USDA Forest Service Technical Assistance Trip

Virunga – Bwindi Region:
Republic of Rwanda, Republic of Uganda,
Democratic Republic of Congo

In Support to the International Gorilla Conservation Programme in Analyzing the Region's Watersheds for Water Supplies to Local Communities

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ACRONYMS LIST

ARASI	*Association Rwandaise pour l'Amenagement et le Saufgarde des Infrastructure* (Rwandan Association for Management and Safeguard of Infrastructure)
AWF	African Wildlife Foundation
BINP	Bwindi Impenetrable National Park
CODECO	*Le Comite de Developpement des Communautes* (Committee for Community Development) – DRC
CRNS	*Le Centre de Recherches en Sciences Naturelles* (The Center of Research in Natural Sciences) – DRC
DFGFI	Dian Fossey Gorilla Fund International
DRC	Democratic Republic of Congo
FFI	Fauna & Flora International
ICCN	*Institut Congolais pour la Conservation de la Nature* (Congolese Institute for the Conservation of Nature)
INERA	*L'Institut National pour Etudes et Recherches Agronomiques* (The National Institute for Agronomic Studies and Research) – DRC
ISAE	*Institut des Sciences Agricoles et d'Elevage* (Institute of Agricultural Sciences and Animal Husbandry) – Rwanda
ISP	*L'Institut Superieur Pedagogique* (Superior Institute of Education) – DRC
ITFC	Institute for Tropical Forest Conservation
KIST	Kigali Institute of Science and Technology
MGVP	Mountain Gorilla Veterinary Project
MINITERE	*Ministère des Terres, de l'Environnement, des Forêts, de l'Eau et des Mines* (Ministry of Land, Environment, Forests, Water, and Mines) – Rwanda
ORTPN	*Office Rwandais du Tourisme et des Parcs Nationaux* (Rwandan Office of Tourism and National Parks)
RVA	*Régie des Voie Aèriennes* (Aviation Authority) – DRC
SNHR	*La Société Nationale d'Hydrolique Rurale* (National Society of Rural Hydrology) – DRC
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USFS IP	United States Forest Service International Programs
UWA	Uganda Wildlife Authority
WCS	Wildlife Conservation Society
WWF	World Wide Fund for Nature

NOTE: Certain lakes, swamps, volcanoes and other features in the region have somewhat different spellings and pronunciations depending on where you are. Therefore, it should be noted that Lake Luhondo is the same as Lake Ruhondo, as are Mt. Gahinga and Mt. Mgahinga, and Mt. Visoke and Mt. Bisoke.

1. INTRODUCTION

The US Department of Agriculture (USDA) Forest Service International Programs (USFS IP) has a long history of promoting sustainable forest management and the conservation of biodiversity in Africa. USFS IP provides targeted technical assistance by working in collaboration with host-country government forest and natural resource management institutions, the US Agency for International Development (USAID), and local and international NGOs. By linking the skills of its field-based staff with partners overseas, the USFS, through the International Programs office, provides its partners with access to the wealth and diversity of skills that the agency possesses. USFS technical experts are able to apply sound natural resources management principles and lessons learned, gleaned from over 100 years of forest and grassland management in the USA, to similar issues faced by partners overseas, and help them address critical resource issues and concerns.

The USFS and the African Wildlife Foundation (AWF) have a well established partnership, particularly in relation to watershed assessments, having worked together on such projects in northern Tanzania and along a portion of the Zambezi River in southern Africa. Building on this existing relationship, a USFS scoping mission to the Virunga – Bwindi region of Rwanda, Uganda, and the Democratic Republic of Congo was requested by the International Gorilla Conservation Programme (IGCP)[1]. This landscape encompasses the Volcanoes National Park (Rwanda), Virunga National Park (DRC), and Mgahinga Gorilla National Park and Bwindi Impenetrable National Park (Uganda). Located in the Albertine rift, a region of enormous biodiversity importance to the world, this part of Africa has a human population density which is among the highest on the continent. Communities surrounding the parks suffer from a lack of access to reliable water sources, forcing them to encroach upon the parks in search of water, increasing the pressures upon this unique and fragile ecosystem. Capitalizing on the broad level of expertise contained within the USFS and gained over many years of managing landscapes at the watershed level, IGCP has partnered with the USFS for the provision of technical assistance to help find solutions to the water supply problem of the area. The USFS team consisted of Jason Gritzner (Hydrologist, Lassen National Forest), Joe Gurrieri (Regional Geologist, Intermountain Region), and Mike Chaveas (Africa Program Specialist, International Programs).

The Virunga Landscape is incredibly rich in endemic, threatened, and numbers of species. This region may be one of the most biodiverse on the planet (Plumptre et al. 2003). As such, ensuring the provision of reliable and safe water supplies to a population as large as that which exists surrounding these parks, while maintaining the integrity of the local habitats is a considerable challenge. In addressing watershed management and water supply development, we want to emphasize the true regional and global importance of this landscape and to ensure that future management is based upon a better understanding of the full range of environmental, social and economic values that it can provide in a natural state.

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[1] IGCP is a collaboration of the African Wildlife Foundation (AWF), the World Wide Fund for Nature (WWF), and Fauna & Flora International (FFI)

While the initial intent of this mission was to spend time assessing conditions on the ground in all three countries, field efforts were concentrated in Rwanda and Uganda due to security concerns and the team's inability to obtain country clearance to cross the border into DRC. In an attempt to gain some perspective on water resource issues in the DRC, a one day workshop was organized in Gisenyi, Rwanda with stakeholders from DRC representing the *Institut Congolais pour la Conservation de la Nature* (ICCN), district level government, and NGOs active in the area. While we were not able to examine conditions first hand in DRC, many of the issues described to the team are similar to those in other parts of the Virunga region. Therefore, this report should be useful to the Congolese, and those working on water access issues in DRC, as they continue the process of addressing the water resource problems of Virunga National Park and its surroundings. Additionally, due to time constraints, only a limited amount of time was spent in and around Bwindi Impenetrable National Park and thus, the assessment of this portion of the region in this report is limited.

2. DESCRIPTION OF THE MISSION'S SCOPE OF WORK

USFS technical experts provided guidance on structuring an analysis of the hydrology of the region, with a particular focus on the improvement of the water supply for local communities. The specific goals of this mission were as follows:

1. Perform a preliminary field survey and provide an initial assessment of the hydrologic systems of the region, characterizing the threats to these watersheds and proposing strategies to minimize them.
2. Gauge the current state of available information and level of monitoring that is occurring across the landscape.
3. Identify what questions need to be answered about the area and what work needs to be completed over the next year and beyond in terms of data gathering to improve the current state of knowledge of these watersheds.
4. Evaluate the state of water resources in the region and suggest methods of improving the quantity and quality of water that is being distributed to local communities.

The expected outputs for this assessment were:

1. An analysis of the current state of information on, and monitoring of, the hydrology of the region.
2. A report of a preliminary characterization of the hydrology of the region, including a description of threats to the health of the watersheds, along with other key issues, and proposed strategies for mitigating threats and managing the systems of the region. The report should also address how threats to the watersheds, and their current condition, within the region are impacting rivers and lakes downstream.
3. A prioritized list of future tasks that need to be performed in fully assessing the hydrology of the landscape, including any future role for USFS technical assistance.

4. Recommendations on improving the water supply to, and the effectiveness of, water supply schemes, focusing on improving quality and quantity of the water.

A full itinerary of the USFS team's activities while in the region can be found in Appendix A.

3. ISSUE IDENTIFICATION

Over the course of the mission – field visits to developed and undeveloped water sources, meetings and discussions with representatives of government land and natural resource management agencies as well as local and international NGOs, and review of as much of the existing data as we could obtain – the USFS team identified the following issues of concern regarding the watersheds of the region and the state of available water for consumption by local communities.

Communities Closest to the Parks are Under the Greatest Threat

The high rates of infiltration of the volcanic soils and rocks of the Virunga volcanoes lead to a scarcity of surface water sources in the dry lava zone where the communities closest to the parks live. Springs in this zone are scarce because rain that falls on the forests of the parks at higher altitudes seeps into the soil and re-emerges mainly through regional flow system springs at lower altitudes, leaving communities higher up on the hillsides with a lack of springs from which to collect water. The inhabitants of this "dry zone" are forced to walk great distances to collect water on a daily basis. A significant number of them attempt to solve their water access problem by entering the parks to collect water from springs, streams, swamps, and lakes in the forest causing associated impacts to these protected areas. While in the parks, people engage in other resource extraction activities, such as cutting wood or setting snares to capture bushmeat. From a standpoint of protecting forest resources, as well as assisting communities whose health and livelihoods are at greatest risk, providing reliable access to safe water supplies in the dry zone is essential.

Lake and Swamp Levels of the Region are Dropping

Repeatedly, over the course of our time in the region, we heard anecdotal evidence from resource management agencies (ORTPN, ICCN, UWA) and from others familiar with the region, that the water levels of swamps and lakes, both in and around the parks, in all three countries have been steadily dropping in recent history. While we were not able to find any hard data backing up (or refuting) climate change in the local area, climate researchers have documented a warming of temperatures over most of Africa during the 20th century and the five warmest years on record have occurred since 1988. Our observations of the hydrology of the region have led us to believe that the probable cause of dropping water levels is climate related. Some of the manifestations of a dryer climate include lake terraces abandoned to permanent agriculture at Ruhondo and Bulera lakes, terrestrial species of vegetation encroaching on the Kabiranyuma Swamp, and the rapid transition of Lake Ngezi in Volcanoes National Park from an open water habitat to a wetland.

No Development of Alternative Water Supplies

Considering the scarcity of surface water available to the local populations surrounding the parks, and the effort required for people to collect water from the nearest source, it was surprising to see a lack of rainwater collection systems in the villages of the area. For a relatively small investment, a great deal of water can be collected with a collection vessel fed by gutters lining the roofs of churches, schools, or individual homes. In Rwanda only a very limited number of these systems were observed on buildings in the dry zone adjoining the park. Uganda appears to be utilizing rainwater systems to a greater extent, but for the most part such systems are still under-utilized. We were told that rainwater collection systems were more prevalent prior to the war but were looted or destroyed when fighting struck the region. Stability has been returning to the region in recent years but feelings of personal insecurity remain and people are still reluctant to invest in rainwater collection structures for fear of having them destroyed or looted again.

Lack of Leadership, Centralized Information, and Data

Presently, there is no individual, government agency, or NGO that is tasked with providing leadership for water resource management, research, inventory, or monitoring, and there is no coordination of such activities across the borders of the three countries. As a consequence, information required for making informed decisions about water supply development or aquatic habitat protection is severely lacking. Data pertaining to springs, swamps, and lakes in and around the parks, as well as biological and climatic data, is scattered and scarce. There are several entities in the region – including government agencies, utility companies, and local and international NGOs – who are collecting information related to the watersheds and natural resources of the area but the information collected is not centralized in any fashion and most of these players are not aware of what information is being collected by other groups. Data is particularly scarce for the time period post-1994 due to the unrest in the region.

Lack of Research, Inventory, or Monitoring of Fauna, Flora and Hydrology of the Region

Due to their high level of biologic and economic importance to the region, a great deal of research and monitoring has been carried out on the mountain gorilla population of these parks. However, far less is known with regards to much of the rest of the ecology of this region, particularly aquatic species. If springs, swamps, lakes, or streams inside the parks are to be developed as water sources, a better understanding of the biodiversity supported by these aquatic systems will be necessary. Disrupting a spring or eliminating the flow of a stream in order to pipe the water to a nearby community could have a significant impact on local fauna and flora. Without any attempt at cataloging species diversity, the loss and ramifications of this loss to the wider ecosystem will not be known. The lack of climatic and hydrologic data in the area hampers assessment of alternatives for water development and analysis of environmental impacts.

Erosion and Long Term Effects of Land Use/Cover Change

Marked differences in hydrological regimes were observed in forested versus deforested watersheds. In the forested watersheds of the region (national parks and the Echuya

Forest Reserve), streams flow with relatively little sediment, while in adjacent deforested watersheds, channels are dry, entrenched, and wetlands show signs of high sediment deposition. Tropical forests form an exceptionally effective screen or filter between the atmosphere above and the ground below. Infiltration rates are usually high under forest cover where the forest floor layer is well developed. Where deforestation occurs, soil protection is decreased leading to overland flow and erosion. Decreased infiltration depletes ground-water reserves. Deforestation and widespread agriculture surrounding the national parks has increased the rates of erosion along stream banks, gullies, and roads. This rapid erosion is threatening to migrate upstream across the park boundaries, threatening soil stability in the forests. Wide spread land conversion from native forest to agropastoral land surrounding the national parks and the building of roads in newly inhabited areas has initiated chronic erosion in areas previously unaffected. The consequences of increased overland flow were observed in the formation of substantial gullies in grazed and cultivated areas, and incised stream channels. These problems are exacerbated in places where runoff is collected and channelized by roads. These erosional features tend to propagate headward, and have the potential of entering the parks, threatening soil stability, depleting groundwater, and decreasing biological productivity (fig. 1).

Figure 1: Severe erosion of volcanic soils in Rwanda. The steep pouroff is a headcut migrating up stream and across a road.

4. ASSESSMENT OF EXISTING INFORMATION / DATA FOR THE REGION

- Geologic maps are available for the entire region.

- Water quality data is not plentiful but does exist for the larger municipal water systems such as Mutobo spring in Rwanda and Cyuho, Nkanka and Rubuguri springs in Uganda. Availability of water quality data for DRC is unknown.

- Hydrologic Data-
  - ITFC monitored the hydrology of the Kabiranyuma swamp for 11 months in 1998.
  - Electrogaz has some data on Lakes Bulera and Ruhondo.
  - Flow data on Mutobo and Rubindi springs in Rwanda, and Rubugeri, Cyuho, and Nkanka in Uganda.
  - Mpenge Spring may have pre-1982 flow data.
  - KIST (Kigali Institute of Science and Technology) may have water data for areas outside Volcanoes National Park.
  - A feasibility study was done on Kamira spring in DRC.
  - Spring and stream inventories have been done by ICCN in Virunga National Park and by consultants outside of protected areas in Uganda.

- Rainfall data is available for stations at most of the airports in the region. Rainfall data of variable quality and reliability is available for the Karisoke Research Station prior to 1994; Ntebeko and Muhavura park patrol stations in Mgahinga Gorilla National Park (15 years); five stations in BINP. Other data may exist at INERA and IASE.

- Plumptre et al. (2003) have compiled all available data on mammals, birds, reptiles, butterflies, amphibians, lake fish, and plants in the Albertine Rift ecoregion including BINP and the Virunga Volcanoes region. However, many areas remain poorly surveyed or not surveyed at all, and no information was found on macroinvertebrates. A reasonable survey of amphibians by Drewes and Vindum (1994) has been done for BINP.

See Appendix B for further information sources in DRC.

5. WATERSHED CONDITIONS

A preliminary assessment of the watersheds on the southern and eastern flanks of the Virunga Massif in and around Volcanoes National Park, and Mgahinga Gorilla National Park in Rwanda and Uganda, and Bwindi Impenetrable National Park (BINP) in Uganda, was performed. Marked differences in watershed conditions exist inside and outside of protected areas (fig. 2). Inside the parks, where primary forest is still intact, there is no bare soil, surface water is relatively plentiful and contains very little suspended sediment, and wildlife is abundant. Similar conditions were observed in Echuya Forest Reserve.

Outside of protected areas where forest land has been entirely converted to agropastoral land, ground cover is sparse, erosion is common, streams flow intermittently and carry huge sediment loads, and wildlife habitat is virtually nonexistant. Because agropastoral land cover types dominated the regional landscape, watershed conditions in the region surrounding the national parks are degraded and are at risk for further degradation. Additionally, due to the degree of resource degradation surrounding protected areas; the natural physical and sociological responses to resource degradation; and a lack of buffer between protected areas and private land, resources within the park are also at risk.

Figure 2: Volcanoes National Park boundary, Rwanda.

5.1 Erosion and regional resource degradation

The degradation of soil, water, and biodiversity as a byproduct of deforestation has been widely documented. Through the process of land conversion from forest to agropastoral land, soils become vulnerable to the erosive powers of wind, precipitation impact and overland flow. In the Virunga region, rain events over agropastoral land are responsible for most erosion. Raindrops impact exposed soils with enormous energy, dislodging particles, making them more readily available for transport by overland flow. The impacts of these processes are intensified on sloping land, typical of this region (fig. 3), where more that half of the soil contained in a raindrop splash is transported downhill (Pimental et al. 1995).

Erosion on agricultural land is estimated to be 75 times greater than what occurs in natural forested areas (Myers 1993). In the agroecosystems of Africa, Asia, and South America average erosion rates are around 30-40 t/ha/yr (tons per hectare per year) (Pimental and Kounang 1998). In mountainous areas that are intensely cultivated this rate is expected to be higher. An example from Nigeria approximates soil loss from a cassava field on a slope of about 12% to be 221 t/ha/yr (Aina et al. 1977 as cited in Pimental and Kounang 1998). In other areas, sloping agricultural land under tropical rainfall loses as much as 400 t/ha/yr (Pimentel and Kounang 1998). This far exceeds the average natural rate of soil formation which ranges from 0.5 to 1.0 t/ha/yr (Troeh and Thompson 1993; Lal 1994; Pimentel et al. 1995).

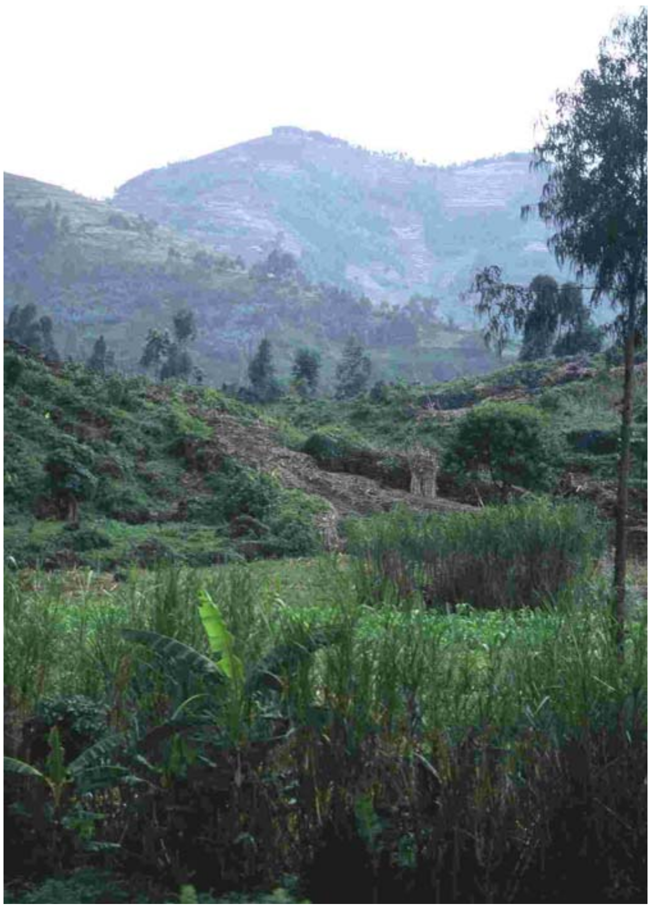

Figure 3: Hillside agriculture, Rwanda.

Wide spread land conversion from native forest to agropastoral land surrounding the national parks and the building of roads in newly inhabited areas has initiated chronic erosion in areas previously unaffected. Hillslope erosional processes tend to intensify in the downhill direction, depending on factors of slope, land cover, and erodibility of soils or bedrock, and propagate in an uphill and lateral direction. These chronic erosion features in the form of gullies on agropastoral land, and headcuts in incising streams have the potential of propagating upward, entering protected areas, and degrading biodiversity on the fringes of, and within, the parks. Sediment from erosion of upland agricultural areas is actively filling in local lakes. An example of this is the large delta building out into Lake Ruhondo from sediment deposition on the north shore.

Erosion decreases biological productivity in a number of ways. The factors that are affected are water holding capacities, nutrients, organic material, soil depths, and associated biologic organisms/activity that contribute to soil building. The most limiting factor in terms of plant growth is available water. As erosion occurs, the water holding capacity of soils decrease and runoff increases. Even moderately eroded soils absorb 10-300 mm less water per hectare per year from rainfall than uneroded soils (Pimentel and Kounang 1998). Depending on rainfall, soil type, slope and other factors, a 20-40% reduction in available water to plants in agroecosystems reduces productivity from 10-25% (Pimentel and Kounang 1998). This in turn decreases the amount of organic material input to the soil, compromises soil structure, decreases habitat for soil biota, and diminishes overall productivity for the area.

Nutrients important to plant growth such as nitrogen, potassium, phosphorous, and calcium are also lost during the erosional process. In fact, research has shown that eroded soils transported from a site contain approximately three times more nutrients than the soils that are left behind (Lal 1980; Young 1989 as cited in Pimental and Kounang 1998). This is due to the fact that nutrient concentrations are often closely associated with concentrations of organic material (Allison 1973 as cited in Pimental and Kounang 1998).

Organic materials in soil are vital for the formation of soil aggregates (Chaney and Swift 1984 as cited in Chenu et al. 2000) which provide the structure needed in soils to facilitate the infiltration and holding of moisture, enhance root growth, stimulate the proliferation of important soil biota, and improve the cation exchange capacity (Allison 1973; Langdale et al. 1992 as cited in Pimentel and Kounang 1998). During the process of erosion, lightweight, fine particles of organic material are preferentially transported by wind and water. Because most organic material exists near the soils surface, great quantities of organic material can be lost with the erosion of topsoil (Pimental and Kounang 1998). Studies have shown that soils removed through erosional processes contain 1.3-5.0 times more organic material than the soils that remain following erosion (Borrows and Kilmer 1963; Allison 1973 as cited in Pimentel and Kounang 1998).

With decreased soil depth and lack of organic material associated with eroded soils, there is a decrease in both availability and quality of habitat for soil biota. Earthworms, insects, and microbes perform a wide range of services in improving the productivity of soils. This includes nutrient cycling, tunneling, and improving aggregate stability which aids in water infiltration, prevents soil crusting, and makes nutrients available to plants, all of which help to improve soil productivity (Pimentel et al. 1980, 1997; Pimentel and Kounang 1998).

The amount of biodiversity in an ecosystem is very closely related to the soil conditions. In areas of high degradation by erosion, soils are less capable of producing the biomass necessary to support a diverse community of plants, animals, microorganism, and other forms of life (Pimental and Kounang 1998). In terms of the human component of the local ecosystem in the Virunga region, as the productivity of soils decreases, the biomass required for human survival in the way of nourishment, fuels, building materials, and other ethnobotanical goods becomes limited.

To compensate for this reduction, existing land use systems must intensify, which requires the use of chemical fertilizers and other inputs to increase production. Otherwise, land use systems need to become more extensive, which requires bringing fallow or forest land under production. In the Virunga region where population densities exceed 300 persons per square kilometer (Wilkie et al. 2001), almost all available land is already under cultivation, therefore individuals will need to increasingly rely on chemical additives and intensive land use to maintain or increase production. Over time this further depletes soil productivity and pollutes surface waters, which degrades both aquatic and terrestrial ecosystems. As populations around the parks continue to increase, pressures on the parks to provide a variety of resources will also increase. Without the appropriate management of watershed resources outside the parks, the ecosystems being protected within the parks will continue to be at risk.

6. PRELIMINARY SURVEY OF THE HYDROLOGY OF THE REGION

6.1 Climate

Water resources are inextricably linked with climate, so the prospect of global climate change has serious implications for water resources and regional development in Africa (Riebsame et al. 1995). Efforts to provide adequate water resources for the Virunga region will confront several challenges; including population pressure, problems associated with land use such as erosion/siltation, and possible ecological consequences of land-use changes on the hydrologic cycle. Climate change – especially changes in climate variability through droughts and flooding – will make addressing these problems more complex. The greatest impact will continue to be felt by the poor, who have the most limited access to water resources.

Temperature rise in Africa corresponds to global temperature rise and potential adverse impacts are possible across the diverse environments of Africa. A very sparse observational network for Africa is a major constraint in improving understanding of local climate and makes predictions of future climate change difficult at the sub-regional to local level (e.g. the Virunga region).

The Intergovernmental Panel on Climate Change (IPCC 2001) reports a warming of approximately 0.7°C over most of Africa during the 20th century based on historical records, a decrease in rainfall over large portions of the Sahel, and an increase in rainfall in east-central Africa. The five warmest years in Africa have all occurred since 1988 (Kaser 1999). Since the 1990's, glacier area in the Rwenzori Mountains of Uganda has decreased by about 75%. With changes in temperature over time, changes can also be expected in precipitation patterns and increased frequencies of extreme events. Local changes in climate have been recognized by a Ugandan district official. He stated that "In the past, the days were cooler and the rains were softer and more evenly dispersed through the year. Today rains fall with more intensity and floods do more damage to farm land and infrastructure" (personal Communication, Paul S. Manirakiza, Deputy Chief Administrative Officer for Kisoro District). While the exact nature of the changes in temperature or precipitation and extreme events are not known, there is general agreement that extreme events will get worse, and trends in most variables will change in response to warming. By the end of this century, global mean surface temperature is expected to increase between 1.5 ° C and 6° C.

The populations of East Africa are particularly vulnerable to climate change and climate variability, including extreme climatic events such as drought and flooding, due, in part, to reliance upon localized (untreated) water supplies and rainfall-fed agriculture. Arid, semiarid, and dry sub-humid regions are particularly vulnerable to reduced precipitation. Although the humid areas of the Albertine rift may not experience prolonged drought, dry seasons may be longer and rainfall and flooding events may become more intense.

Predominantly rural populations in the Virunga region primarily depend upon groundwater for a source of potable water. Current efforts to supply safe water to the rapidly expanding population have targeted groundwater (springs) primarily because surface water is scarce. This demand for groundwater is expected to increase significantly in the next few decades as the current population expands. Despite rapid population growth and dependence upon localized water resources, the impacts of climate change on water resources have been the subject of relatively few studies (Hulme et al. 2001) and remain poorly resolved. Moreover, the assessment of the impact of climate change and climate variability on water resources is in its infancy. There is a need for enhanced capacity to develop an integrated assessment of water resources and the response to climate events.

Africa's large lakes may also be particularly sensitive to climate change (Watson et al. 1998). Regional depression of lake levels and wetlands in the Virunga region appears to be climate linked. How much of this could be contributed by land use/land cover change is unknown. In lakes that have only small outflows, such as Lake Bulera, minor declines in rainfall for extended periods could lead to a cessation of outflow and interruption of power generating capacity.

At lakes Ruhondo and Bulera, receding lake levels is evidenced by lake terraces abandoned to permanent agriculture, and high water marks in the hydroelectric power intake area that are much higher than the present water level. ElectroGaz, a utility company in Rwanda, apparently has historical data on the levels of lakes Ruhondo and Bulera, but the team was unable to obtain this data prior to departure. Seasonal lake level fluctuation data would help discern the degree to which current lake levels are reflecting seasonal cycles, drought, or are affected by drawdown for power generation. Rugezi Marsh plays a major role in the regulation of water flow to Lake Bulera (Weber 1987). Only half of this marsh remains in its natural state. Previous attempts to drain the marsh have had undesirable impacts to hydroelectric production from Lake Bulera. Water regulation services to Lake Bulera provided by the marsh will become more critical as the climate warms.

Another place exhibiting evidence of drying conditions is the Kabiranyuma Swamp. Here, terrestrial species of vegetation are encroaching on the wetland species, an event that has been documented by ITFC (2001). The gravity water system that draws water from the wetland, may contribute to drying of a portion of the swamp in close proximity to the dug channels, but effects to the important upper and lower fens are probably minimal. However, without long-term hydrologic monitoring, the true effects to the swamp from the water scheme are speculation. Rugezi swamp, a similar high-elevation wetland in the region that is not affected by a water system should be monitored in the same fashion as Kabiranyuma swamp to help determine man-induced, versus climatically driven hydrologic and ecological changes.

Some of the most conclusive evidence of drying climatic conditions was observed in closed basin lakes within the parks. Lake Ngezi, in particular, is in transition from an open-water habitat to a wetland (fig. 4). Since Lake Ngezi is in a closed basin (no inflow or outflow streams), lake levels are very sensitive to rainfall and evapotranspiration. Decreases in rainfall and increases in evapotranspiration from warmer temperatures would cause the lake level to drop. In the area where the transition from open-water to wetlands is taking place, several large tree stumps were found (fig. 5) indicating that historically, the lake has experienced extended dry periods that lasted long enough to grow substantial size trees. When wetter conditions returned, the trees were inundated and died. This evidence would seem to support the idea that local lake and wetland water levels are being controlled primarily by cyclical climatic factors rather than man-induced factors.

Figure 4. Ongoing transition from open-water to wetland ecosystem at Lake Ngezi.

Anecdotal information concerning a general reduction in spring flow was received, however, no monitoring data could be found to corroborate these claims. On the park boundary in Rwanda near Kagano spring, macroinvertebrates were found in streams that are reported to only flow seasonally. The presence of these macroinvertebrates indicates that even during dry periods, when surface water is not flowing, there is sufficient hyporheic flow (saturated zone below the streambed) to support these organisms. During wetter climatic periods, these streams may have perennially flowing surface water.

Figure 5. Large tree stump among wetland successional species indicates extended dry periods in the historic past.

6.2 Hydrology of the Virunga volcanoes

The hydrologic systems of the Virunga region are not well understood, however a preliminary hydrologic conceptual model can be constructed based on geologic maps (Department of Geological Survey and Mines, 1966; Department of Geology and Mineralogy, Royal Museum of Central Africa, 1991) and field observations by the USFS team. In addition, investigations by the U.S. Geological Survey in Hawaii (Oki et al. 1999) provide a volcanic terrain hydrologic model from which to proceed. Certain geologic and hydrologic characteristics of the Virunga region favor the occurrence and retention of freshwater in underground aquifers although the geologic and hydrologic characteristics of the aquifers vary widely. The chemical composition and modes of emplacement of the volcanic rocks and sedimentary deposits and the subsequent weathering processes to which they have been subjected have resulted in a wide range of the hydraulic properties that control the storage and flow of water. Surface water is sparse across the landscape due to the high permeability of the volcanic rocks.

Three main groups of volcanic rocks exist: lava flows, dikes, and pyroclastic deposits. Lava flows in the area are mainly basanitic to trachyandesitic. Some types of volcanic rocks are commonly confining units or relatively poor aquifers (dikes, pyroclastic flows, and trachyandesitic rocks). Others, like basanitic rocks are commonly among the most permeable rocks on earth. Both types of rocks occur in the Virunga region. The occurrence of ground water in the volcanic-rock aquifers of the Virunga is summarized in figure 6.

Void spaces in a layered sequence of lava flows impart high permeability. Lava commonly becomes more permeable with increasing distance from the eruptive vent. The layers of clinker at the top and bottom of flows commonly form productive aquifers with permeability similar to that of coarse-grained gravel. However, some lava typically cools as a massive body of rock with much lower permeability. Lava tubes are extremely permeable features that can be several miles long. They form as molten lava drains out from under a solidified crust. Lava tubes were observed in Rwanda in lava flows emanating from the broad saddle between Mt. Visoke and Mt. Sabinyo and in a lava flow on the south flank of Mt. Gahinga.

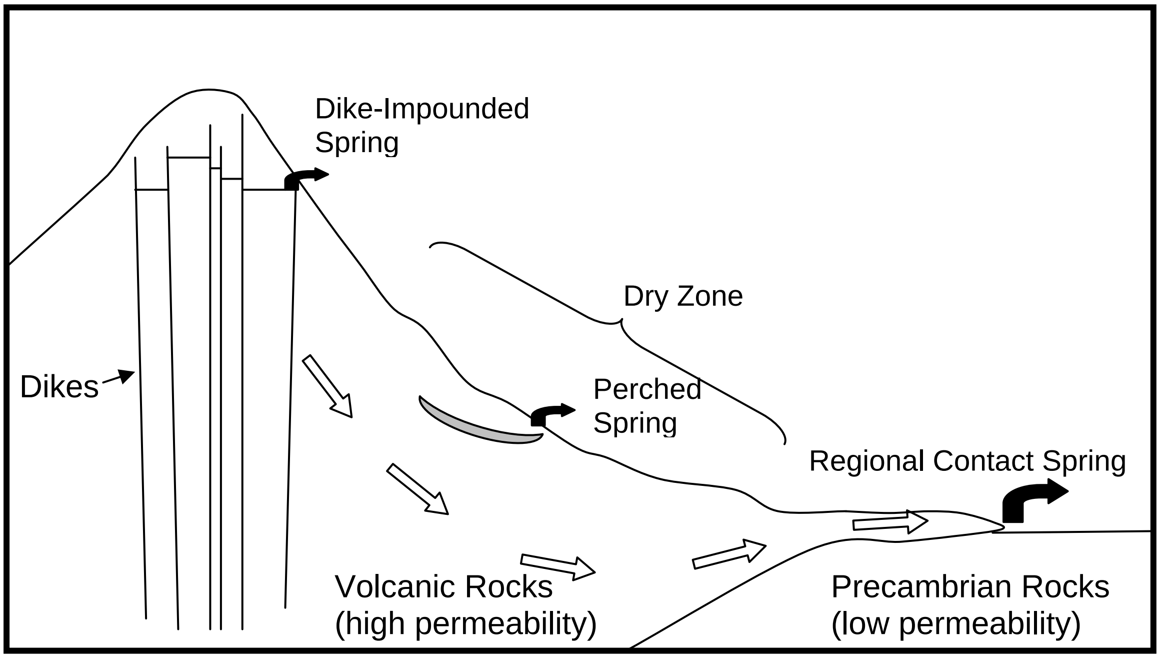

Figure 6: Ground water generally moves from topographically high areas towards the valleys. Ground-water flow is generally downward in the upland areas, upward in the valleys, and horizontal in between (dry zone). Where erosion has exposed dike compartments in stream valleys on the upper slopes of volcanoes, ground water can discharge directly to the streams. In other areas, ground water in dike-impounded systems can discharge to down gradient ground-water systems. Perched water is found in areas where low-permeability rocks impede the downward movement of ground water sufficiently to allow a perched water body to develop. Regional contact springs occur where groundwater is forced to the surface by low permeability rocks.

Lava flows erupt from central calderas and from fissures in linear rift zones along the volcano flanks. As a result, the rift zones likely contain many vertical or steeply dipping dikes which cut through the gently sloping lava flows. Dikes are thin, near-vertical sheets of low-permeability rock that intrude upon existing rocks. Dikes can extend vertically and laterally for long distances and impede the flow of ground water (fig. 6). Within a dike complex, dikes intersect at various angles and compartmentalize the more permeable rock in which ground water can be impounded. Dike-impounded water can be an important source of water on some volcanoes. Where dikes have been eroded or fractured, springs might issue from openings in the dikes. The volume of water stored in dike-confined aquifers is large compared to other sources of high-elevation water and, can provide a relatively stable source of water supply. Compared to the total volume of regional groundwater discharge, however, the amount of dike-confined water is small.

Perched water can occur in areas where low-permeability rocks impede the downward movement of ground water sufficiently to allow a saturated water body to develop over unsaturated rocks (fig. 6). These low-permeability rocks include massive, thick-bedded lava flows and extensive soil and weathered ash layers. Perched water bodies can supply usable quantities of water to springs or wells. Natural storage in perched aquifers is generally small and the flow of perched water springs tends to be relatively unstable. Perched water is important primarily because of its high elevation and its occurrence in the dry zone.

The principal sources of fresh groundwater in the Virunga region are the large contact springs that discharge from the terminus of lava flows (fig. 6). Where the permeable lava flows containing ground water extend to the valley bottom and pinch out over low permeability Precambrian rocks, large volumes of water are forced to the surface. This type of ground water discharge is represented by Mutobo, Rubindi, and Mpenge springs in Rwanda, and Cyuho and Nkanka springs in Uganda.

6.3 Hydrology of Bwindi Impenetrable National Park

The geologic setting of Bwindi Impenetrable National Park (BINP) is completely different than that of the Virunga Volcanoes area. Bwindi is extremely rugged, being part of the Kigezi Highlands that were formed through up-warping of the Western Rift Valley. Precambrian shale phyllite, quartz, quartzite, schist and granite of the Karagwe-Ankolean system underlie the area. These rocks are generally of low permeability and transmit water mainly through large fault structures. As a consequence infiltration is limited, aquifers are limited, and much of the rainfall runs off in streams. Bwindi has a comparatively dense stream network with perennial streams present within and near the boundaries of the park. As such, intrusion into the park by people gathering water is much less of a problem than in the Virunga Volcanoes region.

BINP is a major water catchment area and the source of many rivers that flow north, west and south. The major rivers include the Ivi, Munyaga, Ihihizo, Ishasha, and Ntengyere, which drain into Lake Edward and other rivers flow into Lake Mutanda. BINP is therefore critical to the hydrological balance of the region. The area has experienced a long history of intensive logging, encroachment for agriculture, mining, poaching, fishing and wild fires. Although fishing is banned in BINP rivers, illegal fishing still takes place and the fish fauna remains relatively unknown.

6.4 Hydrology of swamps

The areas of the Kabiranyuma swamp characterized by *Carex spp*, *Lobelia wollastonii* and *Alchemilla johnstonii*, in the upper portion of the swamp, appear to be fens. Fens are peat forming wetlands fed primarily by ground water discharge. They frequently support unique species of plants and animals. In mountainous terrain they tend to form as a peat mound at the base of a mountain slope and slightly above the valley bottom. This is precisely the topography and landscape position of the Kabiranyuma swamp. Peatlands are generally rare on the African continent, however, the summits of the East African high mountains are some of the places in tropical Africa where peat formation is possible. Although peatlands are mentioned in most descriptions of these mountains (e.g. Hedberg 1964), knowledge is still limited. Landscape ecological studies into peatland development, conditions of peat formation, and hydrological functioning are lacking thus far.

A reconnaissance helicopter flight over Volcanoes National Park in Rwanda allowed the team to inspect swamps and lakes from the air. Rugezi swamp, located in the saddle between Mt. Sabinyo and Mt. Gahinga, appears to be very similar to Kabiranyuma swamp in vegetation (giant lobelia) and morphology, indicating that this too is a fen peatland and of ecological importance.

Significant wetlands within BINP are Mubwindi, a rush/sedge swamp, and Ngoto, a papyrus swamp. Though not visited by the team, these wetlands are thought to be peat forming bogs. They consist of soils with varying levels of humus and with acidity ranges from pH 2.9 to 5.2. In contrast to fens, bogs are fed by rainfall instead of ground water and consequently tend to have low pH waters. Low pH bogs tend to support unique plant and animal species.

7. PRELIMINARY SURVEY OF WATER RESOURCES IN THE REGION

The Virunga region, taken as a whole, has plentiful water supplies. The montane forests in the protected areas facilitate the collection, infiltration, and storage of large amounts of water. The highly porous volcanic rocks of the area favor storage of this water in the subsurface rather than in streams. All of the developed and undeveloped water supply sources observed during the site visits are located at ground water discharge points (i.e. springs and swamps). The problem is in the spatial distribution of ground water discharge points relative to the population.

Three options exist to transport water from the sources to populations in need: 1) gravity flow from a source to down gradient users, 2) pumped from a source to up gradient users, and 3) extracted from wells near the location where water is needed. The choice of a method or source of water depends on the resources available and community preferences. Each of these methods has advantages and disadvantages. Table 1 presents a comparison chart that can be used to evaluate the available source water options.

There is widespread consensus among the stakeholders from all three countries that access to water for local communities is a serious problem and needs to be addressed rapidly. While the temptation may be to solve the problem as soon as possible by whatever means available, we did hear a significant contingent express their desire to seek solutions that don’t negatively impact the parks. In those cases where adequate water cannot be supplied from sources outside of the parks, there is a desire by some to look to the parks for water supply development options. The following sections describe the various sources of water available in the Virunga region based on our field survey.

7.1 Rain harvesting

Rain harvesting is a simple technology where rainwater is collected in gutters which drain to a collection vessel through down-pipes. The viability of rain harvesting has been studied and tested in many regions of the developing world (Gould 1992; Gould and McPherson 1987; Nissen-Petersen 1982; Pacey and Cullis 1989; Schiller and Latham 1987; UNEP 1982; Wall and McCown 1989) and in many places has been applied successfully. The Virunga region receives an ample supply of rainfall for much of the year to make rain harvesting a viable technology for rural homes and villages.

As the rooftop is the main catchment area, the amount and quality of rainwater collected depends on the area and type of roofing material. Large roofs on schools and other large buildings can be used to collect and store large amounts of water for dry season use. Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminum, tiles, or slates. Thatched roofs tied with bamboo gutters and laid in proper slopes can produce almost the same amount of runoff less expensively (Gould, 1992) but are least suitable because of possible health hazards. Similarly, roofs with metallic paint or other coatings are not recommended as they may impart tastes or color to the collected water. Roof catchments should also be cleaned regularly to remove dust, leaves and bird droppings so as to maintain the quality of the produced water.

Storage tanks for collecting rainwater harvested using guttering may be either above or below the ground. Precautions required in the use of storage tanks include provision of an adequate enclosure to minimize contamination from human, animal or other environmental contaminants, and a tight cover to prevent algal growth and the breeding of mosquitoes. Open containers are not recommended for collecting water for drinking purposes. Maintenance is generally limited to the annual cleaning of the tank and regular inspection of the gutters and down-pipes. Maintenance typically consists of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place before the start of the rainfall seasons.

The bacteriological quality of rainwater collected from properly maintained rooftop catchment systems, equipped with storage tanks having good covers and taps, is generally suitable for drinking, and frequently meets World Health Organization drinking water standards. Rather than becoming stale with extended storage, rainwater quality often improves as bacteria and pathogens gradually die off. Rooftop catchment and rainwater storage tanks can provide good quality water, clean enough for drinking, as long as the rooftop is clean, impervious, and made from non-toxic materials (lead paints and asbestos roofing materials should be avoided), and located away from over-hanging trees.

Rain harvesting technologies are simple to install and operate. Local community members can be easily trained to implement such technologies, and construction materials are also readily available. It is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Rain harvesting has few negative environmental impacts compared to other water supply project technologies.

Disadvantages of rainwater harvesting technologies are mainly due to the limited supply and uncertainty of rainfall. The feasibility of rainwater harvesting in a particular locality is highly dependent upon the amount and intensity of rainfall. As rainfall in the Virunga area is unevenly distributed throughout the year, other supplementary sources of household water are required during the dry seasons.

The decision maker has to balance the total cost of rainwater harvesting projects against the economic benefit of conserving water supplied from other more expensive sources. Likewise, the cost of physical and environmental degradation associated with the development of available alternative sources should also be calculated and added to the economic analysis.

7.2 Perched aquifer sources

Kagano and Bushokoro springs are successful, low volume gravity developments visited by the team and located in the dry lava zone near the border of Volcanoes National Park. Source water is assumed to be small perched aquifers that yield a small volume of water all year long. In the lava zone near the park boundary, development of small gravity water systems similar to the Kagano gravity system should be pursued. These have the advantage of being located close to the users in greatest need and some may be located outside of the park.

Observations by the team in the Kagano area indicated several areas along the park boundary that had the potential for small seepage collection developments. Potential perched water aquifers may not have springs visibly discharging to the surface but can be identified by the presence of wetland vegetation. Figure 7 shows a construction diagram for a low volume seepage collection system that could be used to develop these perched aquifers.

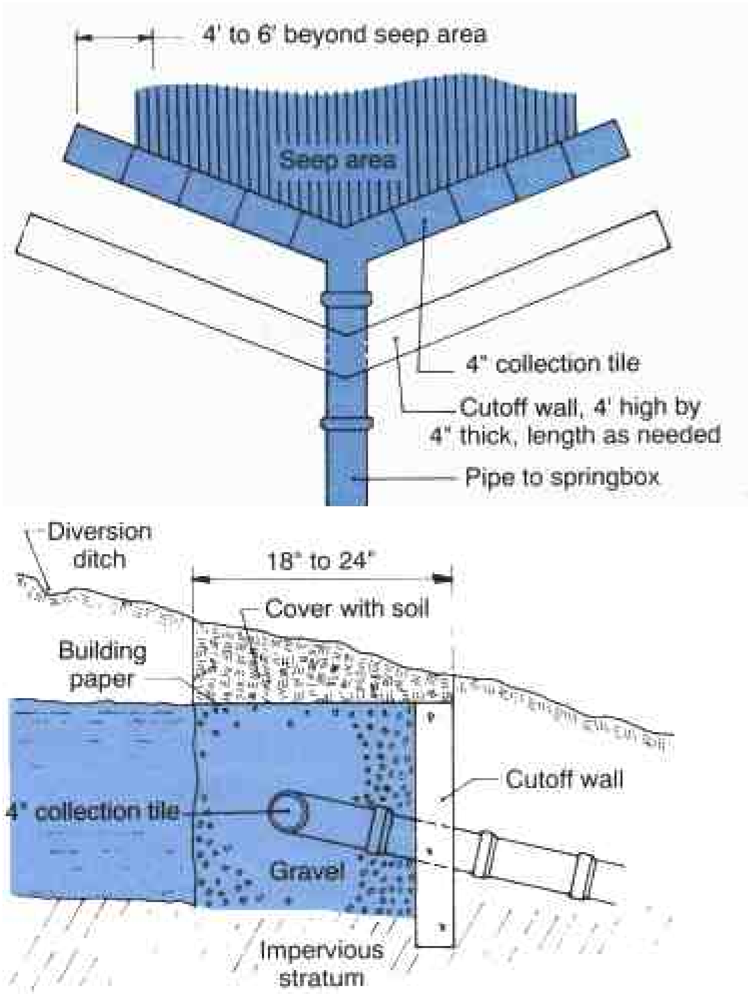

Figure 7. Overhead and cross-section view of a seepage spring development. (From: North Carolina Cooperative Extension Service, Publication Number: AG 473-15) Note: 1”(inch) = 2.54 cm; 1’(foot) = 0.305m

7.3 Regional contact springs

Mutobo, Rubindi, and Mpenge springs in Rwanda, and Cyuho and Nkanka springs in Uganda are large volume regional contact springs located at the geologic contact between volcanic and Precambrian rocks. In Uganda they are located roughly 300 meters in elevation below the lava zone near the park boundary and in Rwanda they are located roughly 600 meters below the park boundary. The quality of the springs is good with the exception of elevated fluoride in some of the discharges at Cyuho and high iron content in those of Mutobo.

These springs have the potential to supply water to large numbers of people. The water is of good quality and seasonal fluctuations in discharge rates are not great. The main disadvantage would be the high capital investment required to construct pumping and distribution infrastructure to supply water to the dry zone located hundreds of meters in elevation above the springs. In the long-term, however, this option may be the most logical solution to the problem.

The Rubuguri gravity water scheme delivers water from a spring inside BINP to the town of Rubuguri. The system appears to be successful and is functioning properly. One disadvantage of having this water supply infrastructure and maintenance personnel inside BINP is potential disruption to gorillas that frequent the area.

7.4 Wetland sources

The Nyakagezi water scheme collects water from a small swamp inside Mgahinga Gorilla National Park near the park boundary. The water appears to be elevated in iron and other minerals which has caused encrustation on the inside of pipes reducing the flow rate. Waters draining from swamps are typically high in organic constituents mainly fulvic acids. Aluminium and iron complexed by dissolved organic matter may become major constituents in swamp water and can cause fouling of piping systems. Evidence of these biogeochemical processes are the iron seeps observed in most of the wetlands visited by the team. Problems with the Nyakagezi scheme illustrate the need for caution when proposing a swamp sourced water development, and the need for an evaluation of water chemistry during the design phase of a water development scheme to prevent fouling of the system.

The Institute of Tropical Forest Conservation, Ecological Monitoring Programme (ITFC) has been monitoring the vegetation, fauna, and hydrology of the Kabiranyuma swamp sporadically since 1997. The security situation has limited the monitoring effort to only 11 months of hydrologic monitoring in 1997-98 (Mulders 1998), three successive vegetation monitoring field visits during 1999, 2000, and 2001; and one small mammal inventory in 1996. No amphibian inventory has been done, despite their importance as sensitive indicators of habitat change. Due to the lack of data, few conclusions can be made concerning ecological changes in the swamp from operation of the gravity water scheme. ITFC (2001) reports a slight increase in dry land species and a decline in some wetland species. Water has been extracted from the swamp since the 1940s. Therefore, it is possible that a new hydrologic and ecological equilibrium was reached long ago before the monitoring began and all changes detected by the present monitoring program are caused by climatic or other natural factors.

It is our opinion that wetland sources in the parks should not be developed for water supply. As the Kabiranyuma and Nyakagezi schemes illustrate, wetland water development schemes are prone to a high failure rate due to a number of socio-economic and engineering factors (Franks et al. 2003). High elevation swamps in the saddles between volcanoes are unique and valuable habitats and may constitute one of the most biodiverse ecological habitats in the Virunga region. The flora and fauna of these habitats exhibit a high degree of endemism (ITFC 2001). Other wetlands that may have equal or greater ecological value are the crater lakes and swamps that exist in the volcanic cones on the low saddle between Mt. Visoke and Mt. Sabinyo, and at the top of some of the major volcanoes. The extreme climate conditions within the afroalpine zone, especially the night frosts, are conducive to peat formation by preventing fast microbial decay of dead plant material.

Another project is being planned for collecting water from the Rugezi swamp between Mt. Sabinyo and Mt. Gahinga to supply water to the people of Ntebeko village in Uganda. This area contains one of the largest complexes of wetlands in the Virunga region. Serious thought should be given to weighing the ecological costs against the socio-economic benefits of this proposal.

7.5 Boreholes

Boreholes are used for water supply in many parts of Africa including Rwanda (fig. 8) and Uganda. Boreholes are used primarily in areas where ground water is the only water available. Several boreholes have been drilled in the Kisoro area with mixed success. Some are still operating sucessfully, and some are non-operational. Boreholes suffer from the same failures as other water supply schemes including pump breakdown, lack of replacement parts, and lack of maintenance. In areas with variable aquifer conditions like the volcanic rock aquifers of the Virunga region, several exploratory boreholes may have to be drilled before one with sufficient yield from a reasonable depth can be located.

Figure 8. Borehole operated with a hand pump supplies water to a village near Akagera National Park, Rwanda.

8. RECOMMENDATIONS AND NEXT STEPS

8.1 Administrative

A primary requirement for successful water resource management is an interested and engaged cadre of people that are versed in the issues, have knowledge of water resource engineering and the science of hydrology and aquatic biology, and have the authority to implement programs and projects. The following are recommendations for developing such a cadre:

1. Identify a regional water resources coordinator and coordinating agency/entity that can organize and direct a water resource information management, inventory, and monitoring program. While complex political factors may hamper effectiveness in this area, the ideal coordinating person or entity would have the capacity to work with NGOs and government agencies across borders in all three countries.

2. Designate/create a central storehouse and a regional data steward for improved communication and information storage and sharing for all water resources and climatic data.

3. Integrate water resource and aquatic species conservation initiatives, goals, and objectives into NGO and government programs.

4. Include hydrologists and aquatic biologists in the water resource planning and development process.

5. Develop a regional training program in monitoring and management of freshwater ecosystems.

6. Within protected areas, educate wardens and other managers about the importance of freshwater ecology and biodiversity (or create wardens specifically for aquatic species and hydrologic monitoring).

8.2 Inventory

Before sound recommendations can be made concerning development of additional water sources, an inventory of available sources and an assessment of the ecological values associated with the sources should be performed.

1. Perched springs: Perform a hydrogeologic investigation in the dry lava zone near the boundaries of the parks to identify and characterize perched aquifers that could be used for a local water supply. Include GPS location, aquifer volume, seasonality of flow, water quality, geologic setting, and wetland flora and fauna.

2. Dike-impounded springs: Perform a hydrogeologic investigation on the upper slopes of the volcanoes to identify and characterize aquifers that could be used for

a local water supply. These sources should only be used as a last resort due to probable ecological impacts from development.

3. Wetlands: Research the size, extent, and composition of wetland ecosystems and riparian forests. Map the periphery (size) and inventory flora and fauna, basic hydrology, and water quality.

4. Streams: Map watershed boundaries and inventory flow regime, water quality, degree of incision, and location of channel erosion in streams around the parks boundaries.

5. Aquatic biota: Establish species composition, distribution, and abundance of freshwater aquatic biota. In BINP information on the composition, distribution, and abundance of fish in Bwindi streams as well as harvest levels by locals will help in assessing the feasibility of sustainable use of river fisheries.

8.3 Monitoring

The lack of climatic and hydrologic data in the area hampers assessment of alternatives for water development and analysis of environmental impacts. The following types of monitoring efforts are recommended:

1. Climate: Improve existing rainfall monitoring stations and install new stations in areas with inadequate coverage. Possible locations include park patrol stations, park headquarters, Kabiranyuma swamp and other selected sites within the parks. Use accurate measuring equipment and train personnel in proper reading and calibration of the instruments.

2. Springs: Begin monitoring the flow rate and seasonal variability of candidate perched springs and dike-impounded springs, and improve the monitoring of flow and water quality of regional contact springs.

3. Lakes and wetlands: Institute a hydrologic monitoring program on: Ngezi Lake, Muderi I and II, Muntango crater lake on Mt. Karisimbi, Lake Bulera and Rugezi marsh, and Rugezi swamp complex between Mt. Sabinyo and Mt. Gahinga. Improve hydrologic monitoring of Kabiranyuma swamp.

4. Aquatic Organisms: Monitor aquatic ecosystem health following development of a spring or swamp water source.

8.4 Water supply development

The following are steps that can be initiated immediately to begin the planning process for water supply system development:

1. Organize stakeholder groups and work through decision making matrix (Table 1).

2. Develop a plan to install rainwater collection systems.

3. Assess the total future water needs of the population based on the per capita projected growth pattern. This will help guide the selection of water sources for development.

4. Start a site specific source water assessment for those sources already identified for development (e.g. Nkanka, Kamira).

5. Perform a groundwater resource evaluation for exploratory borehole drilling.

6. Perform a thorough environmental analysis for any developments or improvements within the parks (i.e. excavating material from wetlands – Ngezi).

7. Avoid developing water systems drawing on wetlands in the parks given their high ecological value within an island of threatened biodiversity. Water from swamps is often exposed to contaminants and should not be used without adequate treatment.

8. Protect the Lake Bulera/Rugezi marsh watershed complex from further disturbance so that climatic shifts don't result in cessation of outflow from Lake Bulera eliminating power generating capacity.

8.5 Suggestions for planning a water supply scheme

The major reason for failure of some of the water supply schemes in the area appears to be poor planning. Before embarking on a project the following important planning steps need to be completed:

1. *Define the problem.* For the Virunga region, the problem is getting water to people in the dry lava zone so that they don't feel the need to go into the parks to collect water.

2. *Organize community support.* The project must have community support to be successful. The project must be promoted so that the community becomes aware of the benefits to their everyday lives. All stakeholders need to be involved in the decision-making process and local people must be trained to operate and maintain the system.

3. *Collect environmental and socio-economic data*. The water development should not damage valuable ecological resources. Water quality and quantity must be analyzed. A water source that dries up or makes people sick is destined to fail. Based on local population growth projections, the project should be designed to supply water to a larger future population.

4. *Analyze alternatives and select a method.* Using Table 1, community input, site specific data, and the water sources available, determine the type of source and distribution system most appropriate to the communities needs. Evaluate the

reasons for success or failure of projects in other communities and adjust the development plan accordingly.

8.6 Conservation efforts surrounding the parks

Continued and/or intensified development of agroforestry programs for the region surrounding the national parks is very important to the area for the conservation of local soil, water, flora, and fauna. Agroforestry can help mitigate further environmental damage to areas both inside and outside of the parks from broad scale land-use/land-cover change. The adaptation of agroforestry practices to site specific physical and socioeconomic situations helps to prevent erosion, loss of soil fertility, improve groundwater supply, and provide socially and economically valuable goods such as firewood and those derived from ethnobotanical species.

The direct benefits to the parks through the implementation of these systems are several. Some of these benefits can be seen in:

- Land stabilization that can prevent the uphill propagation of erosional processes such as headcuts in streams, and gullies on agropastoral land that can enter the parks and cause chronic erosion features which negatively affect soil, water, and ecosystem function.
- An increase in habitat for certain forest species.
- Decreases in pressure on adjacent forest to provide firewood and other resources.

On a regional level, the widespread development of agroforestry provides economic benefits by improving and diversifying farm production, while preserving unique and biologically valuable protected areas. Having more trees on the landscape can also have a favorable effect on local climatic conditions as the roots of trees are able to tap deeper ground water resources which provides increased atmospheric moisture through transpiration, regulate temperatures, and preserves soil moisture through the provision of shade and increased organic materials in soils. Cultural benefits may be realized through the incorporation of ethnobotanical species into agroforestry systems and the preservation of indigenous knowledge.

8.7 Potential future role for USFS

USFS technical experts could help address critical resource issues and concerns. Some of the aspects of this assessment that USFS would be qualified to address are:

1. Training of interested NGOs, park personnel and local government personnel in water flow, water quality, and aquatic biota monitoring and inventory techniques, stream channel stability assessments, and water supply evaluation and investigation techniques.

2. Assist in identification and evaluation of perched and dike-impounded ground-water sources.

3. Conduct a preliminary water resources assessment survey in DRC if the security situation improves.

4. Assist ITFC in designing and setting up a hydrologic component of monitoring for the Kabiranyuma swamp and Rugezi swamp.

5. Assist local entities in locating potential water supply borehole locations.

6. Assist in development of a water resource data management system.

Table 1. Decision matrix for comparing the advantages and disadvantages of available water source options.

Source	Quality	Quantity	Reliability	Accessibility	Ecological Impacts	Cost
Rain Catchments	Good to poor, disinfection may be necessary	Moderate but variable, inadequate during prolonged dry seasons, storage necessary	Good, some maintenance and cleaning required	Good, cisterns located near users	None	Low, one time cost for individual homes, moderate for large buildings
Dike-Impounded Springs	Good	Fair to good, seasonal fluctuations likely	Fair	Poor, located high on flanks of volcanoes and far from population	Long pipeline required in Parks, Possible damage to spring ecosystem	Moderate to high construction, environmental impact analysis and maintenance costs
Perched Springs	Good	Fair, seasonal fluctuations likely	Fair	Good, located where needed most	Possible damage to spring ecosystem	Low to moderate depending on extent of distribution
Regional Contact Springs	Primarily good quality but some undesirable constituents may exist locally	Good, large volume with little seasonal variation in discharge	Good	Good	Possible damage to spring ecosystem	High pumping costs, dependant on head; require operation and maintenance budget at moderate to high cost
Swamps	Poor to fair, treatment generally necessary	Good to moderate, quantity decreases in dry seasons	Maintenance required	Poor	Long pipeline required in Parks, Possible damage to unique wetland ecosystem	Moderate to high construction, maintenance and environmental impact analysis costs
Boreholes	Good, protected from surface contamination sources	Good to Poor depending on yield of local aquifer	Good, minimal seasonal fluctuations	Good	None unless well pumping dewaters surface water systems	High exploration and installation costs, moderate maintenance costs
Reservoirs	Good to poor, requires treatment	Generally good depending on site and source conditions	Fair, subject to sedimentation and climatic variations	Good to poor depending on distribution system; located out of lava zone to prevent excessive seepage	Potentially large impact depending on size of impoundment	High design, construction, and maintenance costs

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APPENDIX A: MISSION SUMMARY AND ITINERARY OVERVIEW

Friday, March 4: USFS team departs the US for Kigali via Amsterdam and Nairobi.

Sunday, March 6: Team arrives in Kigali in the late morning. Held a meeting in the evening with Raphael Rurangwa (IGCP/Rwanda program leader and primary host for the USFS team on this mission) and Maryke Gray (IGCP monitoring specialist) to discuss logistics of the mission and make preparations for an introductory briefing at USAID the next morning. Later in the evening, we were joined by Eugene Rutagarama, the Director of IGCP based in Nairobi.

Monday, March 7: Following a security briefing provided by Robert Karpowski, the Regional Security Officer from the US Embassy, Mr. Chaveas, Mr. Gritzner, and Mr. Gurrieri briefed Andy Karas, the team leader for USAID - Agriculture and Rural Enterprise Development, and other interested parties, on the mission objectives. An introduction to the USFS and to the goals of this mission was provided, followed by a discussion focusing on the water resources in the region and what work was being performed in this regard by the agencies and NGOs represented by those in attendance. This meeting was attended by:

- Andy Karas — USAID/Rwanda
- Wendy Marshall — USAID/Washington, Office of Democracy and Governance
- Albert Yaramba — MINITERE
- Epimaque Ntilivamunda — MINITERE
- Raphael Rurangwa — IGCP
- Emmanuel Hakizimana — ORTPN
- Maryke Gray — IGCP
- Andrew Jones — CARE
- Michel Masozera — WCS

At the conclusion of this meeting, the USFS team traveled to Ruhengeri, accompanied by Raphael Rurangwa and Maryke Gray of IGCP and Wendy Marshall of USAID/Washington. Ms. Marshall joined the team at the request of USAID/Rwanda until Wednesday, March 9^{th} in order to assess possibilities for cross border initiatives in the region.

Tuesday, March 8: A morning meeting was arranged at IGCP's headquarters in Ruhengeri to brief local stakeholders on the mission and to learn of their work in the region. A presentation was delivered by the USFS team on the process of performing a watershed assessment and identifying water resources for use by local communities. This meeting was attended by:

- Epimaque Ntilinameudu — MINITERE
- Peter Muvunyr — ARASI
- Alexis Niyongombwa — CARE
- Charles Nsabimana — ORTPN/PNV
- Mediatrice Bana — IGCP
- Raphael Rurangwa — IGCP
- Maryke Gray — IGCP
- Telesphore Rwarabartizi — ARASI
- Felicia Nutter — MGVP
- Wendy Marshall — USAID

In the afternoon the team was accompanied by Charles Nsabimana (ORTPN) and Justin Rurangirwa (ORTPN, warden of Volcanoes NP) on a field visit to lakes Luhondo and Bolera. A hydroelectric scheme has been developed between these two lakes which lie at different altitudes, by diverting a stream that ran between them and taping its flow for power generation.

This visit was followed by a hike to the Kagamo spring on the border of the park, a tapped source, developed approximately 20 years ago, which feeds a small village and land belonging to the local bishop.

Wednesday, March 9: The morning was spent visiting three taped springs around Ruhengeri with Mr. Nsabimana and Mr. Rurangirwa, as well as Epimaque Ntilinameudu of MINITERE and Mr. Kalisa, the head of ElectroGaz in Ruhengeri, the company which has developed these springs. The springs visited were Mutobo, Rubindi, and Mpenge.

The afternoon was spent visiting Bushohero spring, just inside the park boundaries, which has a small pipe which feeds to a local community. This was followed by an evening meeting with Katie Fawcett, the Director of the Karisoke Research Center run by the Dian Fossey Gorilla Fund International to learn of the monitoring and research performed by this organization.

Thursday, March 10: In the morning helicopter flights were taken by the team for an aerial perspective of Volcanoes National Park on the Rwandan side of the border. Due to weight limitations Mr. Gurrieri and Mr. Gritzner took separate, half hour flights, accompanied each time by Charles Nsabimana (ORTPN).

In the afternoon the USFS team met with Mark Mwine, IGCP Enterprise Officer for Rwanda, to learn of work on various community economic development activities. This was followed by a drive to sector 5 of the park (west side) with Mr. Nsabimana (ORTPN) and Mediatrice Bana (IGCP field officer). This is evidently the driest region surrounding the park, and limited rainwater collection systems were observed here. No water is supplied to these communities and many people enter the park to collect water from a crater in this region. Some who collect return and sell water to others.

In the evening, the USFS team paid a courtesy call to the office of Wilson Rutaganira, the Executive Secretary of the Ruhengeri Province.

Friday, March 11: A full day workshop was organized on this day to make up for the USFS team’s inability to cross the border into the DRC and observe conditions on the ground first hand. Various government and NGO representatives crossed the border from Goma and met with us in the Rwandan town of Gisenyi. During this workshop, the USFS team again presented the goals of the mission and the process of performing a watershed and water resource analysis. Following a question and answer session, the workshop participants were divided into a government and an NGO group and given the task of discussing what the issues were in their home region in terms of community access to water and encroachment into the park for water collection. The groups were also asked to come up with a list of available data that they knew of relating to rainfall and other climatic information, lake and swamp levels, location of weather stations and their historical data, water collection points, geologic maps, any biological surveys performed, and the locations of any boreholes. The participants were asked to provide a list of who possessed any such data. Speakers for each group then presented their conclusions. Notes from each working group can be found in Appendix B. This workshop was attended by the following individuals:

- Raphael Rurangwa — IGCP
- Paulin Ngoboleo — IGCP DRC
- Honore Mashagiro — ICCN/PNVI Sud
- Petillon Lutuya — IGCP DRC
- Deo Kujirakwinja — WCS
- Samuel Boendi — WWF/PEVi
- Masurbuko Kubuya — Administrator, Nyiragongo Territoire
- Bamenya Ntahobari Burunga — Chef de Groupement Kibumba
- Mashagiro Jean-Charpostome — Chef de Groupement Rugari/Rurishuru
- Rusuzi Ladislas — Bureau Provincial de Development, Roqui
- Dio Mbuma — ICCN/PNVi
- Makambo Emola — Charge d'Entreprise

Saturday, March 12: USFS team hiked up to Ngezi Lake with Mr. Nsabimana (ORTPN). According to ORTPN this is a rainfed lake with no streams feeding it and the water level has been receding in recent years. Work has been done in the past by ORTPN to dig out vegetation in the lake and there are plans to repeat these efforts.

Sunday, March 13: Group session in the morning amongst USFS team to brainstorm thoughts on Rwanda side and begin thinking of recommendations. In the afternoon, the USFS team drove to Kisoro, Uganda with Raphael Rurangwa where they were then based for the next four days. Met with James Byamukama, IGCP field officer in Uganda and our primary contact in that country.

In the evening, the team drove to the Echuya forest reserve with Mr. Rurangwa and Mr. Byamukama with stops along the way to look at a new rain collection system on a church and a small pond which is used as a water source by people cultivating the hillsides. Following this activity, we met with Jody Stallings and Paul Crawford of USAID/Uganda and Helga Rainer of AWF/Uganda over drinks and dinner in Kisoro.

Monday, March 14: A morning courtesy call was made to the local district offices for introductions and a brief discussion of our work. In this meeting the USFS team met with:

- Wilbrord Turimaso — District Water Officer
- Dr. Phileon Mateke — Chairperson of the District
- Assa Mugyenyi — District Internal Security Officer
- Mr A. Kiganda — Chief Administrative Officer
- Robina Gagiriba — UWA – Warden of Tourism, Mgahinga NP

In the afternoon the team hiked to the Nyakagezi water scheme inside Mgahinga NP. This scheme is not very productive, and due to the low flow, people are skipping the tap entirely and coming straight to the source in the park to collect water. This was followed by a visit to the Cyuho pumping station which provides water for the town of Kisoro. Some eyes to this spring have high fluoride content and were not tapped, but many people still collect water from this runoff leading to dental problems.

Tuesday, March 15: This day was spent hiking to Kabiranyuma swamp, located on a saddle between Muhavura and Mgahinga volcanoes, with the senior warden for Mgahinga NP, Ghad Mugiri.

Wednesday, March 16: In the morning the team tracked gorillas in Bwindi Impenetrable NP. This was followed by a meeting with the UWA Park Warden for the south side of Bwindi, Moses Oringa. Mr. Oringa informed us that there have not been any recorded incidents of people entering the park to collect water but that they travel great distances to collect it from a stream which forms the boundary of the park and is now included in a new buffer zone.

This meeting was followed by a visit to the Rubuguri water scheme inside of BINP with Victor Magala, the Community Conservation Warden and Silvano Nshekanabo, the Chairperson of the water and sanitation district.

Thursday, March 17: In the morning the USFS team met with local stakeholders to discuss the mission and some preliminary findings. This meeting was attended by:

- Paul S. Manirakiza — Deputy Chief Admin Officer for Kisoro District
- Ghad Mugiri — Senior Warden In Charge, Mgahinga NP
- Moses Olinga — Warden In Charge – Nkuringo (Bwindi south)
- Livingstone Nabimanya — AFRICARE
- Wilbrord Turimaso — District Water Officer – Kisoro
- Dennis Babaasa — ITFC
- W. Ndagijimana — Chairperson – KTWSSB (Kisoro Township Water Safety and Sanitation Board)
- Patience Shorimyana — Kisoro Water Board
- Silvano Nshekanabo — Chairperson WSSB
- James Byamukame — IGCP
- Dorothy Nyiruneza — BTS
- Raphael Rurangwa — IGCP

This meeting was followed by drinks and further discussion at a hotel in Kisoro. In the afternoon, the USFS team, with Mr. Rurangwa, returned to Kigali.

Friday, March 18: In the morning the team met with the USAID/Rwanda mission to provide a debriefing of the mission and some preliminary findings and anticipated recommendations. The USFS presentation was followed by a group discussion on the mission and potential follow up activities. This debriefing was attended by:

- Jim Anderson — USAID/Rwanda Mission Director
- Andy Karas — USAID/Rwanda
- Timothy Karera — USAID/Rwanda
- Venant Safali — USAID/Rwanda
- Tim Muzira — USAID/Rwanda
- Emmanuel Hakizinana — ORTPN
- Raphael Rurangwa — IGCP
- Epimaque Ntilivamunda — MINITERE
- Maryke Gray — IGCP
- Jean-Claude Gasana — CARE

o	Dan Balzer	Regional Environment Officer for East Africa, US State Dept/Addis Ababa
o	Albert Yaramba	MINITERE

Sunday, March 20: USFS team departed Kigali for return flights to US.

APPENDIX B: WORKING GROUP NOTES FROM WORKSHOP WITH DEMOCRATIC REPUBLIC OF CONGO REPRESENTATIVES

Government Group

Watershed analysis for drinking water supplies:

A. Identification of water related problems
   1) Absence of sources in all the villages along the border of the park, notably:
      a. Territory of Nyiragongo: Groupings of Kibumba, Buhumba, Kibati, Muja and Rusayo
      b. Territory of Rutshuru: Groupings of Rugari, Gisigari,Bweza and Jomba
   2) Absence of public and private infrastructure for supplying drinking water
   3) Lack of financing

B. Impact of the lack of water:
   1) The population is condemned to use dirty rainwater, declared unsuitable for consumption by the vulcanologists;
   2) The population is susceptible to water borne diseases;
   3) The population encroaches on the park to search for water.
      Examples:* for the territory of Nyiragongo: the marsh of Gikeri situated at the foot of the Mikeno volcano; *for the territory of Rutshuru: the source of Kizenga at Rugari.
   4) Absence of socioeconomic development projects. For example in the grouping Rugari: relocation of the school St Paul for Bukavu, relocation of the small seminary for Buhimba, the suppression of the boarding school of the primary school Rugari, impracticality of raising livestock in Rutshuru as in Nyiragongo.

C. Hydrologic potential on the ground:
   1) Territory of Nyiragongo: None
   2) Territory of Rusthuru:
      a. Grouping of Rugari: the parish of Rugari partnered with some European organizations to harness some sources:
         i. Sources Rutonyanga - Nyabisiga as far as the Grouping office
         ii. Source Kavumo – Kwezi I - Kwezi II and Cabugurwa to the big road
         iii. Sources Rembwe to the big road.
      All these sources have to low flow levels, which tend to dry up, especially during the dry season.
      b. Grouping of Jomba: the Kamira source, this source has a large flow to provide water the groupings of Jomba, Rugari, Gisigari and of Bweza in the territory of Rutshuru as well as the whole territory of Nyiragongo.
      In the colonial era, water channeling was performed from this source in the grouping of Rugari. This channeling was limited to Nturo (Rugari).

D. Studies already performed:

1) The KAMIRA project by the SNHR (*La Societe Nationale d'Hydrolique Rurale*): this one was subjected to the CEE (?) for financing but it did not benefit from a favorable continuation.

E. Sources of data for the region:
1) Rainfall: RVA (Régie des Voie Aèriennes – airviation authority)
2) Climate: RVA
3) Mapping: ICCN
4) Geology: Division of Mines and Geology

F. Recommendations
To resolve the problem of the lack of drinking water, it will be necessary to finance the Kamira project.

NGO Group

THE PROBLEM OF WATER IN THE WATERSHEDS OF CONGO.

Concerning the different data that one can find on this crucial problem, we present in the lines that follow the different sources of potential data:

A. RAINFALL
1) The RVA
2) *L'Institut National pour Etudes et Recherches Agronomiques* (INERA) (The national institute for agronomic studies and research).
3) A book entitled: Guides to the National Parks of the Virungas which gives different geographic elements.

B. MAPPING
1) The PICG(?) et WWF can furnish geographic maps of the Virungas NP and new cards are being published consistently.

C. GEOLOGIE
1) *Le Centre de Recherches en Sciences Naturelles* (CRNS) (The Center of research in natural sciences) of Lwiro
2) INERA
3) *L'Institut Superieur Pedagogique* (ISP) has a department of geography that can furnish geologic data of the region.

D. WEATHER STATIONS
1) The weather station of Rumangabo is no longer operational since the war. All the equipment were pillaged during the war and the available data have unfortunately disappeared.
2) The RVA can be considered as the only station with available meteorologic data.

E. AQUATIC SPECIES

1) The Biodiversity of the Albertine Rift is a book that provides information on the different aquatic species located in the region which are currently being studied and one can also utilize the web site web www.albertinerift.org for this subject.

F. HYDROGRAPHY

1) Oxfam
2) The International Committee of the Red Cross
3) ICCN
4) *La Societe Nationale d'Hydrolique Rurale* (SNHR) (The national society of rural hydrology)
5) *Le Comite de Developpement des Communautes* (CODECO) (committee for community development)

G. SPECIFIC PROBLEMS LINKED TO WATER

1) The biggest problem is at Kibumba where the population is forced to go to collect water in the park because it has no other source in this area. The only possible alternative would be to look for water from Kamira, which is very far and is in need of investments for improvements.
2) Regarding questions of sources, the socioeconomic study performed jointly by IGCP and WCS furnishes a many pieces of information on this subject. Additionally, the NGOs and local organizations can furnish complementary information.

It is has to noted that the elements that we are presenting in this report are merely indicative and that the diverse data that could be furnished by these different sources could probably expanded considering the time granted to us.

APPENDIX C: CONTACTS MADE

IGCP

Raphael Rurangwa	Rwanda Program Leader (Kigali, Rwanda)
Maryke Gray	Monitoring Specialist (Ruhengeri, Rwanda)
Eugene Rutagarama	Director (Nairobi, Kenya)
Mediatrice Bana	Field Officer (Ruhengeri, Rwanda)
Mark Mwine	Enterprise Officer (Rwanda)
Paulin Ngoboleo	DR Congo Program Leader (Goma, DRC)
Petillon Lutuya	IGCP, DRC
James Byamukama	Field Officer (Kabale, Uganda)

USAID

Rwanda

Jim Anderson	USAID/Rwanda Mission Director
Andy Karas	Team Leader, Agriculture and Rural Enterprise Development
Timothy Karera	
Venant Safali	
Tim Muzira	

Uganda

Paul Crawford	Team Leader SO7, "Expanded sustainable economic opportunities for rural sector growth"
Jody Stallings	Natural Resources Management Advisor

OTHER US GOVERNMENT

Wendy Marshall	USAID/Washington, Africa Coordinator, Office of Democracy and Governance
Dan Balzer	US State Dept, Regional Environmental Officer –Addis Ababa

RWANDA

Government

Albert Yaramba	MINITERE
Epimaque Ntilivamunda	MINITERE
Emmanuel Hakizimana	ORTPN (Kigali)
Charles Nsabimana	ORTPN (Ruhengeri)
Justin Rurangirwa	ORTPN (Warden for Parc National des Volcans)
Wilson Rutaganira	Executive Secretary, Ruhengeri Province

NGOs

Andrew Jones	CARE (Kigali)
Michel Masozera	WCS (Kigali)
Peter Muvunyr	ARASI (Ruhengeri)
Alexis Niyongombwa	CARE (Ruhengeri)
Telesphore Rwarabartizi	ARASI (Ruhengeri)
Felicia Nutter	MGVP

Katie Fawcett	DFGFI
Jean-Claude Gasana	CARE

DEMOCRATIC REPUBLIC OF CONGO

Government

Honore Mashagiro	ICCN
Masurbuko Kubuya	Administrator, Nyiragongo Territoire
Bamenya Ntahobari Burunga	Chef de Groupement Kibumba
Mashagiro Jean-Charpostome	Chef de Groupement Rugari/Rurishuru
Rusuzi Ladislas	Bureau Provincial de Development, Roqui
Dio Mbuma	ICCN
Makambo Emola	Charge d'Entreprise

NGOs

Deo Kujirakwinja	WCS
Samuel Boendi	WWF

UGANDA

Government

Wilbrord Turimaso	District Water Officer (Kisoro)
Dr. Phileon Mateke	Chairperson of the District (Kisoro)
Assa Mugyenyi	District Internal Security Officer (Kisoro)
Mr A Kiganda	Chief Administrative Officer (Kisoro)
Robina Gagiriba	UWA – Warden of Tourism, Mgahinga NP
Ghad Mugiri	UWA – Senior Warden, Mgahinga NP
Moses Olinga	UWA – Park Warden for BINP, South side
Victor Magala	UWA – Community Conservation Warden
Silvano Nshekanabo	Chairperson of the water and sanitation district (Rubuguri)
Paul S. Manirakiza	Deputy Chief Administrative Officer (Kisoro District)
W. Ndagijimana	Chairperson, Kisoro Township Water Safety and Sanitation Board
Silvano Nshekanabo	Chairperson, Kisoro Township Water Safety and Sanitation Board
Dorothy Nyiruneza	BTS

NGOs

Helga Rainer	AWF (Kabale)
Livingstone Nabimanya	AFRICARE
Dennis Babaasa	ITF