environmental flows for Tigithe

	Month	Type	Flow (m^3/s)	Duration (days)	Individual Magnitude (Mm^3)	Combined Magnitude* (Mm^3)
Maintenance Year	***Annual Events***					
	Nov	Freshet	1	7	0.60	0.77
		Freshet	2.9	1	0.25	
	Dec	Freshet	1	7	0.60	0.77
		Freshet	2.9	1	0.25	
	Apr	Freshet	1	7	0.60	0.77
		Freshet	2.9	1	0.25	
	May	Freshet	2.1	21	0.60	5.88
		Freshet	2.9	1	3.81	
		Flood	26	2	4.49	
	Additional Events*					
	May	3-year flood	43	1	3.72	3.72
Drought Year	***Annual Events***					
	Nov	Freshet	0.6	7	0.36	0.36
	Dec	Freshet	0.6	7	0.36	0.61
		Freshet	2.9	1	0.25	
	Apr	Freshet	0.6	7	0.36	0.61
		Freshet	2.9	1	0.25	
	May	Freshet	0.25	14	0.30	3.16
		Freshet	0.6	7	0.36	
		Freshet	2.9	1	0.25	
		Flood	26	1	2.25	

**Combined magnitude values incorporate the magnitude of smaller events into the magnitude of the larger events to avoid double counting*

***Additional events are not included in the annual magnitude calculations for environmental flows*

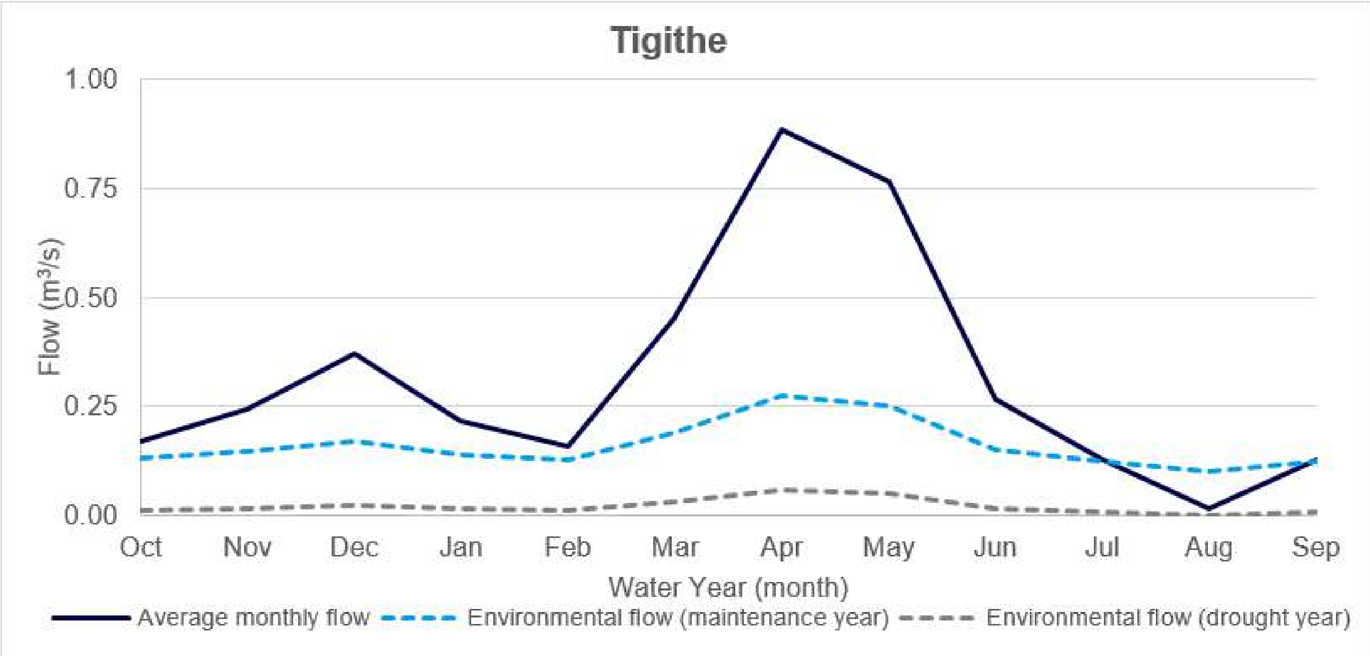


Figure 5-4: Environmental flow values for Tigithe

values at Tigithe can be found in Table 5 23, details on freshets and flow values in Table 5 24, and graph of the environmental flow values in Figure 5 3.

5.3.5 Mara Mines

The motivations and consequences for the Mara Mines EFA study site are similar to those presented for Kogatende because they are both located on the mainstem of the Mara River and the sites provide similar ecological functions. However, crocodiles and hippopotamuses are not commonly seen at this site, and as such, their habitat needs were not considered for this site. One ecosystem function that is specific to Mara Mines is the movement of sediments. Since the substrate is predominantly sand, it is important that higher flows, freshets, and floods move sand and gravels through the system and scour the sand, ensuring gravel bars are maintained and exposed. Otherwise sand will fill important in-channel gravel habitats.

Another prominent difference between Mara Mines and Kogatende is that many local communities utilize the Mara River at Mara Mines (whereas there are no local communities at Kogatende). For these communities, the importance of maintaining proper fish populations is high since 45 percent of the local residents engage in fishing activities. In addition, the annual flood helps to bring back important moisture and nutrients to the agricultural lands close to the river and replenishes seasonal water bodies that are important sources of domestic water. Water quality during the dry months is also important as there is a chance of concentrating pollutants from humans (such as fertilizers, pesticides, and raw sewage) to unsafe levels, causing the water to be unusable for agriculture (i.e., high levels of salts) and/or unsafe for consumption, causing outbreaks in water borne diseases.

The full results of the environmental flow values at

Table 5-27: Environmental flow values for Mara Mines

	Index	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Avg.	Annual Total
	Average flow (m^3/s)	20.19	21.29	28.73	23.46	19.00	26.26	53.34	61.98	33.12	23.93	26.27	32.52	30.84	
Maintenance Year	**Monthly low flows**														
	Environmental flow (m^3/s)	**3.60**	3.80	5.85	4.40	3.17	5.17	12.62	**15.00**	7.06	4.53	5.17	6.89	6.43	
	% Average flow	17%	18%	20%	19%	17%	20%	24%	24%	21%	19%	20%	21%	21%	
	Magnitude (m^3/day)	302,400	328,668	505,346	380,118	274,207	446,719	1,090,454	1,296,000	609,788	391,377	447,000	595,562	555,637	
	Magnitude ($Mm^3/month$)	9.37	9.86	15.67	11.78	7.68	13.85	32.71	40.18	18.29	12.13	13.86	17.87		203.25
	Annual freshets and floods														
	Magnitude (m^3/day)	0	561,600	543,484	0	0	0	561,600	2,770,374	0	0	0	0	369,755	
	Magnitude ($Mm^3/month$)	0	16.85	16.85	0	0	0	16.85	85.88	0	0	0	0		136.43
	Total: m^3/day	**302,400**	**890,268**	**1,048,830**	**380,118**	**274,207**	**446,719**	**1,652,054**	**4,066,374**	**609,788**	**391,377**	**447,000**	**595,562**	**925,392**	
	Total: $Mm^3/month$	**9.37**	**26.71**	**32.51**	**11.78**	**7.68**	**13.85**	**49.56**	**126.06**	**18.29**	**12.13**	**13.86**	**17.87**		**339.68**
Drought Year	**Monthly low flows**														
	Environmental flow (m^3/s)	**1.80**	1.95	2.98	2.25	1.64	2.64	6.40	**7.60**	3.59	2.32	2.64	3.51	3.28	
	% Average flow	9%	9%	10%	10%	9%	10%	12%	12%	11%	10%	10%	11%	11%	
	Magnitude (m^3/day)	155,520	168,768	257,875	194,717	141,301	228,307	552,973	656,640	310,551	200,395	228,449	303,376	283,239	
	Magnitude ($Mm^3/month$)	4.82	5.06	7.99	6.04	3.96	7.08	16.59	20.36	9.32	6.21	7.08	9.10		103.61
	Annual freshets and floods														
	Magnitude (m^3/day)	0	201,600	195,097	0	0	0	201,600	1,287,639	0	0	0	0	157,161	
	Magnitude ($Mm^3/month$)	0	6.05	6.05	0	0	0	6.05	39.92	0	0	0	0		58.06
	Total: m^3/day	**155,520**	**370,368**	**452,972**	**194,717**	**141,301**	**228,307**	**754,573**	**1,944,279**	**310,551**	**200,395**	**228,449**	**303,376**	**440,401**	
	Total: $Mm^3/month$	**4.82**	**11.11**	**14.04**	**6.04**	**3.96**	**7.08**	**22.64**	**60.27**	**9.32**	**6.21**	**7.08**	**9.10**		**161.67**

Environmental flow values in bold indicate those determined during flow setting technical meeting

Mm^3 = million cubic meters

Table 5-28: Freshet and flood events for environmental flows for Mara Mines

	Month	Type	Flow (m^3/s)	Duration (days)	Individual Magnitude (Mm^3)	Combined Magnitude* (Mm^3)
Maintenance Year	***Annual Events***					
	Nov	Freshet	10	2	1.73	16.85
		Freshet	25	7	15.12	
	Dec	Freshet	10	2	1.73	16.85
		Freshet	25	7	15.12	
	Apr	Freshet	10	2	1.73	16.85
		Freshet	25	7	15.12	
	May	Freshet	10	2	1.73	85.88
		Freshet	46	21	83.46	
		Flood	74	1	6.39	
	Additional Events*					
	May	3-year flood	334	1	28.86	28.86
		6-year flood	498	1	43.03	43.03
Drought Year	***Annual Events***					
	Nov	Freshet	10	7	6.05	6.05
	Dec	Freshet	10	7	6.05	6.05
	Apr	Freshet	10	7	6.05	6.05
	May	Freshet	10	7	6.05	39.92
		Flood	22	21	39.92	
	Additional Events*					
	May	3-year flood	122	1	10.54	10.54

** Combined magnitude values incorporate the magnitude of smaller events into the magnitude of the larger events to avoid double counting*

***Additional events are not included in the annual magnitude calculations for environmental flows*

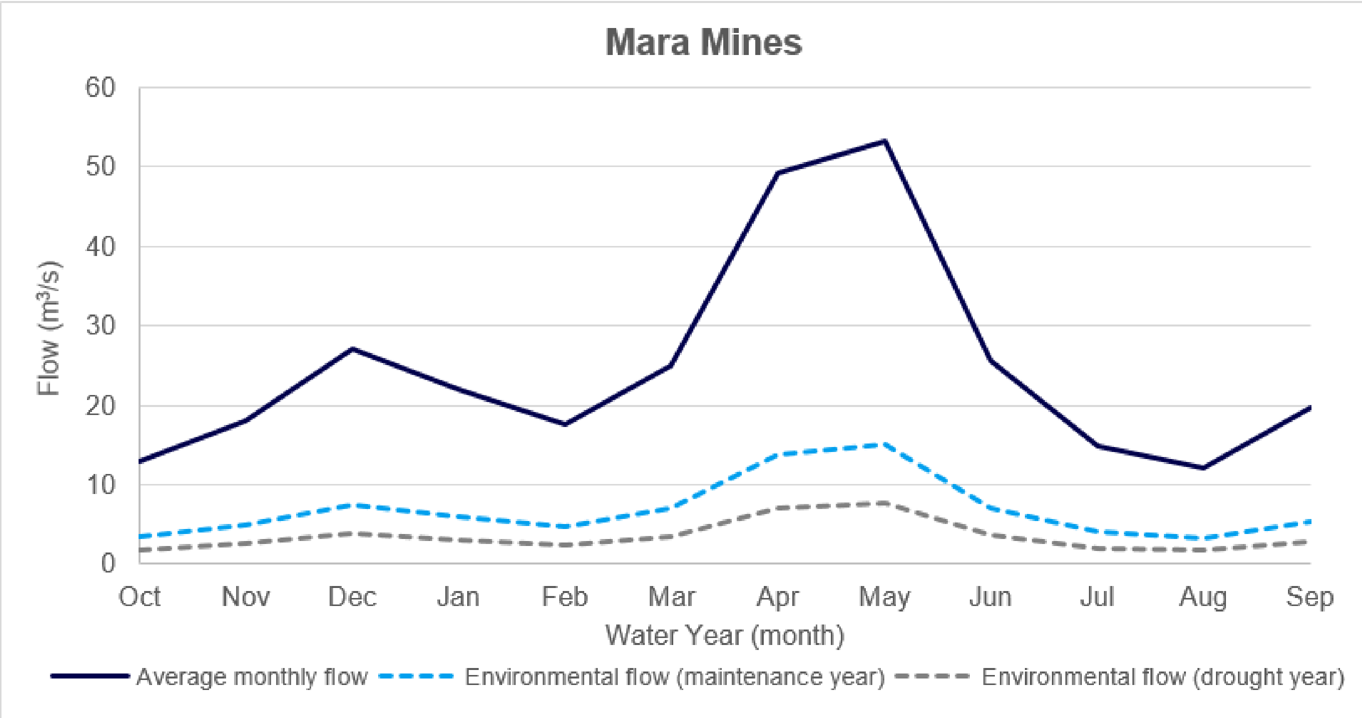


Figure 5-5: Environmental flow values for Mara Mines

Mara Mines can be found in Table 5 27, details on freshets and flow values in Table 5 28, and graph of the environmental flow values in Figure 5 5.

5.3.6 Bisarwi

Dry season low flows are set to support the survival of marginal vegetation. This marginal vegetation provides attachment sites for vegetation associated taxa. It also provides refuge habitat where wetland and migratory species of fish can feed and recruit. If these conditions are not met, there may be a reduction in abundance of marginal vegetation, sensitive and moderately sensitive macroinvertebrate communities, and indicator fish in the study area. During the wet season, low flows promote germination of lower zone plant species. Inundation of marginal vegetation also promotes larval development for a variety of taxa. It also enables resident fish species to breed and recruit, and migratory species to access to habitat and tributaries upstream. If these conditions are not met, there may be poor recruitment of lower zone plant species as well as fish species, potentially decreasing their populations. Many of the vegetation-associated macroinvertebrate taxa may also be reduced, potentially decreasing biodiversity in the area.

Freshets are important at this site because they inundate the higher banks and reach the marginal vegetation. If freshets do not occur, it reduces the chances for reproduction and recruitment of plant species. When this system floods, distributaries are activated along the main channel and backswamp areas are inundated. This flooding is important to maintain connectivity between aquatic, riparian, and floodplain plant communities and provides nutrient inputs and increases moisture in floodplain soils. Access to the wetland and backswamp areas is important for macroinvertebrate diversity, as a wide range of taxa require access to water during their adult stages. Floods also allow floodplain preferring species of fish access to inundated floodplains and backswamp areas.

Because the river banks have formed levees, the main way of inundating the floodplain is through distributaries. If the flood flows are not met, these distributaries will not be activated and maintained, which will reduce the connectivity between the river and floodplain habitats. If floods are not met, it is possible that wetland areas will dry up, allowing terrestrial plant species to encroach on wetland and riparian areas. If the wetlands dry up, many taxa would be lost in the inundated areas, predation would increase in the main channel, and there would be a change in the macroinvertebrate community structure. A lack of access to the floodplain would also prevent some fish species from reproducing, reducing biodiversity in the area.

During drought periods, dry season low flows provide enough water to support the survival of marginal zone vegetation, while wet season low flows provide water to both the marginal and lower zone. Small floods provide enough water to propagate various annual and perennial species. Without these flows, the abundance of flow-sensitive and riparian species may be diminished, as might the habitats for vegetation-associated macroinvertebrate taxa. Dry season low flows provide refreshed pools for fish and macroinvertebrate species while wet season low flows and floods provide relief from extreme drought conditions. It also provides habitat for some species to breed and recruit and other species to move upstream to find additional habitat. When flows become too low, there is the possibility of extreme conditions in specific water quality parameters, including increased temperatures and low levels of dissolved oxygen. There is also the chance of concentrating pollutants from humans (such as fertilizers, pesticides, and raw sewage) to unsafe levels, causing the water to be unusable for agriculture (i.e., high levels of salts) and/or unsafe for consumption.

For the local communities, the importance of maintaining sufficient fish populations (and their food sources) is high since more than 60 percent of the residents engage in fishing activities. In addition, the annual flood helps to bring back important moisture and nutrients to the agricultural lands, and replenishes seasonal water bodies that, along with the Mara River, are important sources of domestic water.

The full results of the environmental flow values

Table 5-29: Environmental flow values for Bisarwi

	Index	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Avg.	Annual Total
	Average flow (m³/s)	20.76	22.10	29.88	24.19	19.50	27.74	56.30	64.48	33.97	24.34	26.32	32.95	31.88	
Maintenance Year	**Monthly low flows**														
	Environmental flow (m³/s)	3.25	3.52	5.08	3.94	**3.00**	4.65	10.36	**12.00**	5.90	3.97	4.36	5.69	5.48	
	% Average flow	16%	16%	17%	16%	15%	17%	18%	19%	17%	16%	17%	17%	17%	
	Magnitude (m³/day)	280,886	304,066	438,550	340,120	259,200	401,546	895,365	1,036,800	509,348	342,861	377,100	491,663	473,126	
	Magnitude (Mm³/month)	8.71	9.12	13.60	10.54	7.26	12.45	26.86	32.14	15.28	10.63	11.69	14.75		173.02
	Annual freshets and floods														
	Magnitude (m³/day)	0	115,200	418,065	0	0	0	115,200	1,532,903	0	0	0	0	181,781	
	Magnitude (Mm³/month)	0	3.46	12.96	0	0	0	3.46	47.52	0	0	0	0		67.39
	Total: m³/day	**280,886**	**419,266**	**856,615**	**340,120**	**259,200**	**401,546**	**1,010,565**	**2,569,703**	**509,348**	**342,861**	**377,100**	**491,663**	**654,906**	
	Total: Mm³/month	**8.71**	**12.58**	**26.56**	**10.54**	**7.26**	**12.45**	**30.32**	**79.66**	**15.28**	**10.63**	**11.69**	**14.75**		**240.42**
Drought Year	**Monthly low flows**														
	Environmental flow (m³/s)	1.15	1.32	2.27	1.57	**1.00**	2.01	5.50	**6.50**	2.77	1.59	1.83	2.64	2.51	
	% Average flow	6%	6%	8%	7%	5%	7%	10%	10%	8%	7%	7%	8%	8%	
	Magnitude (m³/day)	99,653	113,818	196,003	135,851	86,400	173,390	475,168	561,600	239,268	137,526	158,450	228,461	217,132	
	Magnitude (Mm³/month)	3.09	3.41	6.08	4.21	2.42	5.38	14.26	17.41	7.18	4.26	4.91	6.85		79.46
	Annual freshets and floods														
	Magnitude (m³/day)	0	345,600	0	0	0	0	0	334,452	0	0	0	0	56,671	
	Magnitude (Mm³/month)	0	10.37	0	0	0	0	0	10.37	0	0	0	0		20.74
	Total: m³/day	**99,653**	**459,418**	**196,003**	**135,851**	**86,400**	**173,390**	**475,168**	**896,052**	**239,268**	**137,526**	**158,450**	**228,461**	**273,803**	
	Total: Mm³/month	**3.09**	**13.78**	**6.08**	**4.21**	**2.42**	**5.38**	**14.26**	**27.78**	**7.18**	**4.26**	**4.91**	**6.85**		**100.19**

Environmental flow values in bold indicate those determined during flow setting technical meeting

Mm³ = million cubic meters

Table 5-30: Freshet and flood events for environmental flows for Bisarwi

	Month	Type	Flow (m^3/s)	Duration (days)	Individual Magnitude (Mm^3)	Combined Magnitude* (Mm^3)
Maintenance Year	***Annual Events***					
	Nov	Freshet	20	2	3.46	3.46
	Dec	Freshet	50	3	12.96	12.96
	Apr	Freshet	20	2	3.46	3.46
	May	Freshet	50	10	43.20	47.52
		Flood	75	2	12.96	
	Additional Events*					
	May	3-year flood	100	3	25.92	25.92
Drought Year	***Annual Events***					
	Nov	Freshet	12	10	10.37	10.37
	May	Freshet	12	10	10.37	1.37

** Combined magnitude values incorporate the magnitude of smaller events into the magnitude of the larger events to avoid double counting*

***Additional events are not included in the annual magnitude calculations for environmental flows*

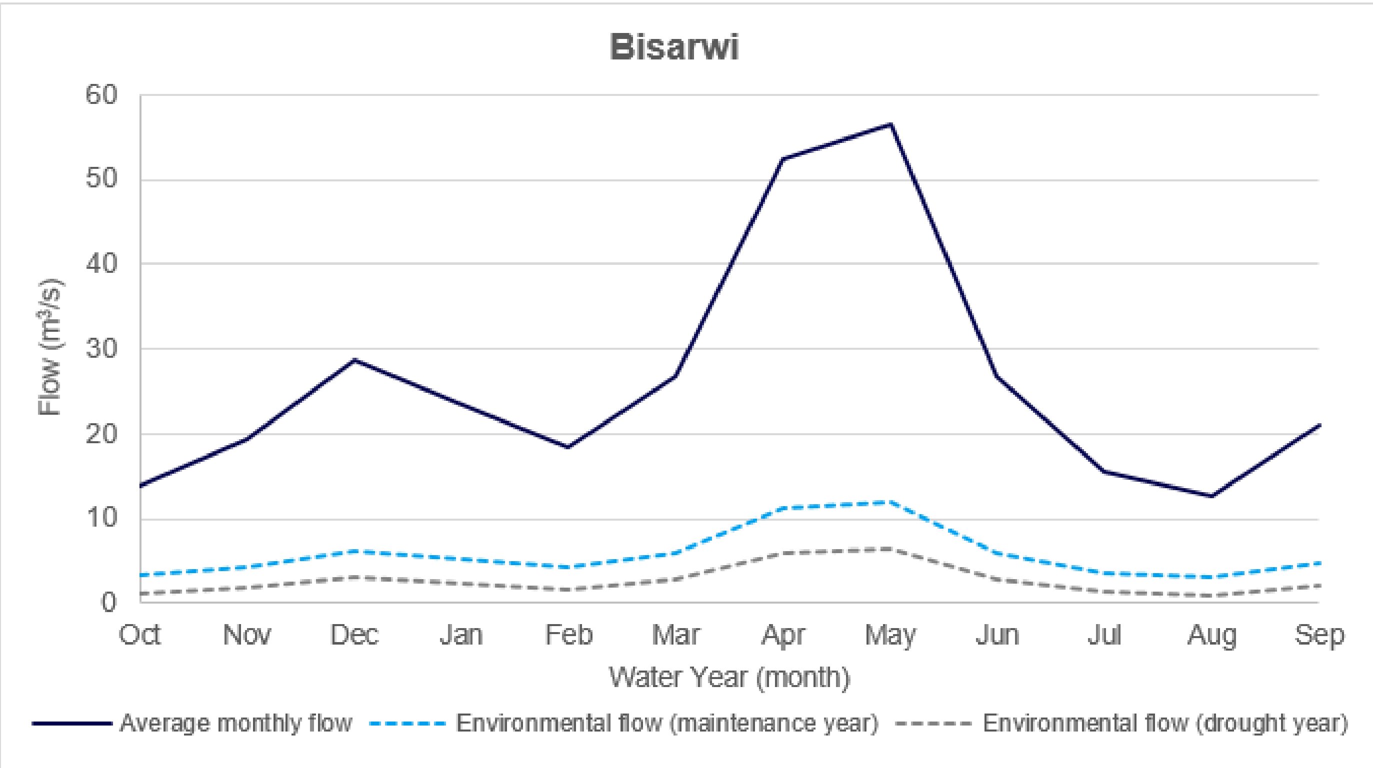


Figure 5-6: Environmental flow values for Bisarwi

at Bisarwi can be found in Table 5 29, details on freshets and flow values in Table 5 30, and graph of the environmental flow values in Figure 5 6.

5.3.7 Mara Wetland

The Mara Wetland EFA study site has specific conditions that make it untenable to set environmental flow values. Firstly, the hydrology of the site shows evidence of being influenced by the level of Lake Victoria, potentially significant inputs from groundwater, as well as upstream inputs from both the mainstem Mara River and the Tigithe River. However, the exact influence each of these vary depending on location in the Mara Wetland, the time of day due to tides in the lake, and the time of year due to changes in river flows. In addition, different hydrological sources may support satellite lakes and small local wetlands located on the edges of the main wetland. This makes it very difficult to quantify how much flow would be required from upstream rivers to maintain ecological and social functions in the system. Secondly, the cross-section of the main Mara Wetland at the EFA study site is covered by floating papyrus vegetation which limits access. This made it impossible to measure left and right bank boundaries of the cross-section or to know how much water and associated water velocities were under the mat of papyrus. While the technical team made measurements at this site, many assumptions were necessary when developing the cross-section and the associated hydraulic model. This reduced confidence in this model to the point that the technical team decided it should not be used. It was decided that the technical team would provide only depth estimates for the different hydrological components based on their field assessments, and that these depth estimates would serve as recommendations for this site. When more data can be collected on the hydrology and hydraulics of the site, additional analyses can be completed to determine environmental flow values. These depth recommendations do meet the conditions of the RQOs, targets, and indicators outlined in Section 5.1.7 since the ecological and social functions at this site are more dependent on inundation depths and time rather than flows.

Maintenance Year

Dry season low flows: August, Depth: 2.7m

Dry season low flows support the survival and recruitment of flow sensitive plant species, including macrophytes that provide necessary attachment sites for certain taxa of macroinvertebrates. These flows also provide refuge habitats for resident wetland species and some migratory species of fish. If these flows are not met, it could decrease the abundance of macrophyte species, impacting macroinvertebrate attachment and young fish recruitment. This could lead to a decrease in macroinvertebrate and fish abundance.

Wet season low flows: May, Depth: 3.3m

Wet season low flows inundate the lower parts of the wetland and support the growth of sedge and grass species. These flows provide habitats for resident fish to breed and recruit by opening access to inundated sedges and allow migratory fish enough water to move upstream to other habitats in the interior of the wetland. The flows provide enough habitat for reproduction and larval development of a variety of macroinvertebrate taxa. If these flows are not met, it could inhibit development of sedge and grass species, decrease the abundance and diversity of macroinvertebrate taxa, and stress fish populations

Freshets and floods:

1 freshet at 4 m for 14 days (annual), 2 freshets at 5 m for 10 days each in May and Nov (annual), 1 flood event at 4.8 m for 14 days (1 in 2 years)

The annual flood should reach the tree line at the site. This will reduce encroachment of terrestrial vegetation as well as deposit silt and clay to replenish moisture and nutrients in the soil. The inundation also connects important wetland and floodplain habitats, which promotes the movement of plant propagules over a large area, encourages germination and growth of woody plant species in the floodplain, and provides floodplain-preferring fish access to new habitats. These inundated areas also provide good habitat for taxa of macroinvertebrates that need aquatic environments during their adult stages. If the floods are not achieved, this would cause a disruption to sediment and nutrient distribution in the outer edges of the wetland, potentially changing plant communities from wetland to terrestrial, altering flow patterns into the wetland from surface runoff, and degrading the quality of wetland habitat for plants, fish, and macroinvertebrates. This could include negative consequences on community composition and biodiversity. Maintaining fish populations are important since 15 to 40 percent of the local communities engage in fishing activities.

Drought Year

Dry season low flows: Aug, Depth: 2.4m

The motivations and consequences are similar to those in a maintenance year. In a drought year, the dry season low flows also ensure good water quality to promote better growth of macrophyte species, which are also important habitat areas for vegetation associated macroinvertebrates. If these flows are not met, it could lead to a decrease in abundance of macrophytes and the species they support.

Wet season low flows: May, Depth: 2.8m

The motivations and consequences are similar to those in a maintenance year. In a drought year, the wet season low flows also provide moisture to sedge, grass, and forb plant species at the edge of the permanent wetland area, supporting their survival during dry times. It also opens up habitat to fish and macroinvertebrate species. If these flows are not met, the plant community at the edge of the wetland could shift away from wetland species, impacting habitat for fish and macroinvertebrates.

Freshets and floods: 1 freshet of 3.2 m for 14 days (annual), 1 flood event of 4.4 m for 14 days (1 in 2 years)

The floods during a drought year have the same motivations and consequences, but to a lesser geographic extent as the inundated area will be smaller. It also helps to refresh the standing water in the wetland and flush out organic matter on the edges of the wetland, promoting the germination of sedge, grass, and forb species. It also would reduce the chance of developing extreme hypoxic conditions in the wetland. A lack of these floods could lead to poor germination and abundance of sedge, grass, and forb species on the edge of the wetland and reduce the abundance of fish and macroinvertebrates.

5.4 Monitoring and Adaptive Management

Monitoring for the Reserve

The reserve is an important value for effective implementation of water resources management in the Lower MRB, but it is not a static value. As conditions in the basin change, the reserve values should be updated regularly for both basic human needs and environmental flows. For basic human needs, the values should be updated using the latest census information, projected to the current planning year. The amount of water should also be updated to reflect any changes in legislation or international best practice. For environmental flows, there are two main monitoring objectives: to ensure the environmental flows are being maintained in the river (compliance monitoring) and to ensure that aquatic ecosystems and important ecosystem services are being protected by the current environmental flow values (effectiveness monitoring).

Once these data have been collected, it is important that they are incorporated into management decision through clearly defined adaptive management cycles. For compliance monitoring, it is important that regular hydrological data are collected at monitoring sites. This can be achieved through automatic monitoring equipment or regular observations from local gauge readers who are able to send information to a central database. When flow values begin to approach the environmental flow value, management actions should be taken to reduce abstractions. Specific values and actions will be determined in the WAP for the Lower MRB, which is being developed by the MoW and the LVBWB. For effectiveness monitoring, information should be collected to allow for the regular assessment of ecological condition. This information can then be linked back to the EFA management objectives and the RQO targets and indicators to see if the objectives are being met. Since the environment flow values were determined using a variety of social and ecological indicators, a variety of monitoring activities should be used.The monitoring recommendations presented here should be reviewed regularly by the LVBWB and updated to reflect their capacity and management priorities. To align monitoring activities to different levels of institutional capacity (including financial and staff capacity), a three-level system is proposed (Figure 5 7). Each level requires different levels of resource commitments, including time, financial cost, and necessary expertise.

Level 1 techniques are non-technical and broad-scale, with data that can easily be collected by a member of the public. Level 2 techniques are easily reported, based on simple instruments, and data can be collected by a management authority who has a basic knowledge of hydrological or ecological processes. Level 3 techniques collect high quality and detailed data and are intended to be completed by experts in the field. While monitoring can be collected at any individual level, the data collected at one level should contribute to the knowledge needed at next level (e.g., basic information collected at Level 1 should provide a foundation of knowledge for information collected at Level 2). It is also not required to have monitoring activities at all three levels. The final monitoring plan

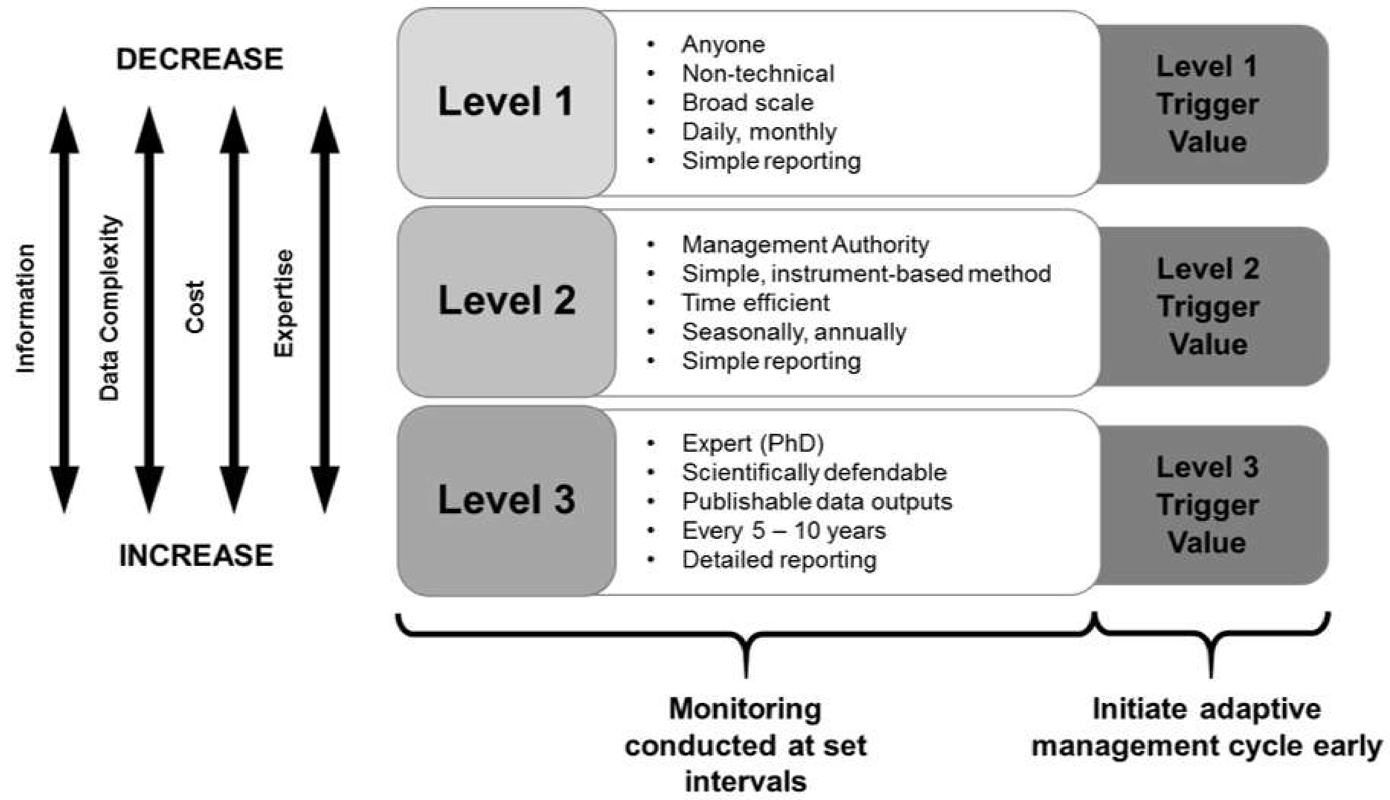


Figure 5-7: Description of the multi-level monitoring plan (CDM Smith, 2018)

should be based on staff and partner agency capacity, financial resources, and the availability of monitoring methods available to collect useful data at each level. Implementing monitoring in the three-level system encourages collaboration with local partners. Potential partners for monitoring include:

Level 1: WUA members, selected households (like those engaged in farming, timber products, non-timber products), village environmental committee, village health centres.

Level 2: Lake Victoria Basin Water Board, Musoma District Fisheries Department, district water engineer's office, other local government authorities, WWF, Nature Tanzania, and other NGOs.

Level 3: The Universities in Tanzania including; Sokoine University of Agriculture, University of Dar es Salaam, Tanzanian Fisheries Research Institute, Ministry of Health, development partners.

As part of the EFA, technical team members suggested specific monitoring activities, including sites, timing, and frequency for monitoring, which are closely linked to the RQO targets and indicators (Table 5 31). These activities were suggested to help provide more insight into the data gaps identified during the EFA process as well as ensuring the suggested EFA management objectives are being met. These will need to be reviewed with the LVBWB and local partners to finalize which activities would provide information critical for management decisions and which organizations would be best suited to carry out the activities.

For both compliance and effectiveness monitoring, it is critical that a functioning river monitoring network be established. At minimum, water levels need to be measured at each EFA sites at regular intervals, such as twice daily or hourly. These water levels can then be translated to flow using regularly updated site-specific rating curves. This allows the LVBWB to know if the reserve flows are being met and if management actions need to be taken, such as restricting abstractions by permit holders (the specific flows at which certain permit holders will be impacted will be determined in the WAP process). The water level can be measured using a variety of methods, including automatic pressure sensors that can measure water levels at specific intervals and send the data back to the LVBWB as well as community-based gauge readers (such as WUA members) that record and transmit information to the LVBWB at specific times of the day. The exact data collection method selected should be based on the capabilities of the LVBWB and its partners, but it should provide accurate, reliable, and timely information to the LVBWB.

The water level and flow information is important because the LVBWB needs to make important water management decisions to ensure the reserve is in compliance. To accurately assess how effective the reserve values are, the flows are also required since the condition of the ecosystem and communities will need to be assessed against the flow record. If the reserve is consistently met, then LVBWB managers and technical experts can assess if the current reserve values are effective in protecting aquatic ecosystems

and ecosystem services. It can help assess if other non-flow related issues are having a negative impact on the system. If the reserve flows are not met, it becomes difficult to determine if any decline in condition is due to lack of flow or other issues.
Maintaining a consistent and effective monitoring program can be a challenge, especially when there are limited funds available and large distances to cover, but there are steps that can be taken to ensure that critical information is available to decision makers when needed:

First, it is important to assign a monitoring program leader who will be responsible for maintaining the monitoring network, organizing the gathered data, and ensuring decision makers have access to the database. This person should also act as a "champion" for the monitoring program, who will apply creative problem solving as issues arise and ensure monitoring is considered a priority for fellow staff members, managers, and budget holders.

Second, it is important to prioritize the types of data collected. Data collection activities that are deemed critical (such as water levels) should be established first and monitored at all times, regardless of the financial situation. The collection of other data may need to be implemented in a phased approach or at a less frequent interval. While it may be difficult to decide which data are critical and which can wait, it is important to establish institutional priorities which are agreed upon by the monitoring program leader and water managers.

Third, it is important that the data collected are well-organized and maintained in a central database, with a quality review conducted on incoming data. Being able to easily read, visualize, and sort data is important for ensuring it will be used in decisions making, and having a review process in place will improve the quality and confidence in the data collected. This can be done using a simple spreadsheet program on a computer or through free, online databases, but the monitoring program leader should ensure it is accurate and up-to-date. It is also important that the EFA information be gathered in a central location and combined with monitoring data from other LVBWB actions. It should not be a standalone database but rather integrated with other LVBWB information so they can be easily compared and used in a variety of decision making activities.

Fourth, when deciding what monitoring methodologies should be used, there are trade-offs that can be made in terms of complexity, reliability, and expense. A simple monitoring method that provides fewer data points but is more reliable may be a better choice than a complex method that collects more data points but is prone to breaking down and expensive to repair. In addition, utilizing the WUAs and community members to gather simple data can be an affordable way to collect data across the basin without needing to travel long distances.

And finally, it is important the budget holders make it a priority to provide an annual monitoring budget for these activities. While there are ways to collect monitoring data in an affordable manner, there are regular expenses that the monitoring program needs to pay in order to function, such as money for fuel, repairs to the monitoring devices, and payments for local assistants. The monitoring program leader

Table 5-31: Reserve monitoring recommendations

Level	EFA Component	Monitoring Activity	Sites	Timing	Frequency
Level 1: Community groups	Social	Records on type of resources accrued from the Mara River Basin	In the household	Throughout in the year	Weekly
	Hydrology & hydraulics	Water level monitoring by local gauge readers	All sites	Same time every day, e.g. 8am	Daily
	Geomorphology	Take fixed point photos of the main geomorphic units, such as riffles, pools, benches, flood plain, etc.	All sites	During low flows after significant flow events	2 times per wet season
	Fish	Identify fish recruitment and diversity of species using simple scoop nets and or observing/monitoring fishermen	All sites, separate riverine sites from wetland sites.	Following flood recession	Every year during wet season
	Marco-invertebrates	TARISSfupi or miniSASS protocol (www.minisass.org)	All sites	Rainy and dry seasons	Quarterly during Feb, August, October
	Water quality	Monitor the general condition of the water (e.g., colour, smell, etc.). Report to the relevant authority any incidences that may be suspected to occur as a result of water quality issues such as disease outbreaks, fish kills etc.	All sites	All months	Weekly
Level 2: Management authorities/NGOs	Social	Collection of information on: – Ecosystem general status, changes as compared to the todays' benchmark/baseline study(status), – Trends in anthropogenic activities – Changes in population for basic human needs assessment	In the basin	Throughout in the year	At least once a year
	Hydrology & hydraulics	Water level monitoring by the LVBWB	All sites	1 hour interval	Continuous with self-contained loggers
	Geomorphology	Collect and assess fixed point photos from community groups	All sites	Any	2 times per year

Table 5-31: Reserve monitoring recommendations

Level	EFA Component	Monitoring Activity	Sites	Timing	Frequency
		Assess habitat quality, extent and position of the various habitat/geomorphic units such as riffles, pools, benches, flood plain, etc. This can be done through photos and rapid field assessments and detailed sketches	All sites	During low flow	Once a year
	Fish	Identify fish recruitment and diversity of species using simple scoop nets and making formal records. This can be done with identification sheets provided to authorities/NGOs.	All sites, separate riverine sites from wetland sites.	Following flood recession	Every two years
	Marco-invertebrates	TARISS/SASS5	All sites	Dry season	Bi-annually (Feb, Oct)
	Water quality	Monitor for physico-chemical and biological components. Monitoring of toxicity (including heavy metals) can be conducted in cases and sites where pollution is suspected.	All sites	All months	Monthly
Level 3: Technical experts/academic institutions	Social	Surveys to determine changes in: – Livelihoods pattern and their relation to flows – Frequency in floodplain inundation in areas locals are practicing recession agriculture, – Extent of soil fertility levels, physical structure and texture of the soils – Level and capacity of aquifer replenishment	In households areas and in the basin	Five years	Once every 5 years-
	Hydrology & hydraulics	Water level and flow velocity across the channel/wetland	All sites	Range of flow depths to build up the database of observations and move away from modelled results	During a range of low to flood flows
	Geomorphology	Quantify habitat quality, extent and position of the various habitat/geomorphic units such as riffles, pools, benches, flood plain, etc. This should be based on field measurements.	All sites	During low flows after significant flow events	Annually

Table 5-31: Reserve monitoring recommendations

Level	EFA Component	Monitoring Activity	Sites	Timing	Frequency
	Riparian vegetation	Change of plant species composition and diversity in floodplain as influenced by extent, duration and timing of inundation	Bisarwi	February and June	Once in 3-5 years
	Fish	Undertake formal fisheries/fish community wellbeing assessment.	All sites, separate riverine sites from wetland sites	Surveys during low flow and high flow period	Every 5 years
	Marco-invertebrates	TARISS and Index of Biotic Integrity (Kerans and Karr, 1994; Masese et al., 2009a)	All sites	Dry season	Annually (every Feb or Oct)
	Water quality	Comprehensive analysis of the water i.e. collet water samples for physico-chemical, biological and toxicological analysis (including heavy metals)	All sites	Wet and dry seasons	Seasonally

should prepare an estimate for the financial needs to maintain the monitoring program for the upcoming year and review it with the budget holder.

5.4.3 Incorporating Monitoring Data into Adaptive Management

A critical part of effectively implementing the reserve is to incorporate monitoring directly into adaptive management cycles. This is achieved through regular monitoring (including data collection activities and regular reporting) and the use of trigger values. These trigger values are numerical values for each monitoring activity that indicate there may be a condition of concern. It does not indicate that there is a real problem, but it does trigger a management action to investigate the issue in further detail. In this way, major problems may be avoided by investigating and/or taking action to alleviate the issue when it is small. For the Lower MRB, the trigger values have been determined in the RQO indicators for each RU. Trigger values can also be updated using the information collected from the monitoring program and utilizing the opinion of LVBWB staff and subject experts.

While adaptive management cycles should be customized to incorporate existing management structures within the LVBWB, the adaptive management for environmental flows could be based off of cycles recommended for the Rufiji Basin Water Board in central Tanzania (CDM Smith, 2018). These cycles separate activities for reserve determination (including updates every 5 years) and reserve implementation. Implementing the reserve means incorporating compliance monitoring into short-term adaptive management action to ensure flows are being met in the river, and incorporating effectiveness monitoring into long-term adaptive management action to help determine if the environmental flow values are achieving their intended objectives. These cycles can be found in Figure 5 8.

The adaptive management cycle can be broken down into different phases: the reserve determination phase and the reserve implementation phase. The reserve determination phase includes setting initial reserve values (completed during this effort) and developing a water allocation plan (being completed in parallel to this effort). The next phase is the reserve implementation phase. The first and most important step in the phase is to complete monitoring activities for both flow conditions and ecological and social conditions. Regular monitoring should occur for both topics, but likely at different time intervals (e.g., flow monitoring should happen continuously while ecological and social monitoring may occur seasonally or annually). During these regular monitoring activities, there are also periodic evaluation periods to analyze if the reserve flows are being met (compliance monitoring) and if the objectives of the reserve are being met (effectiveness monitoring).

If the reserve is not being met, then different management actions can be implemented to ensure that the required amount of water remains in the river, such as restricting certain water permits or reducing the number of permits approved in subsequent years . If reserve flows are being met but the ecological and social objectives are not, then it is time to evaluate the river system to determine the cause. If it is flow related, then the reserve values may need to be adjusted. If it is not flow-related (such as impacts from changes in land cover), then alternative actions should be taken in collaboration with local government agencies and development partners to alleviate the issue. If trigger values are surpassed during routine monitoring, then the analysis phase is activated early (and potentially the next level of monitoring activities) to determine if there is a problem.

In addition to the monitoring, there are regular reporting periods. Hydrological data should be complied, analyzed, and reported in annual hydrological report sent to the MoW. Ecological and social data may need a few years of data collection before trends can be seen. These components should be reported every five to ten years, comparing them against the hydrological record and compliance record for the reserve over that same time period. These monitoring, management, and reporting cycles

[5] *There will be years where the reserve is not met due to natural rainfall conditions. In these situations, it is recommended to use the drought year environmental flow values. However, if the reserve is not being met in average years, it is likely an issue of over abstraction of water from the river.*

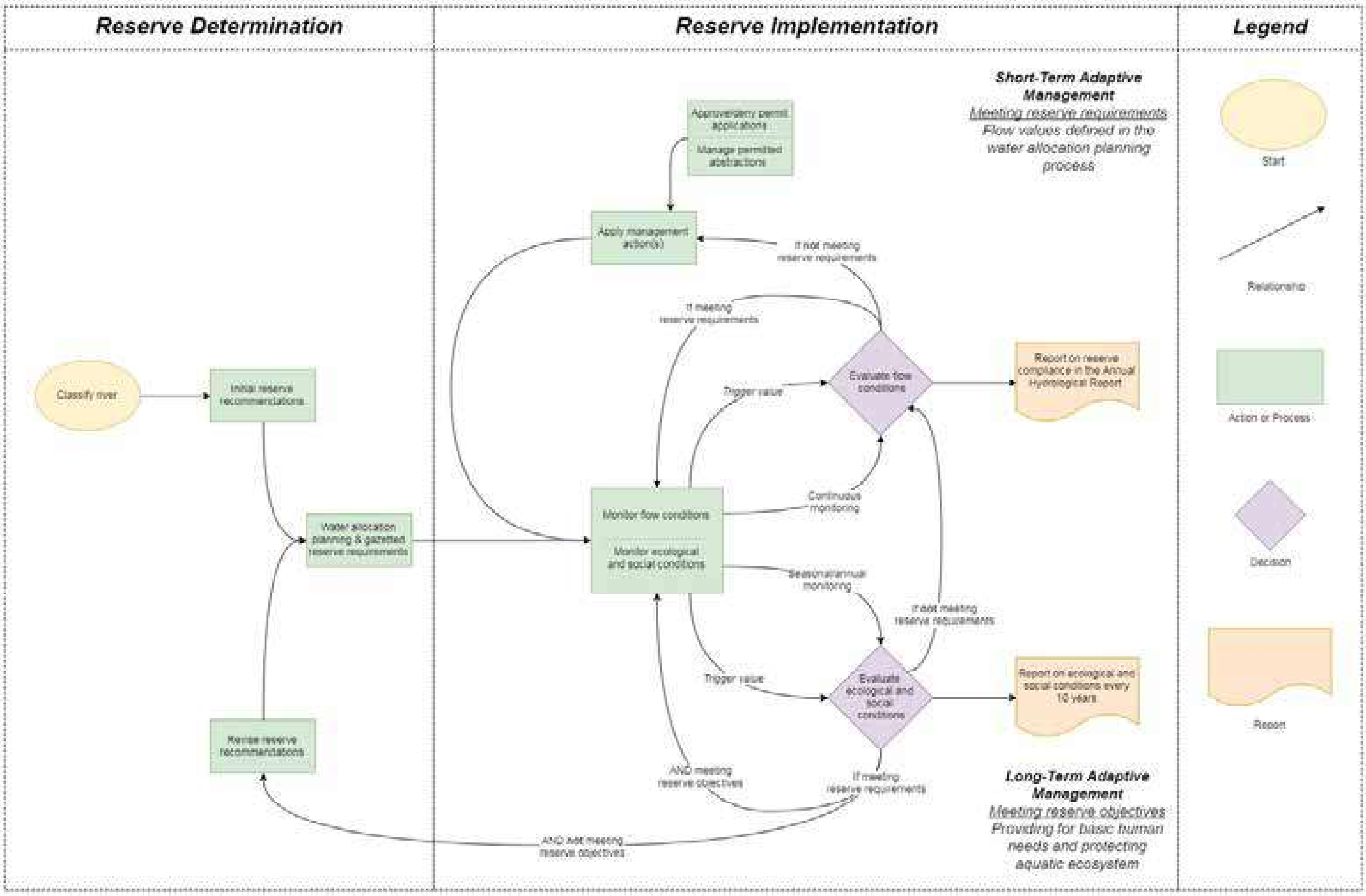


FIGURE 5 8: EXAMPLE OF ADAPTIVE MANAGEMENT CYCLES FOR ENVIRONMENTAL FLOWS FROM THE RUFIJI RIVER BASIN, TANZANIA (CDM SMITH, 2018)

are completed continuously to ensure the reserve is being properly implemented and the correct reserve values are being applied.
This report describes the process and results of an assessment to set RQOs and reserve levels for the mainstem Mara River of Tanzania, its principal tributaries, and the wetland at its mouth. RQOs are management objectives intended to protect water resources and related aquatic biological resources at levels needed to meet the needs of resource users and maintain ecosystems in a desired environmental management class. The reserve is a quantity of water intended to i) satisfy basic human needs by securing a basic water supply and ii) protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resources. RQOs and the reserve are recognized measures under Tanzanian law to protect water resources and aquatic ecosystems. They are to be specified for all water resources in the country by notice of the MoW in the Gazette. They are also to appear as elements of a basin Integrated Water Resources Management and Development Plan. The RQOs and reserve levels determined in this project comply with all requirements and approved guidelines under Tanzanian law and thus qualify for notice in the Gazette and application in continued water resource planning. They are judged to be valid for a period of five years, which corresponds to the validity period of the basin Integrated Water Resources Management and Development Plan. After this period, and in the context of regular water resource planning and management, they should be reviewed and revised if judged necessary.

RQOs have been set for eight RUs (Figure 3 3), which correspond in area to the six WUAs in the basin, SENAPA, and the area around North Mara Mine. Reserve levels have been set for seven sites (Figure 3 9) aligned with the resource units and with Upper and Lower Tigithe combined into one RU. RQOs have taken into consideration water quantity and water quality, the character and condition of in-stream and riparian habitats, and the characteristics, condition and distribution of the aquatic biota. Reserve levels have been determined for each month of the year, as well as for years of normal rainfall and years of drought (Section 5). The monthly interval of reserve levels allows for combining months at seasonal or annual levels in planning processes. Values may also be extrapolated to other points in the river system to align with different sub-basins or sub-units of water resource planning. As a next step in the process, the reserve levels are to be extrapolated to the outlets of sub-basins designated for water allocation planning.
The assessment was conducted by a multidisciplinary technical team working in close cooperation with water authorities and stakeholders and following steps of the Nile E-flows Framework developed by the NBI and adopted by the riparian countries of the Nile, including Tanzania. First, a basin scale situation assessment and alignment process (Section 3.1) was conducted to ensure the project involved the correct authorities and stakeholders from national to local scale, met the requirements of Tanzanian laws and regulations, built upon previous knowledge, and could be integrated into ongoing water allocation planning efforts. Next, authorities and stakeholders were engaged in a participatory process to set RQOs for different RUs (aligned to sub-basins, Sections 3.2). These objectives guided the technical team in the selection of targets and individual indicators for field assessments. Desktop studies were then carried out to quantify hydrological conditions across the basin, classify ecosystem types and evaluate the level of flow alteration already influencing the river system (Sections 3.3, 3.4, and 3.5). Based on these steps, the technical team, including counterparts from the LVBWB, selected seven sites for detailed biophysical field studies and 14 villages for a socioeconomics study, which were carried out during campaigns in February and May 2019 (Section 3.6). Results of field studies enabled the technical team to relate flow levels with the ecological condition of the river and the ecosystem services it provides (Section 4). The final step in the process was a workshop of the technical team and water authorities to set reserve levels that meet RQOs for each site and to develop a monitoring plan to support adaptive management of RQOs and the reserve into the future (Sections 3.7 and 5).

RQOs set during the project reflect the close and multifaceted interdependencies of people and water and aquatic ecological resources in the Lower MRB. People depend on river flows to meet water needs for domestic purposes, livestock, and agriculture across the basin. Groundwater is also an important source for domestic water. Special emphasis was given to dry season flows, but the importance of wet season flows was also highlighted for supporting floodplain agriculture and replenishing surface and groundwater storage for use in subsequent dry seasons. The importance of ecosystem processes is recognized as maintaining an ambient level of water quality needed for healthy fisheries and water for domestic uses, livestock, and agriculture. Instream and riparian habitats and related biota are valued for the direct resources they provide (fish, building materials, etc.) as well as their role in supporting biodiversity. Biodiversity protection is recognized as the predominate use for water in SENAPA but was also noted as important to inhabitants in all parts of the basin. These dependencies and values are recorded in the RQOs set by stakeholders and reported in Section 5.1. In all RUs of the Lower MRB, objectives were set to maintain ecosystems in no less than a somewhat altered condition, which corresponds to a class of B in the draft River Classification System for Tanzania. In this class, the "natural flow regime is affected by water withdrawals, impoundments and/or discharges, but the critical aspects of the flow regime are retained so that effects on the ecosystem are small."

Results of the reserve assessment address the two components of the reserve: the quantity of water needed to both satisfy basic human needs and protect aquatic ecosystems. The basic human needs component of the reserve is equivalent to 25 liters/

person/day and is thus directly related to population. Based on the estimated population for 2018, this amounted to flow levels of 9 to 40 liters per second depending on the resource unit (Section 5.2). The ecological component of the reserve was set to meet the RQOs and the environmental management class of B as described above. Specialists on the technical team set measurable targets and indicators related to the narrative objectives of the stakeholders (Section 5.1). These targets and indicators guided the flow setting process. During years of normal rainfall, results for the environmental flow of mainstem Mara River sites corresponded to 23 to 24 percent of the value of the average flow of the wettest month and 15 to 17 percent of the average flow of the driest month. Environmental flows determined for mainstem sites during drought years were roughly 33 percent lower than those for normal years. Environmental flows for tributaries and the wetland correspond to larger or smaller proportions of estimated average monthly flow and even exceed the monthly average during the driest month. The more extreme proportions at these sites are predominantly due to uncertainties in the estimation of hydrological regimes, which were regionalized from the relationships between precipitation data and mainstem hydrological records.

Environmental flows for normal years are intended to support the full range of ecological process needed to maintain healthy plant and animal communities in the river system. Detailed ecological motivations for each determination are given in Section 5.3. Protection of ecological processes in the river also ensured continued delivery of ecosystem services beneficial to human communities. Environmental flows for drought years are intended to sustaining life in the system until higher flow levels return.

6.1 Implementation of RQOs and Reserve Flows in Water Allocation Planning

As indicated above, the RQOs and reserve levels determined in this project comply with all requirements and approved guidelines under Tanzanian law and thus can be applied in water resource planning. Both are relevant for the water allocation plan currently under development by the LVBWB and the MoW. According to the draft guidelines for water allocation planning developed by the MoW, water resources allocation is "a means by which regulation of water use is done through sharing water resources among competing users, with due regard for the environment, the economy, and the social wellbeing of all Tanzanians" (URT, 2018a).

Setting RQOs is a required step in this process and a mechanism to incorporate stakeholder interests and align them with the requirements of Tanzanian laws and regulations. During the planning stage of water allocation planning, a water balance is to be quantified for individual water bodies of planning units. In this assessment, eight resource units were delineated to serve as the basis for setting RQOs and potentially as planning units for the WAP. If alternative planning units are delineated during the WAP development, the units used in this assessment can be reconfigured to match the final WAP planning units. The water balance of each planning unit can be summarized as follows:

Water Balance = Available Water – (Reserve + Transfers + Summation of Water Allocations)

A positive water balance indicates that there is sufficient available water to meet all water demands, while a negative balance indicates a state of over allocation. The water balance can be calculated at monthly, seasonal, or annual time intervals. The results of this assessment quantified both the basic human needs and ecological components of the reserve at monthly intervals, which allows them to be incorporated into the water balance at whatever time interval is chosen. It will still be necessary, however, to extrapolate reserve values to the outlets of final planning units. This can be done by adjusting the values reported in this document in proportion to the upstream contributing area of each planning unit.

The reserve values are also relevant to the management stage of water allocation planning, including aspects of compliance and enforcement. In the implementation of the WAP, river levels are to be monitored to determine whether water users may continue to withdraw water at the full limit of their permit or whether restrictions should be imposed to protect reserve flows in the river. The Draft Tanzanian WAP Guidelines recognize three levels of flow that are relevant for water resource management; flood flow, normal flow, and reserve flow. Flood flows are flows above an established threshold (e.g., Q80) that represent a condition of abundant flow. Under these conditions all water permit holders are expected to be able to withdrawal water up to the limit of their permits. Normal flows represent flow levels below the flood flow threshold but greater than the reserve flow level. Under normal flow conditions withdrawals may be restricted for some permit holders, such as large-scale irrigators. Other permit holders such as domestic water providers are expected to be able to withdrawal water up to the limits of their permits during normal flow conditions. When flow levels in the river drop to reserve levels, all water permit holders must cease abstractions, except for domestic water providers. However, even domestic water providers should restrict their withdrawals to the basic-human-need level of 25 liters/person/day.

In the water allocation planning activities planned for the concluding months of 2019, RQOs and reserve flows should be considered and used as indicated above.

6.2 Harmonization of Reserve Flows with those set for Kenya

Current estimates are that 75 percent of the water flowing in the Mara River in Tanzania comes from Kenya. Thus, close coordination is necessary between the countries in water allocation and management. This also applies to consideration of the reserve. Fortunately, Tanzanian and Kenyan water laws are consistent in their definition of the reserve and assigning it highest priority in water allocation. Both countries include basic human needs and ecosystem protection as components of the reserve. Both countries recognize the basic human need to be 25 liters/person/day, and both countries have adopted the Nile E-Flows Framework for the determination of the ecological component. This consistency in laws, definitions, and approaches greatly enhances the potential for harmonious management of water resources across the border. Care must also be taken that numerical values of reserve flows and implementation measures are consistent in a manner that ensures Kenyan reserve flows crossing the border are sufficient to meet Tanzanian reserve flow levels. Kenya also recognizes three levels of flow in the allocation and management of water resources, namely flood flow, normal flow, and reserve flow, and uses a similar process of restricting withdrawals based on flow levels. The environmental management objectives of Tanzania and Kenya at the border are similar given the juxtaposition of Serengeti National Park and Maasai Mara National Reserve. This should lead to similar determinations of the ecological component of the reserve. The reserve determined in this assessment at Kogatende in Serengeti National Park is judged sufficient to meet downstream reserve requirements in the five year time period these determinations will remain valid.

6.3 Knowledge Gaps to Address

Uncertainty is inevitable in any scientific assessment of reserve levels, especially in data scarce systems like the Mara River Basin. This assessment has been transparent in acknowledging uncertainties and taking steps to minimize risks associated with them. The assessment team stands behind the reserve flows reported here but also strongly recommends that actions be taken to improve knowledge and understanding of key components resource system.

6.3.1 Basin Hydrology

Urgent action is needed to restore the hydrometeorological monitoring network of the Mara River Basin. There are currently no functional river discharge or precipitation stations in the basin. In this assessment, suitable historical data were available from only one river discharge station (Mara Mines) and two precipitation stations (Nyabassi and Mugumu) which are near but outside the basin. Mean monthly river flows for all assessment sites other than Mara Mines had to be reconstructed as explained in Section 3.3.1. Similarly, high flow values had to be simulated as explained in Section 3.3.4. Almost nothing is known about groundwater, which was not explicitly considered in the reserve assessment. Daily precipitation and flow data are necessary for implementation of the reserve, and long-term data sets are necessary for proper planning of water resource use and allocation.

The lack of historical hydrological data had a minimal impact on reserve flows determined in this assessment because the modified building block method used is based primarily on data collected during the assessment itself. Accurate river discharge measurements were made during the two field campaigns and these data were used to calibrate the hydraulic model used to convert ecologically relevant hydraulic variables like water depth, velocity, and wetted width into discharge values. These hydraulic variables were then linked to requirements of aquatic and riparian plants, fish, macroinvertebrates, and social uses. Flow levels were low during both field campaigns, which means that the hydraulic model is better calibrated for low flow conditions. This is important because aquatic ecosystems of the Mara are currently most vulnerable to flow alteration during low flow conditions. There is considerably more uncertainty in the performance of the hydraulic model at high flow levels, but this is less of a concern because high flow levels in the Mara are largely unaltered and are expected to remain unaltered during the period these reserve determinations remain valid.

The lack of long-term hydrological data for the Somoche, Tobora, and Tigithe tributaries is of concern for water allocation because of the high uncertainties associated with the regionalized data from the water resource assessment. This is especially apparent in systems where groundwater or springs may have a substantial contribution to river flows during dry months since regionalization is unable to capture these sources. There is some anecdotal evidence of this limitation that was encountered during the field campaigns, where local residents said the Somoche, Tobora, and Tigithe Rivers rarely go dry, which contradicts the no-flow values found in the regionalization for these three sites.

This leads to uncertainty in the total quantity of water available during different months of the year and between different years. So, while there is higher confidence in the reserve flows, the uncertainty in the total water available is transferred to the water balance and volume of water available for allocation for uses like domestic, livestock, irrigation, and industry. If regionalized data overestimate the total water available, this could lead to over-allocation of water in permits and an increased risk of not meeting the reserve. If regionalized data underestimate the total water available, this could limit the ability to approve permits and unnecessarily limit the utilization of water resources. It is important that the managing water authority has the confidence in the water balance and the amount of water available for allocation when making such decisions.

6.3.2 Wetland Hydrodynamics

The hydrology and hydraulics of the Mara Wetland also remain largely unknown. During the field assessments the team measured flows in the wetland that significantly exceeded flows into the wetland at Mara Mines. This indicates that flows in the wetland included drainage of stored water as well as inflows from the Mara River. Water levels in the lower portions of the wetland also appear to be influenced by level of Lake Victoria, which diminishes the degree to which these portions of the wetland are dependent on Mara River flows. Improved knowledge of these hydraulic characteristics as well as bathymetric data of the wetland will strengthen the connection between the hydrology and the plant and animal communities, which is required to set appropriate reserve levels in Mara River in order to maintain sustainable habitats in the Mara Wetland.

6.3.3 Low-Flow Ecology

Because the Mara River is presently most vulnerable to flow alterations under low flow conditions, there is urgency to improve knowledge of how aquatic ecosystems function during low flows, especially strategies employed by river and riparian organisms to cope. Low flows are a natural part of the river's hydrograph and riverine and wetland species are adapted to cope with natural low flow conditions. But the increasing water demands of basin inhabitants during dry periods are likely to reduce river flows to unnatural levels and to extend the duration of low flows. This will increase stress on river organisms to levels beyond which those organisms are adapted to cope.

During the field campaigns, the mainstem Mara River flows were less than one m3/s which is near the minimal flows recorded historically in the river. Given these low flows, the technical team was impressed by the abundance of organisms found and their apparent good condition. But many questions remain about what undetected impacts may have been present, how much stress the organisms were under, and what the consequences would have been of extending this stress. The adaptations of human communities to more severe and extended low flows is also an area in need of additional study.

6.4 Special Considerations

6.4.1 Climate Change

Several studies have been conducted on how climate change may impact water resources within the Lower MRB (Mango et al., 2011; Dessu and Melesse, 2012; URT, 2014; Roy et al., 2018; USAID, 2019; WWF-Kenya, 2019). While climate projections vary based on the climate models and scenarios used, in general, the expected impact is a 1.0 to 2.0 degree Celsius increase in average temperature by 2030, a 1.5 to 2.7 degree increase by 2050, and a 3.5 degree increase by 2100. Changes have already been seen in the MRB, with an increase of 0.9 degree Celsius in the average maximum temperature and an increase of 1.1 degree Celsius in the average minimum temperature between 1961 and 2014 (USAID, 2019). An increase in temperature is likely to cause additional or lengthened periods of water stress during dry months and more frequent and intense drought events. Annual average precipitation is also expected to increase, with approximately a 15 percent increase during the wet periods and almost no change during the dry periods, likely increasing the number of extreme rainfall and flooding events. Much of this additional rain will occur during already wet periods, resulting in surface runoff which, when combined with changes in land use, is likely to move quickly to rivers and other surface water sources rather than infiltrate as groundwater recharge. This is also likely to increase erosion as well as turbidity in the water. In addition, the increase in rainfall combined with the increase in temperatures is expected to increase evapotranspiration. These conditions create the potential for larger but shorter hydrological peaks in wet months and extended reduced flow during dry months (Mango et al., 2011), but it is not expected to have a significant impact on average annual flows in the MRB (Roy et al., 2018; WWF-Kenya, 2019). With the potential for an increase in temperature and a decrease in flow during dry months, there is the possibility for water quality issues to arise during these periods.

There are some potential impacts on the indicators used in the EFA. An increase in temperature causes a decrease in dissolved oxygen in surface water, which, if extreme enough, could impact habitats for aquatic species (USAID, 2017). In addition, the low water levels may concentrate nutrients in the system (both natural and human-introduced) to an unsafe level. A further decrease in flow during dry periods may also be of concern, although the system regularly experiences drought conditions and many of the aquatic species have adapted to these conditions. It is important that the mainstem Mara River maintains refuge habitats during the dry months in both maintenance and drought years. These refuges were available during our field campaigns, where we encountered extreme low flows. While individual drought years followed by maintenance years appear to refresh the system properly, multiple years of drought conditions could have a severe negative impacts on the population for species that migrate for reproduction (like fish) and those that require inundated soils (like vegetation). The Tobora and Somoche tributaries were found to be important areas to maintain biodiversity during maintenance years, but were not critical refuge habitat during drought years. Contrary to these, the Tigithe tributary was important refuge habitat during drought years for specific wetland species, showing its vulnerability to a further decrease in flow during dry months. The tributaries are also a primary water source for many people living in those sub-basins and are critical for providing water for basic human needs in those areas.

To increase resilience to the impacts of climate change (or decrease the potential for negative impacts from the expected changes in climate), developing and implementing environmental flows is considered an important step in both the Kenyan and Tanzania sides of the MRB (USAID, 2019; WWF-Kenya, 2019). By including environmental flows in established water management practices, the water required to maintain aquatic ecosystems and their ecosystem services will be considered first priority. The ecosystem services will help to regulate extreme water events through the presence of riparian vegetation (increasing soil infiltration and slowing surface runoff), contribute to food security through the maintenance of fish populations and indigenous fruits and vegetables, and provide enough water for the basic human needs of dependent communities.

There some impacts already being noticed in the Lower MRB, such as the drying up of small streams and some wetlands over the past decades (USAID, 2019, Annex B). However, it is unclear if this is due to climate change or the more immediate impacts from changes in land use types. Converting the native forest cover in the Mau Forest in Kenya (which form the headwaters of the Mara River) to agriculture or grasslands has been shown to cause an increase in peak flows and a decrease in low flows in the Mara River (Mango et al., 2011). In addition, some farmers in the tributaries of Lower MRB are growing plantations of eucalyptus trees species as a source of building poles and fuel, which have the potential to consume a large amount of groundwater and impact local streamflow in arid and semi-arid lands (Scott and Lesch, 1997).

The time scale of the EFA is intended to be five to ten years and should be updated along with the WAP for the Lower Mara. In 10 years from now, there are not expected to be significant changes in the hydrology of Lower MRB. Using the BBM, the environmental flows recommended are not based on the basin hydrology but rather on the ecological and social needs which are linked to habitat conditions (depth, velocity, and inundation period). Once these habitat values have been established, they are converted to flow using site-specific hydraulic models and compared to known hydrology (measured or modelled) in the basin or sub-basin. (This does, however, stress the importance of an accurate hydraulic model and good hydrological data since the final flow values are dependent on these data sources. There is also the possibility of updating these values using improved datasets and models as they become available in the future.) It is important to remember that the reserve is one component of integrated water resources management, and any decisions related to how water is allocated, including in response to any expected changes in water availability due to climate change, will be decided in the WAP.

6.4.2 Heavy Metal Pollution from Mining Activities

In the Lower MRB, there are two main gold mining activities, each of which has its own impacts on water quality: large-scale mining (North Mara Gold Mine), which uses cyanide for extracting gold from raw ore, and artisanal mining, which often uses mercury for the same purpose. For large-scale mining, the use of cyanide chemically unbinds heavy metals (including arsenic) from rocks and soils and results in a highly toxic liquid known as acid mine drainage. While efforts are typically made to prevent acid mine drainage from leaving the mining area, it is capable of contaminating groundwater through seepage in the soil and contaminating surface water through overland spills. There is concern in the Lower MRB that there is inadvertent pollution into the Tigithe River and surrounding ecosystem from the mining activities at the North Mara Gold Mine.

The main impacts from artisanal mining is the release of mercury into the surrounding ecosystem due to improper protections at the informal mining sites. Mercury is a strong neurotoxin and can bioaccumulate in tissue, meaning that a larger organism can retain and build up mercury that comes from the smaller organisms it consumes. In the Tigithe River, there is concern that fish in the system may contain high amounts of mercury that could be dangerous for human consumption. In addition, there have been reports of persistent skin irritation and other ailments in the area, which are thought to come from pollution from mining activities.

There have been a series of studies on heavy metal and mercury contamination in the Lower MRB with varying results. Some studies conducted found no or only traces of heavy metals in Tigithe River and Mara River water samples (GLOWS-FIU and WWF-ESARPO, 2007; Almås and Manoko, 2012; Mataba et al., 2016), while others found that levels of chromium, cadmium, nickel, iron, mercury, and lead were all above Tanzanian Bureau of Standards and World Health Organization standards (Bitala, Kweyunga and Manoko, 2009; Kihampa C and Wenaty A, 2013). One study found that levels of heavy metal were 14 to 260 times higher than when they were measured in 2002, a time before mining was a major industry in the area (Bitala, Kweyunga and Manoko, 2009). Arsenic was not found in any of the river samples in the studies since it breaks down quickly in open waters.

It should be noted that surface water quality changes rapidly and any collected samples are representative of the water quality at that specific moment. If there were consistent leakage into the surface water, there many a chance of collecting it in a sample. Often, however, spills are individual events and are unlikely to be captured by periodic studies.

Sediments can capture pollution from longer time scales since heavy metals in water often bind to sediments when moving through soils in groundwater and when in contact with sediments in surface waters. Contaminated sediments can also be deposited on land from local flooding events. Several studies found elevated levels of heavy metals in soils immediately surrounding large-scale and artisanal mining activities, indicating that there is likely some movement of polluted groundwater from these activities (Bitala, Kweyunga and Manoko, 2009; Mganga, Manoko and Rulangaranga, 2011; Almås and Manoko, 2012; Kihampa C and Wenaty A, 2013; Mataba et al., 2016). While the heavy metal levels in the sediments are higher in concentration than the levels found in the water, the heavy metals are often bound to sediments and may be less bioavailable, decreasing the risk to living organisms (Ikingura et al., 2006). Sediment cores in the upper Mara Wetland show an increase in mercury deposits in the 1960s that are about 2.5 times the background concentrations (although still well below the limits set by the US National Oceanic and Atmospheric Administration's effects range low concentration), but have decreased to almost background levels in the past 20 years. The middle wetland is seeing an increase in mercury deposits. This increase could be coming from contaminated deposits that are slowly moving downstream in the wetland, showing the ability of the wetland to store and attenuate the movement of these heavy metal deposits (Subalusky et al., 2019). A point of concern is that mercury in low oxygen environments (like wetland soils) has the potential to convert to methyl mercury, the most toxic form of mercury for living organisms.

Studies on fish in the Tigithe River and Lake Victoria have also been conducted to see if there is an impact on aquatic species and how far that impact may travel downstream. They found that, in general, the fish tested in the Tigithe River had only slightly higher levels of heavy metals to those found in Lake Victoria, indicating that the mining activities were not having a significant impact on aquatic species in that trophic level (Machiwa, 2003; Mataba et al., 2016). Another study in northwestern Tanzania found elevated levels of mercury in individual fish at sites highly contaminated by artisanal mining, but that these levels were not seen in the general fish population in other parts of the system and downstream in Lake Tanganyika (Taylor et al., 2005). The levels of heavy metals found in the Tigithe River were below the Provisional Tolerable Weekly Intake level when fish is consumed in average amounts, but there may be concerns for people who consume large amounts of fish daily as well as at-risk populations (Mataba et al., 2016).

While water quality does play an important role when deciding environmental flow recommendations, the focus is on parameters that may be impacted by an extreme or persistent change in flow, such as temperature, dissolved oxygen, and nutrients. Heavy metals occur naturally in the earth's crust and are found in water and sediments at trace levels, which do not pose a health concern to aquatic organisms. Elevated levels of heavy metals may pose a threat to aquatic ecosystems and local communities, but are most likely due to non-flow related human activities like mining or other industrial processes. However, environmental flows are not an appropriate management tool for elevated levels of heavy metal pollutants and should not be used as a dilution method for human-introduced contaminants. The management of these pollutants should be conducted separately from environmental flows and be controlled through other activities, such as being included in local management plans and/or the development of pollution prevention and control plans for specific activities.

6.4.3 Wildlife

The Serengeti ecosystem hosts the world's largest overland migration, including 1,300,000 wildebeest, 200,000 zebras, 350,000 gazelles, and 12,000 elands cross the Mara River each year between June and November (Hopcraft, 2010; Tanzania Tourism Board, 2012; Subalusky et al., 2017). Most of these animals cross through the Lower MRB as they migrate between SENAPA in Tanzania and the Maasai Mara National Reserve in Kenya and consume surface water along their journey. The Mara River is a critical water resource during this journey since it is the only perennial water source in the area. The water required for the migration is important, but is not directly related to protecting aquatic ecosystems and hence is not included in the environmental flow recommendations. This consumptive water use is considered as a water demand in the parallel WAP process. There is also an important consideration when it comes to animals which use the Mara River as their primary habitat, such as crocodiles and hippopotamuses. This is particularly important at the Kogatende site inside SENAPA as there are large populations of these species in this area. These species are not a specific indicator for this site since they are not true aquatic species, but they have been considered as part of the process. The low flow recommendations for both maintenance years and drought years consider keeping pools deep enough to provide habitat for both species, which is often a very stressful time period. Since both of these species are mobile, it is expected that they move up and downstream to find pools of an appropriate size.

Downstream of Kogatende, there is less emphasis on these species. This is because there are reduced numbers due to human encroachment on the mainstem sites and the fact that these species don't live in the tributaries (Tobora, Somoche, and Tigithe). There have been some sightings of crocodiles and hippopotamuses in the wetland by local communities, but there is enough water in that habitat for their needs and it is not a major concern at that site.

6.5 Integration into Existing and Future Water Resources Management

The EFA is one piece of many integrated water resources management plans and activities in the Lower MRB in Tanzania, the entire MRB including Kenya, and the East Africa region at large. In the Lower MRB, there are multiple management plans already in place in various parts of the catchment that include environmental flows directly or indirectly. The Mara Wetlands Integrated Management Plan (URT, 2018b), which is being carried out under the Mara Regional Commissioner's Office, has environmental flows listed as Activity 1.7 under the Land Use and Wetland Management Programme as a way to regulate water abstractions. Six WUAs have been created in the Lower MRB, two of which (Somoche and Tobora WUAs) have created and approved subcatchment management plans. The LVBWB is also in the process of developing their Integrated Water Resources Management and Development Plan for the Lake Victoria Basin, in which determining and implementing the reserve is likely to play a foundational role in planning for future water resources development. A previous project funded by USAID project (Planning for Resilience in East Africa through Policy, Adaptation, Research and Economic Development, or PREPARED) developed an economic valuation of biodiversity and ecosystem services in the Mara Wetlands (USAID, 2016) and a conservation investment plan for the Mara Wetland (URT, 2017), both of which support the protection and sustainable use of the Mara Wetland.

For many years, activities have been conducted in the both Kenyan and Tanzanian sides of the basin to protect aquatic ecosystems and biodiversity, ensure the responsible use of water resources, and prepare for impacts from climate change, which all have links to environmental flows. The 2010 Biodiversity Strategy and Action Plan for Sustainable Management of the Mara River Basin (EAC and WWF-ESARPO, 2010) calls for establishing and implementing the reserve as part of its objectives for aquatic habitats.

Between 2014 and 2018, the MaMaSe project worked in Kenya on sustainable resources management, including developing water abstraction reports for each subcatchment, a draft environmental flow assessment, and a preliminary WAP calculations for the MRB located on the Kenya side. The SWP Mara River Basin Activity under USAID is supporting a series of efforts to develop a transboundary WAP between Kenya and Tanzania, of which this report is a critical component. This report was also developed to align with procedures followed under the MaMaSe project so the outcomes could be readily combined as part of the transboundary process. WWF has also developed a Climate Change Vulnerability and Adaptation Assessment for the Greater Mara Ecosystem, covering both the Maasai Mara National Reserve in Kenya and SENAPA in Tanzania (WWF-Kenya, 2019), in which environmental flows is listed as an important activity for increasing resilience to climate change.

Regionally, there has been many similar efforts focused on the Lake Victoria Basin, the East African Community, as well as the larger Nile River Basin. Under PREPARED, a climate change adaptation strategy and action plan for 2018-2023 for the Lake Victoria Basin was developed by the Lake Victoria Basin Commission that outlined activities to protect water and aquatic ecosystems (LVBC, 2018). The East African Community also developed their own climate change master plan for 2011 – 2031 (EAC, 2011), where adaption measures for water security include the promotion of integrated water resources management, protection of watersheds, and sustainable use of wetlands. At the Nile Basin scale, NBI considers "establishment of thresholds for sustainable flow requirements" in wetlands as one their priority outputs in their Wetland Management Strategy (NBI, 2013), which is directly related to the motivation for this effort.

Looking towards the future, these efforts create a strong foundation for further financial investment in the basin, particularly around climate change and sustainable management of water resources. With various sources of global and regional funds available for climate change mitigation and adaptation, funders are looking for "bankable" projects. These projects should define specific issues related to climate change in the basin, clearly articulate how the proposed actions are going to mitigate or adaptive to changes due to climate change, identify a series of ready-to-implement projects, describe how they will reduce potential risks, and align with existing regional management plans and climate strategies (World Bank Group, 2019). Transboundary basins also present an additional challenge of needing a river basin organization to bring together the individual countries and act as the overall project manager. The MRB already meets many of these requirements through the outputs from the efforts listed above, including preparation of the Conservation Investment Plan for Mara Wetlands, and could function through the existing river basin organization, the Lake Victoria Basin Commission. This EFA acts as a project preparation study, providing technical backing to future "bankable"

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7. ANNEXES

WWF-Kenya (2019) Climate Change Vulnerability and Adaptation Assessment for the Greater Mara Ecosystem Climate Change Vulnerability and Adaptation Assessment for the Greater Mara Ecosystem.

Annex A :	Stakeholder Input on Determining Resource Quality Objectives for the Lower Mara River, Workshop Report
Annex B:	Starter Document for Socioeconomics
Annex C:	Starter Document for Hydrology
Annex D:	Starter Document for Hydraulics
Annex E:	Starter Document for Geomorphology
Annex F:	Starter Document for Riparian Vegetation
Annex G:	Starter Document for Fish
Annex H:	Starter Document for Macroinvertebrates
Annex I:	Starter Document for Water Quality

Lower Mara Environmental Flow Assessment: Resource Quality Objectives and Reserve Assessment Report. Prepared by IHE Delft Institute for Water Education on behalf of the Nile Equatorial Lakes Subsidiary Action Program Coordination Unit (NELSAP-CU/NBI) "
This activity was done with support from GIZ, on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under the International Climate Initiative." Project number 14.9029.1

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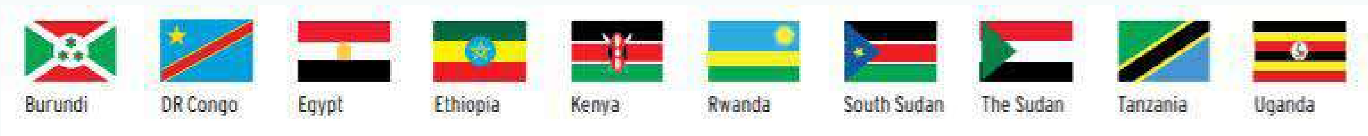

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