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Aquatic ecosystems of the Nile Basin, their wellbeing and response to flow alterations

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Document Sheet

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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.

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Contents

Abbreviations:

BD	Background Document
BDI	Biological Distinctiveness Index
EF	Environmental Flows
EFA	Environmental Flow Assessment
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical Information Systems
LCCS	Land Cover Classification System
NBI	Nile Basin Initiative
NBSF	Nile Basin Sustainability Framework
WWF	Wild Wildlife Fund

1 Executive summary

Aquatic ecosystems in the Nile Basin are exceptionally diverse and provide ecosystem services to communities and the animals that live in or close to these ecosystems. This Background Document (BD) is the second of three for the transboundary guidance assessment on environmental flows for the Nile Basin. This brief builds onto the review of global practices and experiences for environmental flows, the first of the three Background Documents and will contribute to the third which will include a review of Nile Basin environmental flow management practices and experiences as well as relevant policies, conventions and guidelines. In this brief the approach adopted to identify aquatic ecosystem types and the threats to the wellbeing of these ecosystems in the Nile Basin is described. In particular this review considers:

- Factors affecting the classification of aquatic ecosystem types in the Nile Basin
- Aquatic ecosystem types in the Nile Basin
- Wellbeing of freshwater ecoregions in the Nile Basin
- Environmental flows and aquatic ecosystems

Factors affecting the classification of aquatic ecosystem types in the Nile Basin: The outcomes of this assessment show that the Nile Basin contains a high diversity of aquatic ecosystem types from flowing and non-flowing ecosystems that resulted from geomorphological differences across the basin as well as seasonality that influence biodiversity habitats, water quality and human activities. These are also the main drivers of ecosystems dynamics. A good knowledge and understanding of these features allow for their effective management.

Aquatic ecosystem types in the Nile Basin: In Section 3.2 a simple classification system was described based on regional principles to allow for the types of ecosystems to be identified and managed appropriately. Although the Nile Basin is dominated by the riverine processes of the Nile River itself, other socio-ecologically important ecosystems are common, and contribute to social and or ecological values. Some of these ecosystems include the great lakes of the Upper Nile catchments in Tanzania, Kenya and Uganda in particular as well as the Eastern Nile in Ethiopia. Within these lakes some of the globes greatest diversity of aquatic fauna has established. Other important ecosystems include the Sudd wetland system, which is the largest wetland in Africa and the extensive floodplain ecosystems associated with the Nile River. The Nile delta is another ecologically important ecosystem which may have been the most altered single ecosystem type in the Nile Basin. Other important ecosystems considered include the socially-ecologically important springs which provide people, livestock and wild animals with water which governs their lives. Springs derive water from underground sources interlinked with the Nile Basin system.

Wellbeing of freshwater ecoregions in the Nile Basin: The Nile Basin is divided into various freshwater ecoregions with the six main ecoregions being: The Ethiopian Highlands, Lake Tana, Lake Victoria, Upper Nile, Lower Nile and the Nile Delta. The overall wellbeing of these six freshwater ecoregions were evaluated by reviewing the wellbeing of the following: conservation state, threats to ecosystem wellbeing, water quality state, fish conservation state, state of associated fisheries (fish for food sector), other ecosystem biota, and ecosystem services.

The Upper Nile ecoregion includes the vast swamps of the Sudd which is a globally outstanding rare habitat phenomena. The likelihood of future threats is once again considered to be high and classifies the Upper Nile ecoregion as a Priority Class I with a vulnerable conservation status. The wellbeing of the ecoregion is considered to be relatively stable based on the current threat and ecosystem services have only been moderately modified. The water quality data indicates that the wellbeing of the water quality of the ecoregion is fair (moderately modified). Although limited information is available on the wellbeing of the fish, fisheries and other ecosystem components these all seem to be in a fair (moderately modified) state.

The Lake Victoria ecoregion includes Lake Victoria which is the largest tropical lake in the world as well as Lakes Kyogo, George, Edward and the small, deep Lake Kivu. This ecoregion is also considered to be globally outstanding as the species richness and endemism of the ecoregion were both categorised as high and Lake Victoria host a globally outstanding ecological phenomena namely an endemic haplochromine fauna which is an example of explosive speciation and adaptive radiation. Likelihood of future threats to the ecoregion is high making it a Priority Class I ecoregion and its conservation status is critical. There are many current threats that are impacting the wellbeing of the ecoregion classifying it as a largely threatened ecoregion. These threats have also largely impacted on the services that the ecosystem can provide. The wellbeing of the water quality of the ecoregion as well as other ecosystem components are considered to still be in a fair (moderately modified) state. The wellbeing of the fish is classified as largely modified as various factors have led to the extinction of some fish species and the classification of other fish species as threated or endangered. There has also been a general decline in the fisheries within the ecoregion and have been classified as largely modified.

The Ethiopian Highlands ecoregion contains about 70% of Africa's highlands and is known to harbour an endemic biota because of its long history of isolation. It is considered to be bioregionally outstanding as the species richness and endemism of the ecoregion was categorised as medium, based on the Biological Distinctiveness Index. The likelihood of future threats impacting the ecoregion is high classifying it as a Priority Class IV ecoregion and a final conservation status of endangered. Current threats to the ecoregion indicates that it is moderately threatened and vulnerable and services provided by the ecosystem have been moderately modified. Limited information is available regarding the water quality, fish, fisheries and other ecosystem biota of the ecoregion but based on available information, these are all considered to be moderately modified and in a fair state.

Lake Tana is a lake in the Ethiopian Highlands but has its own ecoregion that is classified as globally outstanding because of the high species endemism of the ecoregion and the occurrence of a globally outstanding ecological phenomena namely the only extended cyprinid species flock in Africa. Unfortunately the likelihood of future threats to the ecoregion is high making it a Priority Class I ecoregion and its conservation status is vulnerable. The wellbeing of the ecoregion is relatively stable based on the impacts of current threats and the availability of ecosystem services have therefore only been moderately impacted. The water quality of the lake is being polluted near the densely populated areas but overall is still considered to be only moderately modified. Approximately 70% of the fish species in Lake Tana are endemic and are in a fair (moderately modified) state. Commercial fishing is increasing especially in the southern portion of the lake and there has been a decrease in the annual total catch in the last 10 years indicating that the fisheries are also moderately modified. Limited information is available regarding the other ecosystem components but their wellbeing can also be classified as fair.

The Lower Nile ecoregion consists of the Lower Nile River from Khartoum where the Blue and White Nile Rivers converge and then flow downstream to the Nile Delta. The Biological

Distinctiveness Index categorises the ecoregion as nationally important and the final conservation status is vulnerable. The likelihood of future threats is considered to be medium and is a Priority Class V ecoregion. The ecosystem wellbeing is currently only moderately threatened by various threats but the ecosystem services are considered to be largely modified due to the construction of major dams in the ecoregion. The water quality data indicates that there are some areas of concern in the ecoregion but in general the water quality is moderately modified. Although there are no endemic fish species in this ecoregion, there are many species that are threatened and even some that are regionally extinct resulting in the fish being classified as largely modified. In the same way there have been modifications to certain other ecosystem species populations and these have also been classified as largely modified. The demand and potentially unsustainable use of fisheries in the Lower Nile ecoregion may potentially threaten the wellbeing of the fisheries and is considered to be in a fair (moderately modified) state.

The Nile Delta is the farthest location downstream of the Nile Basin and is considered to be the most polluted and the water quality is in a poor (largely modified) state. As with the Lower Nile ecoregion, the Biological Distinctiveness Index categorises the ecoregion as nationally important but the likelihood of future threats is high for the Nile Delta and therefore has a Priority Class of IV and the conservation status is critical. Current threats are mainly due to the completion of the Aswan High Dam which stopped the flooding cycle of the Delta resulting in the Delta becoming a subsiding and eroding coastal plain. The delta is considered to be largely threatened and ecosystem services have been largely modified. Although there are no endemic fish species in this ecoregion, there are many species that are threatened and even some that are regionally extinct. Various other ecosystem species have also become locally extinct and so the wellbeing of fish and other ecosystem components are both in a poor (largely modified) state. There has also been a decline in the fisheries since the construction of the High Aswan Dam and is classified as largely modified.

Environmental flows and aquatic ecosystems: In this section known threats associated with altered timing, volumes and flow durations have been evaluated. These include habitat alterations, connectivity issues and the fragmentation of species and disruption of ecosystem processes. Other threats include impairment of ecological processes that have provided people and species with goods and services they have depended on for generations. Flow timing impacts have been identified to affect the ecological cues of ecosystems and the associated seasonality of processes including sediment transport, retention and deposition processes. These flow related impacts have directly and or in-directly affected the wellbeing of aquatic ecosystems in the Nile Basin and their ability to support themselves and livelihood. The ecological indicators of the wellbeing of altered flows in the study area include; changes in ecosystems and their inhabitants, water quality and quantity variable changes, seasonality and simulations of flow, biodiversity of plants, animals, sediment transport, habitat change, the existence and prevalence of water borne diseases, awareness and socio-economic changes.

To effectively manage the environmental flows (volume, timing and duration of flows) in the Nile Basin, the socio-ecological consequences of altered flows and future flow related decisions needs to be evaluated. This evaluation should be holistic, consider multiple social and ecological endpoints and trade-offs between them. The approach must take ecosystem structure and function dynamics into consideration and be flexible which required transparency and adaptability. The approach should also be probabilistic and allow for the evaluation of future flow scenarios in multiple spatial scales with different levels of uncertainty (or confidence) and be updatable so that when new information becomes available the risk projections can be improved. With this information a suitable balance between the use and protection of the water resources in the Nile Basin is urgently needed. One that has international buy in for the benefit of all users in a sustainable manner.

2 Study overview

This Background Document (BD) should be considered in context of BD1 titled: "Environmental Flow Assessment: A review of global practices and experiences", which is the first of three BDs for the transboundary guidance assessment on environmental flows (EF) for the Nile Basin. The Nile Basin Initiative (NBI) recognises that the sustainable management of the shared Nile Basin water resources requires the establishment of relevant transboundary policy instruments (within the Nile Basin Sustainability Framework (NBSF)). The sustainable use of the socio-ecologically important water resources of the Nile Basin requires the coordinated management of the environmental flows on meaningful spatial scales. EF describe the quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (Brisbane Declaration, 2007). The NBI does not currently have any general standards and norms for establishment of environmental flows in the basin.

In an effort to establish general standards and norms for establishment of EF in the Nile Basin, NBI has initiated a process to develop a transboundary level guidance document on environmental flows. The objective of the guidance document on environmental flows is to develop a structured and scientifically based NBI procedure for establishing environmental flow requirements for transboundary water resources planning purposes in the Nile Basin. This will be achieved through the implementation of a phased process during this project, namely; stocktaking and development of an appropriate Environmental Flow Assessment (EFA) procedure/s, piloting of the procedure and synthesis of the outcomes. The scope of work will include the following:

1. Stocktaking and procedure development
   a) Review and synthesize global practices/experiences in establishing EFs.
   b) Identify aquatic ecosystem types and wellbeing, and the degradation threats to these ecosystems in the Nile Basin.
   c) Review Nile Basin practices/experiences on EF.
   d) Present/discuss these findings with stakeholders in a regional review/validation workshop.
   e) Review recommended procedures for establishing environmental flow requirements for Nile Basin aquatic ecosystems.

2. Development of EFA procedures for the Nile Basin and presentation of developed methodology in workshop.

3. Pilot EFA procedures at different spatial scales at selected locations in the Nile Basin and reviewing pilot application of developed methodology in workshop.

4. Synthesise the outcomes of the assessment and provide recommendations for future management in the form of a guidance document on EFA in the context of the Nile Basin.

This brief describes the approach adopted and the findings of Point 1b), the identification of aquatic ecosystem types, wellbeing and the degradation threats to these ecosystems in the Nile

Basin as a part of the stocktaking and procedure development phase of the study. The purpose of this brief is to:

- establish a classification system to be used in the Environmental Flow Guidance document for the Nile Basin with reference to know ecosystem types and,
- evaluate the information pertaining to the integrity state or wellbeing of the main riverine ecosystems (primarily) of the Nile Basin to direct the implementation of the EF guidelines towards areas within the basin where management intervention is urgently required to establish and maintain a suitable balance between the use and protection of the ecosystems in the Nile Basin.

To achieve this, this brief contains an introduction to aquatic ecosystem types and wellbeing, reviews factors affecting the classification of ecosystem types and wellbeing in the Nile Basin. This brief then presents an appropriate aquatic ecosystem type classification system for the Nile Basin with references to the types of ecosystems in the Nile Basin. Finally this brief includes a revision of available information to evaluate the wellbeing of major aquatic ecosystems in the Nile Basin according to selected protection and ecosystems service components and threats to these components.

3 Different aquatic ecosystems types and their wellbeing in the Nile Basin

Aquatic ecosystems are a major feature of the Nile Basin. Apart from the Nile River itself which is one of the world's most iconic natural features, the basin contains many globally recognised natural lakes, wetlands and waterfalls for example. Aquatic Ecosystems are differentiated from terrestrial ecosystems as being parts of the ecosystem that are permanently or periodically inundated by flowing or standing water, and whose underlying soils show signs of being permanently or periodically saturated to within 0.5 m of the soil surface (Ollis et al, 2013). The characteristics and variability of aquatic ecosystems in the Nile Basin are affected by climatological, geomorphological and topographical variability in the catchment, as well as flow variability and water resource use scenarios for example (Conway, 2005). To manage the water resources of the Nile Basin effectively it is important to be able to describe the variability of these systems which includes being able to classify aquatic ecosystem types (Figure 1 and Box 1), and then the state of the variables affecting the wellbeing of the ecosystems (Figure 2 and Box 2) and the ecosystems themselves.

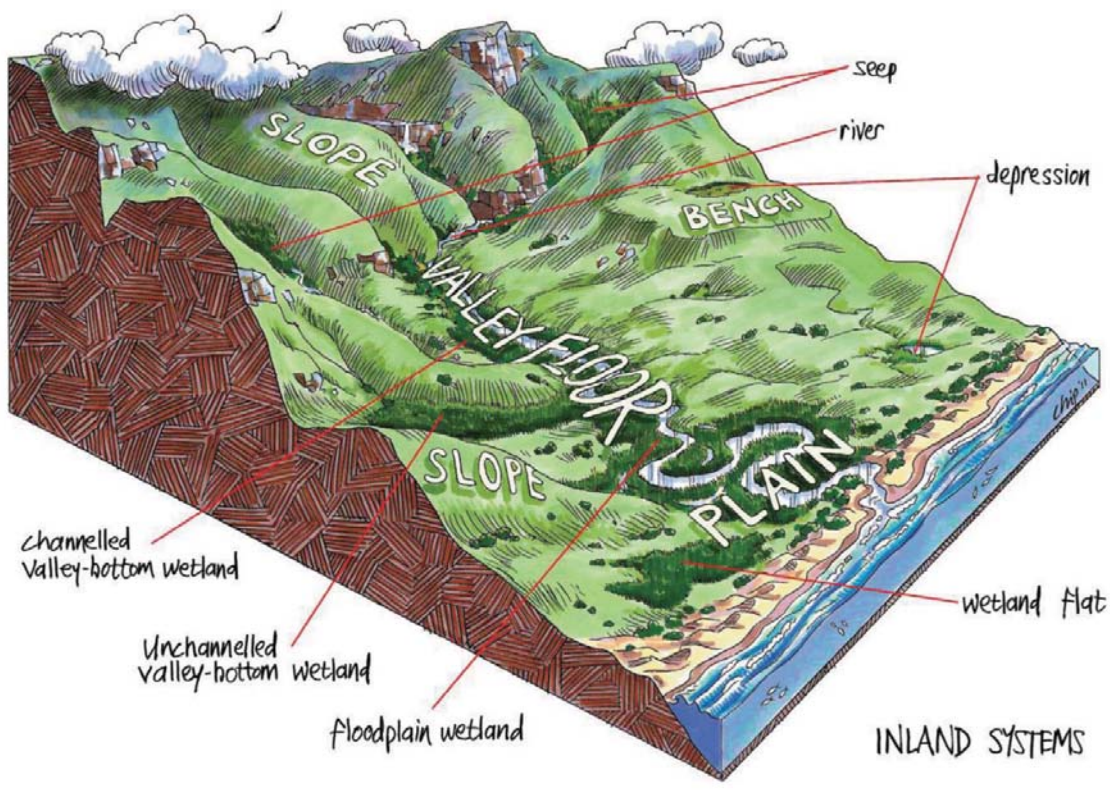

Figure 1: Types of aquatic ecosystems you may find in the Nile Basin (reproduced with permission from Ollis et al, 2013).

Knowledge of the **TYPES OF ECOSYSTEMS** in the basin and the determinants (drivers) of the differences in ecosystem types is required to manage ecosystems effectively. To achieve this a classification system of ecosystem in the Nile Basin is required. The classification of aquatic ecosystem types is a systematic way of describing and assessing the diversity in the aquatic ecosystems of Nile Basin. Given the basin-wide extent of the study area, the classification system needs to be applicable to and comparable with sub-national, national and international classification standards. This system must also be applicable on multiple spatial scales, from a fine scale to understand, manage and protect natural resources on a local or site by site basis scale. A classification system that accounts for the varied ecosystems and their linkages will enable proper management of the volume, timing and duration of flows associated with the Nile Basin. It is therefore important for the aquatic ecosystem type to be characterised and monitored for their key characteristics to allow for suitable management.

Box 1: Ecosystem Types

The wellbeing of the people in the Nile Basin are dependent on the availability of, and condition of ecosystem services the aquatic ecosystems in the Nile Basin provide. An understanding of the manner in which aquatic ecosystems, and the services they provide, are affected by variations in environmental conditions is important to maintain the wellbeing of these communities.

The flow of water into, through and out of the Nile Basin, and its ecosystems, is an important determinant of the wellbeing of the aquatic ecosystems in the Nile, and the people who depend on them. Although the seasonality of flows in many of these ecosystems can be variable, they generally consist of high flow (or wet) periods, when abundance of flows allows the ecosystems to expand and or important ecological processes occur, and low flow (or dry) periods when the processes slow down. These structure and function of the aquatic ecosystems in the Nile Basin depends on these flows.

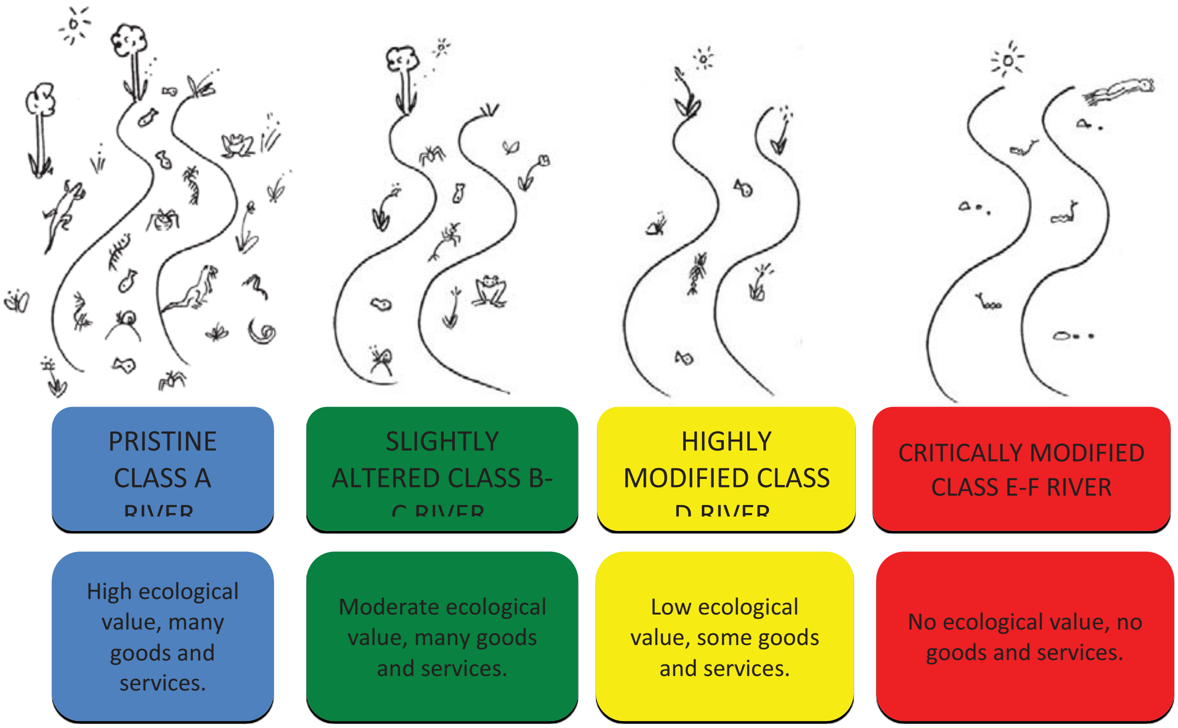

Figure 2: Relationship between ecosystem wellbeing, the ecological value of these ecosystems and the associated availability of ecosystem goods and services (adapted from Palmer et al. 2002).

The classification of the **WELLBEING OF AQUATIC ECOSYSTEMS** refers to the condition of the aquatic ecosystem, or the health of the aquatic ecosystems. The condition of aquatic ecosystems can vary as a result of many factors that might include flooding, water abstractions, invasive species, mining, oil spills, habitat and biodiversity loss. The classification of the aquatic ecosystem wellbeing in the Nile Basin is also important because it gives the basis for monitoring their conditions whether it is still intact or been altered or even if it was created by human activity. Although some ecosystems appear intact and presumably in pristine state, they may be affected by distant linkages whose connectivity has been tampered with. Altered ecosystems are moderated, usually with conditions different from natural state. Their water quality and biodiversity has changed due to human activity and have attracted new biodiversity emergencies. Others may completely be converted and are hence degraded with different conditions from natural states. These include artificial ecosystems which are made, at locations they did not exist. Their wellbeing depends on sustained flow controlled by man. Artificial ecosystems include reservoirs and irrigated areas.

Box 2: Ecosystem Wellbeing

Ecosystem type classification

The classification of the aquatic ecosystems types for the Nile Basin is based on consideration of available type classification systems such as the 2013 Classification System for Wetlands and other Aquatic Ecosystems in South Africa by Ollis et al. (2013) and available information and literature which include:

- WWF ecoregions of the world which gives the first detailed description that is comparable to other global aquatic ecosystems studies such as those on the Lake Tana sub-basin (Teferi, et al 2010),
- classification of inventory of wetlands (Scott and Jones, 1995),
- characteristics that include hydro-geomorphology, vegetation cover, buffer condition, water quality and overall condition index (Kleynhans and Louw, 2007).
- geomorphic approach to classification of inland wetlands (Teferi *et al* 2010),
- flowing systems (lotic) include the riverine wetland, lentic (standing) systems include lakes (lacustrine), swamps (palustrine) and agricultural floodplain wetlands (Hassan et al 2009), whose approaches used experiences of classifying wetlands in Uganda (Scott, 1995; Omoding 1996) and
- African wetlands in general (Hughes and Hughes 1992).

The aquatic ecosystem types of the Nile Basin are driven by a number of factors including

- the geomorphological and hydrological set up of the basin (Semeniuk and Semeniuk 1995), which governs the retention and quantity of water;
- the climatic seasons which regulate the source of water;
- the quality of the water which determines the adaptation of biodiversity whose wellbeing indicates that some few ecosystems are pristine while others have been greatly modified (e.g.. due to modification in their flow as a result of interventions to formulate reservoirs for hydropower or irrigation purposes)

Ecosystem modifications are made out of need to meet socio-economic demands like energy and food. However, such socio-economic benefits which are at expenses of ecosystems wellbeing need to be carefully planned in view of the consideration that ecosystems are sustained by flow and also provide ecosystem services and socio-economic value.

Regional scale efforts to classify aquatic ecosystems in the Nile Basin are varied. For example, Thieme et al. (2005) defines biomes. Each biome could have several aquatic ecosystems. The Ethiopian wetland ecosystem were categorized into several biomes; Sudan-Guinea, Afro-tropical highland, Somali Masai and Sahelo transition zone wetland biomes. In each of these biomes, we could have several ecosystems such as rivers, lakes and wetlands.
On a global scale, aquatic systems have been classified by WWF (2008) into the marine, terrestrial and freshwater ecoregions. Some ecoregions include several ecosystems while others like the Lake Tana ecoregion are considered as one individual ecosystem. Generally, the Nile aquatic ecosystems can be described according to Ollis et al. (2013) using the following criteria:

a) global scale ecosystems including inland ecosystems (freshwater), estuarine and or marine ecosystems,
b) landscape considerations that consider the location of the ecosystem within the basin,
c) hydrogeomorphic considerations that considers the physical features of the ecosystem and the flow of water into and out of the ecosystem,
d) seasonal hydrological considerations which consider the perenniality of flows in the ecosystem, and
e) other ecosystem characteristics (Figure 3).

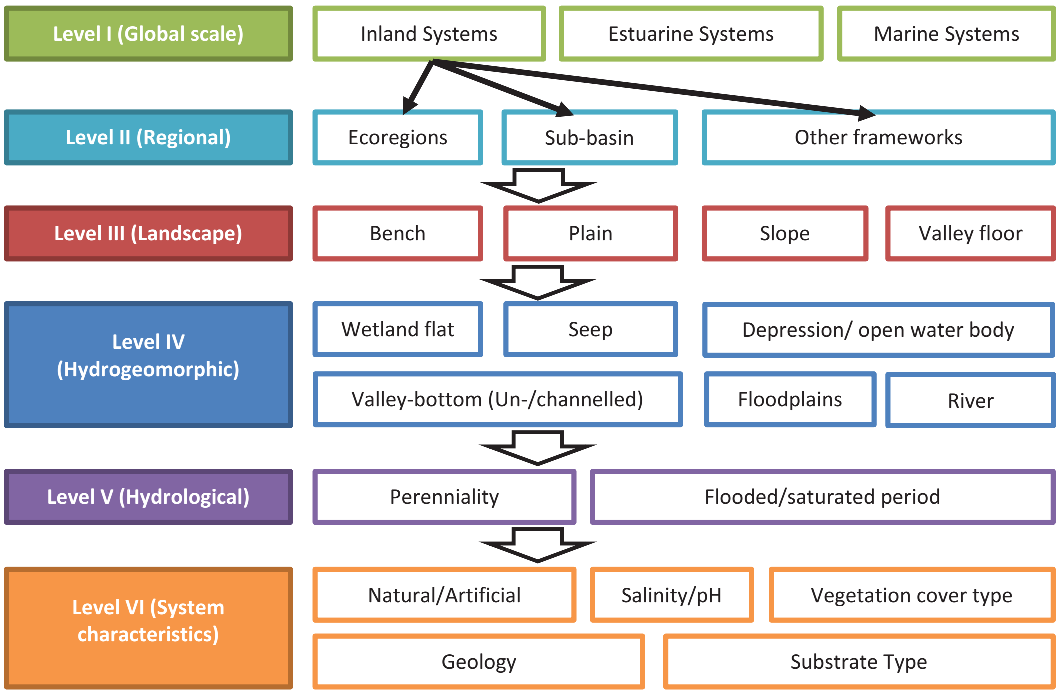

Figure 3: Graphical synopsis of the classification system for wetlands and other ecosystem types by Ollis et al. (2013).

The aquatic ecosystems of the Nile Basin are dominated by three main types including rivers, wetlands and open water bodies (Figure 4):

a) **rivers** are 'lotic' (have flowing water) ecosystems that have a distinct channel and can be permanent or flow seasonally (Ollis et al., 2013),
b) **open waterbodies** are 'lentic' (standing water) ecosystems that have a greater depth than 2m,
c) although **wetlands** *according to the Ramsar definition include all three of the aquatic ecosystem types considered here (including rivers and open waterbodies)* they are commonly considered to be the shallow (< 2m deep) transitional ecosystems between aquatic and terrestrial ecosystems that are characterised by saturated soils and water loving vegetation. *Take note that wetlands may not contain vegetation.*

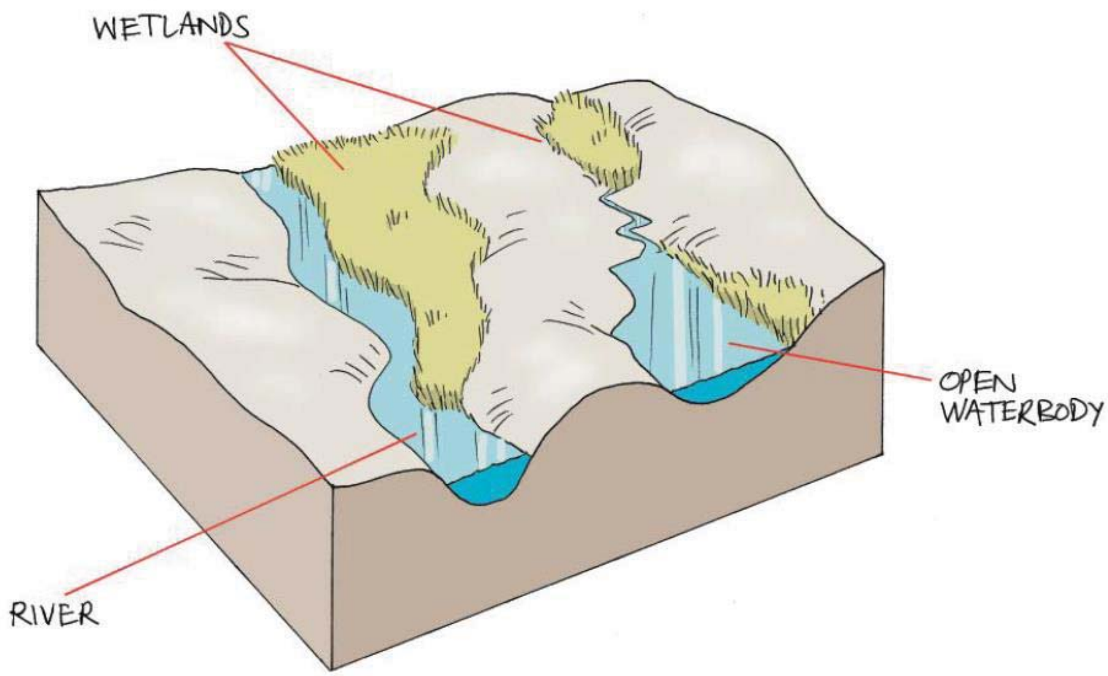

Figure 4: Main types of aquatic ecosystems in the Nile Basin.

The ecosystem type classification system adapted from Ollis et al. (2013) provided in this brief (Section 3.2) will allow all ecosystems in the Nile Basin to be classified and considered according to type in an Environmental Flow assessment.

3.1 Factors affecting the classification of aquatic ecosystem types in the Nile Basin

The state of aquatic ecosystems of the Nile Basin differ considerably, with many variables that can be attributed to the differences. To classify and manage these systems, the differences in the variables that affect the structure and function of aquatic ecosystems in the Nile Basin need to be characterised. The flow of water into ecosystems is determined by the natural basins which govern the tilt or drainage, hence influencing the resident time of water in system. The variables that determine aquatic ecosystems types are presented in Figure 5 and discussed below.

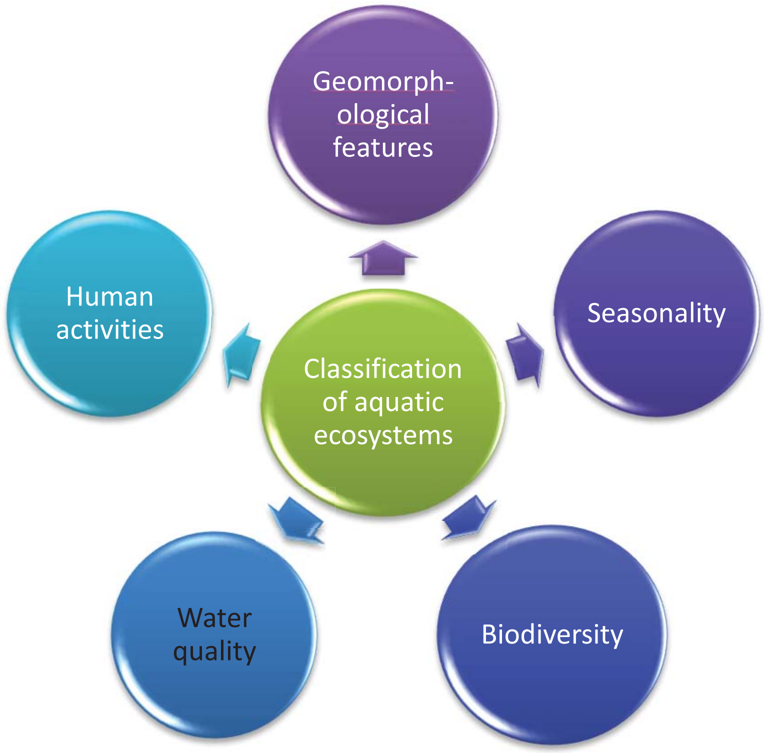

Figure 5: Factors that affect the classification of aquatic ecosystem types in the Nile Basin.

3.1.1 Geomorphology factors of the basin

The morphology of the terrain (tilted or gradient of the basin) determines the size of the aquatic basin and the time the water stays in it (retention of water). Therefore classification types such as "flooded", "riparian" and "waterlogged", are used to describe conditions of the aquatic ecosystems which may be permanent or temporary depending on water that is coming out of them. Lentic (still standing such as a lake) ecosystems have an increased retention than lotic (flowing or running such as rivers). Geomorphology factors (Semeniuk and Semeniuk, 1995), are responsible for presence of aquatic ecosystems whether lakes, rivers or wetlands and they influence shapes of the basins which sub-characterize the aquatic ecosystems. For example in the case of wetlands, the palustrine conditions that result in bogs, flushes, salt marshes, flood savannahs, sedge swamps (some of which occur at high altitudes such as the bogs in Rwenzori Mountains) depend on the geomorphology. The geology of the terrain affects water infiltration to form ground water or when retained forms lakes or wetlands and what may flow across the surface as rivers. The geomorphology therefore influences the flow that determines the wellbeing of ecosystems located in such basins (Beisel et al. 1998).

3.1.2 Seasonality

Although the longevity of water primarily depends on the morphology of the basin, its availability and presence is affected by seasonal events such as rainfall which determines how much water is available for aquatic ecosystems at different times of the year. The geo-climatic factors, especially rain, are drivers of water runoff from terrestrial ecosystems into rivers and subsequently lakes or wetlands within the tropical latitudes. The outflow from lakes and rivers correlates with the amount of rainfall that is received in the upstream catchment of these systems (Kebede *et al* 2006). In the case of the Nile Basin, the upper stream catchments have seasons different from the lower stream catchments

Annual and longer term wet and or dry periods that may be decadal in length, due to climatic variability, affects the structure of aquatic ecosystems on a basin scale even in permanently inundated ecosystems. These environmental variables include:

- habitat variations (Conway, 2005) and
- short- and longer-term flooding and fluctuations in lakes and wetlands (Conway 1996).

These fluctuations have resulted in adaptations and climate sensitivity in organisms (Yates and Strzepek, 1998). Seasonal changes in evaporation potential do affect the quantities of flow, which are greatly affected by evaporation. Temperatures changes also observed in the overall continuum approach influence the composition of communities from the upper to lower reaches of ecosystems. Coupled with geology, seasonality affects the distribution of water in space and time and the size and velocity of rivers (Beisel *et al.* 1998).

Seasonal fluctuations have been reported in aquatic ecosystems (Overton *et al*. 1995) and these include varying levels of lakes and river banks, with intermittent or no flow in some rivers (e.g.. Dinder River in Ethiopia). It is important to note that environmental flow causes seasonality in permanently inundated ecosystems and this phenomenon is important to adaptation and wellbeing of aquatic ecosystems and their habitats.

3.1.3 Biodiversity Composition

The habitats that arise from seasonality and geomorphological conditions mentioned above result into a bio-geographical distribution of organisms (Chapin *et al* 1997) influenced by adaptations that occur at various locations that generally change from north to south in the Nile basin. The types of ecosystems habitats in the basin affect the distribution of organisms notably the vegetation, amphibians, fish and invertebrates. Due to a lack of information on species distributions this has not been applied in the study.

3.1.4 Water quality

Many natural and anthropogenic (or "unnatural" in this brief) derived sources of water quality alterations occur in the Nile Basin which may affect the classification of the types of ecosystems considered in the study. Water quality constituents can loosely be categorised into different groups including:

- **Nutrients** variables which generally include the concentrations, loads and or ratios of water quality constituents (usually nitrogen, its derivatives and phosphates for example) that affect the trophic status of water (Waite *et al* 1998). This includes the use of trophic status classification terminology for ecosystem types such as oligotrophic, mesotrophic and eutrophic conditions where:
    - **oligotrophic** refers to aquatic ecosystems that contain a very low nutrient load, productivity and an associated potential to sustain a low biomass (not diversity) of organisms,
    - **mesotrophic** refers to aquatic ecosystems that contain an intermediate nutrient load, moderate productivity and an associated potential to sustain a moderate biomass (not diversity) of organisms,
    - **eutrophic** refers to aquatic ecosystems that contains a high (often excessive) nutrient load, high (often nuisance) productivity and an associated potential to

sustain a large biomass (not diversity) of organisms. This state may also include the potential for the proliferation algal blooms that may threaten the wellbeing of ecosystems (Figure 6).

- **Salt** content of a water sample technically refers to the class of chemical constituents that are formed by the replacement of one or more hydrogen atoms of an acid with elements or groups. These compounds are formed by the neutralisation of an acid by a base. Although the definition is complicated the salt content of a water sample includes free ions and chemical compounds which generally contribute to increases or decreases in the electrical conductivity of a water sample. These include well known elements such as calcium, sodium, potassium (common cations) and chlorides and sulphates (common anions). As a group salts are associated with the salinization of water, which is produced by natural processes such as weathering of rocks and wind and rain depositing salt over time and through various land use practices and effluent releases into ecosystems which elevate the salt content and the associated salinity unnaturally.
- **Toxics** refers to a wide range of water quality constituents from metals to persistent organic contaminants (such as pesticides) that are known to pose a health or toxicity threat to aquatic animals and or plants (Scheren et al 2000), even if in low concentrations have the potential to affect ecosystem wellbeing in a short time in a significant manner.
- **Aesthetics** generally refers to a range of water quality constituents that affect the way a water sample looks, tastes etc. Although there is a broad overlap between aesthetics and salts or general system variables for example this group of chemical constituents is important to managers as it affects the use of water by various stakeholders.
- **Microbial** constituents refer to the microscopic (too small to see with the naked eye) organisms in a water sample that pose a threat to human health in particular when they occur in excess. These organisms include water borne diseases such as the *Escherichia coli* (*E. coli*) bacteria. Knowledge of the microbial content of a water sample is useful to the evaluation of the “fit for use” assessment of water and the potential contamination of a water sample from a selected range of water resource users.
- **General** system variables group includes a wide range of chemical constituents that belong to many groups of chemical compounds (not discussed above) which are very useful for the monitoring and management of water resources. These variables include for example; pH, alkalinity, oxygen concentration (and saturation potential), water hardness etc. In essence it’s a group for all of the remaining water quality constituents that are useful to the monitoring and management of water resources.

The concentrations (or loads if data is available) of water quality constituents can fluctuate considerably. Best scientific practice requires the use of numerous samples collected over a suitable period to allow for the water quality state of water body to be evaluated in relation to background or historical concentrations/loads. Unfortunately due to financial and human resource constraints once off (snap shot) water samples are usually collected and analysed. These analyses provide an indication of the state of the water quality but usually need validation (more samples) to correctly describe the state of an ecosystem and if required the relationships between a water resource user and the wellbeing of the ecosystem.

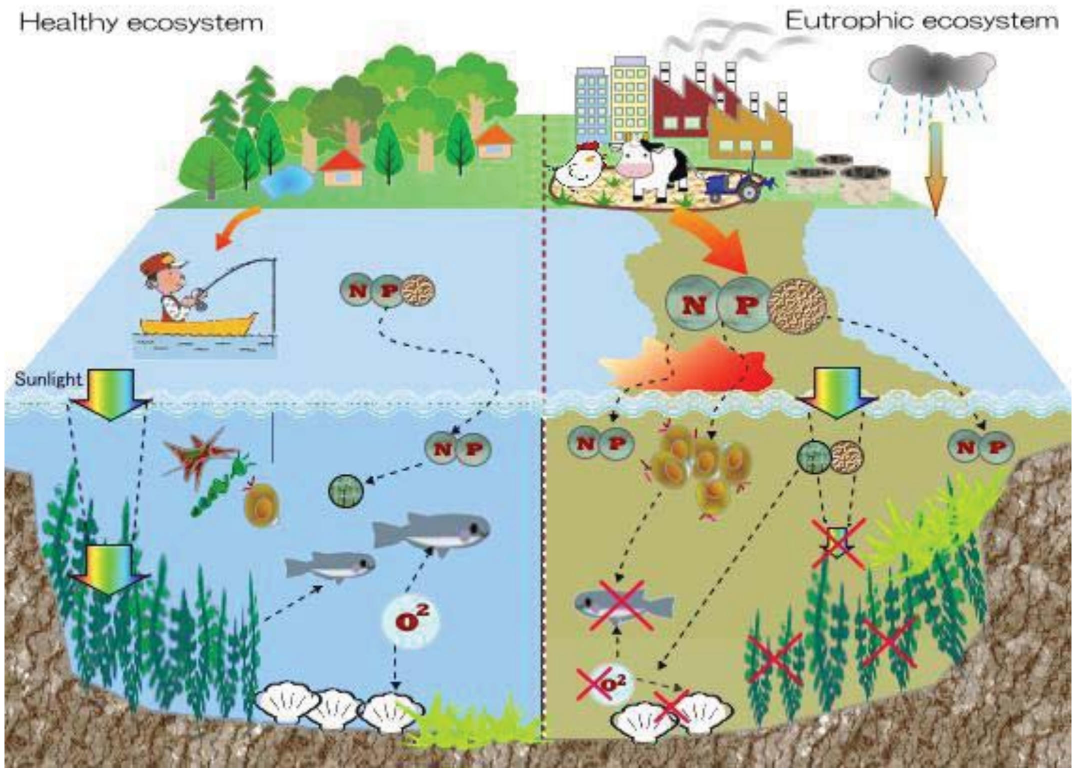

Figure 6: Comparison between an oligotrophic or mesotrophic ecosystem with a "balanced" nutrient load (left) or productivity as opposed to an ecosystem with a high nutrient load which renders the system in a eutrophic state (right).

3.1.5 Human interventions

Human interventions is the major cause of impairment of aquatic ecosystems in the Nile Basin and has resulted in modification of ecosystems and the establishment of manmade lakes (dams/reservoirs) and/or irrigated areas. The wellbeing of artificial aquatic ecosystems differs and depends a lot on physical management of flow. Currently, the largest manmade lakes in the Nile Basin occur in Egypt and Sudan and are both associated with large irrigation schemes. These developments are considered to have a significant effect to the wellbeing of the lower Nile River and its biophysical processes. These artificial ecosystems and other developed systems, including developed wetlands etc. should be monitored and their threat to the wellbeing of ecosystems and associated ecological processes managed. Natural ecosystem depend on water that flows naturally into them whose variability determines the ecological importance of these systems.

3.2 Types of aquatic ecosystems in the Nile Basin

The Nile River is the longest river in the world and its basin is one of the largest (Figure 9), and although socially, economically and ecologically important to millions of Africans, little is known about the aquatic ecosystems in the basin together with the dynamics of their biodiversity, apart from the main Nile River and associated tributaries. In addition, where data is available, different classification techniques have been used to classify the smaller aquatic ecosystems in particular. Here available information and spatial data has been used to classify aquatic ecosystem types in the Nile basin on a coarse, desktop scale using the classification system of Ollis et al., 2013. The Nile Basin contains two main aquatic ecosystems types including the Nile Delta and associated estuarine ecosystem, and the freshwater or inland portion of the Nile River and the associated basin.

1. **Estuarine ecosystems** i.e.. the Nile Delta, is defined as a body of surface water that is (a) part of a water course that is permanently or periodically open to the sea, (b) in which a rise and fall of the water level as a result of the tides is measurable at spring tides when the water course is open to the sea, or (c) in respect of which the salinity is measurably higher as a result of the influence of the sea (after the Integrated Coastal Management Act; Act No. 24 of 2008) (Figure 7).

Figure 7: The Nile Delta entering the Mediterranean sea.

2. **Inland ecosystems**: an inland aquatic ecosystem is defined as a surface (excludes groundwater ecosystems) aquatic ecosystem upstream of the estuary. These ecosystems are characterised by the complete absence of marine exchange and/or tidal influence. Inland aquatic ecosystems broadly include lakes, rivers, wetlands and open water bodies (Figure 8).

Figure 8: The Nile River.

On a regional scale (Level II, Figure 3) the Nile basin consists of three main sub-basins including the White Nile, the Blue Nile and the lower Nile below the confluence of the White and Blue Nile. In addition, the Nile Equatorial Lakes region has been demarcated to include the White Nile and Blue Nile River regions dominated by large natural lakes including; Burundi, Democratic Republic of Congo, Kenya, Rwanda, Tanzania and Uganda, South sudan and parts of Sudan. In the Nile Equatorial sub basin there are many open waterbodies (lakes) and wetlands, while in Eastern Nile Sub-basin (dominated by the Blue Nile), the highland influences the nature of the slope which influence the rains and runoff, makes the Nile more fluvial and more river dominated. The geographical location is a key factor (coupled with the geomorphologic terrains), in influencing the ecosystem type and also determines the location to which the jurisdiction of the ecosystem falls in terms of regional and transboundary managed ecosystems.

Figure 9: Large river basins of the world, adapted from UNEP; WCMC; WRI; AAAS; Atlas of Population and Environment, 2001.

Within the Landscape setting of the Nile Basin the location of the ecosystem being considered is used to demarcate ecosystem types on Level III in Figure 3. Also refer to Figure 1 and Table 1.

Table 1: Landscape Unit (Level III) summary of the aquatic ecosystem classification system used for the Nile Basin (adapted from Ollis et al., 2013).

LEVEL III – Landscape Units (in relation to topography of the basin)		
Landscape Units	Definition	Sub-categories
Valley floor	Base of valley which lies between two side-slopes	
Slope	Inclined section of ground, usually occurring on the side of a mountain	Can include: o Steep (scarp) slopes o Mid-slopes o Foot-slopes
Plain	Large area of low relief, with subtle undulations and a uniform gradient	
Bench	Discrete area of level or relatively level of land, in relation to the broader surroundings	Types: o Hilltop o Saddle o Shelf

Following the consideration of the position of the ecosystem within the landscape, the hydrogeomorphic (HGM) characteristics of the ecosystem are considered. Here the landform, hydrological characteristics and hydrodynamics of the ecosystem are considered (Table 2,

Figure 10).

Table 2: Hydrogeomorphic characteristics unit (Level IV in Figure 3) summary of the aquatic ecosystem classification system used for the Nile Basin (adapted from Ollis et al., 2013).

LEVEL IV – Hydrogeomorphic (HGM) Unit		
HGM Type	Longitudinal zonation/ landform/ outflow drainage	Landform/inflow drainage
River	o Mountain headwater stream o Mountain stream o Transitional o Upper foothills o Lower foothills o Lowland river o Rejuvenated bedrock fall o Rejuvenated foothills o Upland floodplain	o Active channel or riparian zone
Channelled Valley-Bottom Wetland		
Unchannelled Valley-Bottom Wetland		
Floodplain Wetland	o Floodplain depression o Floodplain flat	
Depression (includes open waterbodies including lakes (Important for Nile Basin).	o Exorheic (one or more outlets) o Endorheic (no outlets) o Dammed	o With channelled inflow or without channelled inflow
Seep	o With channelled inflow or without channelled inflow	
Wetland Flat		

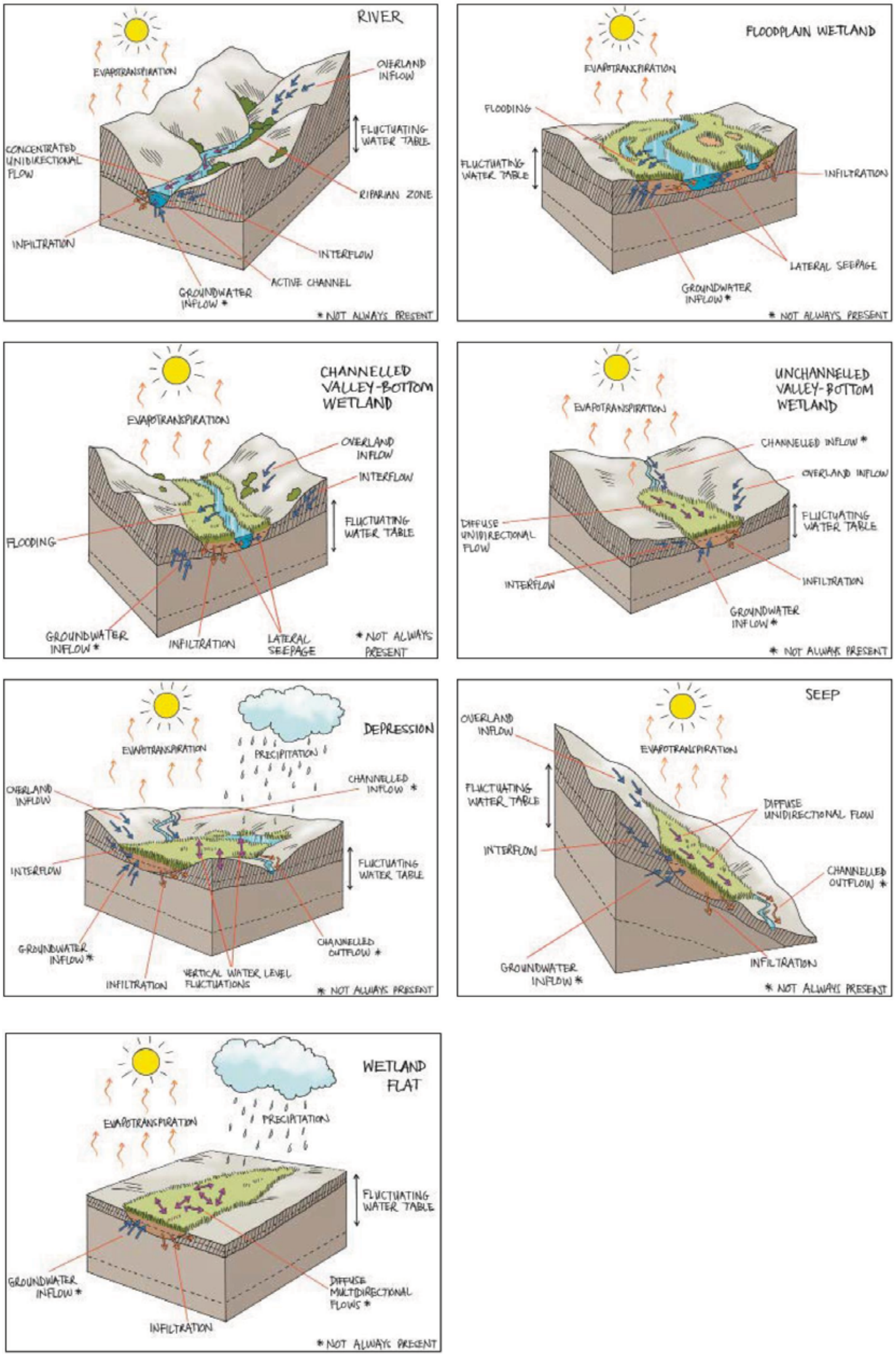

Figure 10: Drawing of the types of hydrogeomorphic ecosystems that may occur in the Nile Basin. Hydrological flow dynamics highlighted by blue (input), yellow (output) and pink (throughput) arrows.

The hydroperiod of the ecosystem is then considered as a part of the Level V tier (Figure 3) of the classification system proposed for the Nile Basin. Here the perennial (flows continuously) versus non-perennial (does not flow continuously) nature of the ecosystem is evaluated based on the period of inundation, saturation and depth classes of the ecosystem.

Table 3: Hydroperiod categories for Level V tier of the classification system proposed for the Nile Basin including period of inundation, saturation and depth classes (adapted from Ollis et al. (2013)).

LEVEL V- Hydroperiod and depth of inundation		
Inundation periodicity (A)	**Saturation periodicity (within 0.5 m of soil surface) (B)**	**Inundation depth-class (C)**
Permanently inundated	NA	○ Limnetic ○ Littoral ○ Unknown
Seasonally inundated	○ Permanently saturated ○ Seasonally saturated ○ Unknown	
Intermittently inundated	○ Permanently saturated ○ Seasonally saturated ○ Intermittently saturated ○ Unknown	
Never inundated	○ Permanently saturated ○ Seasonally saturated ○ Intermittently saturated ○ Unknown	
Unknown	○ Permanently saturated ○ Seasonally saturated ○ Intermittently saturated	

On the Level VI tier (Figure 3) descriptors of the ecosystem type are introduced into the classification system so that ecosystem variability can be considered as a component of an environmental flow assessment for example. The effect of human development on the ecosystems in considered here as a primary descriptor including **natural** (produced by nature – not made/caused by humans) vs. **artificial** (produced by human being, not naturally occurring) ecosystems. Thereafter some board water quality descriptors can be used including salinity and pH:

- Salinity
    - **Fresh** (electrical conductivity (EC) range <500 mS/m or Total Dissolved Salts (TDS) <3g/l)
    - **Brackish** (EC range 500-3000 mS/m or TDS 3-18g/l)
    - **Saline** (EC range 500-8000 mS/m or TDS 18-48g/l)
    - **Hypersaline** (EC range >8000mS/m or TDS >48g/l)

- pH
  - **Acidic** (pH <6)
  - **Circum-neutral** (pH 6-8)
  - **Alkaline** (>8)

Additional descriptors include consideration of substratum type which may include different portion of many of the following substrate types; bedrock, boulder, cobbles, gravel, sand, clay soils, loam soils, silt (mud), organic matter, salt crust and other substrates.

Finally the vegetation cover, form and status should be characterised (Table 4).

Table 4: Level VI vegetation cover, form and status component of descriptor component of ecosystem type classification system for the Nile Basin, adapted from Ollis et al. (2013).

LEVEL VI- Vegetation Cover, Form and Status		
Vegetation cover (A)	**Vegetation form (B)**	**Vegetation status (C)**
Vegetated	Aquatic	○ Floating ○ Submerged ○ Algal mat
	Herbaceous	○ Geophytes ○ Grasses ○ Herbs/Forbs ○ Sedges/Rushes ○ Reeds ○ Restios ○ Palmiet
	Shrubs/thicket	N/A
	Forest	○ Riparian Forest ○ Forested Wetland (swamp forest)
Unvegetated	N/A	N/A

3.2.1 Major types of Aquatic Ecosystems of the Nile

The aquatic ecosystems that dominate the Nile Basin can be differentiated on a hydrogeomorphic classification tier (Level IV). This includes depressions (open waterbodies), wetlands, rivers, floodplains, valley-bottom, seeps, etc.

Depressions (open waterbodies): these lacustrine or lentic ecosystems include lakes, wetlands and meres. They are permanently inundated aquatic ecosystems where standing water is the principal medium within which the dominant biota live. Open water bodies with a maximum depth greater than 2 m are also called limnetic (lake-like) systems. They occur on locations within the basin where geomorphological features allow establishment of basins, which either through flow of an inflowing river or runoff are filled with water. Their physical conditions modify the habitats for example they can be shallow or deep, have small or large surface area. The geomorphological conditions coupled with climatic factors govern the characteristics that drive resilience and adaptation. These ecosystems include:

- **Large Shallow Basins** of the Nile include Lake Victoria (Figure 11), the world's second largest freshwater lake and the largest in the Nile Basin with a surface area of 69,000 km^2, followed by the three other major lakes of the East African Rift Valley including Lake Albert, Kyoga and Edward. The existence of these lakes and associated ecosystems depend on flow. Fluctuations in their surface levels has been reported in the past and is associated by changing seasons and alterations in their incoming or outgoing flows. The basins of Lake Victoria and the three smaller lakes to the west Lake George, Edward and Albert are continguos with floodplains, wetlands and smaller satellite lakes that support an abundant diversity of animals and plants and many water-dependent ecosystems. Lake Tana within the Blue Nile Basin is another great lake of the Nile Basin and has a surface area of 3,200 km^2.

Figure 11: Lake Victoria

LARGE SHALLOW BASIN LAKES with lentic characteristics, shallow depths and large surface areas are usually eutrophic with high productivity and associated with rich content of nutrients. The total area of open water in the Nile basin is about 90,000 km^2 (Nile Information System). The Common large basins associated with the Nile Basin located at the Nile equatorial lakes (See Appendix) include Lakes Victoria, Kyoga, Edward, George, Albert, White Nile (sections of areas in the Sudd have open water zones which behave as lakes). And in the Blue Nile Lake Tana occurs. These large shallow basins depend on flows and provide the basis of socio-economic benefits to local communities including the fisheries industry, hydro electricity generation, transport and recreation.

Box 3: Large Shallow Basin Lakes

- **Large Deeper Basins:** These include the rift valley lakes which have been named due to their location in the Western Rift Valley. They are associated with deep waters with zones deep enough to cause pseudo - meromixis (failure for deeper waters to mix with surface waters) e.g.. Lake Edward, Albert, and George. These lakes have a large volume due to their extraordinary depths.

- **Small lake Basins** which include lakes of relatively smaller sizes usually not larger than 25km^2 and characterise many areas of the great lakes region of the Equatorial Nile Basin. These include:

- **Satellite lakes**: Large lakes like Victoria form satellite lakes like Lake Nabugabo (Figure 12) and Lake Kanyaboli which are connected during rare high lake level periods. These lakes are of particular importance as the flow of species from these lakes and the greater lakes is of great ecological importance. During periods of low levels species diverge from parent stocks in isolated lakes. When the lake levels rise, satellite lakes are connected to the main lake and populations mix. If some mechanisms prevent interbreeding, two distinct species may be recognised from one common ancestor. Therefore natural flow is important in this phenomenon in large lakes.

Figure 12: Lake Nabugabo in Uganda.

- **High Altitude Lakes:** These are specific in small basins that occur in high altitudes and mountainous areas. These are exemplified by Lakes Kitandara, Bujuku and Mahoma occur above 2500m above sea level on Mount Rwenzori.

- **Crater Lakes:** are basins caused by volcanic activities. When they contain water they become crater lakes. Usually their water flows into them from the surrounding catchments. Some are seasonal and saline e.g.. Lake Katwe (Figure 13) and Lake Kasenyi in Eastern Uganda.

Figure 13: Lake Katwe in Uganda.

- **Oases:** occur in the desert ecosystems. An oasis forms when shallow sub-surface waters interact with the surface in desert ecosystems in the form of springs. These features are usually associated with bedrock features close to the surface where rain fed aquifers interacts with the surface. In some occasions wind action can cause erosion that causes depressions or opens depressions that are filled with water.

SMALL BASIN LAKES – these smaller basin lakes also have socio-ecological importance as they provide food for the Nile riparian communities. For example in the Kagera Sub basin, there are a number of small lakes such as Lakes Mburo, Mutukula, Kabandate, Mishera, Nakivali, which have a surface area of less than 15km^2 and are situated in western Uganda. Others like Karunga, Kijanebalola, Kachira, Mutanda, Muleke, Bunyonyi, Chafari and Kayumbu are all depended on flow and support small but important artisanal fisheries. The small lakes of Rwanda, like Lakes Cyohoha North, Cyohoha South, Rweru, Bugesera, Ihema, Hogo, and Rwanyakizinga all depend on the flow of the Nile and despite their smallness support livelihood to a large population of human dependants in addition to their roles in maintaining ecosystem. Of these Lake Cyohoha South is a seasonal lake. Other small lakes include the Mara, Sio, Yala, Kyoga, theBaro –

Box 4: Small Basin Lakes

- **Artificial/man-made aquatic ecosystem**
  These exist so long as there is human intervention to hold flow, or alter the distribution of water (Figure 14). They include:
  - Irrigated ecosystems
  - Reservoirs or dams and manmade lakes. Man-made lakes are a significant feature of the lower reaches of the Nile, where Lake Nasser (Lake Nubia) has a potential area of 4,200 km^2, making it the world's second largest artificial lake.
  - Aquaculture ponds for fish, crocodiles etc.

Figure 14: Lake Nasser in Egypt.

  Artificial ecosystem are important in addressing demands for livelihood support especially food and energy. It is therefore important that flow regulations that do not compromise ecosystems' wellbeing are put in place so that water is available for irrigation, aquaculture as well as production of energy through hydro-power generation.

- **Wetlands ecosystems**
  The wetlands of the Nile Basin consist of habitats which support a number of globally threatened species and restricted range species, such as water turtles, crocodiles, monitor lizards, snakes, otters and a large variety of water birds including herons, egrets, ducks, warblers and weavers. Their other biodiversity including vegetation types together with their soils support a wide range of livelihood, agriculture and construction industries (NBI State of Basin report 2009; 2012). A great amount of evaporation attributed to great losses of water is reported to occur particularly in the Sudd area (Figure 15) (by many reports including the NBI MSOIA report of 2014). However, evaporation is a naturally hydrological process through which other ecosystems receive water through the

hydrological pathway. This role performed by the wetlands is of much value and could be considered as a process that require considerable flow to balance water between the wetlands functions and other uses.

Figure 15: The Sudd wetland in the Nile Basin.

Rivers

These include ecosystems of visibly running water that allow adaptive rheophilous organisms to occupy them. They are fluvial and can be seasonally or permanentas described below:

- permanently flowing rivers like the main Nile River course,
- seasonally flowing and intermittent rivers usually caused by low flow in dry season
- floodplains – rivers during peaks of rainy seasons overfill their banks to flood in the plains causing permanent or seasonal water logging. This is common in the Marshal Marshes whose ecosystems depend so much on the flooding of the rivers. This aspect of flooding which is ecologically very important is referred to as spillage in some reports to justify that rivers should only move in their channels.
- Blackish / salty ecosystems – these are estuarine which are partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea. The Nile delta flows is an example of such ecosystems. River size is a factor.

As mentioned in sections above, seasonality is a factor which affects volume and quality even in permanently inundated rivers, hence in flow measurements, it is important to monitor the timings when the rivers banks are full or low. This in effect is important to biodiversity which is adapted to such fluctuations.

Rivers are characterised with a zonation which starts with the spring region. Many of the springs that arise from the ground water flow into valleys and water is stored in wetlands.

Figure 16: The Enapuiyapui Swamp in Kenya, the source of the Mara River.

The gently sloping valleys with reduced runoff usually hold water for a long time hence storing water which is released in time and space. This function of wetlands is important for the continued flow of rivers because the water is released into rivers continuously during dry seasons when there is no water flowing into the wetlands. The interconnectedness of aquatic ecosystems is mainly done by rivers and wetlands and this is therefore very important in understanding the dynamics of flow, e.g.. River Mara flows from Enapuiyapui Swamp (Figure 16) which is a 6-hectare wetland situated in the Kiptunga Forest and is source of Amala River.

3.2.2 The Nile Basin Ecoregions

The Nile River Basin has been divided into a group of aquatic (Figure 17) and terrestrial (Figure 18) ecoregions. An ecoregion is a relatively large unit clustering terrestrial and/or aquatic ecosystems. It contains a geographically distinct assemblage of natural communities with boundaries that approximate the original extent of the natural environment (prior to major land use changes). In Annex I terrestrial and freshwater ecoregions per Nile Basin Country have been provided.

Although climatic factors, (weather, temperature for example) animals and plants primarily drive terrestrial ecoregions in the Nile Basin, different factors (including altitude, flow linkages and the associated movement of aquatic species) primarily drives aquatic ecosystems in the Nile Basin.

As such the Nile Basin ecoregion is a large area encompassing one or more freshwater system/s that contains a distinct assemblage of natural freshwater communities and species. The freshwater species, dynamics, and environmental conditions within a given ecoregion are more similar to each other than to those of surrounding ecoregions and together form a conservation unit.

The first ever classification of the freshwater ecoregions of the world is provided by Abell *et al* (2008) who describes freshwater ecoregions based on the distributions and compositions of freshwater fish species and incorporates major ecological and evolutionary patterns. With this classification ecoregions of the world have been mapped , together with associated species data, into a useful tool for underpinning global and regional conservation planning efforts (particularly to identify outstanding and imperilled freshwater systems).

Box 5: First classification of the freshwater ecoregions

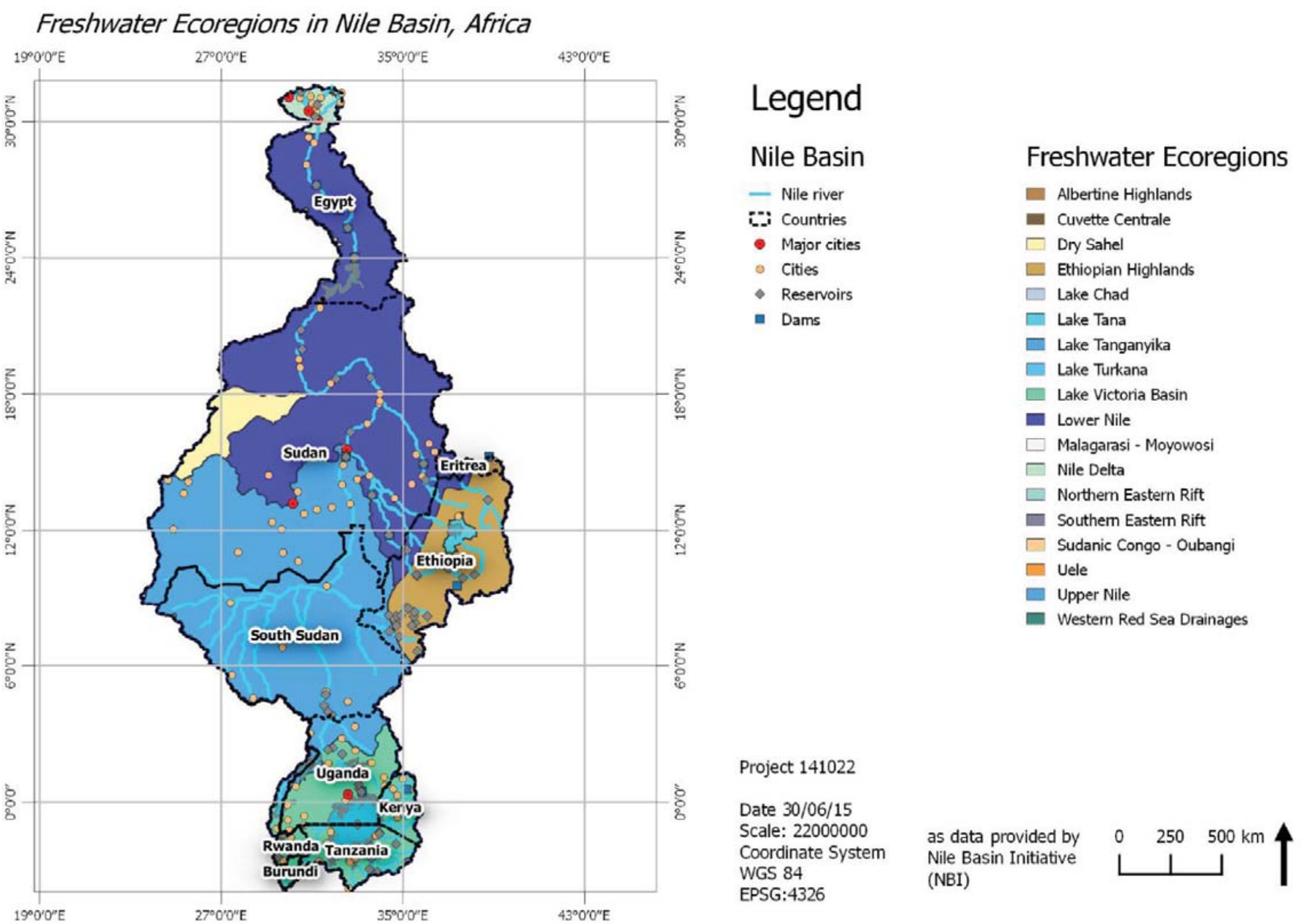

Figure 17: The Nile basin in Africa with major rivers, aquatic ecoregions and country boundaries included.

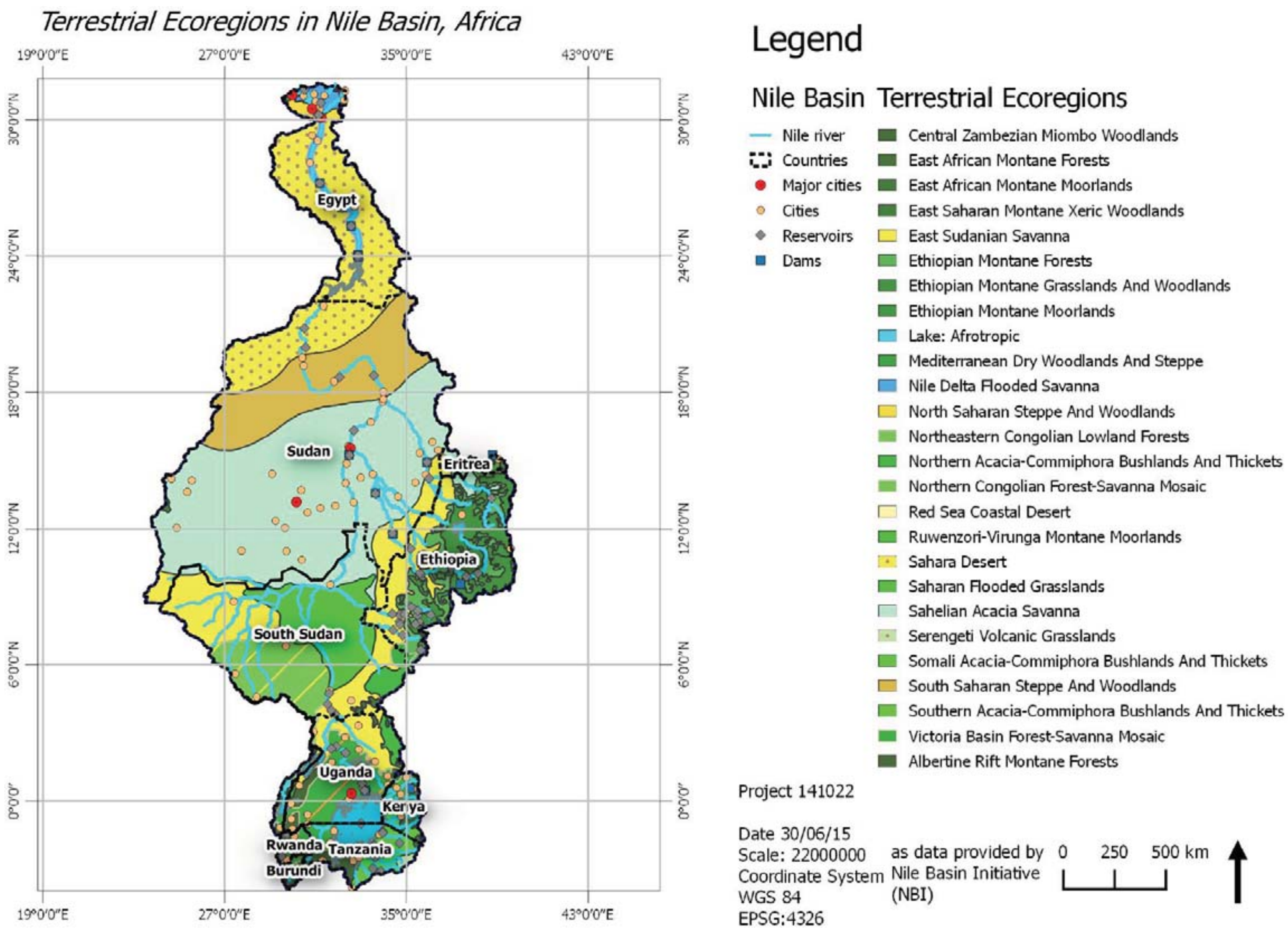

Figure 18: The Nile basin in Africa with major rivers, terrestrial ecoregions and country boundaries included.

In the Nile Basin there are 18 recognised freshwater ecoregions (Figure 17). Of these ecoregions six make up over 95% of the Nile Basin and are relatively well known (Ethiopian Highlands, Lake Tana, Lake Victoria Basin, Lower Nile, Nile Delta and Upper Nile), the remaining twelve are discrete and share many features with the main six ecoregions. In this brief we will discuss the six main ecoregions.

1. The Nile Delta Ecoregion

A river delta is a landform that forms at the mouth of a river, where the river flows into the sea. Deltas form from deposition of sediment carried by a river as the flow leaves its mouth. These sediments raise the profile of the river and cause it to branch often resulting in large branching rivers and associated floodplains which enter the sea through multiple mouths (Figure 19). The Nile Delta extends about 175 km from its apex at Cairo to the Mediterranean Sea, and is about 260 km wide along the coast (Hughes & Hughes 1992). This ecoregion is defined by the extent of the delta and associated marshes. This forms part of the Main Nile River describe by Hassan et al 2009).

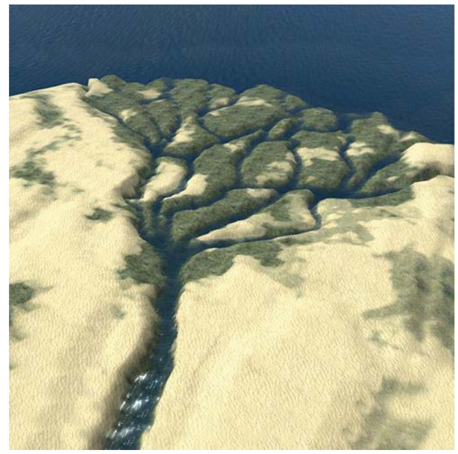

Figure 19: Digital elevation model of the Nile Delta.

Since the construction of the Aswan High Dam (completed in 1970), water flow through the delta dramatically decreased and its floodplains are no longer subject to annual flooding. As a result, the Nile River now occupies only two main channels - the Rosetta (western) and the Damietta (eastern). Today several small lakes occupy former river channels such as El Mannah, El Qatta, Faraonyat, Sinnéra and San El Hagar. The main wetlands in the delta are the coastal Lakes of Manzala, Burullus, Idku and Lake Maryut.

Changes in the aquatic vegetation of the delta reflect changes in the Nile's flow and sediment distribution. The *Cyperus papyrus* swamps that previously existed in the wettest areas of the delta disappeared with the closure of the Aswan High Dam. Reeds *Phragmites australis* and *Typha* sp. are now common throughout the delta wetlands, along with some species of sedge *Juncus* sp. (Hughes & Hughes 1992). *Ceratophyllum* covers many of the delta lakes where water is fresh or slightly brackish. In lacustrine areas of higher salinity *Potamogeton pectinatus* and *P. crispu s*p redominate (Burgis & Symoens 1987). This ecoregion is delineated based on the extent of the Nile Delta and its marshes and is distinguished by a Nilo-Sudanian freshwater fauna with some brackish and marine elements. Its suggested in this study that considerations in restoring the ecological functions of the Nile Delta should be made to enable it support the original communities of biodiversity from which livelihood is supported.

Example of the application of the classification system for the Nile Delta:

- Level I – Estuarine ecosystem
- Level II - Nile Delta Ecoregion
- Level III - Plain
- Level IV – Nile River, with an extensive associated floodplain,
- Level V – Nile River is permanently inundated with defined limnetic and littoral zones,

- Level IV – The delta is brackish and usually slightly alkaline, dominated by alluvial sandy soils with abundant vegetation which includes aquatic (floating, submerged and algal mats) and herbaceous (grasses predominantly) plants.

2. Lower Nile (Ecoregion)

The lower Nile River provides a vital oasis for terrestrial and aquatic wildlife as it runs through the semi-arid Sahel and arid Saharan Desert of northern Sudan and Egypt. The boundaries of this ecoregion are defined by the lower Nile River from Khartoum, where the White and Blue Nile rivers converge, downstream to the Nile Delta. Notable features of the ecoregion include four major cataracts over which the Nile flows before emptying into the Aswan High Dam's massive reservoir, named Lake Nubia in Sudan and Lake Nasser in Egypt. This region together with the delta region are described as the Main Nile by Hassan *et al* (2009) and is largely moderated due to creation of reservoir and dams for production of hydro-electricity and water for irrigation.

In the lower Nile River, the flood flows fluctuate between June and November (Kendle 2001; Collins 2002) due to contributions from different sub catchments but the control of the flow of the river causes many of the habitats in this section of the Nile to be modified. Lake Nubia/Nasser is riverine in the south and more lacustrine in the north (Hughes & Hughes 1992). The Aswan High Dam also significantly altered the Nile's hydrologic regime (Beadle 1981). Previously, annual floods in the lower Nile River, laden with nutrient-rich sediments sustained swamps between Khartoum and lower Egypt (Dumont 1986). The dam caused the floodplains to virtually disappear (Welcomme 1979). When not in flood, the shallow (7-8 m average depth) lower Nile today has little energy and meanders through the wide, older channel, creating many in-channel islands (Abdelbary 1996; El-Sherbini et al. 1996).

From Khartoum downstream, the Nile valley is a broad flat plain over 300 km wide at its narrowest point and almost devoid of vegetation throughout the desert of northern Sudan. However, drought-tolerant plant species, such as *Polygonum* spp. and *Potamogeton* spp., occur in local stands and create narrow fringes along the mainstem Nile. Stands of *Phragmites* proliferate where the Nile flows into Lake Nubia (Dumont 1986; Hughes & Hughes 1992). Below Lake Nasser, the Nile flows across a desert plateau, dividing it into two regions: the western desert, Sahara el Gharqiya, and the eastern desert, Sahara el Sharqiya (Hughes & Hughes 1992). The western desert is an arid sea of blown sand, becoming rocky towards the mainstem Nile. The eastern desert is bound by a discontinuous range of mountains that separates the Nile valley from the Red Sea. These mountains are extensively dissected by *wadis* (dry riverbeds that sometimes flow during flood events). The valley of the Nile River below Aswan Dam varies between 20-30 km in width and is confined by steep sides (Collins 2002). At the northern edge of the ecoregion, west of the Nile mainstem, Lake Qârûn lies at the bottom of the Fayum depression, which is 71 km long and 20 km wide. Once fed by the Nile, Lake Qârûn now receives most of its flow as runoff from surrounding irrigated lands. As a result, its waters are becoming increasingly saline (Collins, 2002).

The headwaters of the Blue Nile and Atbara Rivers are also separated into the Ethiopian Highlands ecoregion due to their swift-flowing, steep nature and different aquatic fauna. The valley of the Nile River was inundated by the Tethys Sea up through the Cretaceous period (approximately 65 million years ago) (Dumont 1986). Five geologic phases of the Egyptian Nile can be distinguished, each separated by a dry period of no flow: the Eonile, Palaeonile, Protonile, Prenile, and the present Neonile (Rzóska 1978; Dumont 1986). The present Nile valley developed at the end of the Miocene. The rise of the high volcanic plateaus in Ethiopia, probably during the Oligocene, is responsible for the origin and direction of the Blue Nile and the Atbara River (Rzóska 1978). Tectonic movement and climatic changes have changed the Nile's course and flow many times. The Nile Basin has few endemic fish, due to the frequent cessation of flow that inhibited the evolution and persistence of aquatic species (Beadle 1981; Dumont 1986).

Example of the application of the classification system for the Lower Nile Ecoregion – the Aswan Manmade Dam:

- Level I – Inland ecosystem
- Level II – Lower Nile Ecoregion
- Level III – Valley floor
- Level IV – Exoheric dammed depression with channelled inflow,
- Level V – the lake is permanently inundated with defined limnetic and littoral zones,
- Level IV – The lake is artificial, fresh and generally neutral (pH), with alluvial sand, silt and organic sediments which is generally vegetated.

3. Ethiopian Highlands - Ecoregion

This ecoregion includes major habitat types consisting mostly of Montane freshwaters spread Countries across Eritrea, Ethiopia and Somalia. In the Nile Basin Wetlands study, (Teferi et al. 2010), this region was describe as Tekeze Atbara and the Abay Basins. This high-altitude ecoregion is defined by the two blocks of highlands in Ethiopia, separated by the rift valley and distinguished by a freshwater fauna adapted to the ecoregion's swift-flowing rivers. The highlands extend from Eritrea in the north to Kenya in the south. With a long history of isolation, the Ethiopian Highlands are known to harbour a highly endemic biota. Rivers of the western highlands generally flow towards Sudan.

The westward flowing rivers (the Tekezze, Angereb, Atbara, Abay, Baro and Akobo) form part of the Nile drainage basin. Three major highland lakes, Lakes Hayq, Ardebo and Ashengie, lie near the edge of the western escarpment of the rift valley at altitudes between 2,000 and 2,500 m. Lake Hayq, located in northern Ethiopia's Wollo region, has an area of 5 km^2 and a maximum depth of 23 m, and is noteworthy for its extremely clear water (Kebede *et al.* 1992). Lake Ardebo is located about 5-km southeast of Lake Hayq. This lake is smaller in size than Lake Hayq and flows into Hayq via the Anchercah River (Kebede *et al.* 1992). Lake Ashengieis located north of Lake Hayq in the Tigray region, and sits at an altitude of 2,460 m. The lake covers an area of 25 km^2 with a maximum depth of 20 m and a mean depth of 14 m (Wood & Talling 1988). The lake is fed by a number of small streams from the surrounding areas and there is no drainage out of the lake (Ethiopian Wildlife and Natural History Society 1996).

The Ethiopian highlands receive about 950 mm or more of rainfall due to a double passage of the inter-tropical convergence zone. The high mountains east of Lake Tana and the south-western mountains stand out as places of higher rainfall. They receive 2,000 mm or more of rainfall each year (Westphal 1975). A rainfall regime that peaks in March-May and June-August is typical for the Ethiopian Highlands.

Ecosystem studies indicate that few scientific studies have been made on the fauna of the river systems of Ethiopia; (Getahun & Stiassny 1998; Golubstov and Berendzen, 2005). River systems particularly in the Tekezze-Angereb basin have not been studied at all due to security problems in the past. Preliminary reports indicate that the large river bodies of this basin support a rich fish fauna and research is needed to confirm this. Some information on the benthic fauna of Ethiopian mountain streams and rivers is available in Harrison and Hynes (1988).

Figure 20: The Ethiopian highlands through which the Blue Nile originates.

Example of the application of the classification system for the Ethiopian Highlands Ecoregion – high altitude wetlands:

- Level I – Inland ecosystem
- Level II – Ethiopian Highlands Ecoregion
- Level III – Slope
- Level IV – Seeps without channelled inflow
- Level V – the wetlands are intermittently inundated seasonally,
- Level IV – The wetlands are natural, fresh and generally acidic (pH), with organic sediments and well vegetated with herbaceous (geophytes, sedges/rushes etc.) dominant vegetation.

4. Lake Tana Ecoregion

Lake Tana, a lake in the highlands of Ethiopia lies in the north of Ethiopia and is the source of the Blue Nile. The Blue Nile descends from Lake Tana to Tissisat Falls (Figure 21) (c. 40 m high), effectively isolating the upstream movement of the Blue Nile River species below the falls from the lake's freshwater fauna. Lake Tana was formed by a volcanic blockage that reversed the previously north-flowing river system (Beadle 1981). The total area of the Lake Tana basin is 16,500 km^2 and the lake itself covers about 3,150 km^2. Numerous seasonal streams and four perennial rivers feed the lake, while only one, the Blue Nile, leaves it (Nagelkerke, 1997). The lake is situated in the highlands of Ethiopia at about 1800 masl, and experiences a tropical highland climate (Burgis and Symoens, 1987).

The isolation of the lake from all but in flowing rivers has led to a highly endemic freshwater biota. Fish species in the lake are most closely related to those of the Nilo-Soudanian biogeographic region. Lake Tana hosts the only extended cyprinid species flock in Africa. The only other known flock, in the Philippines' Lake Lanao, has been decimated by introduced species. Fifteen species of large barbs have been described from Lake Tana (Nagelkerke, 1997; Nagelkerke & Sibbing 1998; Nagelkerke & Sibbing 2000). The species flock is believed to be less advanced in its evolution than Lake Lanao's cyprinid flock (Mina *et al.* 1996). Eight of the large barbs are piscivorous, and *Barbus humilis* and the newly described small species, *Barbus tanapelagius*, are thought to be the major prey species (De Graaf *et al.* 2000; Thieme *et al.* 2005). It is likely that the Lake Tana barbs evolved from one ancestral species that probably resembled *Barbusintermedius* (Nagelkerke 1997). The tilapia (*Oreochromis niloticus*) of Lake Tana belongs to a widespread species but is described as an endemic subspecies, *Oreochromis niloticus tana* (Seyoum & Kornfield 1992) and *Clarias gariepinus* form part of this fishery. Many other endemic animals occur in this region.

Figure 21: The Tissisat Falls below Lake Tana in Ethiopia.

Example of the application of the classification system for the Lake Tana Ecoregion – Lake Tana:

- Level I – Inland ecosystem
- Level II – Lake Tana Ecoregion
- Level III – Valley floor
- Level IV – Exoheric depression with channelled inflow,
- Level V – the lake is permanently inundated with defined limnetic and littoral zones,
- Level IV – The lake is natural, fresh and generally neutral (pH), with alluvial sand, silt and organic sediments which is generally vegetated.

5. Upper Nile Ecoregion

Major habitat types of this ecoregion include the tropical and subtropical floodplain rivers and wetland complexes. This ecoregion is the major habitat type in the Nile Basin and includes tropical and subtropical floodplain rivers and wetland complexes. It encompasses the basin of the White Nile River; its major tributaries, the Sobat River and Bahr el Ghazal; Lake Albert; and Lake Albert's main influent, the Semliki River. The point at which the White Nile joins with the Blue Nile marks the northernmost border of the ecoregion (Rzóska 1974; Dumont 1986; Hughes & Hughes 1992).

The ecoregion extends through the Democratic Republic of Congo, Ethiopia, Sudan and Uganda. The wetlands found in this region have been described by Hassan et al (2009) as those that fall in the Barh el Jebel, Barh al Ghazel, the White Nile sub basins and BaroAkoboSobat sub basins. The socio-ecologically important Sudd wetland occurs in this ecoregion with its basin, which supports an assemblage of floodplain-adapted species (Figure 15). The size of the Sudd varies depending on the flow (Rzóska 1974; Hughes & Hughes 1992), and supports a rich biota of twenty-two families and 118 species of fish currently known to occur within the Upper Nile ecoregion, including 16 endemics. Cyprinids dominate the fish fauna with Alestiidae, Cichlidae, Mochokidae, Mormyridae, Poeciliidae, and Schilbeidae also represented by high numbers of species. Many fish species migrate from the rivers into the nutrient-rich floodplains during the seasonal floods to feed and breed (Welcomme 1979).

Main rivers or other water bodies include the Bahr el Ghazal and its tributaries: the Sue, Jur, Pongo, Lol, and Bahr el Arab, drain the south-western portion of the ecoregion and flow into the Sudd, which sits in the heart of the ecoregion. The Sobat River and its tributaries, the Kangen, Akobo, Baro, and Pibor, drain the south-eastern portion of the ecoregion. Running north between the Bahr el Ghazal and the Sobat is the Albert Nile (named Bahr el Jabal in Sudan), which drains Lake Albert (Murakami, 1995), flows into the Sudd, and merges downstream with the Bahr el Ghazal to form the White Nile (Bahr el Abyad, in Arabic).

At the southernmost edge of the ecoregion, the Semliki River flows through the Rwenzori Mountains from Lake Edward to Lake Albert. A series of rapids however prevents faunal exchange between the two lakes; for this reason, Lake Edward is placed outside this ecoregion. Most of the Semliki's flow is from Lake Edward, though tributaries entering it from the northern slopes of the Rwenzoris also contributing some water inflow. Lake Albert sits at 615 m, with two escarpments up to 2,000 m high bordering it. The lake is about 150 km long, 35 km wide on average, and has a maximum depth of 56 m. Most of the lake's inflow comes from the Semliki River, though the much larger Victoria Nile, draining Lakes Kyoga and Victoria, flows into Lake Albert's far northern end, just before the Albert Nile outlet. The Victoria Nile has only a small effect on Lake Albert's water quality but serves to maintain a fairly constant outflow from the lake (International Lake Environment Committee 2001).

The southern and highest upstream part of this ecoregion is situated in the Rift Valley (Food and Agriculture Organization 1997), with a climate ranges from sub equatorial in the south to xeric in the north (Rzóska 1974). The area has a flood plain ecosystem which supports a variety of plant species with a succession from those adapted to mesic environments to those adapted to more xeric environments. Moving from the interior of the swamps, the floral zones of the Sudd grade outward from open-water and submerged vegetation of the river-lake, to floating fringe vegetation, to seasonally flooded grasslands, to rain-fed grasslands, and finally to floodplain woodlands (Hickley & Bailey 1987). *Cyperus papyrus* is dominant vegetation in the perennially flooded swamp (Howell et al. ,1988), *other plants* include *Coccinia grandis, Cayratiai buensis, Luffa cylindrical, Zehneriami nutiflora, Vigna luteola,* and the fern *Cyclosorus interruptus*. *Phragmites* and *Typha.* Seasonal flood planes are dominated by wild rice *Oryza longistaminata and Echinochloa pyramidalis,* while mixed woodlands of *Acacia seyal*, *Ziziphus mauritiana*, *Combretum fragrans*, and *Balanitesa egypticaca,* beyond the flood plains bordering grasslands (Denny 1991).

Other noteworthy aquatic biotic elements along the Sudd occurs on the major eastern flyway for migrating birds between Europe/Asia and Africa, it is one of the most important wintering grounds in Africa for Palaearctic migrants, and it provides essential habitat for millions of intra-African migrants (Howell *et al.* 1988). Herons, storks, ibises, and other water birds are abundant and occur at the swamp margins. During the dry season these birds exploit the fish that become available as pools dry up. Palearctic populations of the endangered great white pelican (*Pelecanus onocratalus*) fly over 2,000 km from Eastern Europe and Asia to overwinter in the Sudd wetlands (Shmueli *et al.* 2000). The floodplains of the Sudd also support the largest population of shoebill (*Balaeni cepsrex*) in Africa, estimated at 5,000 individuals (Stuart *et al*. 1990). Populations of the near-threatened black-crowned cane (*Balearica pavonina*), also depend on the wetlands (Shmueli *et al*. 2000).

Example of the application of the classification system for the Upper Nile Ecoregion – Sudd Wetland:

- Level I – Inland ecosystem
- Level II – Upper Nile Ecoregion
- Level III – Plain
- Level IV – Exoheric depression with channelled inflow,
- Level V – the wetland is seasonally saturated/inundated in relation to upstream flows with defined littoral zones,
- Level IV – The wetland is natural, fresh and generally neutral (pH) and dominated by alluvial soils with abundant vegetation which includes aquatic (floating, submerged and algal mats) and herbaceous (grasses predominantly) plants.

6. Lake Victoria Basin Ecoregion

The major habitats of this ecoregion consist of large lakes in the countries Burundi, Democratic Republic of Congo, Kenya, Rwanda, Tanzania, Uganda described as the equatorial sub basin (Hassan *et al* 2009). The major lakes in this ecoregion include Lakes Victoria, Edward, George, and Kyoga. Lake Victoria is the largest lake in Africa and contains one of the world's most important examples of rapid species radiations among its endemic halpochromine cichlid fauna. With an area of approximately 68,800 km^2, Lake Victoria is the largest tropical lake in the world as well as the second largest freshwater lake in the world (Spigel & Coulter 1996). Stretching 412 km from north to south and 355 km from west to east, Lake Victoria spans the borders of Tanzania, Uganda and Kenya. Its massive catchment (over 193,000 km^2), reaches well into Rwanda and Burundi (Hughes & Hughes 1992). Lake Victoria occupies a shallow depression 1,134 masl, between the west and east African rifts. The water balance of the lake is maintained primarily through rainfall and evaporation, rather than inflows and outflows (Spigel & Coulter 1996). Due to this dependence on rainfall and evaporation, the residence time of water in Lake Victoria is 23 years (Cohen *et al.* 1996; Spigel & Coulter 1996). Lake level in Victoria has varied by about 2 meters in the last century in response to changes in rainfall and evaporation. The Lake basin itself is about 400,000 years old, but several recent studies suggest that the lake was completely dry for several thousand years and re-filled only 15,000 years ago (Johnson *et al.* 1996; Johnson *et al.* 2000).

Numerous rivers and streams drain into Lake Victoria. The principal affluent is the Akagera River, which enters the lake along its western shore, draining the highlands of Burundi and Rwanda. The Akagera River is about 360 miles long and the Ruvuvu River is its principal tributary. A series of swamps (2-18 km wide) and small lakes occur along the course of the Akagera River with several water falls in its upper reaches (De Vos et al. 2001). The Nzoia River is also a perennial affluent of Lake Victoria. It drains the Elgon Massif, the Cherangani Hills and Sergoit, entering the lake in the northeast. Inflows from rivers in the north-western and south-eastern portion of the ecoregion constitute the remainder of the riverine input. Rivers entering the lake from the northeast tend to be swift flowing whereas, rivers of the northwest tend to be sluggish and perennial (Hughes & Hughes 1992).

The only outlet from Lake Victoria is the Victoria Nile River, which flows through Lake Kyoga and then to Lake Albert, to the north and northwest, respectively (Hughes & Hughes 1992). Passing through extensive areas of swampland, the Victoria Nile enters Lake Kyoga from the south. Lake Kyoga is part of a permanently flooded series of shallow lakes and swamps called the Kyoga Lake-Kwania Swamp complex, which contains 3,416 km^2 of open water and shallow lakes and 2,184 km^2 of permanently flooded swamp (Hughes & Hughes 1992).

Lakes Edward and George lie in the western portion of the ecoregion. Surrounded by extensive swamps, Lake George straddles the equator and is fed by numerous rivers, which drain the eastern slopes of the Rwenzori Mountains, the highlands of the Western Rift Valley and the Virunga Massif. In general, Lake George is well mixed, though it does have a diurnal stratification cycle (Thompson 1976; Hughes & Hughes 1992). Lake George's main inflows are the Rivers Nsong, Mubuku, and Bumlikwesi (Beadle 1981) and Nyamwamba, Rwimi, (Busulwa 2001). The enormous swamp surrounding Lake George is dominated by papyrus (*Cyperus papyrus*), which typically comprises over 95% of the plant biomass (Thompson 1976). Lake Edward is connected to Lake George by the Kazinga Channel, which 40 km long and has a maximum width of less than 1 km (Beadle 1981). Just 5 km off its western shore in the DRC, Lake Edward plummets to a depth of 112 meters, and then slopes gradually up to its eastern shore in Uganda (Hughes & Hughes 1992). The major outflow from Lake Edward is the Semliki River and its main inflows are the Rivers Nyamugasani, Ishasha, Rutshuru and Rwindi, with an inflow by the Kazinga Channel which drains the Lake George catchment (Beadle 1981).

The Lake Victoria ecoregion is also endowed with several small satellite lakes. A few of these include Lakes Kanyaboli, Sare, Namboyo in Kenya; Lakes Nabugabo, Gigati, and Agu in Uganda; and Lakes Ikimba and Burigi in Tanzania (Aloo 2003). These lakes are valuable habitats of biodiversity, and many of them are still relatively undisturbed by human activities.

The Lake Victoria ecoregion has an equatorial climate with two rainy season; one during April/May, and the other during October/November, (Burgis & Symoens 1987; Lowe-McConnell 1987; Beadle 1981). Temperature of the lake varies from 23-27 °C with a mean temperature of 25 °C throughout the year (Witte & Van Densen 1995). Lake Victoria experiences annual stratification and overturn with an associated upwelling of nutrients, as in temperate lakes (Talling 1966; Lowe-McConnell 1987). Wind speeds increase during the dry season, between May and June when strong southerly winds exceeding 15 m/s blow over the ecoregion (Spigel & Coulter 1996). These strong southerly winds cause high evaporation rates, water mixing and a decrease of surface temperatures. Seasonal algal blooms coupled with shallow water upwellings as a result of wind action, affect seasonal transparency patterns in the lake (Witte & Van Densen 1995).

The ecoregion's lakes and shallow bays are home to many types of emergent and submerged vegetation (macrophytes). In the Lake Victoria basin, the dominant macrophytes include; *Cyperus papyrus*, *Miscanthidium violaceum*, *Phragmites mauritanius,* and *Typhad omingensis*, among others. The most extensive papyrus swamps (*C. papyrus*) in East Africa occur along the perimeter of Lake Victoria and along the perimeters of the other lakes within this ecoregion (Chapman *et al*. 2001). The valley swamps fringing the rivers flowing into Lake Victoria are dominated by *Miscanthidium violaceum*. These two swamp types also support a diversity of other plant species, with both types reported to contain upwards of thirty other species (Chapman *et al.* 2001). The interface between open water and permanent swamp sustains a distinctive plant and animal community. However, many fewer species are adapted to the often oxygen poor environment of the permanent swamps and their dense stands of fibrous papyrus mats. Grasses and trees also grow on the seasonal floodplains and stands of A*cacia* occur throughout the landscape adjacent to the lake and inflowing rivers (Hughes & Hughes 1992). Over 600 endemic fish are known from Lake Victoria alone, although estimates of species numbers vary widely (Seehausen 1996; Kaufman *et al*. 1997; Turner *et al.* 2001). The total number of cichlid species within Lakes Edward and George is about 80, with nearly sixty of these being. Currently, 28 fish species are known from Lake Kivu and its effluents. Nineteen of the 28 are cichlids, 9 are non-cichlids (Greenwood 1981; Kaufman 1992; Kaufman *et al*. 1997; Galis & Metz 1998; Seehausen & Van Alphen 1998, 1999; Seehausen et al. 1999). In addition to Cichlidae, the lakes of the Victoria ecoregion also host fish fauna from the families Alestiidae, Amphiliidae, Clariidae, Cyprinidae, Mochokidae, Mormyridae, Poeciliidae and Protopteridae. About one-third of the approximately 90 non-cichlid fish species are endemic to the ecoregion. In addition to the lacustrine species there are also many riverine fish. For example, at least 55 fish species live in the Rwandan portion of the Akagera River. Several of these are anadromous fishes like *Labeo* spp., *Clarias* spp., *Bagrus* spp., and *Barbus* spp., among others, which utilize the river for spawning purposes (Okedi *et al.* 1974). The ecoregion's swamps and wetlands also support numerous waterbirds. Among these, the vulnerable papyrus yellow warbler (*Chloropetagra cilirostris*), the vulnerable white-winged warbler (*Xenolige amontana*), the locally rare papyrus gonolek (*Laniarius mufumbiri*) and shoebill (*Balaeni cepsrex*), and the more common Carruther'scisticola (*Cisticolacar ruthersi*), great egret (*Ardea alba*) and Baillon's crake (*Porzanapusilla*), inhabit wetlands bordering Lake Victoria (Bennun & Njoroge 1999, 2001). Congregations of *Caledonia's leucopterus*, *Egretta garzetta, Phalacrocorax africanus, P. carbo, Laruscirro cephalus* also occur in marshes, bays, islands, and swamps along the margins of the lake (Baker & Baker 2001; Byaruhanga *et al.* 2001).

The ecoregion is also rich in other taxa, including aquatic-dependent reptiles, amphibians, and mammals, plankton and freshwater molluscs. In particular, there is a high species richness of frogs, with over 60 species known from this ecoregion, one-quarter of which are endemic (and mainly confined to forest habitats). Aquatic obligate vertebrate species in the Lake Victoria environs, include five species of freshwater turtle, two aquatic snakes, monitor lizard, Nile crocodile (*Crocodylus niloticus*), three species of otters (*Aonyxcapensis*, *A. congicus*, and *Lutrama culicollis*), and hippopotamus (*Hippopotamus amphibius*)(Hughes & Hughes 1992). The waters of Lake Victoria and other lakes are rich in plankton species, for example with around 80 species of planktonic diatoms. The ecoregion's waters also support an abundant mollusc fauna comprising 54 species, with about one-fifth endemic to the ecoregion (Brown 1994).

From a biodiversity perspective, Lake Edward is very important because it is among the least disturbed of those great lakes that contain endemic faunas since much of the lake lies within national parks in Uganda and Democratic Republic of the Congo. In addition, the riverine faunas in the tributaries of the Edward-George system are very rich and include the antecedents to the lacustrine radiations, although many of the tributaries remain unexplored. The system is currently undergoing natural and anthropogenic turmoil. There are increasing pressures on environmental resources from fishing villages inside and communities outside the protected areas. The Nile crocodiles have become re-established in the system after an estimated 8,000 years of absence and hippopotamus populations together with other wildlife species increasingly responding to habitats with protection provided by the parks.

This ecoregion is outstanding for its cichlid species radiation with 22 endemic cichlid genera and 3 additional endemic genera (*Xenoclarias* [Clariidae], *Cynopanchax*, *Laciris* [Poeciliidae]) (Thieme *et al.* 2005). This ecoregion is defined by the basins of Lakes Victoria, Edward, George, and Kyoga characterized by a lacustrine fauna with cichlid species radiations typical of those within the Great Lakes bioregion, these fish species are also shared with Lake Kivu which is not in the Nile Basin. The mountains of Karamoja region enclose the ecoregion in the northeast. In the east, the highlands of the Eastern Rift Valley are comprised of the Cherangani Hills, Elgeyo Escarpment and Mau Escarpment. The Rwenzori Mountains and the Virunga Massif are the highlands that enclose the ecoregion in the west. The southwest is dominated by a chain of mountains in Rwanda, along the rim of the Western Rift Valley (Hughes & Hughes 1992).

The Lake Victoria Region has provided a model for relationships between land form and evolution of fishes. Our understanding of the evolution of these extraordinary faunas is increasing as faunal and paleolimnological surveys continue in the region. But, there is a huge missing piece in the puzzle, the Lakes Edward-George region. Lake Edward is one of the less explored ichthyofaunas in Africa. Lake George is better known, although it is named a Ramsar site itself, the extensive wetland remains relatively unexplored. The Lake Edward-George system is very exciting biogeographically because it represents the confluence of the Albertine and Victorine faunas.

In a nutshell, the six ecological regions above are what they are because of their geomorphologic locations which influenced flow of water into them. Their uniqueness is a product of adaptations which have been going on for a long periods of time resulting into specific communities that occur in them. Their survival is based on instinctive responses to seasonality that affects the availability of water in the ecosystems. Organisms with relatively wider specific requirements exhibit behavioural patterns that include migrations in fishes, birds and animals in order to meet their normal life cycles. Alterations in flow must therefore consider such migratory behaviours.

Example of the application of the classification system for the Lake Victoria Basin Ecoregion – Upper Mara River in Kenya:

- Level I – Inland ecosystem
- Level II – Lake Victoria Basin Ecoregion
- Level III – Valley floor
- Level IV – Mountain stream with an active channel and riparian zone,
- Level V – the river is permanently flowing with a limited littoral and limnetic zone,
- Level IV – The river is natural, fresh and clear generally with a neutral (pH) and dominated by bedrock, boulder, cobble, gravel and sandy substrates. The vegetation surrounding the river creates a closed forest canopy.

3.3 Wellbeing of freshwater ecoregions in the Nile Basin

The wellbeing of the six main freshwater ecoregions of the Nile Basin were evaluated with available information to review the wellbeing of the overall; (1) conservation state (conservation assessment), (2) threats to ecosystem wellbeing, (3) water quality state, (4) fish conservation state, (5) state of associated fisheries (fish for food sector), (6) other ecosystem biota, and (7) ecosystem services as follows:

1. **Conservation assessment** provides information for large scale biodiversity conservation by focussing on the global biodiversity values of a region. The assessment is a summary of the information provided in the book "Freshwater Ecoregions of Africa and Madagascar; A Conservation Assessment" (Thieme *et al*, 2005) and includes the following categories:
    - **Final Biological Distinctiveness Index**: The Biological Distinctiveness Index (BDI) is a measure of the degree to which the biodiversity of an ecoregion is distinctive at a range of biographical scales. The criteria used to determine the biological distinctiveness of an ecoregion are; species endemism and species richness. To determine the final distinctiveness ranking for each ecoregion, rare ecological and evolutionary phenomena and rarity of habitat types were evaluated. The categories used to rank the BDI and associated scores are listed in Table 5.

Table 5: Scoring of categories for Final Biological Distinctiveness Index

Description	Score
Globally outstanding	1
Continentally outstanding	2
Bioregionally outstanding	3
Nationally important	4

    - **Likelihood of Future Threats**: considered climate change, population increase and future planned infrastructure to determine the likelihood of future threats to an ecoregion and are classified low, medium or high (Table 6).

Table 6: Scoring of categories for Likelihood of Future Threats

Description	Score
Low	1
Medium	2
High	3

    - **Final conservation Status**: evaluates land-based and land degradation threats, aquatic habitat threats and threats to biota from exploitation and exotics. These results provide a snapshot conservation status which is modified by the likelihood of future threats. If the likelihood of future threats was high for an ecoregion then the snapshot conservation status was raised by one level to determine the final conservation status. Ecoregions with low or medium likelihood of future threats were left unchanged. The five categories for conservation status and their general descriptions are provided in Table 7. Not all the conditions listed in the description need to occur in an ecoregion to warrant the classification but the descriptions reflect how increased habitat loss, fragmentation and degradation can affect the ecological processes and populations can no longer occur in natural ranges and variations.

Table 7: Scoring of categories for Final Conservation Status

Name	Description	Score
Relatively intact	Native communities are largely intact. Populations of sensitive species are not diminished. Species move and disperse naturally within the ecoregion. Hydrographic integrity is unmodified and surrounding land-use does not impair aquatic habitat. Maintenance of current conditions will conserve native species over both the long and short term.	1
Relatively stable	Natural communities have been altered in certain areas and disturbed areas may be extensive but ecological links between intact habitats are still largely functional. Hydrographic integrity, if altered, may be restored by the implementation of minor changes. Surrounding land use practices do not impair aquatic habitats or could be modified easily to minimise impacts. Exotic species pose little or no threat to natives. A nearly full complement of native species still exist.	2
Vulnerable	Remaining intact habitat occurs in large to small segments and populations will probably persist over next 10-20 years especially with intervention. Hydrographic integrity may be restored in some areas by implementation of moderate change. Established exotic species may be controllable. Some species may already be extirpated or are extinct.	3
Endangered	Remaining intact habitat is limited and populations have medium to low probability of persistence over next 5-10 years without intervention. Surrounding land use practices are largely incompatible with maintaining aquatic habitat structure and function. Hydrographic integrity has been modified by structures of varying size and permanence. Spread of exotic species poses potential serious threat to native species populations. Poor water quality excludes many species from remaining habitat. Some species are already extirpated or are extinct.	4
Critical	Remaining intact habitat is limited and populations have low probability of persistence over next 5-10 years without intervention. Surrounding land use practices are incompatible with maintaining aquatic habitat structure and function. Hydrographic integrity has been seriously altered. Established exotic species seriously threaten native species populations. Consistently poor water quality excludes all but hardiest species from large portions of remaining habitat. Many species are already extirpated or are extinct.	5

- **Priority Class**: highlights ecoregions that support outstanding levels of biological diversity, contains globally unique species and assemblages or harbour the last viable example of important ecological processes. The five priority classes described in Table 8 are based on the combination of their biological distinctiveness and conservation status category and provide direction for conservation investment in the future.

Table 8: Scoring of categories for Priority Classes

Class	Description	Score
I	Contains globally outstanding ecoregions that are highly threatened	1
II	Contains continentally outstanding ecoregions that are highly threatened	2
III	Contains globally or continentally outstanding ecoregions with relatively intact aquatic systems	3
IV	Contains bioregionally outstanding and nationally important ecoregions that are highly threatened	4
V	Contains ecoregions bioregionally outstanding and nationally important ecoregions with relatively intact aquatic systems	5

2. **Threats to ecosystem wellbeing** provides a summary of possible threats to the wellbeing of different ecosystems within an ecoregion. These threats include land-based and land degradation threats, aquatic habitat threats and threats to biota from exploitation and exotics (Table 9). The scoring of the five categories are listed in Table 10.

Table 9: Categories of threats used to assess the treats to ecosystem wellbeing

Land-based Threats	Aquatic Habitat Threats	Biota Threats
Intensive logging and associated road building.	Degraded water quality.	Unsustainable fishing or hunting.
Intensive grazing especially in riparian zone.	Habitat fragmentation from dams or other barriers to dispersal, migration and movement in general.	Unsustainable extraction of plants or wildlife as commercial products.
Widespread mining or other resource extraction.	Excessive recreational impacts.	Competition, predation, infection or hybridization by established exotic species.
Agricultural expansion and clearing for development.	Altered hydrographic integrity resulting from dams, surface or groundwater withdrawals, channelization, interbasin water transfer etc.	
Urbanization and associated changes to runoff.	Loss of aquatic habitat due to flooding by reservoirs or desiccation.	
Loss or conversion of riparian and floodplain vegetation.		
Reduced organic matter input, including woody debris.		

Table 10: Scoring of Threats to the Ecosystem Welling

Name	Description	Score
Natural	Unmodified, natural (Relatively intact) - **Unthreatened**	1
Good	Largely natural (Relatively stable) - **Largely unthreatened**	2
Fair	Moderately modified (Vulnerable) - **Moderately threatened**	3
Poor	Largely modified(Endangered) - **Largely threatened**	4
Seriously to critically modified	Seriously to critically modified (Critical)- **Seriously threatened**	5

3. **Water quality** of the Nile Basin is influenced by both natural and human factors (NBI, 2012). Studies have shown a trend of lower water quality in the downstream basin when compared to the water quality upstream (Hazma, 2014). This is mainly due to the following factors (Hazma, 2014):
    - All year flow from south to north which dilutes existing pollutants and carries them downstream.
    - More industrialisation of downstream countries.
    - Water multi-use and recycling are not common practises in upstream countries.
    - Lower population densities and less modernised sewerage systems in the upstream countries.

    This section provides a summary of the surface water quality for each ecoregion and provides an overall score based on the classification system listed in Table 11.

Table 11: Scoring of the classification system using six ecological integrity categories (based on Kleynhans and Louw, 2007)

Name	Description	Score
Natural	Unmodified, natural.	1
Good	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	2
Fair	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	3
Poor	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	4
Seriously modified	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	5
Critically modified	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	6

4. **Fish** are important from an ecological and social perspective and are used to assess the wellbeing of an aquatic ecosystem because (Barbour et al, 1999):
   - They are good indicators of long term effects and broad habitat conditions because they are mobile and live for a relatively long time;
   - Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and so the fish assemblage structure is reflective of integrated environmental health.
   - They are at the top of the aquatic food web and are consumed by humans, making them important for assessing contamination.

   This section provides a summary of available information regarding the fish for each ecoregion as well as an overall score for the wellbeing of fish based on the classification system listed in Table 11.

5. **Fisheries** and fishing activities on the major water bodies in the Nile Basin is an affordable animal protein source, especially in the poorer countries, and provides employment, income and export opportunities to riparian communities (Hazma, 2014). Fisheries in the Nile Basin are fairly diversified, including (NBI, 2012):
   - established, export-orientated Nile perch fishery on Lake Victoria;
   - traditional fisheries on wetlands and large and small water bodies;
   - tuna fisheries on the Indian Ocean coast;
   - fish production on small-scale fish ponds in the Equatorial Lakes region and Sudan;
   - young fish export industries on the Red Sea coast,
   - thriving semi-intensive fish farms in the Nile Delta.

   With the exception of Egypt, fish production is dominated by capture fisheries. The combined fish production for all the Nile countries is estimated to be 1.8 million tons/annum of which one-third is by fish farming and two-thirds is contributed by capture fisheries. This section provides a summary of the fisheries for each ecoregion as well as an overall score based on the classification system listed in Table 11.

6. **Other ecosystem biota** assesses the wellbeing of other biota like molluscs, amphibians, crocodiles, odonatan, birds etc that are associated with the aquatic ecosystems within the ecoregion as an indication of the overall wellbeing of the ecoregion. This section provides a summary of other ecosystem biota of interest for each ecoregion and an overall score based on the classification system listed in Table 11.

7. **Ecosystem goods and services** are the benefits people obtain from ecosystems and include provisioning services, regulating services, cultural services that directly affect people and supporting services that are needed to maintain the other services. (Alcamo and Bennett, 2003). Table 12 provides examples of the different services the ecosystem can provide. The wellbeing of these services were scored based on the classification system listed in Table 11.

Table 12: Ecosystem services (Alcamo and Bennett, 2003).

Provisioning Services Products obtained from ecosystem	**Regulating Services** Benefits obtained from regulation of ecosystem processes	**Cultural services** Non-material benefits obtained from ecosystems
Food	Climate regulation	Spiritual and religious
Fresh water	Disease regulation	Recreation and ecotourism
Fuel wood	Water regulation	Aesthetics
Fiber	Water purification	Inspirational
Biochemical	Pollination	Educational
Genetic resources		Sense of place
		Cultural heritage
Supporting Services Services necessary for the production of all ecosystem services		
Soil formation		
Nutrient cycling		
Primary production		

3.3.1 Wellbeing of the Ethiopian Highlands Freshwater Ecoregion

The Ethiopian Highlands ecoregion contains about 70% of Africa’s highlands and is known to harbour an endemic biota because of its long history if isolation. The Great Rift Valley bisects the highlands into the eastern and western massifs which are surrounded by escarpments. The north western part of the highlands is the source of the headwaters for the Blue Nile which flows to the north and forms a large floodplain in Egypt.

The wellbeing assessment of the Ethiopian Highlands freshwater ecoregion is described in Table 13 and graphically presented in Figure 22 to Figure 31.

Table 13: Synopsis of the desktop evaluation of the wellbeing of the Ethiopian Highlands freshwater ecoregion.

Category	Description	References	Classification	Score
Conservation Assessment	• Final Biological Distinctiveness Index was bioregionally outstanding as the species richness and endemism of the ecoregion was categorised as medium indicating that the biological distinctiveness of the ecoregion was bioregionally outstanding. No globally or continentally outstanding ecological phenomena occurs in this ecoregion so the final BDI remains bioregionally outstanding.	Thieme et al, 2005	Bioregionally outstanding (Figure 22)	3
	• Likelihood of future threats are high as major threats include: ○ Loss of riparian forests ○ Canal formation for irrigation purposes ○ Dam building		High (Figure 23)	3
	• Final Conservation Status for the ecoregion is endangered as past agriculture and timber harvesting has led to the loss of riparian vegetation for most of the rivers and streams in the ecoregion. • The rivers and stream are also being altered by damming and canalisation. • In some of the high-altitude rivers only exotic rainbow and brown trout are found. • Several lakes have also been stocked with *Oreochromis niloticus* for commercial fishing.		Endangered (Figure 24)	4
	• The information above classifies the ecoregion as a Priority Class IV as it is a bioregionally outstanding and nationally important ecoregion that is highly threatened.		Class IV (Figure 25)	4
Threats to ecosystem wellbeing	**Ecoregion:** • Domestic solid waste and effluent are the major non-point sources of pollution from the major towns as most of the population does not have access to sanitation facilities and there is almost no solid waste collection and treatment practice in the Basins. • Ethiopia is mainly an agrarian country so the main sources of non-point pollution is faecal pollution from cattle, pesticide and fertiliser run-off. • Most of the rivers and streams in this ecoregion have lost their riparian vegetation due to past agriculture and timber-harvesting activities especially in the northern, north eastern and central parts. The deforestation impacts on the nutrient regimes, water temperature, pH and turbidity of the rivers and erosion of the soils results in sedimentation of the rivers. • Damming and canalisation occurs widely in the ecoregion which alters the rivers and streams and affects the lifecycle of migratory fish.	Thieme et al, 2005 NBI, 2005	Moderately modified (Vulnerable) – Moderately threatened (Figure 26)	3

Category	Description	References	Classification	Score
	• Tannery industries have an impact on the rivers within this ecoregion. The estimated effluent volume in 1993 of 8 selected tanneries in the country was 1,058,000 m^3/year with a mean chromium discharge load of 3,787 kg/year. Other pollutants from this industry include hydrogen sulphide, dyes and caustic soda. **Conclusion:** • These threats have resulted in more than 50% of the land area of the ecoregion being degraded. The dynamic physical processes of the aquatic habitat are modified. There is some abandonment and disruption of migratory or breeding movements caused by physical barriers or habitat destruction. Pollutants or linked effects are commonly found in target species or assemblages. There is moderate exploitation or disturbances to biota by exotics. The wellbeing of the ecoregion is considered *moderately modified* (vulnerable) based on the impacts of these threats.			
Water quality	**Ecoregion:** • Calcium (Ca^{2+}), and magnesium (Mg^{2+}) are prevalent in the Ethiopian and Eritrean headwater areas. **Rivers:** • The average annual electrical conductivity for the Blue Nile (Abay) was between 241 and 300 µS/cm. **Conclusion:** • Water quality data for this ecoregion is limited but based on the available information the water quality was classified as *moderately modified*.	NBI, 2012	Moderately modified (Figure 27)	3
Fish	**Ecoregion:** • The Baro-Akobo basin is particularly rich in fish diversity. • *Nemacheilus abyssinicus* is an endemic species found in the Baro-Akobo drainage basin. **Conclusion:** • Fish data for this ecoregion is limited but based on the available information the wellbeing of fish was classified as *moderately modified*.	FEOW, 2013	Moderately modified (Figure 28)	3
Fisheries	**Ecoregion:** • Fishing contribution to the Gross Domestic Product (GDP) of Ethiopia is very low. In general the fishery production in Ethiopia is overexploited due to inappropriate fishing practices. **Conclusion:** • Fisheries data for this ecoregion is limited but based on the available information the wellbeing of fisheries was classified as *moderately modified*.	Janco, 2014	Moderately modified (Figure 29)	3

Category	Description	References	Classification	Score
Other ecosystem components	**Ecoregion:** • The ecoregion support a rich aquatic mollusc fauna with over 20 species described. **Conclusion:** • Data on other ecosystem components for this ecoregion is limited but based on the available information its wellbeing was classified as *moderately modified*.	FEOW, 2013	Moderately modified (Figure 30)	3
Ecosystem service components	**River:** • Headwater wetlands of Baro Akobo regulates flow in the Baro Akobo River and is believed to help maintain downstream dry-season river flows. **Conclusion:** • In consideration of the threats to the ecoregion (referred to threats to ecosystem wellbeing section) the availability of ecosystem services in the ecoregion have been moderately impacted/altered (*assigned moderately modified*).	Rebelo & McCartney, 2012	Moderately modified (Figure 31)	3

3.3.2 Wellbeing of the Lake Tana Freshwater Ecoregion

Lake Tana is a lake in the Ethiopian Highlands and is the source of the Blue Nile. The lake covers approximately 3150 km^2 and the Lake Tana basin has a total area of 16500 km^2. Four perennial rivers and many seasonal streams feed the lake but only the Blue Nile leaves it. Not far downstream of the lake, the Blue Nile descends the Tissisat Falls isolating the lake's freshwater fauna from the rest of the Nile.

The wellbeing assessment of the Lake Tana freshwater ecoregion is described in Table 14 and graphically presented in Figure 22 to Figure 31.

Table 14: Synopsis of the desktop evaluation of the wellbeing of the Lake Tana freshwater ecoregion.

Category	Description	References	Classification	Score
Conservation Assessment	• Final Biological Distinctiveness Index for the ecoregion is globally outstanding. The species richness of the ecoregion was categorised as medium and species endemism as high indicating that the biological distinctiveness of the ecoregion was continentally outstanding but because it has a globally outstanding ecological phenomena (only extended cyprinid species flock in Africa) the final BDI is elevated to globally outstanding.	Thieme et al, 2005	Globally outstanding (Figure 22)	1
	• Likelihood of future threats is high as diversion for water is increasing as farmers build small dams on tributaries that flow into the lake which could lower the lakes levels and cause water quality changes to the lake. • Introduction on exotic species could decimate the unique fish fauna. • Increased fishing and deforestation also pose future threats.		High (Figure 23)	3
	• Final Conservation Status is considered to be vulnerable as the fairly pristine lake with no established exotics and little pollution is threatened by: ○ fishing, ○ diversion of water for irrigation and ○ changes in the supply and quality of water entering the lake due to pressures associated with a growing population.		Vulnerable (Figure 24)	3
	• The information above classifies the Lake Tana ecoregion as a Priority Class I as it contains a globally outstanding ecoregion that is highly threatened.		Class I (Figure 25)	1
Threats to ecosystem wellbeing	**Ecoregion:** • Deforestation is affected the hydrology of the system. **Lake:** • Lake Tana is fairly pristine with little pollution and no established exotic species. • The largest threat to the ecoregion is fishing but water for irrigation as well as population growth also affect the supply and quality of the water entering the lake. **Conclusion:** • These threats have resulted in more than 50% of the land area of the ecoregion being degraded. The dynamic physical processes of the aquatic habitat are somewhat modified. There is some abandonment and disruption of migratory or breeding movements and pollutants may be found in target species or assemblages. There is low exploitation or	Thieme et al, 2005	Largely natural (Relatively stable) – Largely unthreatened (Figure 26)	2

Category	Description	References	Classification	Score
	disturbances to biota by exotics. The wellbeing of the ecoregion is relatively stable based on the impacts of these threats and is considered to be *largely natural* (relatively stable).			
Water quality	**Lake:** • Lake Tana is chemically and bacteriologically polluted near densely populated areas like the city of Bahir Dar (*assign moderately modified*). • The average annual electrical conductivity for Lake Tana was between 241 and 300 µS/cm. **Conclusion:** • Water quality data for this ecoregion is limited but based on the available information the water quality was classified as *moderately modified*.	Dumont, 2009 NBI, 2012	Moderately modified (Figure 27)	3
Fish	**Lakes:** • Lake Tana hosts the only extended cyprinid species flock in Africa. • Approximately 70% of the fish species in Lake Tana are endemic, including 18 endemic cyprinids. • Fifteen (15) species of large barbs have been described from Lake Tana. • The tilapia of Lake Tana belongs to a widespread species but is described as an endemic subspecies namely *Oreochromis niloticus tana.* • The only river loach (family Balitoridae) known from Africa, *Nemacheilus abyssinicus* has been recorded in the lake as well as in the upper Omo River. • The large catfish, *Clarias gariepinus*, lives in the lake and forms an important part of the fishery. **Rivers:** • The river loach, *Nemacheilus abyssinicus* has been recorded in the upper Omo River. **Conclusion:** • The available fish data for this ecoregion indicates that the wellbeing of the fish is *moderately modified*.	Thieme et al, 2005 FEOW, 2013	Moderately modified (Figure 28)	3
Fisheries	**Lake:** • Commercial fishing is increasing especially in the southern portion of the lake and data suggests that fish stocks are declining because of overexploitation of spawning fish (assigned largely modified). • The fisheries in the Tana – sub basin are in treat because of overfishing, fishing during spawning season, use of unsuitable fishing tools as well as unnecessary activities. The main threat to fisheries is the use of undersized monofilament gillnets. The common practise has become to stretch 4 – 7cm mesh at all spawning grounds during peak spawning seasons.	Hamza, 2014 Mequanent and Sisay, 2015	Moderately modified (Figure 29)	3

Category	Description	References	Classification	Score
	• 81.35% of fishermen interview during a study undertaken in 2014, reported that the fish supply has decreased in the last 10 years (*assigned moderately modified*). • The annual total catch in Lake Tana fell to 255 metric tons in 2001 from a value of 360 metric tons in 1997 (a*ssigned largely modified*). **Conclusion:** • The fisheries data for Lake Tana ecoregion indicates that there has been a decline in the fisheries and had been classified as *moderately modified*.			
Other ecosystem components	**Lake:** • Fifteen (15) species of molluscs have been recorded, including one endemic. • An endemic freshwater sponge, *Makedia tanensis*, has recently been discovered in the lake. • A high diversity of wetland birds lives by the lake and many Paleartic migrant waterbirds also depend on the lake as feeding and resting grounds. **Conclusion:** • Data on other ecosystem components for this ecoregion is limited but based on the available information its wellbeing was classified as *moderately modified*.	FEOW, 2013	Moderately modified (Figure 30)	3
Ecosystem service components	**Conclusion:** • In consideration of the threats to the ecoregion (referred to threats to ecosystem wellbeing section) the availability of ecosystem services in the ecoregion have been moderately impacted/altered (*assigned moderately modified*).		Moderately modified (Figure 31)	3

3.3.3 Wellbeing of the Lake Victoria Freshwater Ecoregion

Lake Victoria is the largest tropical lake in the world and the second largest freshwater lake with an area of approximately 68 800 km^2. It is also the largest lake in Africa and is the most important example of rapid species radiations among its endemic haplochromine cichlid fauna. Other lakes in the ecoregion include Lakes Kyogo, George, Edward and the small, deep Lake Kivu. Numerous rivers drain into Lake Victoria but the principle affluent is the Akagera River. The only outlet from Lake Victoria is the Victoria Nile River which flows through Lake Kyoga to Lake Albert. Lake Kivu lies in the Western Rift Valley and Lakes Edward and George lie in the western portion of the ecoregion.

The wellbeing assessment of the Lake Victoria freshwater ecoregion is described in Table 10 and graphically presented Figure 22 to Figure 31.

Table 15: Synopsis of the desktop evaluation of the wellbeing of the Lake Victoria freshwater ecoregion.

Category	Description	References	Classification	Score
Conservation Assessment	• Final Biological Distinctiveness Index was globally outstanding. The species richness and endemism of the ecoregion were both categorised as high indicating that the biological distinctiveness of the ecoregion was globally outstanding. The ecoregion also host a globally outstanding ecological phenomena (Lake Victoria's endemic haplochromine fauna which is an example of explosive speciation and adaptive radiation) so final BDI remained globally outstanding.	Thieme et al, 2005	Globally outstanding (Figure 22)	1
	• Likelihood of future threats are high from increasing agricultural, industrialisation, deforestation and high population pressures.		High (Figure 23)	3
	• Final Conservation Status is critical as the Lake Victoria basin has undergone extreme ecological changes over the last century due to: ○ Intensification of fishing activities ○ Introduction of exotic fish (mainly Nile Perch) ○ Increased human populations and associated increased agricultural and industrial activities. • The introduction and spread of water hyacinths have also drastically altered the functioning of the lakes.		Critical (Figure 24)	5
	• The information above classifies the Lake Victoria ecoregion as a Priority Class I as it contains a globally outstanding ecoregion that is highly threatened.		Class I (Figure 25)	1
Threats to ecosystem wellbeing	**Ecoregion:** • The system is currently under threat from natural and anthropogenic sources. There is increasing pressures on environmental resources from fishing villages inside the protected areas. The Nile crocodiles have become re-established in the system after an 800 year absence and hippopotamus populations are increasing in response to one decade of protection within the parks. • Within Kenya, the main sources of pollution are caused by the activities in agriculture, urbanisation, industry, leachates from solid waste tips, sediments, salts, fertilizers and pesticide residues. Localized eutrophication occurs as most municipal sewerage plants discharge partially treated or untreated wastewater into surface watercourses. Receiving waters are also polluted by effluent containing organic loads, heavy metals and other toxic	Thieme et al, 2005 FEOW, 2013 NBI, 2005 NBI, 2012 NEMA, 2010 WID, 2001	Largely modified (Endangered) - Largely threatened (Figure 26)	4

Category	Description	References	Classification	Score
	substances as most tanneries, pulp and paper mills, coffee processing factories, breweries and sugar cane processing facilities typically do not have effective wastewater treatment plants. Poor application of agricultural chemicals results in the release of high nitrate, phosphate and pesticides and poor agricultural practices results in soil erosion and soil cover destruction or overgrazing. • Within Tanzania, the main sources of pollution are caused the discharge of municipal and industrial wastewater, erosion and run-off from agricultural lands. • In Burundi, mining causes heavy metal pollution as well as toxic substances like arsenic. An example of this is the mine of Kabarore which pollutes the Nwogere River which is a tributary of the Kanyaru River. • Within Uganda, the major threats to water quality include the following: ○ Siltation from the degradation of wetlands, riverine or lake shore ecosystems and the degradation of land cover. ○ Discharged industrial effluents not meeting national standards. ○ Agricultural run-off containing agrochemicals like fertilizers and pesticides. ○ Eutrophication. ○ Water hyacinths. ○ Wetland degradation. ○ Increasing population contributing to urban run-off, municipal effluent and solid waste. ○ Heavy metals discharged from tailing dams from redundant copper mines. **Lakes:** • The rise in commercial fishing in Lake Victoria has deteriorated the ecological balance of the lake. In the 1950s and early 1960s, Nile perch and other exotic tilapia species were introduced to the lake when catches of indigenous fish declined. This lead to a dramatic increase in the Nile perch population in the 1980s and a further decline in the population of several indigenous species. Since then, the over fishing of Nile perch has resulted in the resurgence of some of the indigenous fish. • A rapid rise in population as well as increases in agriculture, fisheries, industrialisation and urbanisation all contribute to the degradation of the lake waters. • Water hyacinths are a problem within Lake Victoria. **Rivers:** • Water hyacinths is a problem in the headwaters of the White Nile and especially in the Akagera River.			

Category	Description	References	Classification	Score
	Conclusion: • These threats have resulted in more than 50% of the land area of the ecoregion being degraded. The dynamic physical processes of the aquatic habitat are modified. There is some abandonment and disruption of migratory or breeding movements caused by physical barriers or habitat destruction. Pollutants or linked effects are commonly found in target species or assemblages. There is high exploitation or disturbances to biota by exotics. The wellbeing of the ecoregion is *largely modified* (endangered) based on the impacts of these threats.			
Water quality	**Ecoregion:** • The average annual electrical conductivity for the ecoregion was between 60 and 120 µS/cm while the average total dissolved solids was 10 to 100mg/L. **Lakes:** • Studies of the water quality of Lake Victoria have indicated notable changes in the physical, chemical and biological features of the lake ecosystem during the last three decades. This has resulted in increasing eutrophication and decreasing water transparency and decreasing dissolved oxygen concentrations at the hypolimnion layer during periods of stratification (*assigned largely modified*). Studies on the exposure of Nile perch and Nile tilapia from southern Lake Victoria to DDT (dichlorodiphenyltrichloroethane) and endosulfan isomers concluded that most of the analysed samples contained residue levels higher than the method detection limits but below or within the Accepted Daily Intake (ADI) limits (*assigned largely modified*). • Water quality monitoring undertaken at Thruston Bay (Lake Victoria) found that water temperature had increased and transparency had decreased when compared to results from earlier studies. Nitrite concentrations were relatively higher in the inshore sites when compared to the offshore sites. Heavy metals were also recorded in both the water and the fish samples (*assigned moderately modified*). • Gold mining plants in the Lake Victoria basin discharge mercury into water at levels hundreds of times greater than deemed safe for wildlife and up to 25 times greater than deemed safe for humans. A study undertaken between 2006 – 2008, recorded mercury levels ranging from <0.0001 to about 0.0005 mg/L. The same study revealed nickel concentrations to be high compared to those of mercury and copper and ranged from 0.02 mg/L to about 0.085 mg/L and copper levels ranged from <0.001 to about 0.014 mg/L (*assigned largely modified)*. **Rivers:**	Hamza, 2014 Muyodi et al. 2011 NBI, 2005 NBI, 2008 NBI, 2012	Moderately modified (Figure 27)	3

Category	Description	References	Classification	Score
	• Water quality monitoring undertaken on the Sio, Nzoia, Yala, Nyando, Gucha /Migori, Mara and Sondu/Miriu Rivers indicate that the water quality was satisfactory with the following two exceptions: ○ An excessively high nitrates result of 614 mg/l at a monitoring point on the Yala River (*assigned largely modified*). ○ A very high Total Dissolved Nutrients (TDN) result of 430 mg/l at a monitoring point on the Nyando River (*assigned largely modified*). • The Akagera River and the rivers in western Kenya such as the Yala and Nzoia carry heavy silt loads to the equatorial lakes region where suspended solids range from 1 – 1500 mg/L. • Sodium (Na^+) and potassium (K^+) are prevalent in the Equatorial Lakes headwater areas. • A study undertaken in Rwanda in 2002 revealed that the water quality for the Akagera River was generally good and that differences in conductivity and different lithologies of the sub-catchments influenced the water quality. Other water monitoring revealed elevated fluoride and copper in the Nyabugogo River due to industries located in Kigali, but their polluting effects quickly reduce downstream (*assigned moderately modified*). • Data from the surface water (Akagera River Basin) in Burundi indicated that: ○ Water has faecal contamination (*assigned largely modified*). ○ Water quality is suitable for all water uses. ○ Waters are generally warm (between 19 and 26ºC). ○ Waters have relatively low conductivity (< 100 µS/cm). ○ Waters are rich in dissolved oxygen. ○ Water potability limits for iron and manganese are exceeded in 30% of cases (*assigned moderately modified*). ○ Nitrogen and phosphorous increase with increasing discharge as a result of leaching of agricultural soils so concentrations increase during rain events (*assigned moderately modified*). • A water quality study was undertaken of the Yala River catchment, the Kisat River and the Molasses plant discharge point. The results indicate that the levels of conductivity, turbidity, hardness, alkalinity, Biological Oxygen Demand (BOD), levels of ammonia, soluble reactive phosphorus (SRP), Total Nitrogen (TN) and Total Phosphorus (TP) were very high for the Kisat River and the Molasses plant discharge point and are the worst polluters of the Yala catchment. The data also show that the discharge from the Yala River poses insignificant threat so far to the Lake in terms of the chemicals and heavy metals compared to that of the River Kisat and the Molasses plant (*assign largely modified*).			

Category	Description	References	Classification	Score
	• Analysis for heavy metal in water and sediment samples were higher in the Yala and Geita catchments (categorized as urban-influenced catchments) as compared to the Thruston Bay (a rural-influenced catchment) (*assigned moderately modified*). • Results for nitrate, nitrite and ammonium loadings in the Geita catchment area are very high when compared to those in the Thruston bay and Yala catchments and is reflected in the general decline in water quality of the lake (*assigned largely modified*). **Conclusion:** • The water quality for the ecoregion was classified as *moderately modified* as the information suggests that the water quality of Lake Victoria is probably more impacted than that of the rivers.			
Fish	**Ecoregion:** • This ecoregion is outstanding for its cichlid species radiation with 22 endemic cichlid genera and 3 additional endemic genera. **Lakes:** • The lakes of the ecoregion also host approximately 90 non-cichlid fish species of which about one third are endemic to the ecoregion. • Lake Victoria hosts over 600 endemic fish although estimates of species numbers vary widely. The endemic haplochromine fauna of Lake Victoria is one of the world's most outstanding examples of explosive speciation and adaptive radiation. Lake Victoria contains many threatened fish species. Many of the lakes cichlids were thought to be extinct but more recent surveys have found small pockets in the lesser known parts of the lake as well as in satellite lakes. The southern and western drainages to Lake Victoria hold large number of threatened species. The Lake Kyoga/Victoria Nile catchment also hold high numbers of threatened species due to overfishing and sedimentation (a*ssigned largely modified*). • *Haplochromis cavifrons* is a critically endangered fish species that is endemic to Lake Victoria (*assigned largely modified*). • Lakes Edward and Lake George host a total number of about 80 cichlid species, with nearly 60 of these being endemic. • Lake Edward is very important from a biodiversity perspective as preliminary surveys of the fish fauna of the lake yielded many new species of cichlids. • Freshwater fish that are endangered or threatened in the lakes of Uganda include 9 critically endangered freshwater cichlids in Lake Nawampasa, 2 are in Lake Nabugabo, and 1 is in Lake Victoria (*assigned largely modified*).	Darwell et al, 2005 FEOW, 2013 Thieme et al, 2005 NEMA, 2006	Largely modified (Figure 28)	4

Category	Description	References	Classification	Score
	• Currently 28 fish species have been recorded from Lake Kivu and its affluents of which 19 are cichlids. **Rivers:** • There are at least 55 fish species in the Rwandan portion of the Akagera River. • *Neochromis simotes* is a critically endangered fish species that is restricted to Kakindu and Ripon Fall, both on the Victoria Nile in Jinja, Uganda (*assigned largely modified*). • The riverine faunas in the tributaries of the Edward-George system are very rich and include the antecedents to the lacustrine radiations. **Conclusion:** • The fish data indicates that the ecoregion has high species richness and endemism but various factors have led to the extinction of some fish species and the classification of other species as threated or endangered. Based on this information, the overall wellbeing of the ecoregion is classified as *largely modified*.			
Fisheries	**Lakes:** • Fisheries in Lake Victoria have found to generate an annual GDP of approximately US$3-4 billion and provides an annual income of between US$90-270 per capita for more than 25000 people. • Lake Victoria's fisheries are dominated by 2 introduced species namely; Nile perch (*Lates niloticus*) and Nile tilapia (*Oreochromus niloticus*), and one native cyprinid (*Rastrineobola argentea*). The lakes fisheries production increased markedly after the introduction of the Nile perch but started to decline in the early 2000's because of the overexploitation of the fisheries resources and an increase in the number of motorized boats used for fishing. The current haul is estimated at 45 kg/boat/day compared with the 80 kg/boat/day figure during 1990's (*assigned largely modified*). • A study undertaken of the Thruston Bay, Yala catchment and the Geita catchment of Lake Victoria indicated that local communities have to sometimes fish at distances of 10 kilometers sometimes even up to 60 kilometers to find fish. **Rivers:** • Capture fisheries data for the Akagera River basin indicates that the fish stocks in most of the lakes in Rwanda have been overexploited (*assigned largely modified*). Problems include: ○ Uncontrolled fishing methods and lack of proper fishing gear which results in the catching of immature fish stock which could lead to the extinction of a species.	Dumont, 2009 Hamza, 2014 Muyodi et al. 2011 NBI, 2008	Largely modified (Figure 29)	4

Category	Description	References	Classification	Score
	○ Continued dependency on one species which can again lead to the loss of biodiversity and extinction of that species. ○ Lack of services to educate local communities on sustainable fishing methods. **Conclusion:** • Fisheries information indicates that there has been a general decline in the fisheries within the ecoregion and was classified as *largely modified*.			
Other ecosystem components	**Ecoregion:** • The ecoregion is rich in taxa, including aquatic-dependent reptiles, amphibians, and mammals, plankton and freshwater molluscs. • There is a high species richness of frogs in the ecoregion, with over 60 known species of which one-quarter are endemic. • The ecoregion's waters also support about 54 mollusc species of which about one-fifth are endemic to the ecoregion. **Wetlands:** • The ecoregion's swamps and wetlands support numerous waterbirds of which some are considered vulnerable (*Chloropeta gracilirostris* and *Xenoligea montana*) and locally rare (*Laniarius mufumbiri* and *Balaeniceps rex*) (*assigned moderately modified*). **Conclusion:** • The ecoregion is rich in other ecosystem taxa but there have been impacts to some species populations and wellbeing so other ecosystem components was classified as *moderately modified.*	FEOW, 2013	Moderately modified (Figure 30)	3
Ecosystem service components	**Ecoregion:** • A study undertaken in Uganda showed that the lakes, rivers, wetlands and floodplains of the country generated goods and services valued at more than $334 million a year. **Lakes:** • Introduction of the exotic fish, Nile Perch has led to the loss in biodiversity in Lake Victoria as it has been blamed for the near extinction of over 200 endemic fish species in the Lake Victoria fishery. • Exotic water hyacinths in Lake Victoria are also responsible for the loss in biodiversity as it starves fish and plankton of oxygen and sunlight and reduces the diversity of important aquatic plants. • A study undertaken of the Thruston Bay, Yala catchment and the Geita catchment of Lake Victoria indicated that the communities living along the beaches in the three main research	Muyodi et al. 2011 NBI, 2008 NEMA, 2006 Thieme et al, 2005	Largely modified (Figure 31)	4

Category	Description	References	Classification	Score
	areas had most of their livelihood activities related to fishing and that 47% of the residents have their principal occupation as fishing. More than 50% of the respondents in the study indicated that the disappearance of the fish, reduced income and ill health was probably due to the poor water quality. **Wetlands:** • The wetlands of the Akagera River Basin provide various benefits ranging from waste water treatment, recreation and eco-tourism purposes to sources of raw materials for handcrafts and potential areas for hunting and fishing. • It has been estimated that households in rural areas in Uganda get up to US$200 per year by harvesting papyrus grass from wetlands. • It has also been estimated that wetlands have been found to provide potable water supplies valued at about US$25 million per year. • A study undertaken in 2006 suggested that water supply may not be a problem for Uganda but this will only be true if the present recharge rates do not deteriorate and that supply from external sources are not reduced. However the National Wetlands Program estimates that Uganda is expected to experience water stress by the year 2025, possibly due to the continuing degradation of the country's wetlands which are a major source for water capture and storage and a principal factor in determining the country's internal renewable water resource. Most of its wetlands face reclamation and degradation in Uganda. Between 1990 and 1992, Ugandans converted 7.3% or 2,376 km2 of the total original wetland area. **Conclusion:** • In consideration of the available information and the threats to the ecoregion (referred to threats to ecosystem wellbeing section) the availability of ecosystem services in the ecoregion have been largely impacted/altered (*assigned largely modified*).			

3.3.4 Wellbeing of the Upper Nile Freshwater Ecoregion

The Upper Nile ecoregion is situated mainly in South Sudan with smaller regions in Sudan, Uganda, Ethiopia and the Democratic Republic of the Congo (DRC). The primary feature of the Upper Nile ecoregion is the vast swamps of the Sudd. This dynamic wetland contains a diversity of habitats and supports a rich aquatic and terrestrial fauna. The Upper Nile ecoregion consist of the following:

- White Nile River and its major tributaries the Sobat River and Bahr el Ghazel.
- Lake Albert and its main influent the Semliki River.
- The Bahr el Ghazel and its main tributaries the Sue, Jur, Pongo, Lol and Bahr el Arab which drain the south western portion of the ecoregion and flow into the Sudd.
- The Sobat River and its main tributaries the Kangen, Akoro, Baro and Pibor Rivers which drain the south eastern portion of the ecoregion.
- The Albert Nile (named Bahr el Jabal in Sudan) drains Lake Albert and flows north into the Sudd and then mergers downstream with the Bahr el Ghazel to form the White Nile (Bahr el Abyad in Arabic).

The wellbeing assessment of the Upper Nile freshwater ecoregion is described in Table 16 and graphically presented in Figure 22 to Figure 31.

Table 16: Synopsis of the desktop evaluation of the wellbeing of the Upper Nile freshwater ecoregion.

Category	Description	References	Classification	Score
Conservation Assessment	• Final Biological Distinctiveness Index is globally outstanding. The species richness of the ecoregion was categorised as low and species endemism as medium indicating that the biological distinctiveness of the ecoregion was bioregionally outstanding but because it has a globally outstanding rare habitat phenomena (swamps and floodplains of Sudd are one of the most important wetlands in Africa and support a rich biota) the final BDI is elevated to globally outstanding.	Thieme et al, 2005	Globally outstanding (Figure 22)	1
	• Likelihood of future threats is considered high as there is a possibility of resumed civil war in Sudan that threatens both human populations and wildlife conservation. • There are also several planned development projects that pose a threat to the ecological integrity of the ecoregion. One of these projects is the proposed Jonglei Canal that will divert the floodwaters from the Sudd downstream for agricultural development but will have various negative impacts on the Sudd wetland, wildlife and the movment of people; just to mention a few.		High (Figure 23)	3
	• Final Conservation Status is considered vulnerable because years of civil war has led to the drastic decline in nearly all mammal populations in many parks in southern Sudan due to poaching. There has even been a decline in the wildlife numbers of the Radom National Park which is designates as a biosphere reserve.		Vulnerable (Figure 24)	3
	• The information above classifies the Upper Nile ecoregion as a Priority Class I as it contains a globally outstanding ecoregion that is highly threatened.		Class I (Figure 25)	1
Threats to ecosystem wellbeing	**Ecoregion:** • The major threats to the ecoregion is human impacts on the natural environment and converted land. **Wetlands / swamps:** • Much of the Sudd swamps remain as a vast near-wilderness area but years of civil war have seriously compromised the protected areas as the poaching of large animals continues unchecked. • Excessive development of agricultural activities to the Sudd wetlands has also been identified as a driver of the threat to the wetlands in South sudan. • Water hyacinths is a problem in the entire system but especially in the Sudd.	FEOW, 2013 Thieme et al, 2005 NBI, 2012	Largely natural (Relatively stable) - Largely unthreatened (Figure 26)	2

Category	Description	References	Classification	Score
	Conclusion: • These threats have resulted in 25 - 50% of the land area of the ecoregion being degraded. The dynamic physical processes of the aquatic habitat are somewhat modified. There is some abandonment and disruption of migratory or breeding movements and pollutants may be found in target species or assemblages. There is low exploitation or disturbances to biota by exotics. The wellbeing of the ecoregion is *largely natural* (relatively stable) based on the impacts of these threats.			
Water quality	**Lakes:** • The average annual electrical conductivity below Lake Albert was more than 420 µS/cm while the average total dissolved solids was a 1000mg/L. **Rivers:** • Sulphate concentrations, in the White Nile, increase from the contributions of the western rift system but drop again after passing through the Sudd. • The White Nile, just before Malakal, has a relatively low suspended sediment concentration due to the sediment retention property of the Equatorial Lakes as well as the Sudd and Machar marshes. • The average annual electrical conductivity for the White Nile from below Malakal to below Jelhac was between 361 and 420 µS/cm. From Jelhac the electrical conductivity in the White Nile decreased to between 181 and 240 µS/cm at Khartoum. • The average annual electrical conductivity for the Semuliki River was between 301 and 360 µS/cm in 2005. • The water quality for the White Nile in Sudan is satisfactory based on the limited parameters monitored (*assigned moderately modified*). • The average annual electrical conductivity for the Bahr el Jebel and the Sudd was between 121 and 180 µS/cm in 2005 while the average total dissolved solids at Malakal was <20mg/L. **Wetlands / swamps:** • The extensive wetlands of the Sudd impact water quality by: ○ bringing about a reduction in suspended solid load, ○ decreasing dissolved oxygen concentrations, ○ increasing acidity, ○ increasing dissolved carbon dioxide concentrations, ○ reducing sulphate concentrations and ○ increasing total dissolved solids concentrations. **Conclusion:**	NBI, 2005 NBI, 2012	Moderately modified (Figure 27)	3

Category	Description	References	Classification	Score
	• The available information indicates that the general water quality for the Upper Nile ecoregion is *moderately modified*.			
Fish	**Ecoregion:** • This ecoregion is known to host 22 families and 118 species of fish including 16 endemic species. • There are many of the fish species that migrate from the rivers into the nutrient-rich floodplains during the seasonal floods to feed and breed. **Lakes:** • Lake Albert has a Nilotic riverine ichthyofauna comprised of 15 families and 46 species of which 7 endemic species are found in Lake Albert. **Conclusion:** • Available fish information indicates that the wellbeing of the fish in the Upper Nile seem to be *moderately modified* and affected by exploitation, flow alterations, water quality impacts associated with land use practices and alien and invasive species.	FEOW, 2013	Moderately modified (Figure 28)	3
Fisheries	**Rivers:** • White Nile reservoir in Sudan has a fish catch potential of 15000 tons/year but the actual yield is only 13000 tons/year so only 86% of the fishing potential is being exploited. **Wetlands:** • The Sudd region has a fish catch potential of 75000 tons/year but the actual yield is only 30000 tons/year so only 43% of the fishing potential is being exploited. **Conclusion:** • The demand and potentially unsustainable use of fisheries in this ecoregion may potentially *moderately modify* the wellbeing of the fisheries.	Hamza, 2014	Moderately modified (Figure 29)	3
Other ecosystem components	**Ecoregion:** • The system is diverse and highly productive; being home to abundant grasses, cructaceans, molluscs, and aquatic insects. • The endemic and threatened Nile lechwe (*Kobus megaceros*) has its center of population in this ecoregion **Lakes:** • There are 3 critically endangered species of mollusc which are only known to occur in a small stretch of shoreline at Butiaba in Lake Albert (*assigned moderately modified*). **Wetland / Swamp:**	FEOW, 2013	Moderately modified (Figure 30)	3

Category	Description	References	Classification	Score
	• The Sudd is one of the most important wintering grounds in Africa for Palaearctic migrants, and it provides essential habitat for millions of intra-African migrants. About 60 known species and a maximum of nearly three million birds have been recorded at one time. **Conclusion:** • Information on the wellbeing of other ecosystem components for the Upper Nile ecoregion is limited but indicates that it is *moderately modified*.			
Ecosystem service components	**Lakes** • Lake Albert regulated the flow between the White Nile and its headwaters. Without it the White Nile would be reduced to a seasonal stream and could play no significant role in maintaining the base flow of the main Nile. **Wetlands / Swamps:** • The wetlands of the Sudd attenuate flows to the White Nile and its tributaries and minimise seasonal variation in flow by reducing flood peaks and supporting dry-season river flow. **Conclusion:** • In consideration of the available information and the threats to the ecoregion (referred to threats to ecosystem wellbeing section) the availability of ecosystem services in the ecoregion have been *moderately modified*.	Rebelo & McCartney, 2012	Moderately modified (Figure 31)	3

3.3.5 Wellbeing of the Lower Nile Freshwater Ecoregion

The Lower Nile River runs through the semi-arid Sahel and the arid Sahara Desert of northern Sudan and Egypt. The ecoregion consists of the Lower Nile River from Khartoum where the Blue and White Nile Rivers converge and then flow downstream to the Nile Delta and areas draining to the Lower Nile from the west and from the east, including the Blue Nile and the Atbara Rivers but excluding their uppermost reaches. The ecoregion also includes four major waterfalls over which the Nile flows before emptying into the Aswan High Dam reservoir, named Lake Nubia in Sudan and Lake Nasser in Egypt.

The wellbeing assessment of the Lower Nile freshwater ecoregion is described in Table 17 and graphically presented in Figure 22 to Figure 31.

Table 17: Synopsis of the desktop evaluation of the wellbeing of the Lower Nile freshwater ecoregion.

Category	Description	References	Classification	Score
Conservation Assessment	• Final Biological Distinctiveness Index was nationally important as the species richness of the ecoregion was categorised as high but endemism as none indicating that the biological distinctiveness of the ecoregion was nationally important. No globally or continentally outstanding ecological phenomena occurs in this ecoregion so the final BDI remains nationally important.	Thieme et al, 2005	Nationally Important (Figure 22)	4
	• Likelihood of future threats is considered to be medium as agriculture and infrastructure development pressures related to growing human population are expected to increase and place heavy pressure on limited water resources. • Changes in flow due to climate change is another potential threat which will influence the ecology of the Lower Nile.		Medium (Figure 23)	2
	• Final Conservation Status is vulnerable as all major rivers in this ecoregion are managed for flood control, irrigation and electricity. • Various dams have been built in the ecoregion but the Aswan High Dam is one of the highest dams ever built and has had a tremendous impact on the ecology of the Nile River and the Nile Delta. • Irrigated agriculture has a significant impact on the Lower Nile system as numerous irrigation barrages exist along the river and large quantities of water is extracted.		Vulnerable (Figure 24)	3
	• The information above classifies the ecoregion as a Priority Class V as it is a bioregionally outstanding and nationally important ecoregions with relatively intact aquatic systems		Class V (Figure 25)	5
Threats to ecosystem wellbeing	**Ecoregion:** • Within Sudan, pesticides from various forms of agriculture is a threat. The use of fertilisers also cause severe problems in run-off and resulting in the rise of the nutrients in the rivers leading to algal blooms. Nutrients in the rivers also result in the eutrophication of the lakes and the proliferation of water hyacinth. Other treats include increased urbanisation resulting in sewerage pollution and problems with solid waste sites. **Rivers:** • Irrigated agriculture has a significant impact on the lower Nile system as numerous irrigation barrages exist along the river and extract large amounts of water. Two large reclamation projects also extract water from the river.	Thieme et al, 2005 NBI, 2005; Abdelbary, 1996	Moderately modified (Vulnerable) – Moderately threatened (Figure 26)	3

Category	Description	References	Classification	Score
	• Pollution to the Nile River located within Egypt is due to increases in population, new irrigated agriculture projects, industrial development and other activities along the Nile River. Pollution sources include: industrial wastewater pollution, domestic wastewater pollution, agricultural drainage water pollution and pollution originating from dumping of solid waste. **Dams:** • There are various dams in the ecoregion. The Aswan High Dam has especially had a tremendous impact on the ecology of the Nile River and the Nile Delta. **Conclusion:** • These threats have resulted in 5-25% of the land area of the ecoregion being degraded. There is low habitat quality for sensitive species. Physical barriers and habitat destruction has resulted in abandonment and disruption of migratory or breeding movements. Pollutants or linked effects are widespread and recorded in several trophic levels. There is moderate exploitation or disturbances to biota by exotics. The wellbeing of the ecoregion is *moderately modified* (vulnerable) based on the impacts of these threats.			
Water quality	**Dams:** • Suspended sediment concentrations downstream of Aswan Dam are in the low range of 20 to 50 mg/L all year round. • The average total dissolved solids recorded at Aswan was 171mg/L. **Rivers:** • The average annual electrical conductivity for the Blue Nile was between 241 and 300 µS/cm. • The average annual electrical conductivity for the Main Nile River from Khartoum to downstream of Atbara was between 181 and 240 µS/cm but increases to 241 to 300 µS/cm as the river flowed towards Cairo where the electrical conductivity was 301 to 360 µS/cm. • The average total dissolved solids from Khartoum to Dongola was 20-120mg/L. • The Nile River near Khartoum and Cairo have a chemically and microbiologically degraded water quality. • The BOD value of the Nile River has remained fairly stable between 1991 and 2001, though the BOD values of about 30% of the sampling points was over 6 mg/l, the Egyptian standard limit. Lead and nickel were over 0.01 mg/l in many monitoring points in 2001 (*assigned moderately modified*). • Mid-stream conditions of the Nile River in Egypt are still, on the average, at a fairly clean level as organic and inorganic pollutants discharged into the river are strongly diluted and degraded. Riverbanks are however polluted. 90% of the *E.coli* results for the Nile River are below the use-as-drinking-water norm. Dissolved oxygen is usually close to saturation except	Dumont, 2009 NBI, 2005 NBI, 2012 Wahaab and Badawy, 2004	Moderately modified (Figure 27)	3

Category	Description	References	Classification	Score
	for the first 40 km below the High Aswan Dam. A number of parameters, such as total P, nitrates, BOD stay below the maximum norms in all cases (*assigned moderately modified*). • The quality of the Nile and Blue Nile in the Sudan is satisfactory for the limited parameters monitored with the exception of one fairly high value for ammonia recorded on the Suba Blue Nile, probably due to faecal pollution (*assigned moderately modified*). **Conclusion:** • The water quality data indicates that there are some areas of concern in the ecoregion but in general the water quality is *moderately modified*.			
Fish	**Ecoregion:** • Over 70 species of fish live in the ecoregion but none are endemic. **River catchment:** • The Nile River, downstream of Lake Nasser has 11-19 threatened fish species. This number decreases to between 4 and 9 threatened fish species before the Nile Delta. This decline in fish species is attributed to water pollution and human impacts (*assigned largely modified*). • Various regionally extinct freshwater fish used to be found within the Nile River basin in Egypt. Their regional extinction may be due to the construction of the Aswan Dam (*assigned seriously modified*). **Conclusion:** • Although there are no endemic fish species in this ecoregion, there are many species that are threatened and even some that are regionally extinct resulting in the fish being classified as *largely modified*.	Garcia et al, 2010 Thieme et al, 2005 FEOW, 2013	Largely modified (Figure 28)	4
Fisheries	**Ecoregion:** • In Sudan, fishing is unevenly distributed especially north of Khartoum. Most of the fishing is subsistence fishing including in the Sudd marshes. **Lakes:** • Lake Nubia portion in Sudan has a fish catch potential of 5100 tons/year but the actual yield is only 1000 tons/year so only 19.6% of the fishing potential is being exploited. • The total fish catch from Lake Nasser has been estimated as 28,153 tons/year and the fish have been exploited. **Rivers:** • The Blue Nile reservoir in Sudan has a fish catch potential of 1700 tons/year but the actual yield is only 1500 tons/year so only 88% of the fishing potential is being exploited. • The Senner reservoir in Sudan has a fish catch potential of 1100 tons/year but the actual yield is only 1100 tons/year so only 91% of the fishing potential is being exploited.	Dumont, 2009 Hamza, 2014	Moderately modified (Figure 29)	3

Category	Description	References	Classification	Score
	Conclusion: • The demand and potentially unsustainable use of fisheries in the Lower Nile ecoregion may potentially threaten the wellbeing of the fisheries moderately (*assign moderately modified*).			
Other ecosystem components	**Ecoregion:** • Fifteen (15) gastropods and 9 bivalves occur in the ecoregion. **Lake:** • Lake Qârûn supports large number of waterbirds with 32,000 birds recorded at the lake in the winter of 1989-1990. **Rivers:** • Various species of Odonata are considered threatened in the Nile Valley and some are regionally extinct (*assigned largely modified*). **Conclusion:** • The information on other ecosystem components is limited but indicates some large modifications to certain species populations (*assign largely modified*).	Garcia et al, 2010 Thieme et al, 2005 FEOW, 2013	Largely modified (Figure 30)	4
Ecosystem service components	**Ecoregion:** • With the construction the major dams in the Lower Nile Ecoregion, some additional ecosystem services have been available such as fisheries in the lakes. However the construction of the dam has negatively affected many other ecosystem services such as flood control regulation in the lower Nile River/floodplain and in particular the productivity of the Nile floodplain and the associated agriculture and fisheries The reduction in productivity has been attributed to the reduction in fine and course particulate organic matter in the Nile River due to the dam development. **Conclusion:** • In consideration of the available information and the threats to the ecoregion (referred to threats to ecosystem wellbeing section) the availability of ecosystem services in the ecoregion have been largely impacted/altered (*assigned largely modified*).	White, 1988.	Largely modified (Figure 31)	4

3.3.6 Wellbeing of the Nile Delta Freshwater Ecoregion

The Nile Delta is a fertile fluvial triangle in one of the driest desserts in the world. It is situated in northern Egypt and extends about 175km from its apex at Cairo to the Mediterranean Sea. The construction of the Aswan High Dam has dramatically reduced the water flow to the delta and the floodplains are no longer subject to annual flooding. Where the Nile River used to flow as numerous channels through the delta it now only occupies two main channels; the Rosetta branch (western) and the Damietta branch (eastern). The main wetlands in the delta are the coastal lakes of Manzala, Burullus, Idku and Maryut.

The wellbeing assessment of the Nile Delta freshwater ecoregion is described in Table 18 and graphically presented in Figure 22 to Figure 31.

Table 18: Synopsis of the desktop evaluation of the wellbeing of the Nile Delta freshwater ecoregion.

Category	Description	References	Classification	Score
Conservation Assessment	• Final Biological Distinctiveness Index was nationally important as the species richness and endemism of the ecoregion were categorised as low indicating that the biological distinctiveness of the ecoregion was nationally important. No globally or continentally outstanding ecological phenomena occurs in this ecoregion so the final BDI remains nationally important.	Thieme et al, 2005	Nationally Important (Figure 22)	4
	• Likelihood of future threats is high as further increased in human population and related activities threaten the remaining ecological functioning of the delta. • The potential for sea levels to rise to inundate the freshwater marshes and lagoons of the delta is a serious concern.		High (Figure 23)	3
	• Final Conservation Status is considered critical as human settlements and agriculture occupy almost the entire delta landscape. • Small pockets of natural habitat include wetlands and coastal dunes and salt marshes but these are disappearing rapidly as the irrigation system of the delta is highly controlled. • The completion of the Aswan High Dam stopped the flooding cycle and as a result the delta has eroded by 2km since the 1960s. • The delta is also incapable of flushing out water pollutants without the seasonal flooding. Accumulated pollutants threatens plant and animal populations and possibly groundwater reservoirs. • Alien invasive species are a serious threat to the native diversity especially water hyacinths.		Critical (Figure 24)	5
	• The information above classifies the ecoregion as a Priority Class IV as it is a bioregionally outstanding and nationally important ecoregion that is highly threatened.		Class IV (Figure 25)	4
Threats to ecosystem wellbeing	**Ecoregion:** • The natural wetlands, coastal dunes and salt marshes mostly in the extreme north of the delta are disappearing as the irrigation system of the delta is highly controlled. **Delta:** • The closure of the second Aswan High Dam stopped the flooding cycle of the Delta resulting in the Delta becoming a subsiding and eroding coastal plain. Seawater intrusion of the Delta threatens the water quality of coastal lakes, rivers and groundwater. Water hyacinths is a problem in the Delta and has displaced native floating aquatic vegetation • Major sources of pollution for the Damietta branch of the delta are the:	Thieme et al, 2005 NBI, 2005; Abdelbary, 1996	Largely modified (Endangered) –Largely threatened (Figure 26)	4

Category	Description	References	Classification	Score
	○ Talkha Fertilizer Factory, ○ High Serw 1 Drain and ○ High Serw Power Station. • The Rosetta branch receives relative high concentrations of organic compounds, nutrients and oil & grease with the major sources of pollution being the: ○ Rahawy drain (which receives part of Greater Cairo wastewater), ○ Sabal drain, ○ El- Tahrer drain, ○ Zawirt El-Bahr drain, ○ Tala drain and ○ wastewater from Maleya and Salt & Soda companies **Conclusion:** • These threats have resulted in more than 50% of the land area of the ecoregion being degraded. There is low habitat quality for sensitive species. There is abandonment and disruption of migratory or breeding movements due to physical barriers and habitat destruction. Pollutants or linked effects are widespread and recorded in several trophic levels. There is moderate exploitation or disturbances to biota by exotics. The wellbeing of the ecoregion is largely modified (endangered) based on the impacts of these threats.			
Water quality	**Ecoregion:** • As the Nile Delta is the farthest location downstream of the Nile Basin, it is the most polluted and has the lowest water quality. • Dissolved oxygen concentrations below 5 mg O2 /L have been recorded in the Nile Delta. • The average annual electrical conductivity for the Nile Delta was between 361 and 420 µS/cm. **Delta:** • Water quality results from an assessment undertaken in 2001 for the Damietta branch indicated the following: ○ Dissolved oxygen concentration from the southern to the northern part ranged from 7.8 mg/L to 6.2 mg/L. ○ Nutrients concentration (nitrogen & phosphorous) were within the permissible limits. ○ The chemical oxygen demand (COD) exceeded the standards (*assigned largely modified*) but the values were similar to those of the Nile water from Aswan to Delta Barrage.	Hamza, 2014 NBI, 2005 NBI, 2012	Largely modified (Figure 27)	4

Category	Description	References	Classification	Score
	○ BOD values complied with the consent standard with the exception of one location at the end of the branch (*assigned moderately modified*). ○ TDS values were within the permissible limits and increased from 240 mg/L to 372 mg/L. ○ Faecal Coliform counts exceeded the WHO Guidelines in almost all sampling sites indicating faecal pollution (*assigned seriously modified*). • The water quality for the Rosetta branch was as follows: ○ Dissolved oxygen concentrations from the southern to the northern part ranged from 5.1 mg/L to 6.3 mg/L. ○ Nutrient concentrations were within the permissible limits. ○ COD and BOD values exceeded the standards (*assigned largely modified)* but were similar to those recorded from Damietta Branch. ○ TDS ranges from 240 mg/L at the Delta Barrage up to 415 mg/L at the end of the branch. ○ High Faecal Coliform counts were detected at Kafr El-Zayat, but downstream they were less than 1000. Total coliform concentrations of of 150,000 cfu/100 mL have been recorded in heavily polluted sections of the Rosetta branch of the Nile Delta (*assigned seriously modified).* **Conclusion:** • The available water quality data indicates that the water quality for the Nile Delta is *largely modified* which may be expected as it is the farthest location downstream of the Nile Basin and it is the most polluted.			
Fish	**Ecoregion:** • The ecoregion is host to a dynamic mix of freshwater and saline fish species. • The Cichlidae and Mormyridae fish families are the most common of the about 30 fish species present within the ecoregion. • No endemic fish are found within this ecoregion. **Delta:** • 4-9 fish species within the Nile Delta are considered to be threatened (*assigned largely modified*). • Some fish species have become regionally extinct in the Nile Delta. (*assign seriously modified* score) **Conclusion:**	FEOW, 2013 Garcia et al, 2010	Largely modified (Figure 28)	4

Category	Description	References	Classification	Score
	• Although there are no endemic fish species in this ecoregion, there are many species that are threatened and even some that are regionally extinct resulting in the fish being classified as *largely modified*.			
Fisheries	**Delta:** • Fish landing in the Nile Delta now exceeds the limits of sustainability but fish farming is starting to increase in the area (*assign moderately to largely modified*). • The total catch of sardines in the Mediterranean Sea decreased by 90% after the construction of the High Aswan Dam in 1965 and annual shrimp landing decreased by 75% (*assigned largely modified*). • Annual fish production of the four lakes within the Nile Delta accounted for >50% of the total annual yield in 1985 for the country, but according to the year 2001 records, this declined to about 30% of the total annual yield of Egypt (*assign moderately modified*). **Conclusion:** • In consideration of the threats and continued exploitation of the fisheries in the ecoregion a moderate alteration in the fisheries wellbeing is proposed (*assign moderately modified*).	Drinkwater and Frank, 1994 Dumont, 2009 Hamza, 2014	Moderately modified (Figure 29)	3
Other ecosystem components	**Ecoregion:** • One endemic mollusc has been recorded for the ecoregion. • The Nile soft-shelled turtle (*Trionyx triunguis*) and the Nile crocodile (*Crocodylus niloticus*) used to inhabit the region, but have become extinct locally (*assigned seriously modified).* • Six (6) amphibian species are found within the ecoregion including the endemic Nile Valley toad, (*Bufo kassasii*). **Delta:** • The Nile Delta is part of one of the world's most important sites for migratory birds as more than one million ducks and shorebirds use the area on their annual migration from Europe to Africa. • *Chambardia letourneuxi*, is a mollusc species that was endemic of the Nile Delta but no live specimens have been found since the early 20th century and therefore is thought to be extinct (*assigned seriously modified*). • The nominate form of Bosc's Lizard (*Acanthodactylus boskianus*) is endemic to the Nile Delta. **Lakes:** • The Delta lakes are also internationally important sites for wintering waterbirds, providing valuable habitat for several hundred thousand birds. **Conclusion:**	FEOW, 2013 Garcia et al, 2010	Largely modified (Figure 30)	4

Category	Description	References	Classification	Score
	• The available information indicates there are various species that used to inhabit the ecoregion but are now locally extinct, indicating that other ecosystem components are *largely modified*.			
Ecosystem service components	**Ecoregion:** **Delta:** • The Delta protects the coastal freshwater sources by limiting saline intrusions from the Mediterranean Sea. Land use developments and the construction of the High Aswan Dam, have resulted in reductions in freshwater flow into the delta region of the Nile River, resulting in the increasing frequency and extent of salt water intrusions which has largely altered the wellbeing of the ecosystem service availability in the delta (*assign largely modified*). • Prior to the construction of the High Aswan Dam, the flood waters of the Nile River would flow into the delta bringing with it high nutrient levels, and large quantities of organic matter which would ultimately flow into the Mediterranean Sea contributing to an intense phytoplankton bloom and gave rise to increased zooplankton biomass. Sardines would migrated into the area to feed on the zooplankton increasing the fat content of the sardines, An extensive fishery of sardines and shrimp developed, based on this migratory stock but has since declined due to the construction of the High Aswan Dam and the resulting low water discharges (*assign largely modified*). **Conclusion:** • In consideration of the available information and the threats to the Nile Delta (referred to *threats to ecosystem wellbeing section*) the availability of ecosystem services in the delta have been largely impacted/altered (*assigned largely modified*).	Drinkwater and Frank, 1994 Rebelo & McCartney, 2012	Largely modified (Figure 31)	4

3.3.7 Overview of the wellbeing of the Freshwater Ecoregions of the Nile Basin

The Final Biological Distinctiveness Index for six most important freshwater ecoregions of the Nile Basin is presented in Figure 22 and indicate that the Lake Victoria, Upper Nile and Lake Tana ecoregions are all globally outstanding. The Ethiopian Highland ecoregion is bioregionally outstanding but Lower Nile and the Nile Delta are nationally important.

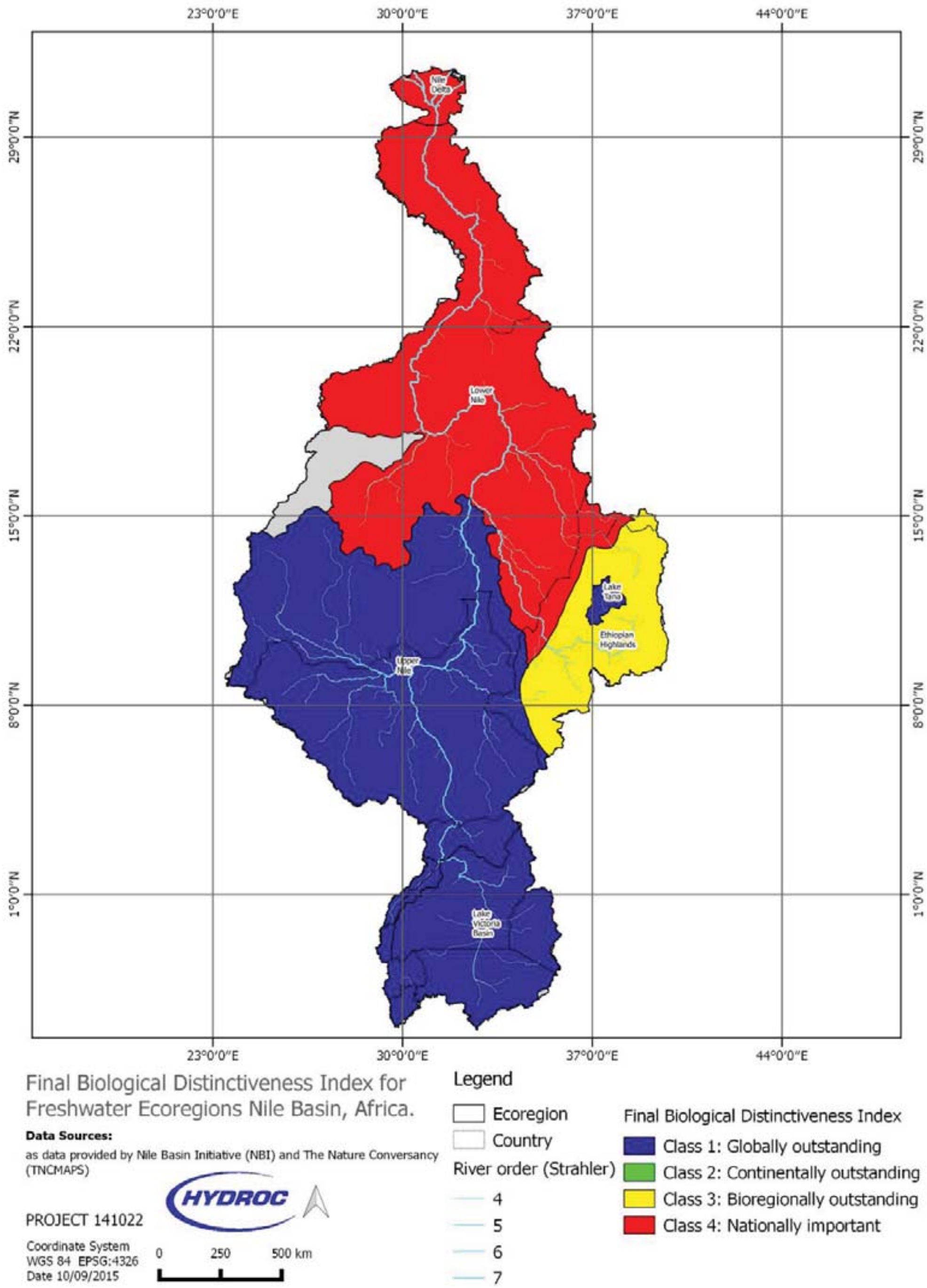

Figure 22: Results of the Final Biological Distinctiveness Index for the freshwater ecoregions of the Nile Basin.

The likelihood of future threats is high for all the ecoregions, with the exception of the Lower Nile Ecoregion (Figure 23).

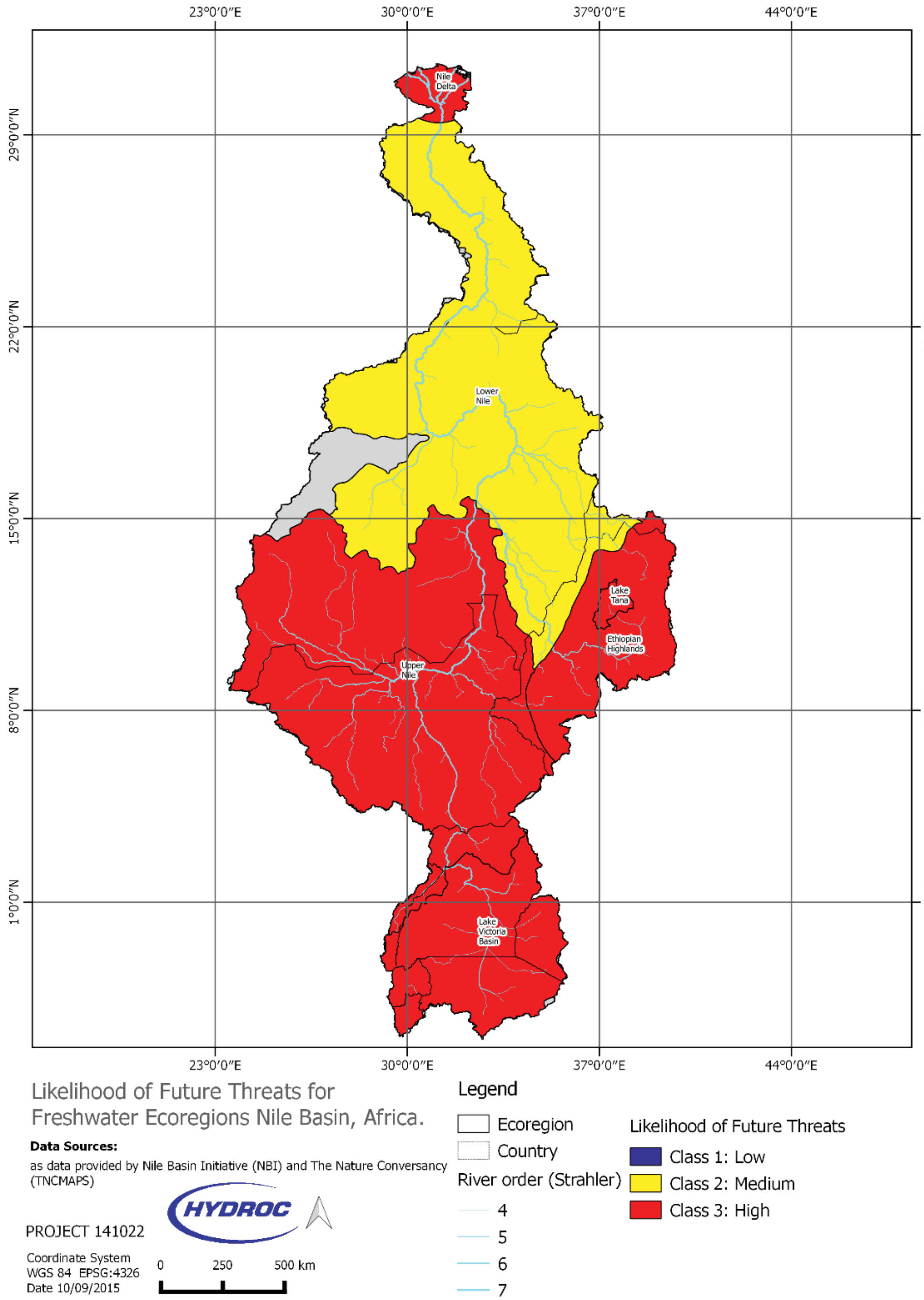

Figure 23: Likelihood of future threats for the freshwater ecoregions of the Nile Basin.

The Final Conservation Status indicate that the Lake Victoria ecoregion and the Nile Delta are both considered to be critical (Figure 24). The Ethiopian Highlands is considered to be endangered while Lake Tana, and the Upper and Lower Nile ecoregions are Vulnerable.

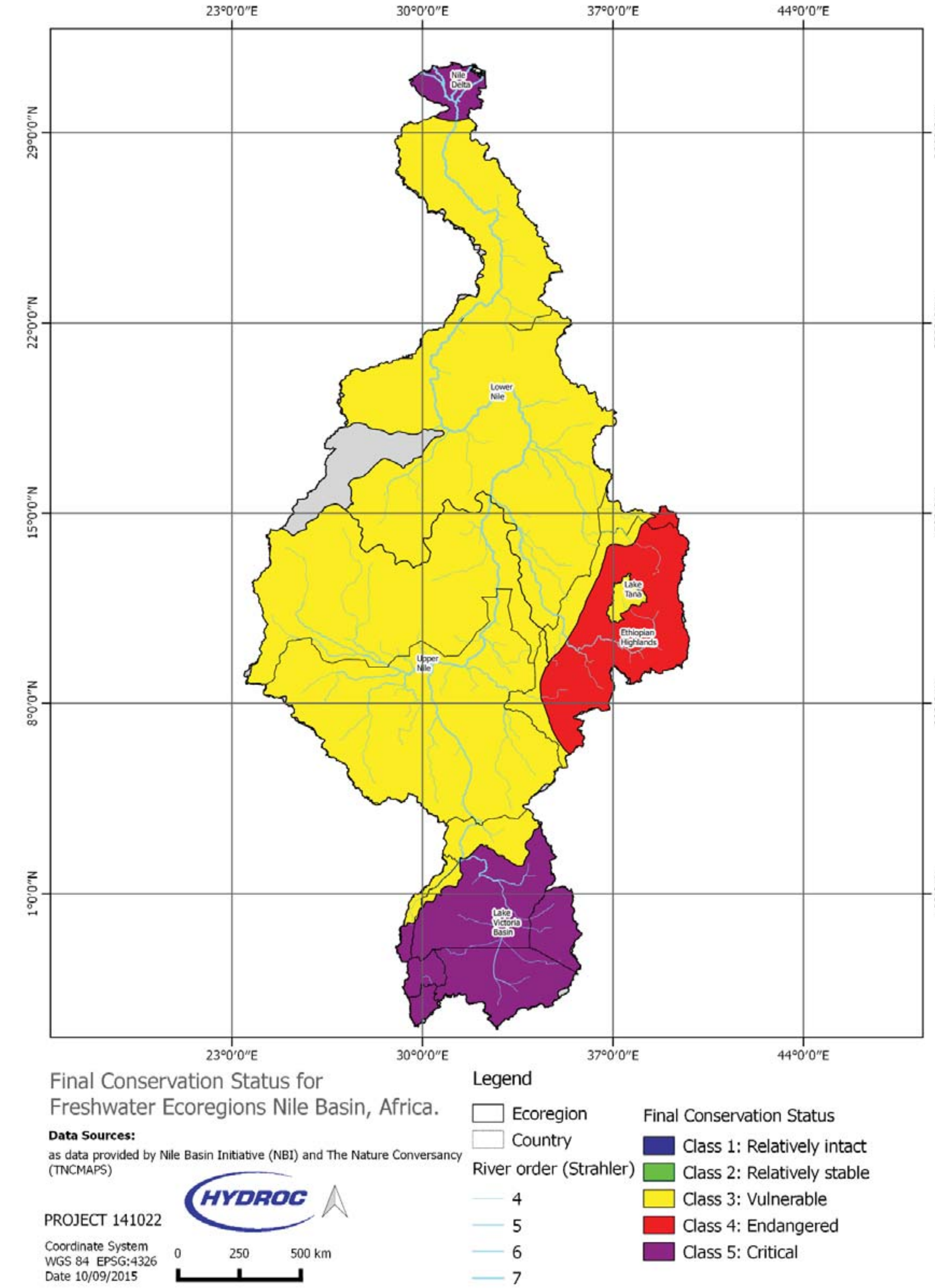

Figure 24: Final Conservation Status for the freshwater ecoregions of the Nile Basin.

The priority classes indicate the Lake Victoria, Lake Tana and Upper Nile ecoregions are all Class I ecoregions that are globally outstanding and highly threatened (Figure 25). The Nile Delta and the Ethiopian Highlands are Class IV ecoregions that are bioregionally outstanding or nationally important and are highly threatened. The Lower Nile has a priority class of V as it is a nationally important ecoregion with relatively intact aquatic systems.

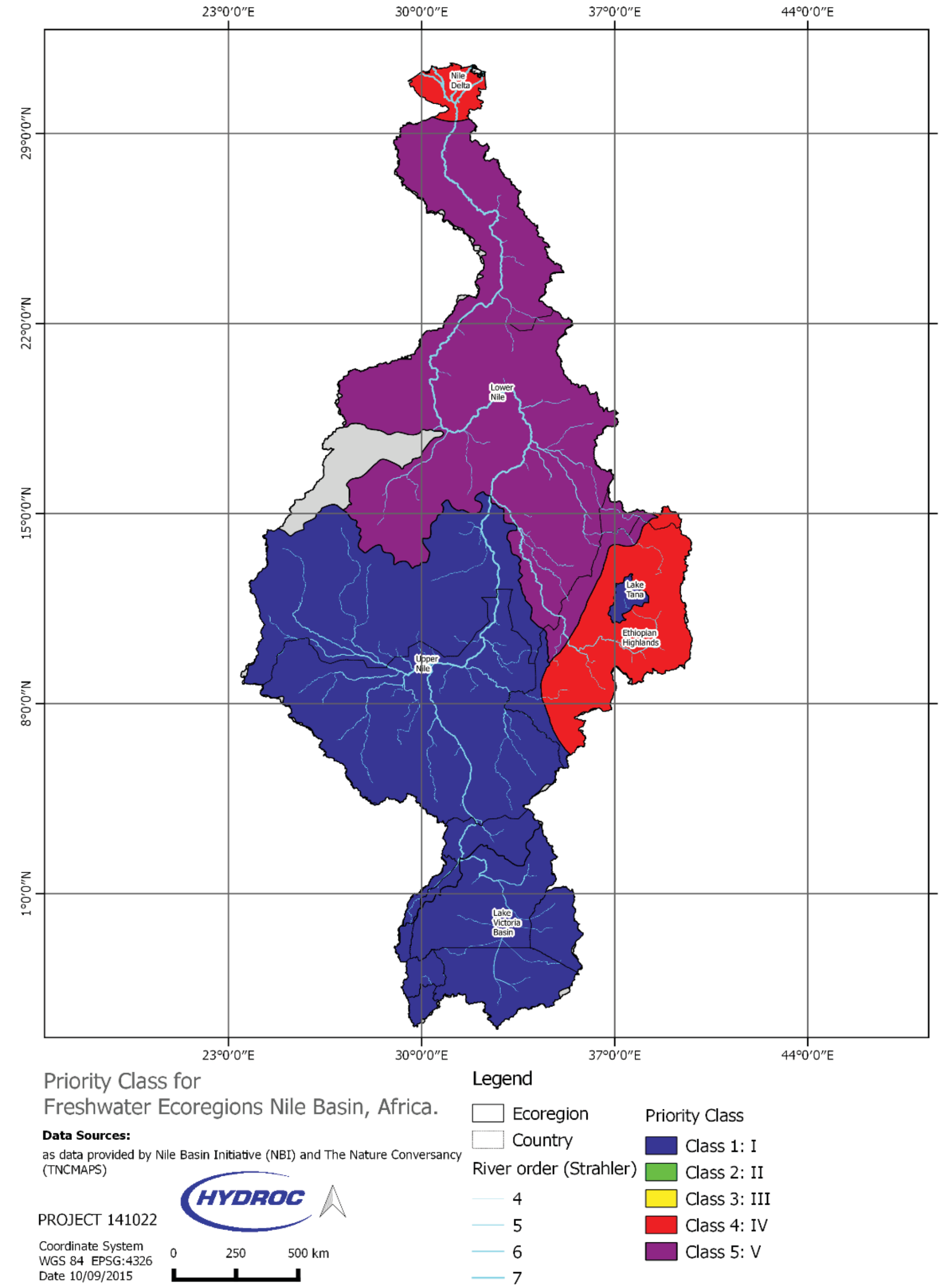

Figure 25: Priority Classes for the freshwater ecoregions of the Nile Basin.

The assessment of the threats to the ecosystem wellbeing indicates that the Lake Victoria and the Nile Delta are both largely threatened while the Ethiopian Highlands and Lower Nile ecoregions are moderately threatened (Figure 26). Lake Tana and the Upper Nile ecoregions are the only two ecoregions that are consisted to largely unthreatened.

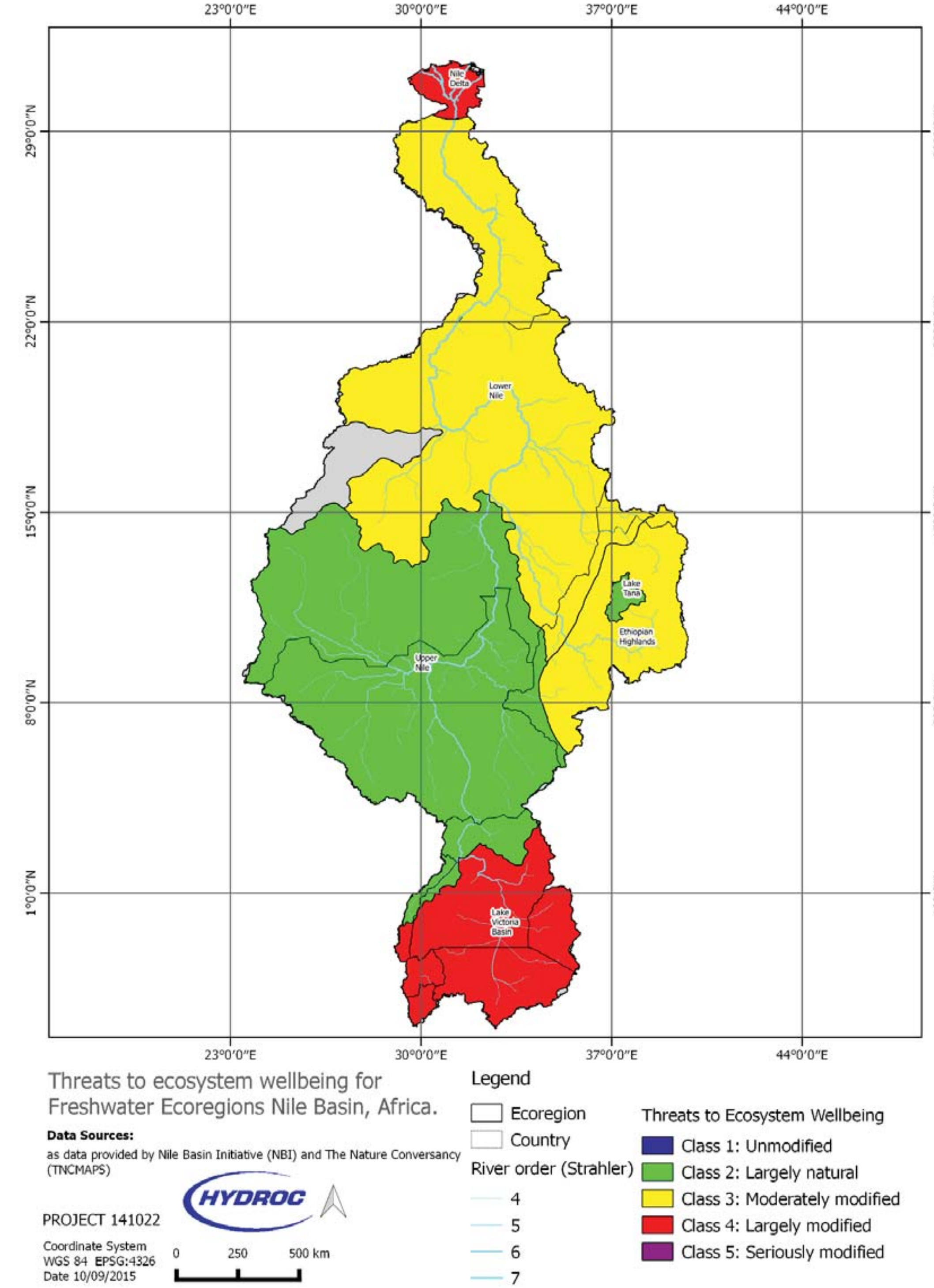

Figure 26: Threats to ecosystem wellbeing for the freshwater ecoregions of the Nile Basin.

The water quality for most of the Nile Basin is considered to be moderately modified with the exception of the Nile Delta that is largely modified (Figure 27).

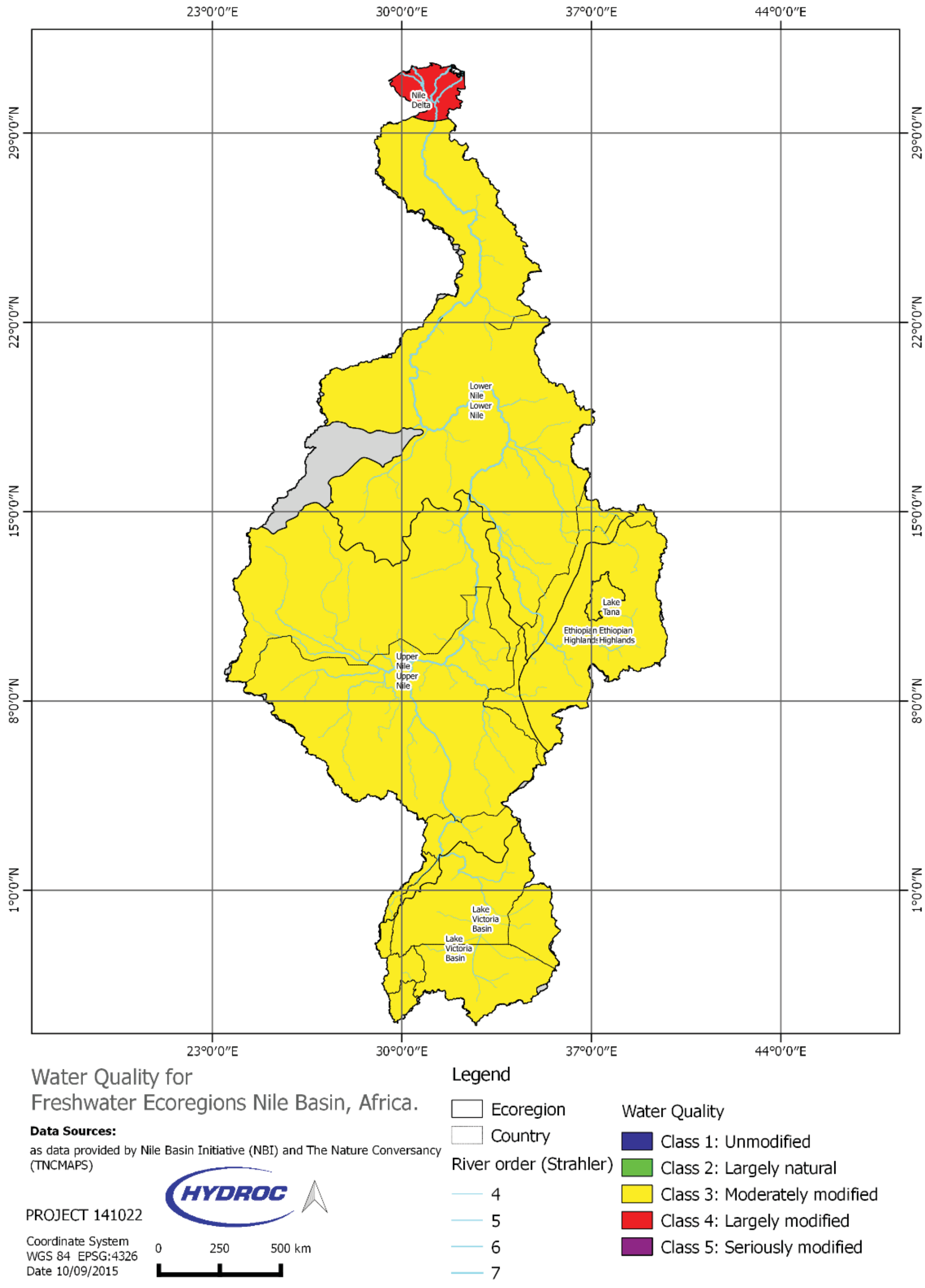

Figure 27: Wellbeing of water quality for the freshwater ecoregions of the Nile Basin.

The fish within the Lake Victoria and the Lower Nile ecoregions are considered to be largely modified but the remaining ecoregions are moderately modified (Figure 28).

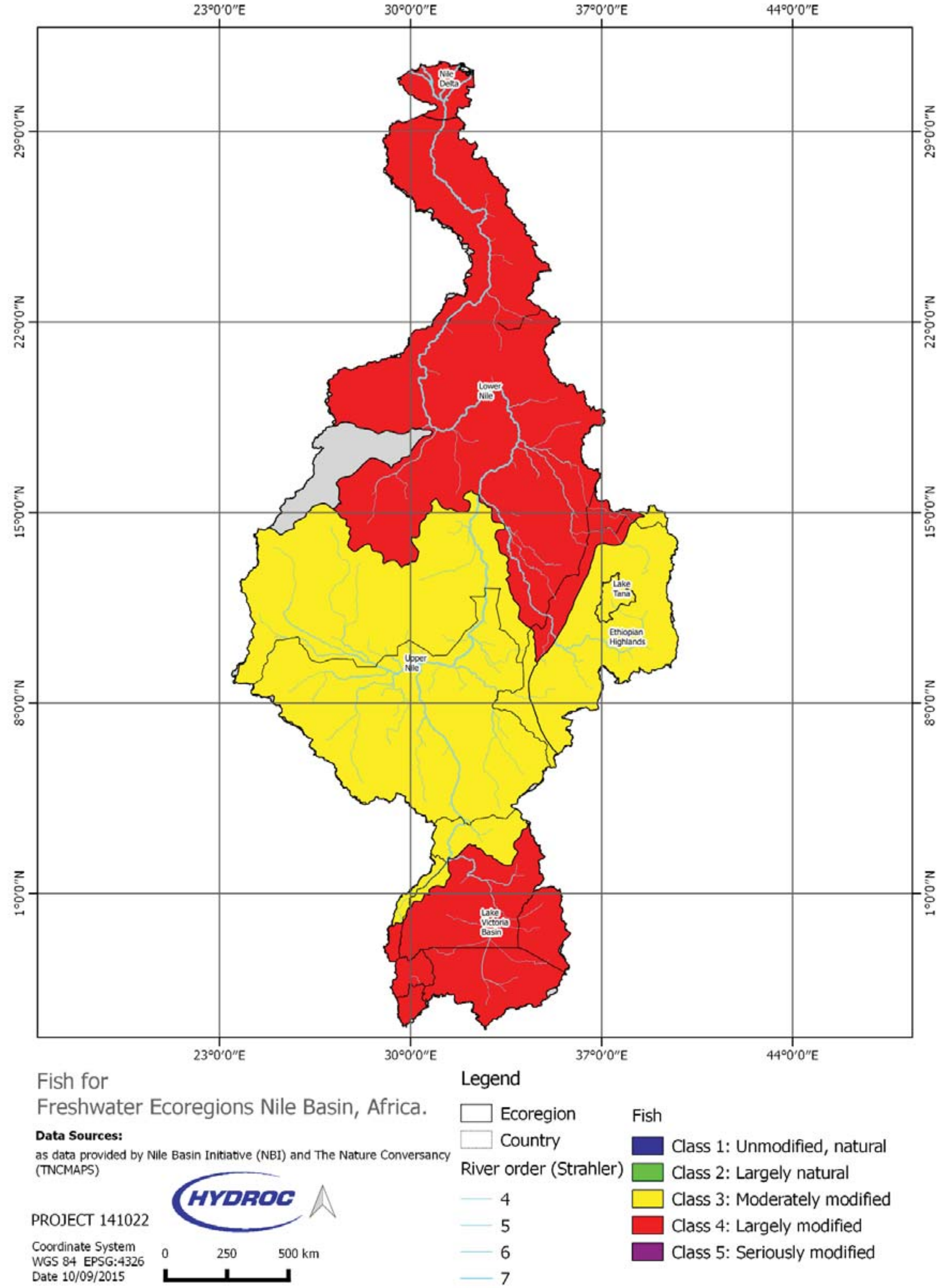

Figure 28: Wellbeing of fish for the freshwater ecoregions of the Nile Basin.

The fisheries in the Lake Victoria considered to be overexploited and largely modified whereas the fisheries within the remaining ecoregions are all moderately modified (Figure 29).

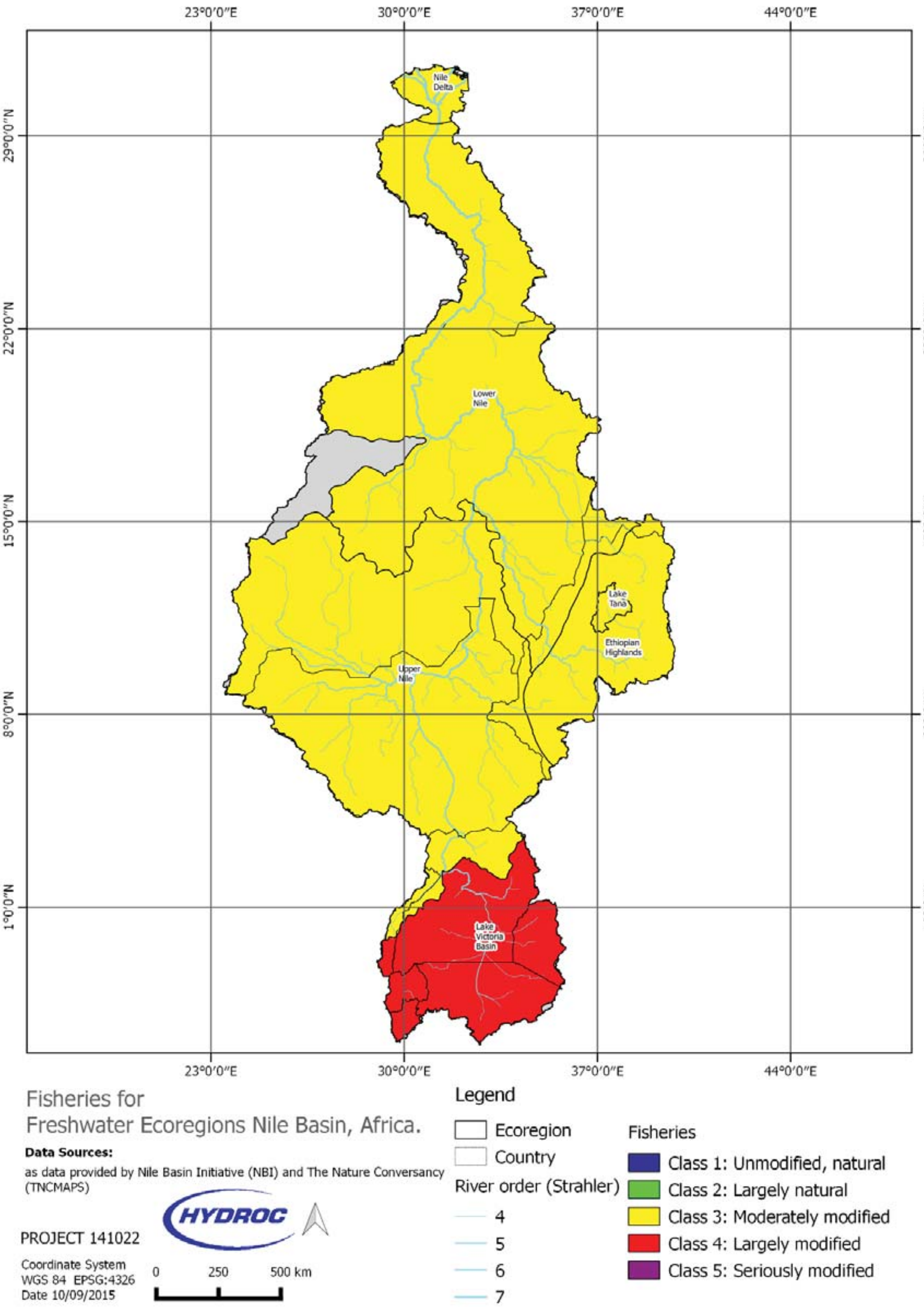

Figure 29: Wellbeing of fisheries for the freshwater ecoregions of the Nile Basin.

There are various species from other ecosystem components that have become extinct or are considered to be threatened or endangered and is why the Lake Victoria and Upper Nile ecoregions as well as the Nile Delta have been classified as largely modified (Figure 30).

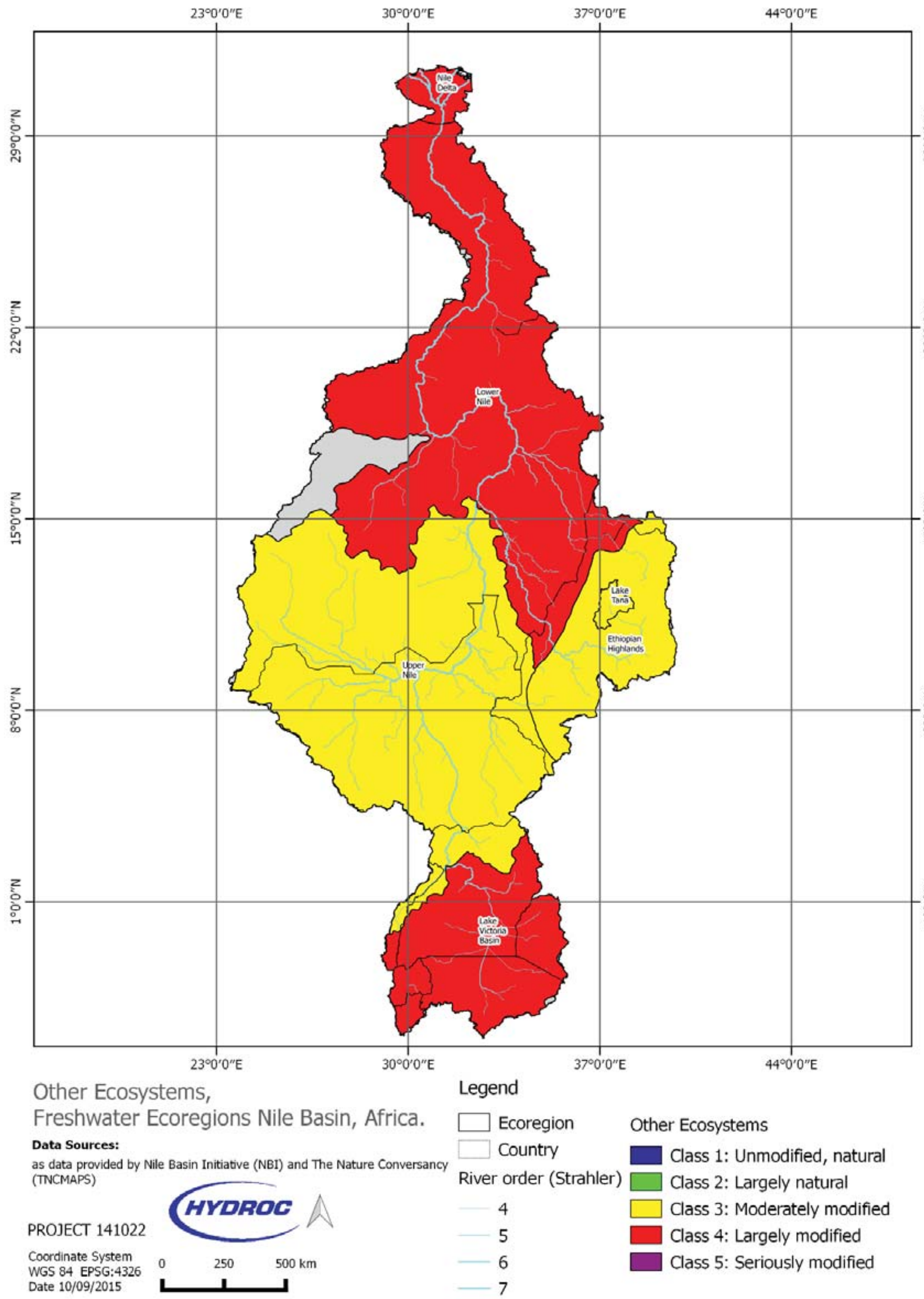

Figure 30: Wellbeing of other ecosystem components for the freshwater ecoregions of the Nile Basin.

The changes to the wellbeing of the various ecosystem has led to changes in the services that they can provide. Figure 31 indicates the ecosystem services of the Lake Victoria, Upper Nile and Nile Delta ecoregions are all largely modified. The ecosystem services of Lake Tana, the Ethiopian Highlands and the Upper Nile ecoregions are considered to be moderately modified.

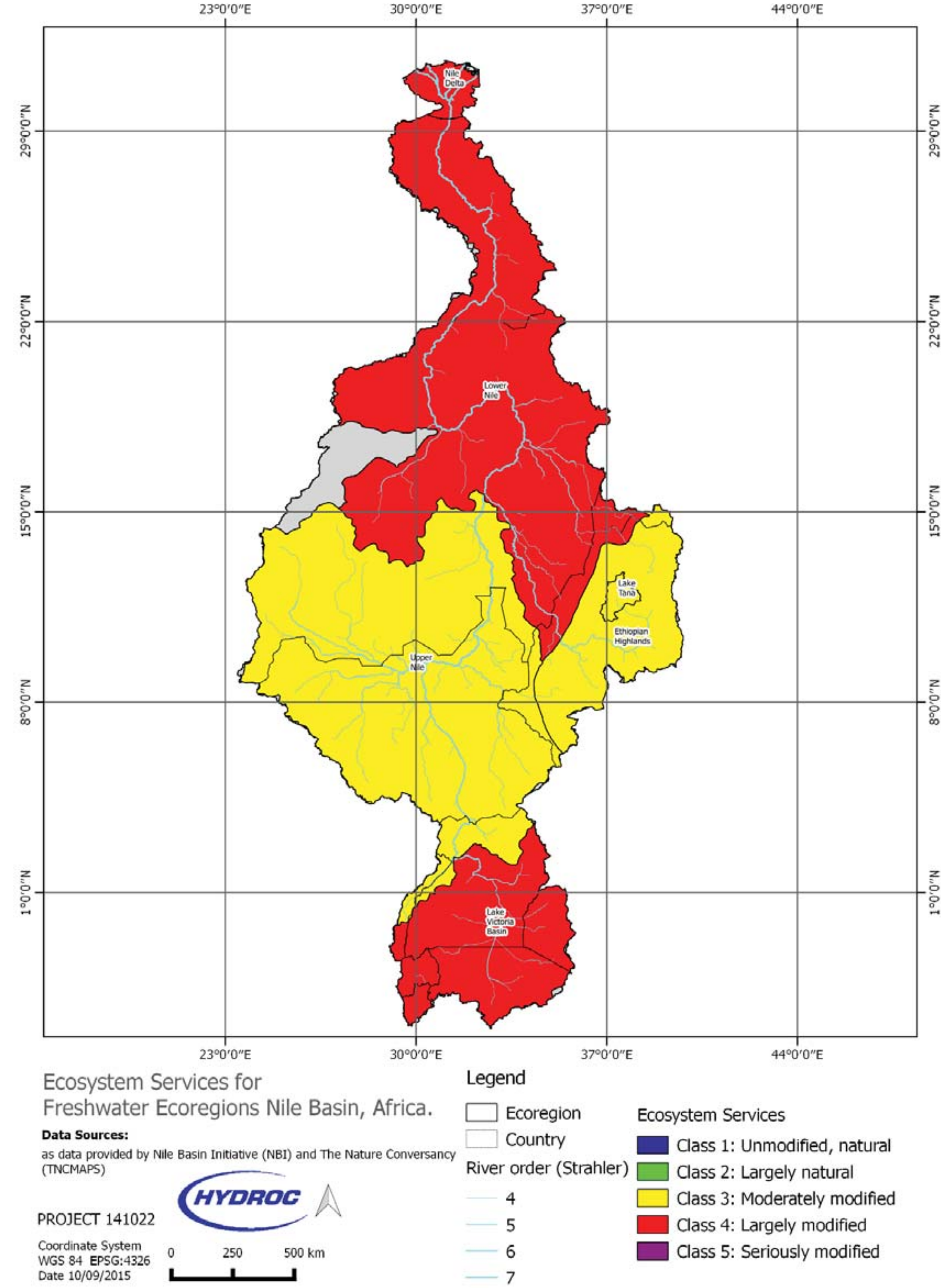

Figure 31: Wellbeing of ecosystem services for the freshwater ecoregions of the Nile Basin.

4 Environmental flows and aquatic ecosystems

Aquatic ecosystems of the Nile are interconnected with the dominant features that maintain their existence being water movement which facilitates biophysical processes occurring with these ecosystems (Renofalt *et al* 2010). The linkages invariably results into surface-subsurface, lake–stream, river–floodplain, and estuaries i.e.. marine–freshwater interactions, such as in the Nile Delta region. The amount and timing of flow into these systems regulates the ecological processes that include the primary production, nutrient cycling, organic matter processing, and secondary production involving exchanges of materials from aquatic ecosystems to terrestrial systems.

Aquatic ecologists have long been recognised in the importance of the movement of materials through ecosystems which play a major role in shaping the physical linkages of ecosystems, and in some ways, serve as a framework on which other relationships depend. Flow alterations also affect natural dispersion processes which affect riverine organisms and sediment dynamics that may alter nutrients and biodiversity composition and abundance (Renofalt *et al* 2010). Movement of energy and nutrients such as in the migrations of fishes, are influenced by flow (Lamberti *et al* 2010). The fish populations are affected both in species and size.

Water flow also provides the main mechanism for inter-ecosystem movement of inorganic nutrients and other dissolved ions with their biological linkages. A classic example explained in previous chapters indicate effects of the hydrological blockages like the Aswan dam on altering inorganic movement and sedimentation and how this resulted into adverse ecological changes in the light of the environmental conservation and socio-economic development in the Nile Delta region. In this case, the channelization (prevented flooding which used to occur annually), resulted into altering of species composition of vegetation and fish populations of the delta region consequently leading to increased reclamation which led to reduction in lagoon area (Gu *et al*, 2011).

Flow volume determines ecosystems variations, taking into account the shape of the basin, and the time water stays in the system before it proceeds to another system. Hence organisms have developed traits to live respond to this variation with phenomena which occur seasonally. Movements and migrations in fish, and aquatic animals (Lamberti *et al* 2010), is an amazing phenomenon dependent on the quality and quantity of water and nature of flow. This is instinctively known in fish and other migrating animals. Some fishes of River Nile could be potandromuos (fish with migrations that are usually shorter, typically from lake to stream or vice versa) e.g.. *Clarias gariepinus* is known to migrates within streams and rivers (Teugels, 1986). Other migratory fish include cyprinids and bayads which migrate on regional and basin scales. There are other phenomena of migrations that include aphidromous, anadroumous, catadromous and diadromous which also occur and are triggered by alterations in flow

Aquatic plants are known to vary greatly in their anatomy, physiology, life-history traits, and ability to tolerate inorganic and biological stressors (Paresh & Bill, 2006). The inorganic stressors are associated with altering flow velocity which in turn affect, salinity, temperature, nutrients, and pollutants. Organic stressors are associated with competition, herbivory, and disease which may also limit the ability of species to utilize otherwise suitable habitats. Change in flow can therefore result in stresses that are detected because many species have low tolerances in their

adaptive conditions and are hence potentially indicators of environmental conditions for example, seasonal variation in Lake Phytoplankton (Sacramento, 2006) is associated with seasonal variations in water quality which is influence by processes like stratification whose cycles of stability depends on flow.
Lakes large or small depend on water that flows in them, to sustain the dynamics of their physical environments and biotic interactions, which in turn support livelihoods which depend on them. It is important to note that flow affect seasonality in lakes, although they are permanently inundated. This too influence the dynamics of biodiversity patterns of ecosystems notably fish and vegetation. And as mentioned above some fishes can only breed during certain seasons (Lamberti *et al* 2010), which are influenced by flow. Other terrestrial animals and bird exhibit long term seasonal migrations which depend on these flow.

Naturally occurring floods are important in maintaining the health of some ecosystems like wetlands. Floodplains diffusedly receive their water from filling river banks, for example when the banks of River Sobat fills with water during the rainy season, the Machar marches are flooded. These ecosystems have for ages continued to survive on this kind of flow, which has been reported as “spillage” but is the main way the Marsha marshes receive water. Any proposed developments upstream should take care of the natural function that enables the marshal marshes to receive water (Norplan *et al*. 2006) and consequently this will affect the socio-economic styles of the people who depend on the wetland (ENTRO 2007b).

The hydrological roles of inland aquatic ecosystems in storing and regulating flow is the main reason why rivers have continuous flow and is the existence of sustained ground water recharge which flow in springs. The seasonality, intermittence or permanency inundations are regulated by flows and consequently maintain ecosystem diversity with rich biodiversity unique to each portion the aquatic ecosystem. The complex hydrological conditions that characterise aquatic ecosystems need to be understood in the context of ecosystem linkages and functioning of their rich biodiversity. Their distinctive flora and fauna are likely to first be impacted by changes in the flow regimes. This hydrological nature of the system naturally shaped the ways and patterns in which communities have developed together with their livelihood supports. The changes in the flow must be sensitive to such socio-economic impact on livelihoods for example farming, fishing and pastoralism.

The wellbeing of the aquatic ecosystems of the Nile is mainly affected by their provision for social economic benefits which are the main providers of livelihood support. The economic benefit of aquatic ecosystems is dependent on flow of water which provide either indirectly habitats or directly products which support livelihood. In the process of deriving livelihood support, the wellbeing of ecosystems are affected. Environmental flows is as determinants of ecosystem health and wellbeing is important in case there are other competing uses, which should not compromise the community structure and biotic components are directly or indirectly depended on them.

Indirect livelihood support
Water storage: All aquatic ecosystems store water and distribute it in space and time which maintains its interconnectivity. This very important function is important for availability of water in ecosystems in time and space, hence the perennial flow in rivers and availability of water in

wetlands, lakes and ground water. There are many benefits derived from aquatic ecosystems function of storage of water.

i) Aquatic ecosystems as habitats – Aquatic ecosystems exhibit various habitats with a high degree of adaptations. There are rivers, lake, wetlands and their biodiversity e.g.. fish, birds, reptiles and mammals. The function of the habitat depends on the flow which enables such habitats to maintain their integrity.
ii) The Lakes, Rivers and Wetlands have internal geographical or geological isolation barriers which continuously make them gene pools that distinguish biodiversity associated to each aquatic habitat as indicators of environmental health. The flow and distribution of water ensures that such roles and specialization in each ecosystem is maintained.
iii) The various aquatic ecosystems are very important in the maintenance of ecosystem integrity. Energy flow cycles are important in maintaining ecosystems hence. Altering flow from one aquatic ecosystem can therefore impact on another
iv) The longitudinal hydro-connectivity of the river is dependent on flow. It is surprising that the Nile can consistently flow from its sources to the Delta region. Cases of seasonality and intermittent flow depended on seasonality. The interconnectedness ensure survival based on seasonal variation of water.
v) Many self-natural recovery processes depend on ecosystems stability, e.g. rivers self-regulatory processes, population regulatory processes, carbon storage and sinks, water storage, etc. The spectacular wildebeest migration in Serengeti in the river Mara system and the White eared kobs in Boma national park in South sudan are some of the natural spectacular processes that depend on ecosystem stability.

Direct benefits.

These are visibly acknowledged products extracted from ecosystem whose benefits depend on the human needs. Such direct benefits have led to misunderstanding of economic roles of the aquatic ecosystems in favour of their ecological indirect benefits usually leading to their conversion (especially wetlands) and over exploitation. Such benefits which need to be regulated include the following:

i) Generation of Energy through hydropower production. Hydro electricity is the main source of energy which drives economic growth in the basin and depends on flow of water.
ii) Food - Fish as source of proteins. Inland fish is still the cheapest source of protein for human and animal feeds industry in the Nile Basin region. Food is also source of income and is exported (the Nile Perch fishery in the Lake Victoria supports the East African economies). Many lakes support artisanal fisheries, hence many people are employed in this industry. In addition, animals and plants in the aquatic ecosystems of river Nile are hunted for food i.e.. Crocodiles, antelopes, snakes, tortoises, and are hence dependable as source of animal protein by local communities.
iii) Many aquatic plants and animals are medicinal both traditional and modern. Only sections of a few flora and fauna have been document to perform this role. Many people depend on local medicine for local cure of diseases.
iv) The aquatic ecosystems are tourist attractions, i.e.. The Murchison falls, Karuma falls, beaches, etc. Sports like rafting is popular on the Victoria Nile while Sport fishing for

Hydrocynus species i.e.. in the lower Murchison falls is popular. The animals associated with the Nile attract tourists.

v) Materials for Building and Construction e.g. water, sand, clay for bricks. Many livelihood depend on harvesting materials from aquatic ecosystems and are a source of income. The availability of extractable solids (sand or clay formation processes are driven by flow) is important to sustain livelihoods who depend on them.

vi) Large basin lakes are used in a transboundary manner. As means of transport connecting to more than two states but indirectly as store for water which flow into rivers. The water from Lake Victoria for example benefits the flow of White Nile.

Water for various benefits i.e. domestic purposes, urbanisation, industries, agriculture and recreation. Need education about the different benefits of water so that communities do not take it for granted.

4.1.1 Threat of Environmental Flow to Aquatic ecosystems

The biggest threat of Environment Flow to aquatic ecosystems is lack of education and awareness about the values of aquatic ecosystems and the appreciation that their inhabitants depend on the amount of water that enter or leave them. This knowledge gap is coupled with inadequate data on many aspects that would enable proper articulation of variables that are dependent on flow such as the zonation of ecosystems and their biodiversity that include seasonality of ecosystems and their functioning. The knowledge gap also contributes to development of weak policies and institutions frameworks and basin wide coordination mechanisms for the management of ecosystems. Environmental flow need regular data collections and monitoring to maintain the socio-economic benefits of people often requiring them to adapt to new lifestyles which result from effects of EF.

However, more serious threats as a result of flow alterations can be manifested in ecosystem changes. For example, presence of irrigation at locations where water did not exist or creation of dry conditions where water existed. The consequences of such conversions are not sustainable and usually result into ecosystems' disequilibrium that affect socio-economic wellbeing of people e.g. diseases, emergencies of new colonies, and changing lifestyles together with reduction of resilience by individuals of the altered ecosystems. Monitoring is important to document the ecological successions at locations where flow has been altered to avoid disastrous outcomes by such inventions, since people are unaware of the consequences that result from ecosystem change, that can be costly and difficult to reverse. Some of these changes include:

- Socio-economic change resulting from utilisation of the emerging ecosystems, usually people taken unaware. This is manifested in
    - Increased pressure due to pasture grazing and looking for fodder
    - Encroachment by settlements
    - Draining and dike construction
    - Conversion of ecosystems e.g. wetlands to agricultural area
    - Poaching – animals will be vulnerable
    - Pollution – Affluent discharge from cities and agriculture will affect the natural removers of pollution and this is the main cause of environmental diseases
    - Reduced resilience lead to colonisation and emergency or introduction of invasive species

  - Changing life styles and adapting to use of new areas
- Change in flow can result in reversal of the signals that trigger animal migrations for example. Many fresh water fish migrate for various reasons that include spawning, e.g. Cyprinids, Clarids (Cat fishes). Migrations are also manifested in birds which move from Europe along the Nile River to South Africa. Other animals such as the white eared kob in Boma national park and the Wilderbeasts in Serengeti national parks also respond to national migrations phenomena triggered by flow. Environmental flows therefore threaten the patterns of migrations which is the at the survival mechanism for these animals.
- Likewise, the vegetation patterns at different locations of the Nile depend on flow. *Papyrus* spp and many other sedges are known to respond to flow. *Papyrus* will only survive in permanently inundated areas, while *Phragmites* and *Miscanthidium* spp occupy seasonally inundated areas. The vegetation pattern of the riparian communities of the Nile Basin is therefore threatened. But this as primary producers are responsible for the survival of other ecosystems including being the major source of organic matter into the system that is dependable by various trophic levels.
- Connectivity and governance of the sub basins require transboundary mechanism whose institutional arrangements regulates use of water. Environment flow must ensure connectivity of ecosystems but the governance must be in place to ensure ecosystems survive. The transboundary management practices and standards for water and ecosystem biodiversity are crucial to governance of ecosystem health. There is need for coordination mechanisms that will regulate the collection of data, monitor ecosystem uses and practices and share data for proper flow regulations.

- Ecosystem conversion results into encroachment and human settlements in biodiversity hotspots especially wetlands, causing wildlife – human conflicts. Conversion also change flow into rivers for example drainage of wetlands for agriculture purposes cause water to leave their system faster and removes the natural regulation of flow. Flow if not well handled can lead to ecosystem conversion.

- The Nile basin organisation is threatened by absence of accredited mechanism to produce capture ecosystem data to enable better understanding of ecosystems and their linkages to flow. Presence of such mechanism would benefit the promotion and visibility of ecosystem services and benefits and make them recognized and incorporated in national development programmes. There is need for a well-coordinated mechanism to capture and store data.

- Change in water quality and quantity. Water naturally changes if its flow is reduced or increase. Ecosystems are sensitive to changes in water quality. Most river sub-basins of the Nile have not been studied in detailed to reveal such ecological characteristic. It is important to identify indicators based on the characteristics of the sub-basin in order to recognise the major variables that regulate the ecosystems and account for surviving biota (Bayley, 1995). When flows are altered, natural functions can disappear because modifications tend to prevent regular flooding, as already experienced in the Nile Delta. If a river is regulated, the flood extent and nutrient load will change but the nature of change and magnitude and time periods remain unforeseeable (Christer & Kajsa 2009).

The change in water quality therefore affects the quality of ecosystems and their inhabitants.

4.1.2 Ecological indicators of flow alterations

The following have been identified as indicators of flow alterations

- **Changes in ecosystems and their inhabitants:** Flow alterations cause changes in vegetation, and faunal biodiversity. The nature and type of biodiversity sensitivity has to be identified right from river upstream, moderation (Warfe *et al* 2014), and where impact, due to anthropogenic (Malmqvist & Rundle 2002) activities. The selection of the species that respond to flow require a consistent set of data and documentation and should be updated regularly. The following are some of the indicator species
  - Diapausing insects
  - Breeding behaviours in frogs and reptiles
  - **Migratory fishes**
  - **Aestivating fishes**
  - **Water fowls**
  - Vegetation species associated with different aquatic ecosystems **i.e. Inundated, seasonally flooded vegetation**
  - Bio indicators e.g. benthos, frogs, fish, pollen etc.
  - Phytoplankton

  Biomonitoring is one of the most effective indicators that monitor environmental flows in aquatic ecosystems (Kleynhans and Louw, 2007), through use of responses of plants and animals found in aquatic habitats as they respond to flow changes. Organisms respond to various environmental conditions, not only to pollutants but to changes in physical habitat conditions, which are sometimes difficult to assess with traditional chemical and toxicity monitoring tools (Rosenberg & Resh, 1993).

- **Water quality and quantity:** Changes in water quantity and quality can be sources of environmental stressors. Flow can lead to modification of nutrients which can be monitored for their effects as a result of alterations (Marshall, 2003). As water flows, the nutrients in it change, so basin wide monitoring can be good indicator of flow alterations. Basin wide parameters can be agreed on e.g. conductivity, Total Phosphates, Total Nitrates. Likewise, the amount of water that flows from streams need to be monitored even for small perennial streams. Some aquatic ecosystems will be permanently inundated but exhibit seasonality in the volumes or quantities of water that flow through them.
- **Seasonality and simulations of flow:** The resident time of water in the system has to be monitored (Blann *et al* 2009) as it reportedly transforms the nutrient and hydrologic dynamics, of aquatic ecosystems. The connectivity of flow from streams to rivers and lakes has to be monitored. Ecosystems are very sensitive to flow alterations causing changes in the longitudinal connectivity of the rivers (Christer & Kajsa, 2000). Rivers with natural flow regimes support a distinctive ecology (Warfe *et al* 2014), whose characteristic is adapted to flow regimes caused by seasonal variations. Therefore it is important to ensure that water flows in ecosystems following a natural pattern that

would prevent ecological disequilibrium, but simulates the natural processes as much as possible. His should be as realistic as possible because is not easy to restore damaged aquatic ecosystems (Cains, 2006). Alterations reportedly cause and invasive species which disrupt ecological processes (Christer & Kajsa 2009). Since water availability and use depends on flow (Piniewski *et al* 2014), and hence indicators for perennial, or intermittent flow and flooding are essential to monitor ecosystem health.

- **Studies on ecosystem effects of environmental flows:** modelling and experimental floods in a dryland river in Arizona (Shafroth et al 2010) indicate the importance of response flow thresholds, which are commonly driven by geomorphic thresholds or mediated by geomorphic processes, and the importance of spatial and temporal variation in the effects of flows on ecosystems, which can result from factors such as longitudinal complexity and ecohydrological feedbacks. Manipulation of flow standards should depend on the geomorphological nature of the basin and velocity of the water in the system. The ecosystem effects in the Eastern Nile will presumably be different from the Nile Equatorial lakes.

- **Sediment transport:** Water sediment moves with flow which is also an important factor to monitor sediment because flows either increase, in case of irrigation or decrease in case of dams
- **Habitat change:** Shrinking of wetlands, and forests. The effect of terrestrial ecosystems which can be affected by flow regulations need to be monitored
- **Diseases:** monitor diseases whose infestation may increase or decrease due to alteration of their habitats, there many be colonization of new comers. For example, in Kabale, Uganda, the reclamation of wetlands created environments which were occupied by anopheles mosquitoes which used not to habit that part of the country. The people in Kabale used not to get Malaria as it is today.

  Diseases have to be monitored in wild populations as well. Alterations in ecosystems have can cause diseases to wild organisms e.g. a multi-host parasite (*Ribeiroiaondatrae*) that cause severe limb malformations among frog and salamander hosts, is caused when populations of the parasitic trematode, *Ribeiroiaondatrae* are altered through nutrient enrichment and eutrophication, which increase snail populations and parasite output from infected snails, and from landscape-scale factors such as wetland loss that concentrates the three required hosts to the same water body (Lunde, 2005). Phytoplankton and microbial studies are indicators of pollution in the Nile waters (Ali *et al* 2000). Wildlife diseases can be used to monotor aquatic species. For example, chytrid fungus (*Batrachochytrium dendrobatidis*) has caused extinctions and declines in amphibians species around the world, including in the Sierra Nevada mountain range of California. Some wild populations get naturally diseased due to disturbance of their environment.

- **Social economic change:** It is important to monitor the socio-economic growth and dependence of the people in the riparian states using socio-economic tools like Knowledge Attitude and Practicesor Participatory appraisals

A data base for ecological indicators for the Nile Basin will be useful to monitor stressors caused by flow alterations. Future ecological studies should consider environmental flow aspects that will enable upgrading of existing data bases into a tool that can be used for decision making purposes.

5 Conclusion

This background document describes the approach adopted and the identification of aquatic ecosystem types and the degradation threats to these ecosystems in the Nile Basin as a part of the stocktaking and procedure development phase of the study. This review includes considerations for:

- The classification of aquatic ecosystem types in the Nile Basin: The outcomes of this assessment show that the Nile Basin contains a high diversity of aquatic ecosystem types from flowing and non-flowing ecosystems that affected by geomorphological differences across the basin as well as seasonality, biodiversity, water quality and human activities. These drivers of change affect the types of ecosystems. Knowledge of these features allow for effective management.
- Aquatic ecosystem types in the Nile Basin: In this section a simple classification system was established based on regional classification principles to allow for the types of ecosystems to be identified, classified and managed appropriately. Although the Nile Basin is dominated by the riverine processes of the Nile River itself, other socio-ecologically important ecosystems are common and in many instances have greater social and or ecological values compared with the Nile River. Some of these ecosystems include the great lakes of the upper Nile catchments in Lake Victoria and Ethiopian eco regions. Within these ecosystems some of the globes greatest diversity of aquatic fauna has established. Other important ecosystems include the Sudd wetland system and the extensive floodplain ecosystems associated with the Nile River. The Nile delta is another ecologically important ecosystem which may have be the most altered single ecosystem type in the Nile Basin. Other important ecosystems considered include the socially-ecologically important springs which provide people, livestock and wild animals with water which governs their lives.
- Aquatic ecosystem wellbeing in the Nile Basin: In this section a desktop evaluation of the availability of major ecosystems, their importance and wellbeing was assessed. Results show that the water resources in the Nile River have generally been altered considerably with only a few areas pristine conditions considered to still occur. In the upper reaches of the basin; agriculture, urban and peri-urban settlements pose the greatest threat to ecosystem wellbeing, with many other impacts such as alien invasive species and over-exploitation also affecting ecosystems considerably. These activities result in alterations to the volume, timing and duration of flows, water quality changes, habitat changes and direct and indirect predation and or competition with local biodiversity. This in turn affects the ecological process that the people who live in the basin depend on. In the Middle reaches of the basin the Sudd wetland is a prominent feature which is only moderately modified but largely unknown. In the Blue Nile high demand for water is affecting the wellbeing of ecosystems in the region. In the lower reaches of the Nile Basin the Dam developments have affected the Nile River considerably and has resulted in a reduction in the availability of ecosystem services associated with the Nile River in Egypt. These flow alterations have also significantly altered the structure and function of the Nile Delta which itself is poorly known. It is very important to remark that all the ecosystems of the Nile Basin are Vital, Valuable and critical in providing goods and services to the well being of communities who survive on them. Ecosystems which are largely modified and might dispensable, can be recovered through restoration while vital, critical and valuable ecosystems should be managed and closely monitored.

- Environmental flows and aquatic ecosystems: In this section known threats associated with altered timing, volumes and flow durations have been evaluated. These include habitat alterations, connectivity issues and the fragmentation of species and disruption of ecosystem processes. Other threats include impairment of ecological processes that have provided people and species with goods and services they have depended on for generations. Flow timing impacts have been identified to affect the ecological cues of ecosystems and the associated seasonality of processes including sediment transport, retention and deposition processes. These flow related impacts have directly and or in-directly affected the wellbeing of aquatic ecosystems in the Nile Basin significantly. The ecological indicators of the wellbeing of altered flows in the study are include; changes in ecosystems and their inhabitants, water quality and quantity variable changes, seasonality and simulations of flow, biodiversity of plants, animals, sediment transport, habitat change, the existence and prevalence of water borne diseases, awareness and social economic changes.

To effectively manage the environmental flows (volume, timing and duration of flows) in the Nile Basin, the socio-ecological consequences of altered flows and future flow related decisions needs to be evaluated. This evaluation should be holistic, consider multiple social and ecological endpoints and trade-offs between them. The approach must take ecosystem structure and function dynamics into consideration and be flexible which required transparency and adaptability. The approach should also be probabilistic and allow for the evaluation of future flow scenarios in multiple spatial scales with different levels of uncertainty (or confidence) and be updatable so that when new information becomes available the risk projections can be improved. With this information a suitable balance between the use and protection of the water resources in the Nile Basin is urgently needed. One that has international buy in for the benefit of all users in a sustainable manner.

6 Way forward

The scope of this brief has been to evaluate the ecosystem classification methods that have been used in the region, propose a suitable classification system for the aquatic ecosystems in the Nile Basin, identify and classify the aquatic ecosystems in the basin and identify and evaluate the threats to ecosystem wellbeing on desktop level of confidence. The outcomes of this Background Document will be used with the outcomes of Background Document 1 (*Environmental Flow Assessment: A review of global practices and experiences*), and in the context of the outcomes of Background Document 3 proposed to be titled: *Management of environmental flows in the Nile River Basin: practices and experiences*.

This information will allow stakeholders of the Nile Basin Initiative (NBI) to evaluate best flow management principles, in the context of the ecosystems in the Nile basin and their wellbeing and the local legislative context of the study area so that a suitable framework for environmental flow assessments in the Nile Basin can be developed.

This study will proceed to the regional stakeholder review/validation workshop. At this workshop recommended procedures for establishing environmental flow requirements for Nile Basin aquatic ecosystems will be discussed and reported on to propose a best practice environmental flow framework for the Nile Basin. The framework and selected environmental flow assessment methods will then be tested on different spatial scales in the Nile Basin and the outcomes of the assessment will be synthesised to provide recommendations for future management.

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Freshwater Ecoregions of the World (FEOW). (2013). 522 Upper Nile. [ONLINE] Available at: http://feow.org/ecoregions/details/upper_nile. [Accessed 03 September 15] Authors: Emily Peck and Michele Thieme. Reviewers: Fiesta Warinwa and M. S. Farid

Freshwater Ecoregions of the World (FEOW). (2013). 523: Lower Nile. [ONLINE] Available at: http://feow.org/ecoregions/details/lower_nile. [Accessed 03 September 15] Authors: Emily Peck. Reviewers: Robert Collins and M. S. Farid.

Freshwater Ecoregions of the World (FEOW). (2013). 524: Nile Delta. [ONLINE] Available at: http://feow.org/ecoregions/details/nile_delta. [Accessed 03 September 15] Authors: Emily Peck and Michele Thieme. Reviewers: M. S. Farid and S. Baha El Din.

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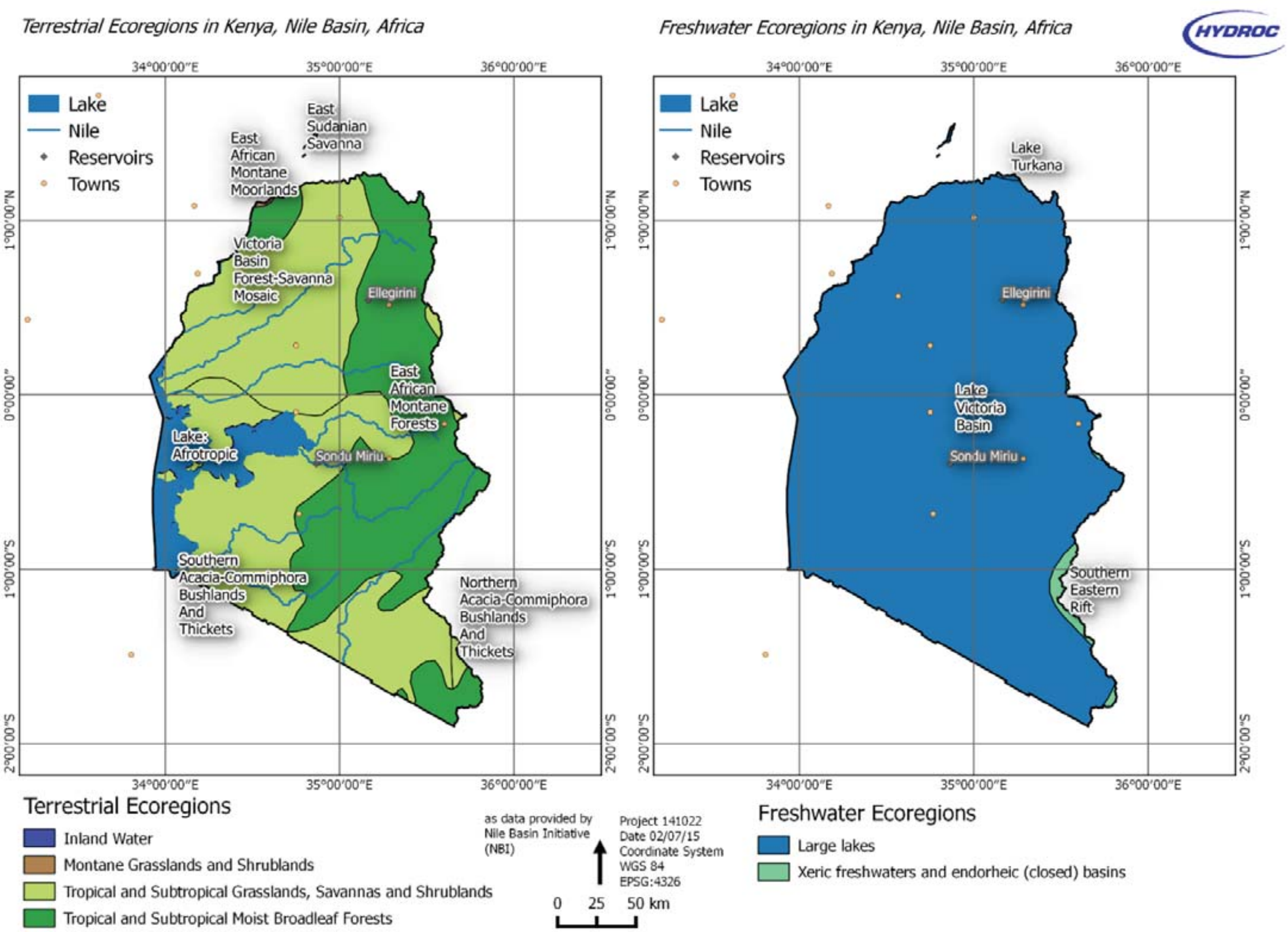
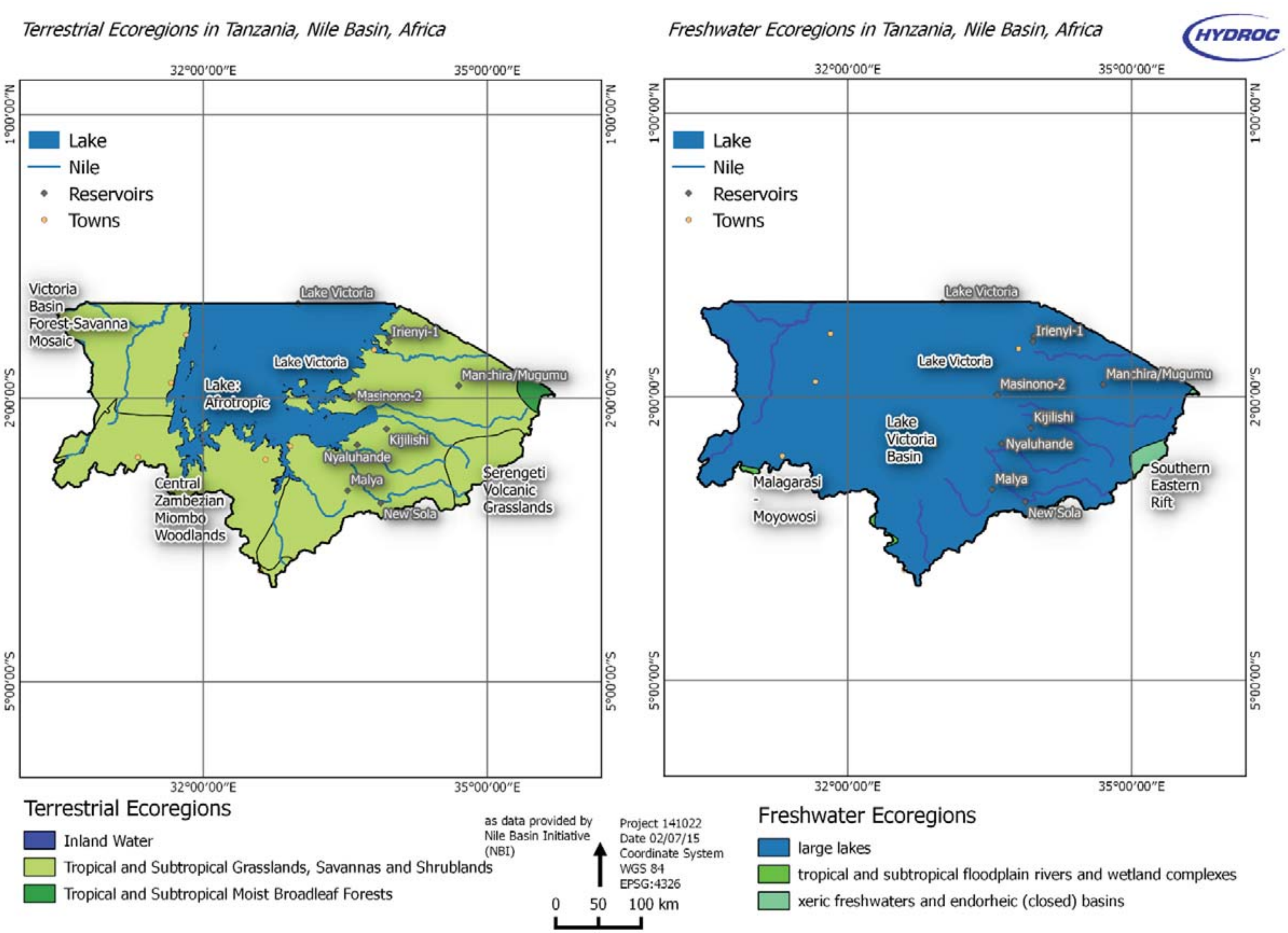
Annex 1: Terrestrial and freshwater ecoregions per Nile Basin country

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Freshwater Ecoregions in Tanzania, Nile Basin, Africa
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Lake
Nile
Reservoirs
Towns
Victoria Basin Forest-Savanna Mosaic
Lake Victoria
Irienyi-1
Manchira/Mugumu
Masinono-2
Lake: Afrotropic
Kijilishi
Nyaluhande
Malya
New Sola
Central Zambezian Miombo Woodlands
Serengeti Volcanic Grasslands
Lake Victoria Basin
Malagarasi - Moyowosi
Southern Eastern Rift
Terrestrial Ecoregions
Inland Water
Tropical and Subtropical Grasslands, Savannas and Shrublands
Tropical and Subtropical Moist Broadleaf Forests
as data provided by Nile Basin Initiative (NBI)
Project 141022
Date 02/07/15
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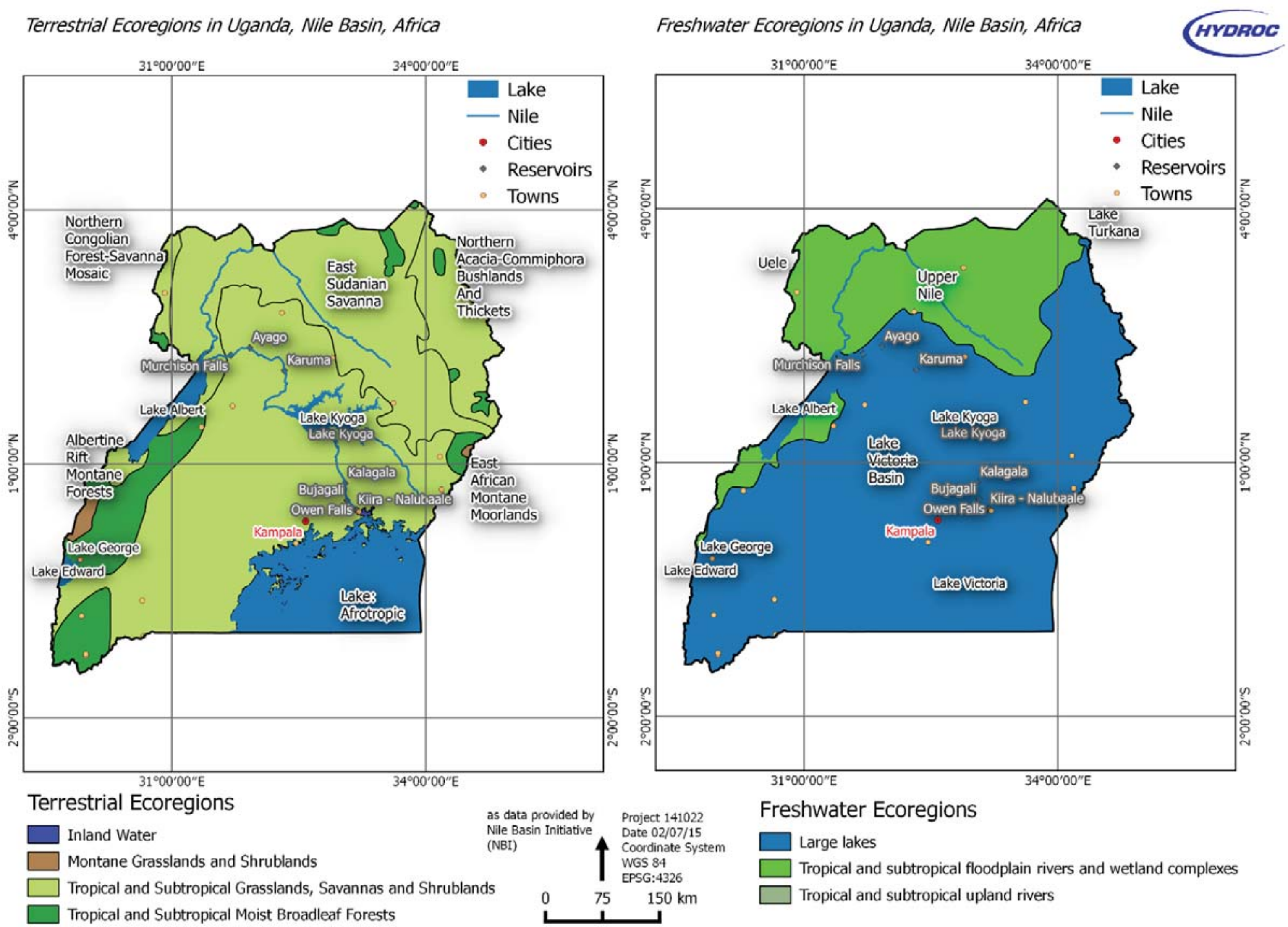
Freshwater Ecoregions
large lakes
tropical and subtropical floodplain rivers and wetland complexes
xeric freshwaters and endorheic (closed) basins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Freshwater Ecoregions in Uganda, Nile Basin, Africa
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Lake
Nile
Cities
Reservoirs
Towns
Northern Congolian Forest-Savanna Mosaic
East Sudanian Savanna
Northern Acacia-Commiphora Bushlands And Thickets
Albertine Rift Montane Forests
East African Montane Moorlands
Lake: Afrotropic
Ayago
Karuma
Murchison Falls
Lake Albert
Lake Kyoga
Kalagala
Bujagali
Owen Falls
Kiira - Nalubaale
Kampala
Lake George
Lake Edward
Uele
Upper Nile
Lake Turkana
Lake Victoria Basin
Lake Victoria
Terrestrial Ecoregions
Inland Water
Montane Grasslands and Shrublands
Tropical and Subtropical Grasslands, Savannas and Shrublands
Tropical and Subtropical Moist Broadleaf Forests
as data provided by Nile Basin Initiative (NBI)
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Freshwater Ecoregions
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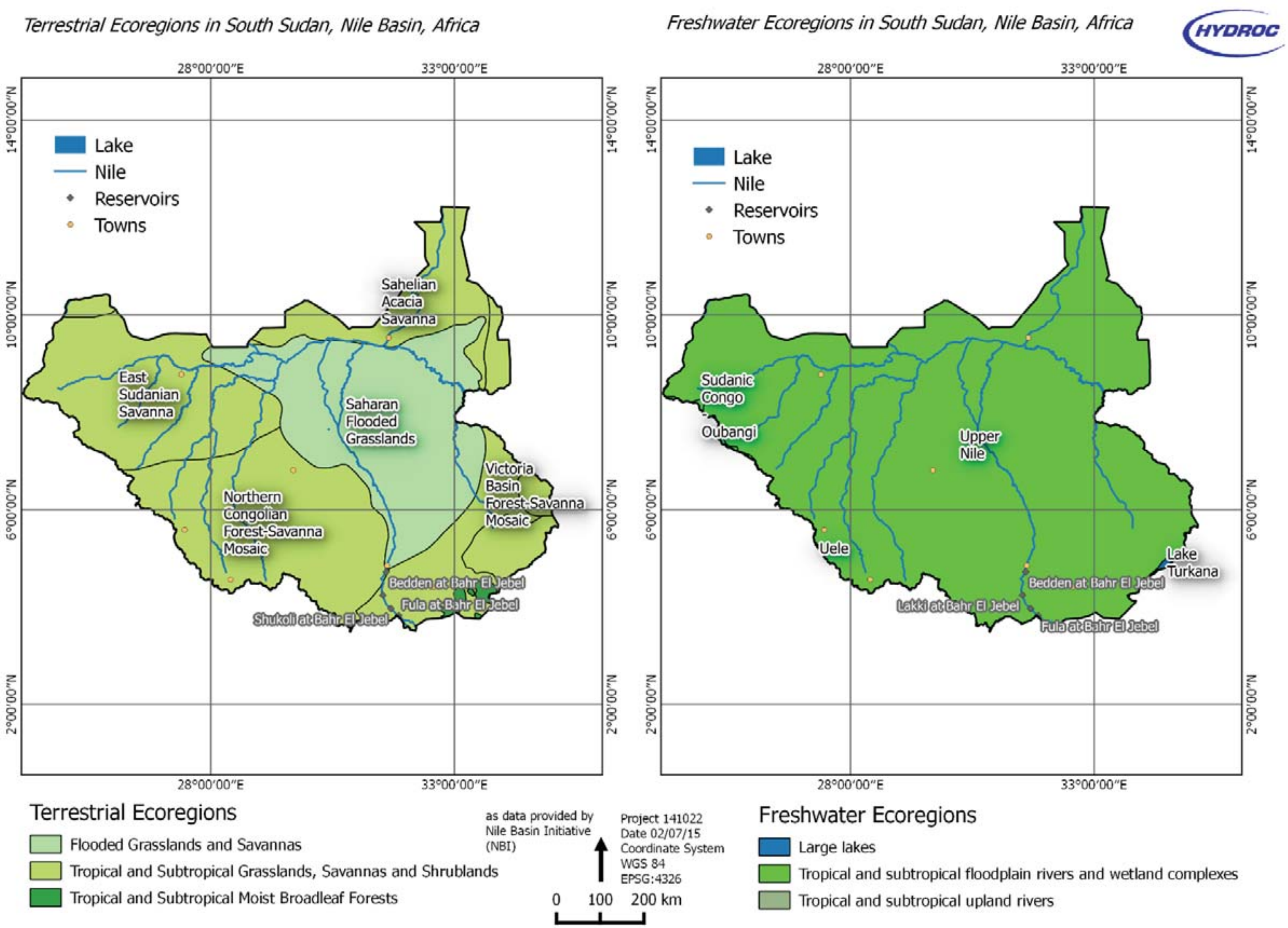
Tropical and subtropical floodplain rivers and wetland complexes
Tropical and subtropical upland rivers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Nile
Reservoirs
Towns
Sahelian Acacia Savanna
East Sudanian Savanna
Saharan Flooded Grasslands
Northern Congolian Forest-Savanna Mosaic
Victoria Basin Forest-Savanna Mosaic
Bedden at Bahr El Jebel
Fula at Bahr El Jebel
Shukoli at Bahr El Jebel
Terrestrial Ecoregions
Flooded Grasslands and Savannas
Tropical and Subtropical Grasslands, Savannas and Shrublands
Tropical and Subtropical Moist Broadleaf Forests
as data provided by Nile Basin Initiative (NBI)
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Date 02/07/15
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Freshwater Ecoregions in South Sudan, Nile Basin, Africa
HYDROC
Sudanic Congo
Oubangi
Upper Nile
Uele
Lake Turkana
Bedden at Bahr El Jebel
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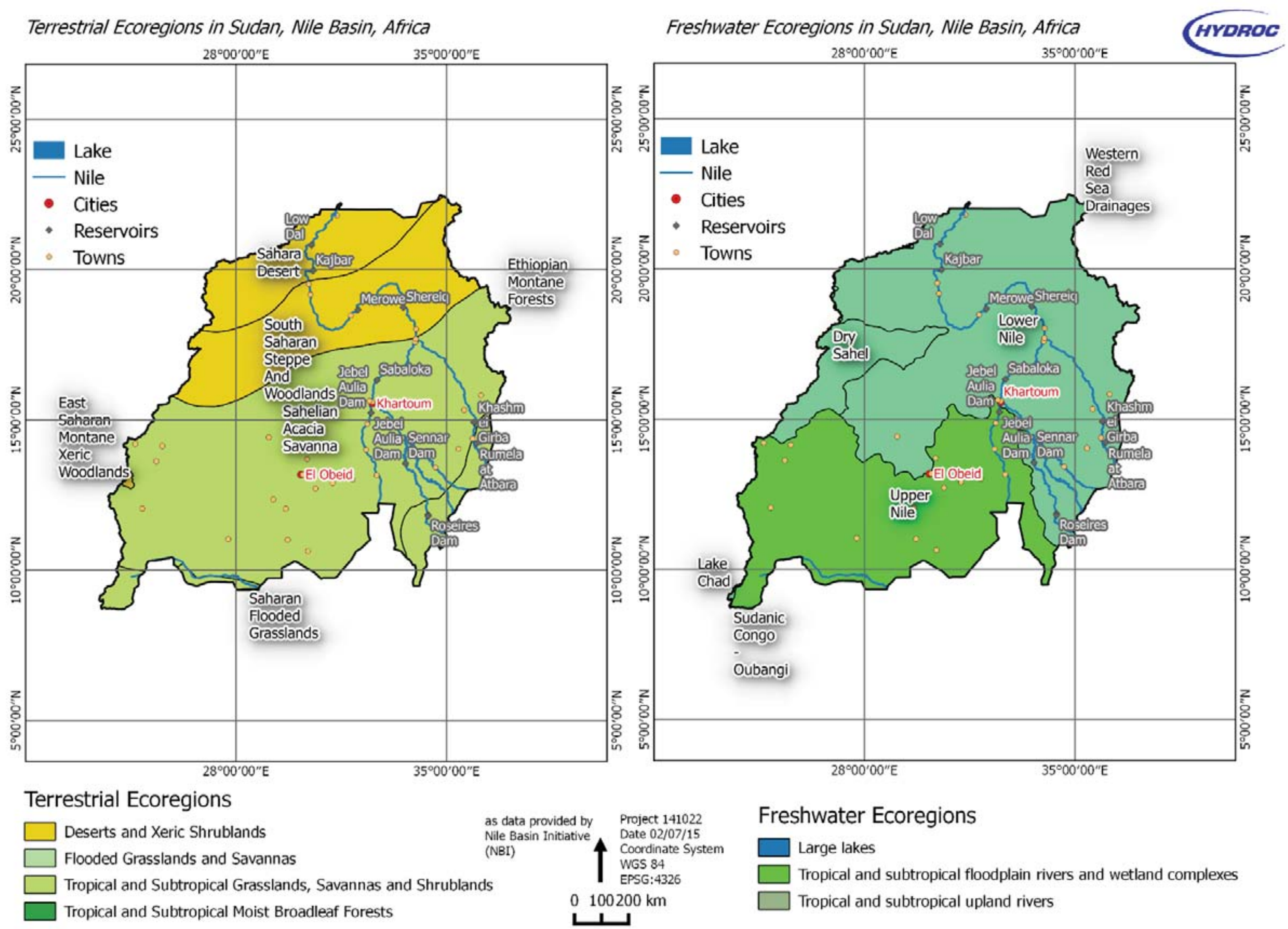
Freshwater Ecoregions
Large lakes
Tropical and subtropical floodplain rivers and wetland complexes
Tropical and subtropical upland rivers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Reservoirs
Towns
Low Dal
Sahara Desert
Kajbar
Merowe
Shereiq
South Saharan Steppe And Woodlands
Sahelian Acacia Savanna
Jebel Aulia Dam
Sabaloka
Khartoum
Jebel Aulia Dam
Sennar Dam
El Obeid
Ethiopian Montane Forests
Khashm el Girba
Rumela at Atbara
Roseires Dam
East Saharan Montane Xeric Woodlands
Saharan Flooded Grasslands
Terrestrial Ecoregions
Deserts and Xeric Shrublands
Flooded Grasslands and Savannas
Tropical and Subtropical Grasslands, Savannas and Shrublands
Tropical and Subtropical Moist Broadleaf Forests
as data provided by Nile Basin Initiative (NBI)
Project 141022
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Coordinate System
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Freshwater Ecoregions in Sudan, Nile Basin, Africa
HYDROC
Western Red Sea Drainages
Dry Sahel
Lower Nile
Upper Nile
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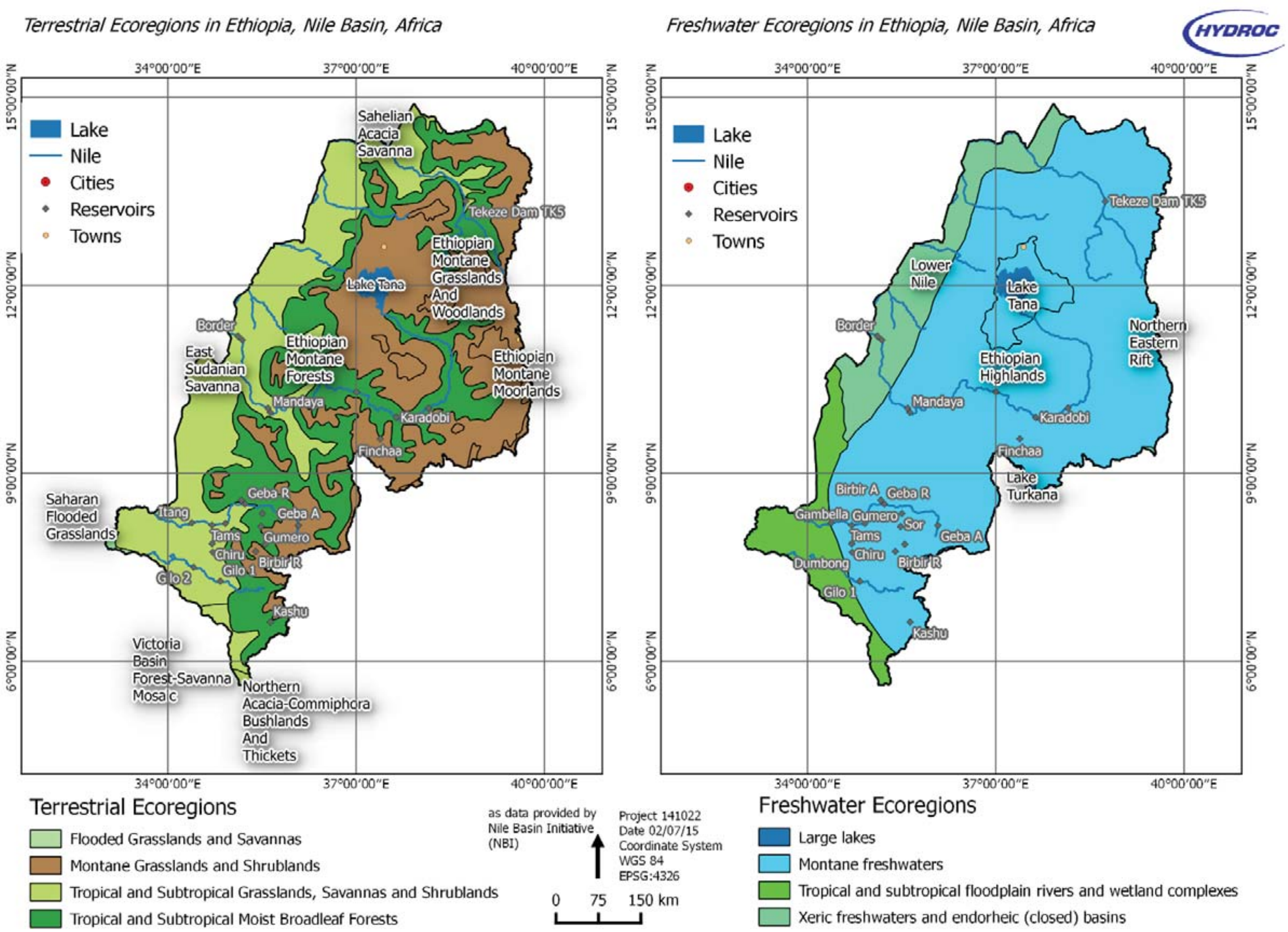
Sudanic Congo - Oubangi
Freshwater Ecoregions
Large lakes
Tropical and subtropical floodplain rivers and wetland complexes
Tropical and subtropical upland rivers


Terrestrial Ecoregions in Ethiopia, Nile Basin, Africa
Freshwater Ecoregions in Ethiopia, Nile Basin, Africa
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Reservoirs
Towns
Sahelian Acacia Savanna
Tekeze Dam TKS
Ethiopian Montane Grasslands And Woodlands
Lake Tana
Border
East Sudanian Savanna
Ethiopian Montane Forests
Ethiopian Montane Moorlands
Mandaya
Karadobi
Finchaa
Saharan Flooded Grasslands
Itang
Geba R
Geba A
Tams
Gumero
Chiru
Gilo 1
Birbir R
Gilo 2
Kashu
Victoria Basin Forest-Savanna Mosaic
Northern Acacia-Commiphora Bushlands And Thickets
Lower Nile
Northern Eastern Rift
Ethiopian Highlands
Lake Turkana
Birbir A
Gambella
Sor
Dumbong
Terrestrial Ecoregions
Flooded Grasslands and Savannas
Montane Grasslands and Shrublands
Tropical and Subtropical Grasslands, Savannas and Shrublands
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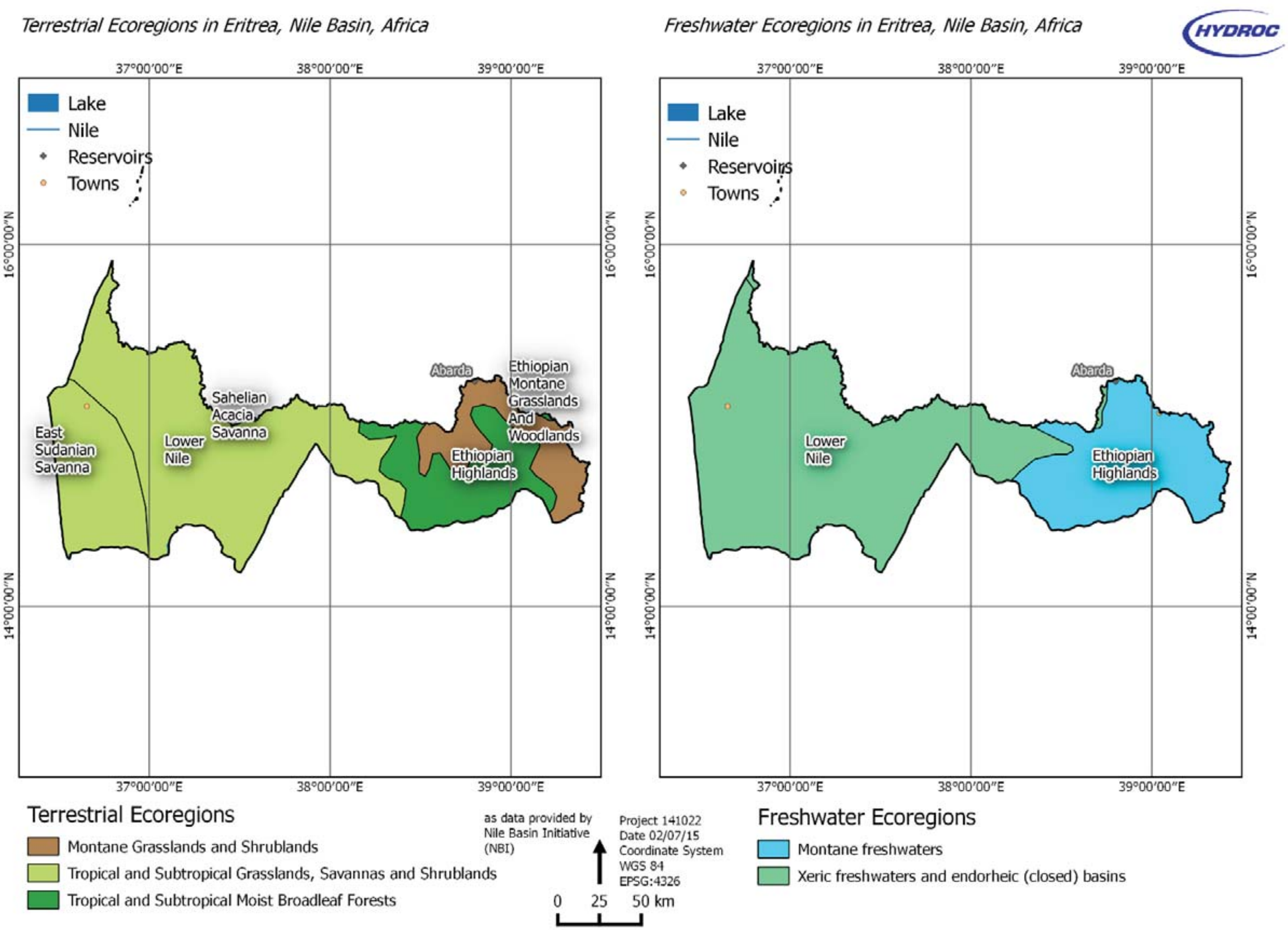
Freshwater Ecoregions
Large lakes
Montane freshwaters
Tropical and subtropical floodplain rivers and wetland complexes
Xeric freshwaters and endorheic (closed) basins


Terrestrial Ecoregions in Eritrea, Nile Basin, Africa
Freshwater Ecoregions in Eritrea, Nile Basin, Africa
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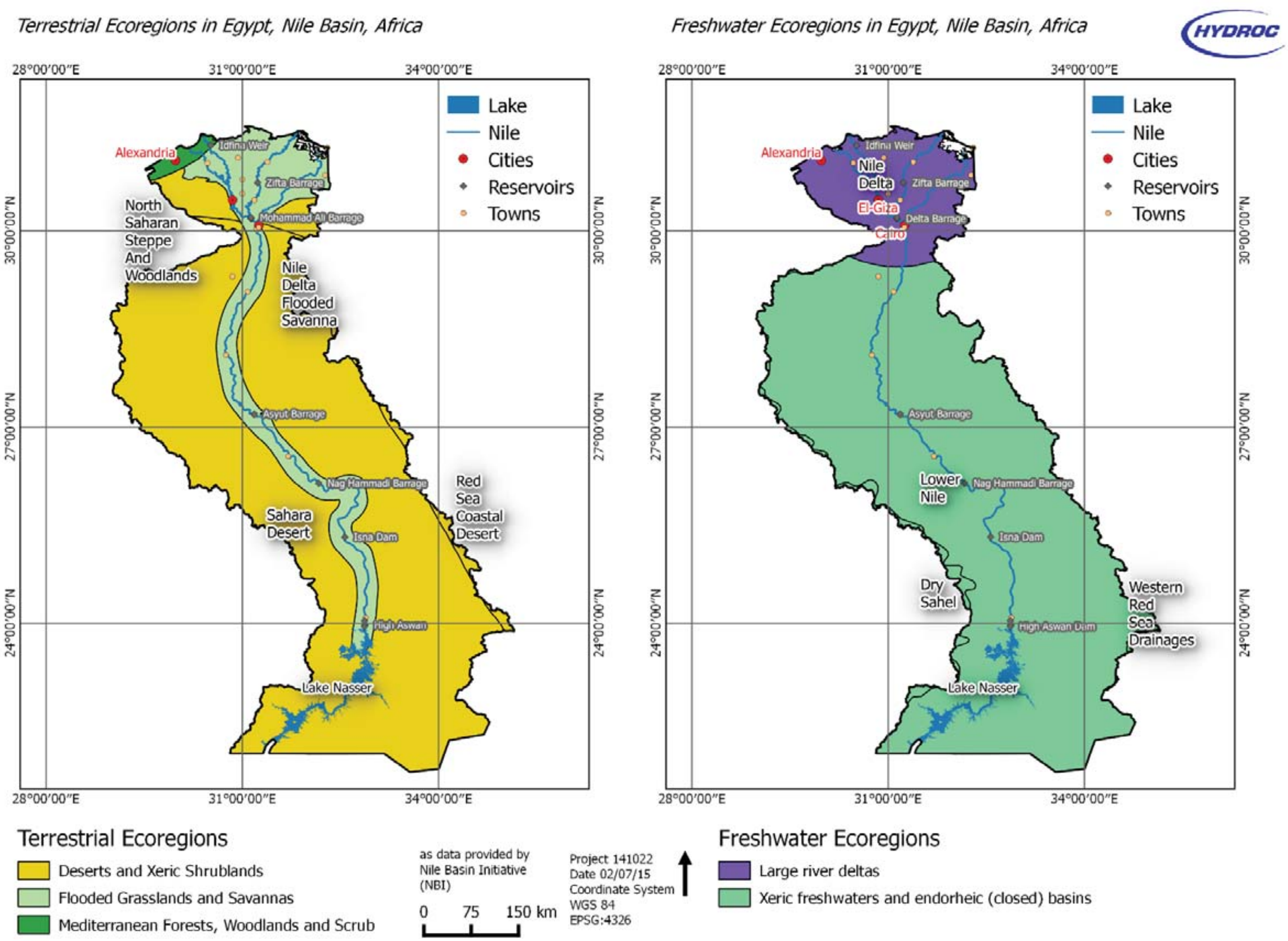
Lake
Nile
Reservoirs
Towns
East Sudanian Savanna
Lower Nile
Sahelian Acacia Savanna
Abarda
Ethiopian Montane Grasslands And Woodlands
Ethiopian Highlands
Terrestrial Ecoregions
Montane Grasslands and Shrublands
Tropical and Subtropical Grasslands, Savannas and Shrublands
Tropical and Subtropical Moist Broadleaf Forests
as data provided by Nile Basin Initiative (NBI)
0 25 50 km
Project 141022
Date 02/07/15
Coordinate System
WGS 84
EPSG:4326
Freshwater Ecoregions
Montane freshwaters
Xeric freshwaters and endorheic (closed) basins


Terrestrial Ecoregions in Egypt, Nile Basin, Africa
Freshwater Ecoregions in Egypt, Nile Basin, Africa
28°00'00"E
31°00'00"E
34°00'00"E
30°00'00"N
27°00'00"N
24°00'00"N
Lake
Nile
Cities
Reservoirs
Towns
Alexandria
Idfina Weir
Zifta Barrage
Mohammad Ali Barrage
North Saharan Steppe And Woodlands
Nile Delta Flooded Savanna
Asyut Barrage
Nag Hammadi Barrage
Red Sea Coastal Desert
Sahara Desert
Isna Dam
High Aswan
Lake Nasser
Nile Delta
El-Giza
Cairo
Delta Barrage
Lower Nile
Dry Sahel
High Aswan Dam
Western Red Sea Drainages
Terrestrial Ecoregions
Deserts and Xeric Shrublands
Flooded Grasslands and Savannas
Mediterranean Forests, Woodlands and Scrub
as data provided by Nile Basin Initiative (NBI)
0 75 150 km
Project 141022
Date 02/07/15
Coordinate System
WGS 84
EPSG:4326
Freshwater Ecoregions
Large river deltas
Xeric freshwaters and endorheic (closed) basins

ONE RIVER
ONE PEOPLE
ONE VISION

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