Preliminary Environmental Impact Assessment of Lake Katwe Salt Plant Western Uganda

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PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT OF LAKE KATWE SALT PLANT, WESTERN UGANDA

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This report is based on a study that was conducted by a team from the Makerere University Institute of Environment and Natural Resources and the IUCN from 6 to 14 April 1989.

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I INTRODUCTION

This is one of two reports which present the results of preliminary Environmental Impact Assessments (EIAs) for the proposed Kasese cobalt processing plant and rehabilitation of the Lake Katwe Saltworks.

These studies were undertaken for a number of related reasons, viz:

With the establishment of Makerere University Institute of Environment and Natural Resources (MUIENR), a body of expertise is being formed to provide advice to Government and Industry on environmental aspects of the many projects now being developed as part of Uganda's rehabilitation and further development. Whilst staff and associates of the Institute have ample experience in their own disciplines, they have generally not been exposed to the integrated, project-orientated approach required in EIA. Training in that approach is therefore necessary, and it was felt that direct involvement in 'live' EIA studies would be the most beneficial form of training.

Growing commercial interest in the rehabilitation and development of two major industrial enterprises on the margins of Queen Elizabeth National Park indicated that the time had come to initiate EIA's for the projects, to ensure that environmental protection and conservation were adequately considered within future engineering studies and designs.

Increasing pollution arising from the existing cobalt sulphide stockpiles indicated that the Kasese site needed investigation regardless of whether a cobalt plant project is ultimately initiated.

The nature of the two studies undertaken was Preliminary EIA. That is, a series of studies with the objectives of:

- o Initial identification of the major potential impacts.

- o Preliminary assessment of the scale and significance of the impacts.

- o Determination of further studies required at the detailed assessment stage to confirm and quantify impacts.

- o Recommendation of the main ameliorative measures required to avoid or minimise the adverse impacts initially identified.

Whilst the two projects are discussed in two separate reports they do however, have certain linkages, such that their contemporaneous study was both economically and intellectually beneficial. Both project sites are immediately adjacent to Queen Elizabeth National Park and have the capability of affecting it; indeed the Kasese site already does. Similarly, both are adjacent to the Lake George/Edward system. Both projects use local raw materials and produce wastes that need to be disposed of, and the Kasese plant could use waste from the Katwe plant as one of its raw material inputs.

As in any EIA, these two studies included the collection of existing information on the proposed processes and the proposed industrial sites. However, given the skills available to MUIENR, considerable emphasis was placed on field studies of baseline environmental quality and existing anthropogenic effects on the environment. As a consequence, an important part of the training exercise was the development of skills required to convert field data into assessments and interpretations of use to the decision-maker in Government and industry.

The study and preparation of this report were made possible through financial and technical support from the World Conservation Union (IUCN), to whom MUIENR is most grateful. The study group received co-operation from many organisations and individuals alike, but special thanks go to the management of Lake Katwe Salt Company and Kilembe Copper Mine Limited, and to the many artisan salt workers at Lake Katwe whose assistance was most invaluable. We hope that the discussions presented in this and the sister report on cobalt processing at Kasese will help to create suitable environments for all the people and the entire biotic community in and around Katwe and Kasese towns.

II <u>REGIONAL SETTING</u>

The landscape with which one is greeted when approaching the Rift Valley is certainly very impressive. A number of features combine to create this impressive landscape.

The extensive earth movements and volcanic eruptions which shaped the region's physiognomy to its present form occurred mainly during the past half million years during the Pleistocene period, which in geological terms is relatively recent. The recent nature of the earth movements which formed the valley is shown by the steepness of some of the bounding escarpments, and by the fact that the Rwenzori mountain range (affectionately known as the Mountains of the Moon) emerges almost directly from the plain with virtually no significant foothills (Fig. 1).

The Rwenzori range is an up-faulted (horst) block of mountains found in the middle of the rift valley, and consisting of pre-cambrian highly metamorphosed and deformed rocks. Owing to high precipitation, the range is naturally covered by lush forest at lower altitudes which gradually changes to alpine vegetation at higher altitudes. The highest mountain peaks are covered in permanent glacier.

On its floor, the rift valley is largely covered by inconsiderate fluvial-lacustrine sediments with a thin veneer of soil on top. The valley floor vegetation is therefore mostly savannah, with only scattered trees and shrubs. Most of this land constitutes the Queen Elizabeth National Park (QENP).

The main water bodies in the area are Lakes Edward and George which are connected by the Kazinga Channel. The Rwenzori mountain range together with the eastern escarpment constitute the main catchment for this water system.

Katwe and Kasese towns/settlements lie on the valley floor. They are, respectively, very close to the southern and south-eastern foothills of the Rwenzori Mountain Range. Katwe lies on the shore of Lake Edward, whereas Kasese is situated close to Songo swamp whose waters join the Lake Edward-Lake George system.

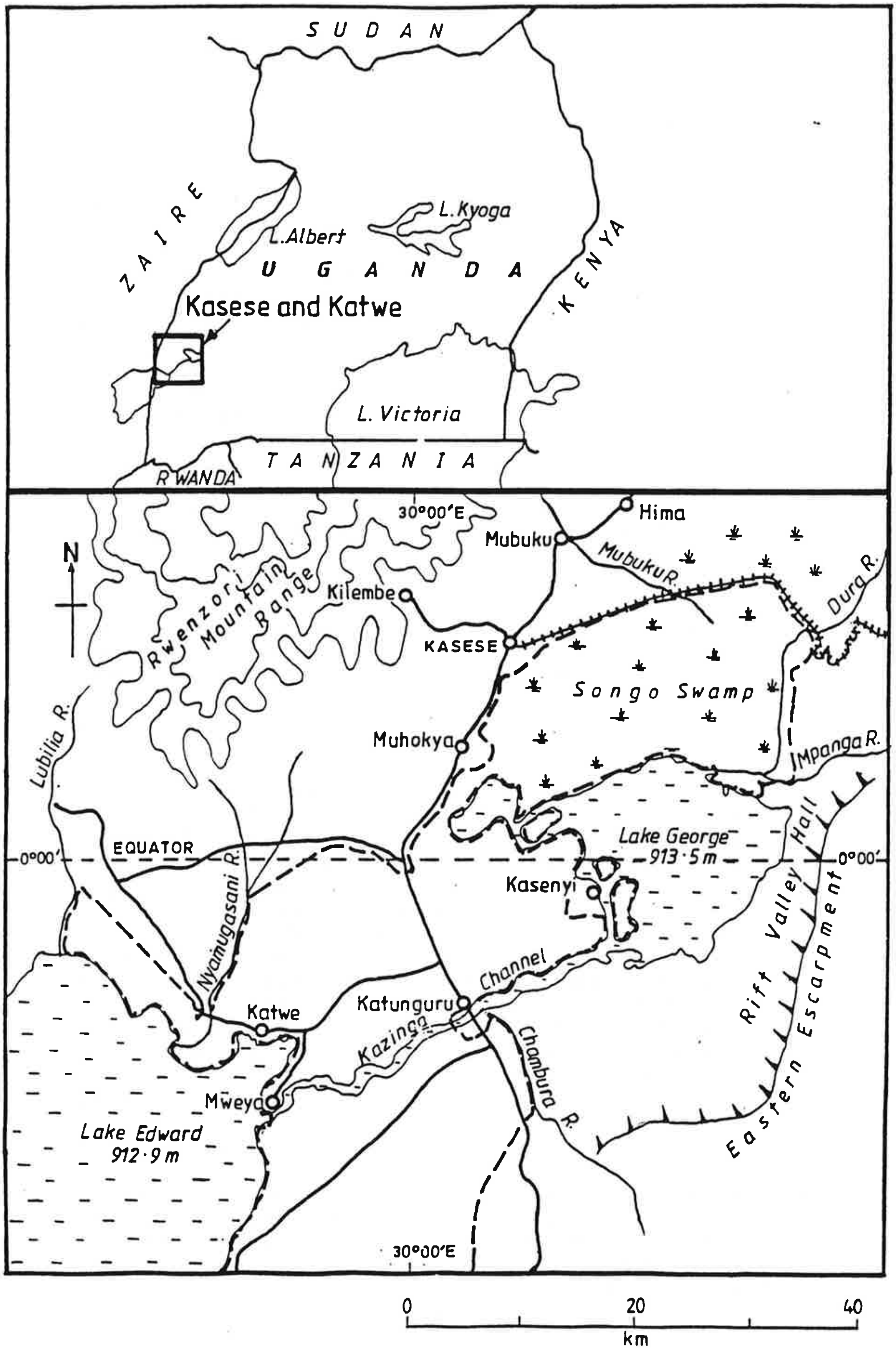


Figure 1: Part of the western rift valley of Uganda, showing Kasese and Katwe in relation to their surroundings.

III LAKE KATWE SALT PLANT

1. THE NATURAL ENVIRONMENT

1.1 Geology

The geology of the western rift valley has been detailed by Bishop (1970). Suffice it to mention here that this part of the valley is an area of extinct volcanic activity, and a number of volcanic explosion craters are found (Fig. 2). Some of the craters are dry, but others contain water. The water may be fresh, brackish or saline. The best known of these craters is Lake Katwe, which has been the source of salt in the region for many centuries. Even today, Katwe town's main human activities are directly or indirectly related to the local artisan salt extraction industry from the lake. The other salt lakes include Lake Munyanyange, Lake Nyamununka and Lake Kasenyi. Of these, only Lake Kasenyi does sometimes have appreciable deposits of salt for extraction, but even then the deposits are never of the quantity and quality to match those of Lake Katwe.

1.2 Soils

The soils at Katwe fall under the Kyamutuma series of grey black soils derived from volcanic ash. Inside craters, the soils are often saline.

1.3 Climate

The climate is tropical with two rainy seasons each year, in March-May and September-November, and with mean annual rainfall of about 800 mm. The mean annual temperature is 23°C, with mean annual maxima of 28°C and mean annual minima of 18°C. No month differs from these figures by more than 1 or 2°C in either direction. Monthly mean sunshine periods are between 5.5 and 8.0 hours, with the lowest values in October and November. Solar radiation is also high, but does not precisely follow the sunshine pattern because of extensive smoke haze which develops during the dry season. Potential evaporation at Mweya (nearby to Katwe) exceeds precipitation in almost all months, thus explaining the severe aridity that is sometimes experienced in the area.

1.4 Vegetation

The vicinity of Lake Munyanyange provides a typical vegetation profile for the crater lakes in the area. The vegetation around Lake Munyanyange was however singled out because it will be at most risk from the proposed development of the Katwe Salt Industry. The vegetation around the lake is as follows:

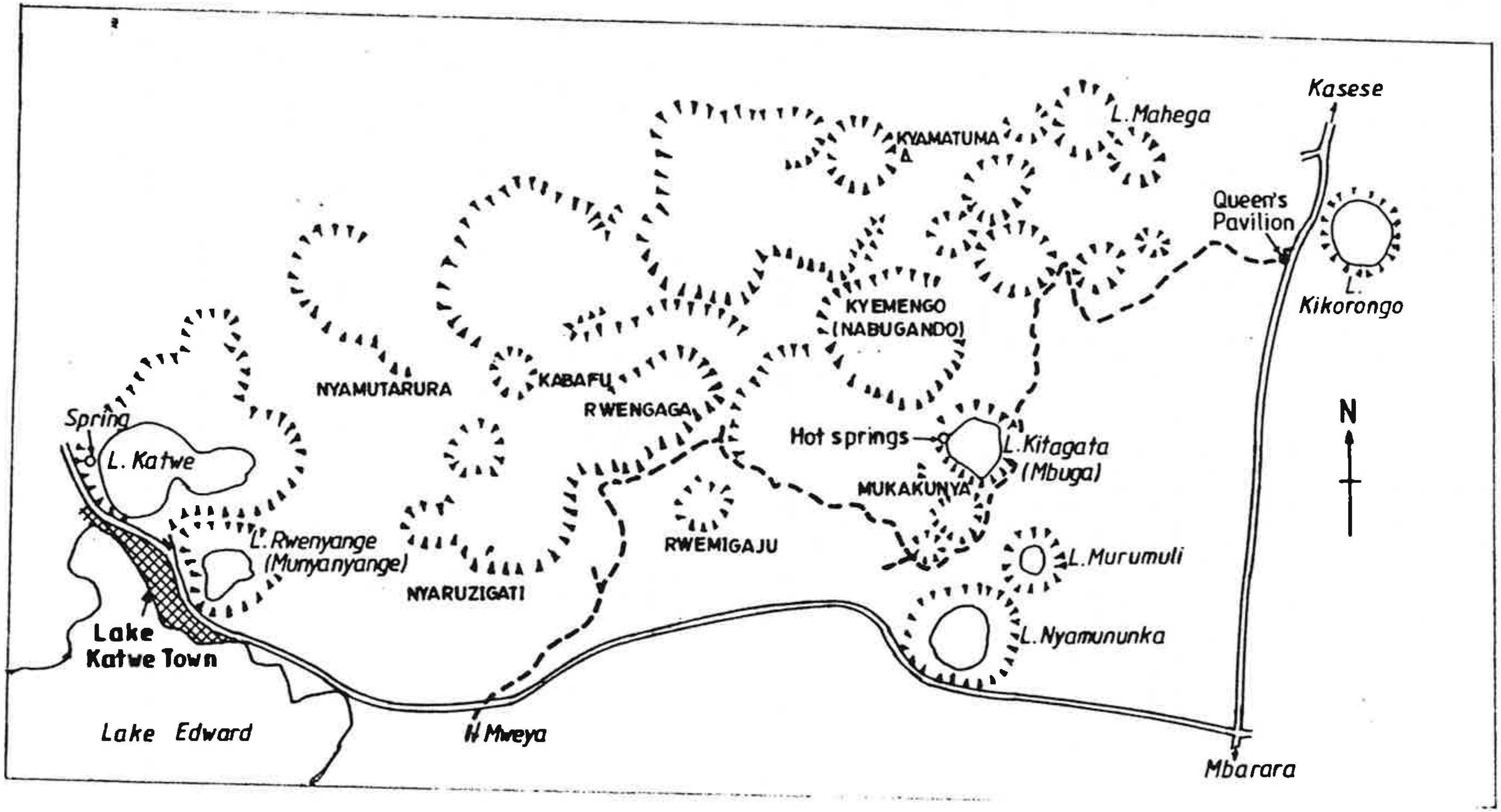


Figure: 2: The explosion craters in the Katwe-Kikorongo area.
All the lakes shown are Saline.

Crater Slopes: The vegetation here may be termed as *Sporobolus pyramidalis* grassland which is heavily grazed mainly by domestic animals. There are many patches of bare ground, especially at the beginning of slopes. The dominant grass species include *Bothriochloa insculpta, Digitaria scalarum, Chloris gayana, Microchloa kunthianum, Sporobolus stapfianus, Cenchrus ciliaris, Hyperrhenia filipendula* and *Sporobolus pyramidalis*, with scattered trees of *Euphorbia candelabrum* and *Acacia hockii*.

Crater Floor: The vegetation here is dominated by *Cyperus laevigatus* which occurs in an almost pure stand at the edge of the saline water or mud. Around the *Cyperus* community is another almost pure stand of *Sporobolus homblei*. The two communities are associated with *Odyssea jaegari*, a very rare grass species which in Uganda only occurs around Lakes Katwe and Munyanyange. The subzone further away from the lake consists mainly of *Sporobolus/Chloris* grassland, dominated by *S. pyramidalis, S. homblei*, and *C. gayana*, but with small associations of *Cyperus tenerifae, Portulacca foliosa, Craterostigma lanceolata*, and *Pulchea ovata*. There are scattered thickets of *Azima tetracantha*.

1.5 Birds

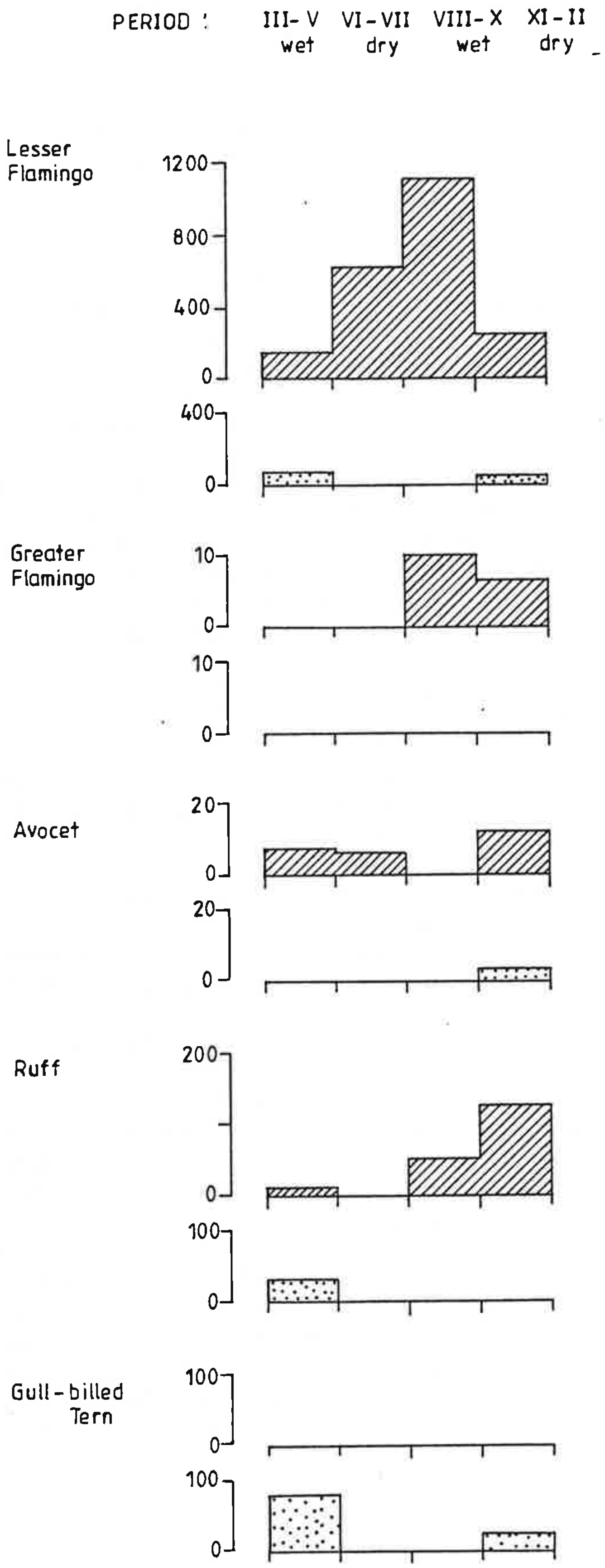
As far as bird populations are concerned, Lake Munyanyange is definitely the most important of the saline lakes in the region. Between 1984 and 1989, the lake was visited 25 times, and waterbirds counted on each occasion.

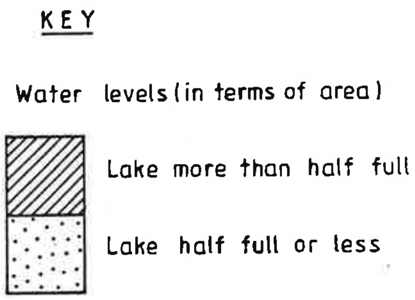
Well over 40 species of water birds were recorded during the study. These are detailed in the Appendix. Numbers of five of the most interesting species are depicted in Figure 3 which shows average numbers according to season and water level (on two visits, only flamingos were counted).

Lesser Flamingos were seen on 16 occasions, the maximum number recorded being about 3000 in July 1987. It happened that the lake was then fairly full, although usually it would be low in July. As the figure shows, there are usually more flamingos at times of higher water levels. (When the lake is low, as during our visit in April 1989, there may be larger numbers on the adjacent Lake Katwe). Whilst at the lake, birds spend much of the day feeding, but they also rest there too.

The **Greater Flamingo** is much rarer. The highest number recorded so far has been 11 in November 1984. This species feeds mainly on zooplankton; which were probably most abundant in the lake at this time.

Figure 3





Period (months)	III-V	VI-VII	VIII-X	XI-II
Approx rain (mm)	270	60	260	200
Number obs -				
- lake med/high	4	3	1	4
- lake low	4	2	3	2

Avocets are not known to occur anywhere else in Uganda. At Lake Munyanyange it is easy to watch them from a short distance. The lack of records during the northern summer months suggests that the birds here are Palearctic migrants, although the species does also breed in East Africa.

The **Ruff** can be taken as representing waders generally. These species all breed in the Palearctic and are hence seasonal in occurrence. The peak numbers correspond to the northern winter.

Gull-billed Terns are common in the western rift valley, but have recently been seen in unusually high numbers. Like other gulls and terns, they use the lake mainly as a safe resting place.

1.6 Mammals

Mammal records have been kept for the same period as bird records. No rare species has been recorded, partly perhaps because the crater is heavily grazed and there is a considerable amount of human activity. Thus the following list is probably not exhaustive, even for the larger species.

Spotted Hyena.	Footprints and dung are often found.
Lion.	Residents report that they are often heard at night.
Warthog.	Quite common, often with young.
Hippopotamus.	Grazes in the crater at night, coming from Lake Edward.
Bushbuck.	Seen twice.
Bohor Reedbuck.	Only seen here twice, but probably not uncommon.
Uganda Kob.	Common, with numbers up to about 100.
Defassa Waterbuck.	Occasional, to judge from its dung.

1.7 Limnology

A list of phytoplankton species for Lakes Edward, Katwe and Munyanyange is presented in Table 1. Whereas Lake Edward is characterised by a diversity of phytoplanktonic genera, Lake Katwe is dominated by only two genera i.e. *Euglena* and *Chlamydomonas,* and Lake Munyanyange by four genera, namely *Lyngbya, Spirulina Anabaena* and *Phormidium.* That the latter two lakes are dominated by a narrow range of phytoplanktonic genera is indicative of the specialised nature of these aquatic habitats. Lake Katwe is obviously saline and only species which are specially adapted to such a medium can survive. Hence the small range of resident phytoplankton species. Lake Munyanyange is similarly saline, although much less so, and again only specialised species can survive. The productivity of Lake Munyanyange's micro-flora is quite high and forms the basis of food chains for many types of micro- and macro- fauna that occupy the lake, including the Greater Flamingos which feed mainly on zooplankton.

The large diversity of phytoplankton in Lake Edward, associated with their high productivity, are an important resource for a considerable fish population. Lakes Edward and George contain no less than 57 different species, some of which constitute an important fishery resource. Fish landings from Lake Edward alone sometimes go up to 46 or more metric tonnes per month, in spite of the shortage of fishing gear and equipment often experienced by fishermen in this region.

Table 1: Phytoplankton of Lakes Edward, Katwe and Munyanyange

Species	Edward	Katwe	Munyanyange
Cyanophyceae (blue green algae)			
* *Microcystis aeruginosa*	x		
* *M. flos aquae*	x		
Gleoscapsa sp	x		
Aphanocapsa gravillei	x		
Merismopedia spp	x		
Gemphosphaeria spp	x		
Spirulina spp			x
Lyngbya spp			x
Anabaena spiroloides			x
Phormidium spp			x
Bacillariophycea (diatoms)			
Melosira spp	x		
Fragillaria spp	x		
Surirella linearis	x		
Chlorophyta (Green algae)			
Pediastrum spp	x		
Scenedesmus spp	x		
Staurastrum spp	x		
* *Chlamydomonas* spp		x	
Euglenophyceae			
* *Euglena* spp		x	

* These species were found to be most numerous (as a proportion of the total biomass).

1.8 Analysis of Environmental Samples

For fresh water lakes, water samples were taken from the surface. Water samples from Lake Edward were taken from a site close to Lake Katwe salt factory (Table 2: station 1), from an intake pipe system inside the lake (station 2) and from three other sampling sites which were free from the factory influence (stations 3-5).

The sampling of saline lakes was done by collecting surface water from different points. In Lake Katwe one of the points was where the pipes would pump out brine to the factory, and the other was near the point where the rafts anchor.

Salt and sediment samples were also collected from shore and centre positions in all the lakes. All samples were kept in polythene bottles.

Different methods of sample solution preparation were employed in the analysis of soil, brine, salt and water samples. In the case of soil samples, they were dried at 100°C over night and ground to fine powder and a representative sub sample taken. This was placed in a teflon cup, and concentrated nitric acid (4 ml), 60% perchloric acid (1.0 ml) and 48% hydrofluoric acid (5 ml) added. The cup was placed in a Uniseal bomb which was sealed and heated at 150°C for 3 hours. After 15 minutes of cooling the sample solution was evaporated to dryness and the residue dissolved in a known volume of distilled water.

For brine samples, no special treatment was required except that the samples were filtered to remove large particles.

For salt, a known weight of salt samples was dissolved in a known volume of distilled water. Water sample portions (100 ml) were each placed on evaporating basins and heated to dryness. The residue obtained was transferred into a uniseal bomb and treated as soil samples above.

All the sample solutions were analysed, after appropriate dilution, by conventional atomic absorption for Na, K, Ca, Mg, Fe, Cr, Co, Cu, Cd, Pb and Zn. For the analysis of CO_3^{--} and HCO_3^{-}, the usual titrimetric procedures were employed. With the analysis of chloride, Morh's method was used, while the amplification method was used for bromide. Sulphate was determined by the usual precipitation method with barium nitrate.

Water Quality
Table 2 presents data on the concentration of metal elements and other parameters in offshore waters of Lakes Edward, Katwe, Munyanyange, Kasenyi and Nyamununka. The latter four lakes are obviously saline and the high values of metals and conductivity are not surprising. Lake Edward is a freshwater lake and its water is in fact used for domestic purposes. When the data in Table 2 are compared with international limits for acceptability of water for domestic use (Table 3), it becomes clear that Lake Edward has scarcely any pollution in that all values of the measured parameters fall within acceptable ranges. The values shown for the various parameters in the three lakes may therefore be taken as being very close to geochemical background values.

Table 4 shows that light penetration for Lake Edward allows for a relatively deep trophic and therefore productive zone for the lake. The phytoplankton which support the lake's rich fish population live in this zone. Phytoplankton density would sharply decline if the lake waters became polluted.

Sediments
Sediment samples were taken from Lakes Edward and Munyanyange. The results of their analyses are shown in Table 5. Trace metal concentrations at the centre of either lake are more or less similar to concentrations in shore sediments. The ratios of centre/shore are roughly unity, showing that the trace metals deposited in the bottom sediment at the shores by the run-off water simply get shifted to the centre of the lakes.

1.9 Air Quality

No information is available on air quality, but since there is no industry in the area and relatively little settlement, air quality is presumed to be good.

1.10 Sociology

The permanent population of Katwe town is estimated to be about 5000 people. The people are of diverse ethnic background with virtually all Uganda's ethnic groups represented, and they also represent a diversity of social groups. Some are entrepreneurs owning enterprises such as salt pans, fishing boats, bars or shops, while others are labourers in a large variety of activities.

Table 2. Conductivity, pH and metal concentration in water samples from Lakes Edward, Katwe, Kasenyi, Munyanyange and Nyamununka (ug/ml)

Places Sampled	Conductivity cm^{-1}	pH	Fe	Cr	Co	Cu	Cd	Pb	Zn
Lake Edward									
Station 1	5.60×10^{-4}	9.10	0.69	0.0055	0.0036	0.13	0.007	0.009	0.40
2	5.61×10^{-4}	9.00	0.69	0.004	0.0076	0.13	0.002	0.006	1.25
3	5.70×10^{-4}	8.10	0.50	0.002	0.006	0.50	0.008	0.028	0.45
4	2.30×10^{-4}	9.45	0.50	0.006	0.0011	0.25	0.008	0.002	0.44
5	1.90×10^{-4}	8.70	0.50	0.002	0.0013	0.38	0.005	0.003	1.02
Lake Katwe									
Station 1	10.3×10^{-2}	9.75	13.1	0.0059	0.023	9.38	0.008	0.009	2.13
2	10.6×10^{-2}	9.70	9.38	0.085	0.027	7.50	0.006	0.03	2.38
Lake Kasenyi									
Station 1	22.8×10^{-2}	9.51	8.38	0.11	0.026	0.088	0.001	0.01	1.31
2	3.2×10^{-2}	9.41	18.5	0.74	0.032	0.12	0.008	0.014	1.76
Lake Munyanyange									
Station 1	7.9×10^{-2}	9.85	25.6	0.012	0.015	6.25	0.01	0.007	1.26
2	7.4×10^{-2}	9.85	6.88	0.011	0.022	5.00	0.008	0.02	1.88
3	7.6×10^{-2}	9.80	9.38	0.001	0.032	0.500	0.01	0.08	1.07
Lake Nyamununka									
1	5.5×10^{-2}	9.90	17.3	0.094	0.044	4.12	0.009	0.04	1.02

Table 3: International Limits for Substances Affecting the Acceptability of Water for Domestic Purposes (ug/ml = mg/l)

Substance	WHO International Limits	EEC Limits	USSR Limits
pH	6.5 - 9.2	6.5 - 9.5	6.5 - 8.5
Fe	1.0	0.3	0.3
Cr	-	0.05	0.05
Co	-	-	-
Cu	1.5	0.05	1.0
Cd	0.01	0.01	0.01
Pb	0.1	0.05	0.1
Zn	15	0.1	5.0

Table 4. The percentage of white light penetration into Lake Edward.

DEPTHS (m)	% PENETRATION
0.0	100.0
0.5	89.0
1.0	76.8
1.5	66.7
2.0	56.5
2.5	46.4
3.0	31.9

Table 5 Concentration of metal Elements in Sediment samples from Lakes Edward and Munyanyange (ug/g dw)

Lake Edward

STATION	Fe	Cr	Co	Cu	Cd	Pb	Zn
CENTRE 1	58,600	24.3	21	446	94.2	1170	123
CENTRE 2	63,500	21.4	14	743	87.2	1290	66
CENTRE 3	60,000	22.2	17	1226	92.4	3080	94
SHORE (near salt factory)	42,800	38.2	28	635	57.4	969	192

Lake Munyanyange

STATION	Fe	Cr	Co	Cu	Cd	Pb	Zn
SHORE 1	74,200	38.3	14.1	1263	107	1320	392
SHORE 2	69,500	36.5	18.0	1070	98	1290	620
CENTRE 1	61,300	31.7	21.2	957	120	2210	268
CENTRE 2	67,300	33.2	13.3	979	134	2300	230

Katwe is, however, characterised by a largely migrant population, so that the numbers at any given time depend on the balance between emigration and immigration. This migration is itself dependent upon the seasonal variation in the type and level of economic activity. Immigration corresponds mainly with the periods of intense salt-winning activities at Lake Katwe, which correspond with the two dry seasons in the year; these normally peak in February and August. Overall, the entire population of Katwe town directly or indirectly depends either on fishing from Lake Edward (and Lake George) or on salt-winning from Lake Katwe.

Production of salt from Lake Katwe traditionally takes two forms; one is the production from salt pans on the south-eastern shore of the lake, while the other is the mining of rock salt deposited at the floor of the lake.

In 1988, there were 2049 salt pans. In 1989, there were 1932 salt pans; so we take 2000 as the annual average figure. The number of owners ranges from 600 to 900. An average salt pan measures up to 12 cubic metres, with a capacity to produce around 10 bags of salt per season. Each bag of salt weighs about 120 kg, and in the dry season, sells for about 2500/=. There are two seasons for salt-winning. This would put the annual value of local salt production at 2500 x 10 x 2000 x 2 = 100,000,000/=.

The owner of a pan can work on it himself using family labour, but the majority of owners rely on hired labour, especially during the period of peak productivity. Hence the migratory nature of the majority of the labour force in Katwe town.

A productive pan would usually be worked by four to six people, and given that there are about 2000 pans, it becomes clear why the population of Katwe surges during the salt season.

Rock salt extraction is a more demanding job, and the number of extractors is limited to only 80 licences, a measure designed to ensure sustainability of the resource. Extraction of rock salt therefore contributes a small proportion of the labour force in Katwe, and the finances accruing from the activity are correspondingly lower. For example a 120 kg bag of the salt costs only shs 1,000/=, compared with an average of shs 2,500/= for the same weight of Grade 2 salt.

Fishing on Lake Edward is one other viable activity in Katwe town. Fishing boats are privately owned, but must be licenced by the government's Fisheries Department which oversees the activities of the fishermen to ensure, for example, that appropriate net mesh sizes are used to maintain sustainability of the industry. There are three fish landings in the neighbourhood of Katwe town on Lake Edward, namely Kazinga, Kisenyi and Katwe itself with 18, 20 and 35 licenced fishing boats, respectively. The catch on Lake Edward goes up to 46 metric tonnes per month, which is valued at 2,000,000/=. The annual value is thus 12 months x 2 million = 24,000,000/=.

On average each boat employs three to six people. In addition to the fishermen, there are fishmongers and others employed in associated occupations such as fish smoking, fishing gear maintenance and so on. Thus the fishing industry significantly contributes to the economic activities of a considerable proportion of the population.

2 THE EXISTING SALT INDUSTRY

2.1 Background

The salt lakes of western Uganda, which include Katwe, Kasenyi, Nyamununka and Munyanyange, are of volcanic origin and so far free from pollution by anthropogenic sources. This is mainly due to the fact that the area is thinly populated and is far from any big town or industrial area. The local salt production is presently from two sources, the Katwe and Kasenyi crater lakes.

Lake Katwe is a 2.5 km^2 saline lake, the surface of which is 30 m below that of the adjacent freshwater lake, Lake Edward. The mineral salt deposits in the lake have been formed by the evaporation of dilute saline spring inputs, a process which continues today contributing about 2000 tonnes of salt to the lake per annum. All of the spring inflow and rainfall onto the lake is evaporated, maintaining an average water depth of about 0.5 m over the salt deposits depending on season. These deposits, which extend to at least 40 m below lake level, are estimated at 22.5 million tonnes, of which 2 million tonnes are sodium chloride, one of the more soluble salts present. The salt evaporates are mainly present as the following minerals:

HALITE	$NaCl$	White cubes
TRONA	$Na_2Co_3.\ NaHCO_3.2H_2O$	White glassy acicular crystals, which effloresce slightly when dry.
BURKEITE	$Na_2CO_3.\ 2Na_2SO_4$	Both usually fine grained; occur in crusts, often mixed with trona.
HANKSITE	$9Na_2SO_4.\ 2Na_2CO_3.\ KCl$	

The standing water in the lake and the interstitial water within the lake deposits is a strong brine, the concentration and constituents of which vary with season as follows:

Analysis of the Lake Brine (g/l)

	Dry season (Feb 1967)	Wet season (June 1967)
Na	150	70
K	37	17
CO_3	47	23
HCO_3	5	2.5
Cl	154	72
SO_4	62	30
Br	1.2	not analysed
F	0.1	not analysed
Total	456.3	215.5

Lake Katwe has been used as a source of salt since time immemorial. In recent times it has formed the basis of both an artisan industry and a technological industry for salt production which are briefly described below.

2.2 Artisan Industry

Salt is still recovered from Lake Katwe by traditional means. The number and effectiveness of the salt producers has grown over the years, but is now controlled by a cooperative. The sociological and economic aspects of salt production are described separately in section 1.10.

Traditionally, three qualities of salt are obtained. The best quality (No. 1) is crystalline NaCl (93%) which forms on the lake surface at the end of the dry season (February and August) and is collected on grass hurdles at the lake shore where it is blown by the wind. No. 2 quality is produced by solar evaporation of brine in small pans along the South Eastern shore of the lake. The third quality consists of solid salt deposits, prised from the lake bed and transported ashore on small rafts of ambatch (*Aeschynomene elaphrocylon*). The three qualities of salt have the following constituents:

Average Analysis (%)

	No. 1	No. 2	No. 3
NaCl	93	65	50
Na_2SO_4	2	18	25
Na_2CO_3 + HCO_3	1	10	15
K_2SO_4	1.5	3	5
H_2O	1.5	3	3
Insolubles	1	1	2

Once collected, the various grades of salt are simply stacked, dried and bagged before being sold and then transported by pick-up or bicycle to distant markets.

The winning of salt by these traditional methods uses hardly any materials apart from wood used for rafts, hurdles and evaporation-pond construction. It is presumed that all of this wood is taken from the adjacent National Park, but the quantities must be relatively small.

2.3 Technological Industry

In 1980, a salt plant was commissioned for industrial processing of brine from Lake Katwe. Twenty-one brine wells were drilled in the lake bed and these were connected to a manifold and pump house constructed near the middle of the lake at the end of a purpose-built causeway. Brine was pumped to the salt plant constructed on the shore of Lake Edward near a good supply of cooling water.

The process employed involved the heating of brine by steam heat exchangers, and the differential crystallisation of the constituent salts in a series of evaporators operating at different temperatures. The steam heating system was oil-fired. Salt crystals were separated from the brine liquor by a series of hydrocyclones, centrifuges and filters. Vent gases which were contaminated with H_2S from the lake deposits were passed through a Klaus sulphur-recovery plant. Waste Burkeite in solution was piped to Lake Munyanyange for disposal.

The plant was designed to produce 3 tonnes/hour of crystalline NaCl at 90% purity and 1 tonne/hour of KCl of unknown purity. However, right from the commissioning stage, problems were experienced with attempts to operate the plant. After a matter of months, chronic corrosion problems were experienced and ultimately the plant was abandoned without ever having operated properly.

3. ENVIRONMENTAL IMPACT OF EXISTING INDUSTRY

3.1 Artisan Industry

As Lake Katwe is so close to Lake Munyanyange and the waters of the two lakes are of more or less similar composition, it is probable that a peaceful Lake Katwe might also have had resident populations of Flamingos. The disturbance by salt-winning activities precludes these birds in any numbers. Uncontrolled exploitation of ambatch (*Aeschynmene elaphroxylon*) cut from Queen Elizabeth National Park for the making of rafts used in ferrying rock salt ashore may constitute a significant impact. The large human population contributes to the high levels of game poaching and firewood extraction in adjacent parts of the Park. Otherwise the existing artisan salt industry is environmentally benign.

3.2 Technological Industry

The legacy of the attempt at industrialisation of salt-winning consists largely of the totally derelict factory on the shore of Lake Edward and its supporting infrastructure of brine wells, pumps and pipes, which have fallen into disrepair. The plant is theoretically awaiting refurbishment and has not therefore been completely closed down. The staff housing area to the west is still being occupied and its potable water supply system based at the salt works is still in operation.

Whilst burkeite was apparently pumped into Lake Munyanyange during initial plant operations, it is believed that this was not in sufficient quantity to make any significant change to the environment of that lake, as indicated by the analytical results reported earlier (section 1.8).

4. PROPOSED SALT INDUSTRY

4.1 Process

The government would like the derelict salt plant to be rehabilitated. The rehabilitation would also include some modification and simplification of the process to make it easier to operate and more efficient at producing the primary product, table quality (95%) NaCl crystals, which would also be of greater purity than previously. In the new process, hydrocyclones would be replaced by thickeners, the KCl plant would be completely shut down and NaCl would be separated from Burkeite by differential crystallisation temperature alone and removed from suspension by centrifugation. The inappropriate Klaus sulphur recovery plant would be replaced by a simple scrubber system for the removal of H_2S from the vent gases. The NaCl production capacity would be 6 tonnes/hour or 40,000 tonnes/year.

The proposed process is demonstrated in the flow diagram (Figure 4). In summary, brine is fed through a set of preheaters to evaporator D-102. There, a part of the Burkeite is crystallised and is removed as slurry to the first static thickener. The concentrated slurry is passed by gravity flow to the Burkeite centrifuge. The Burkeite cake is collected in the Burkeite dumping tank, and dissolved in water, prior to disposal. The 'mother liquor' from the first thickener overflows the centrifuge and is pumped through a preheater to evaporator D-101. As the lowest solubility at that temperature is reached, more Burkeite and some soda are crystallised. The slurry is passed through the second static thickener also to the Burkeite centrifuge. The overflow from the second thickener is pumped to evaporator D-103. Further concentration takes place in order to come close to saturation of KCl. During this procedure NaCl is crystallised and removed as slurry to the third thickener and fed to the NaCl centrifuge. Part of the thickener overflow is recirculated through another preheater back to evaporator D-102. The rest of this 'mother liquor' is discharged The NaCl crystals from the centrifuge are moved by a belt conveyor to the fluid bed dryer. The dried NaCl product is then passed to the silos and finally to the bagging unit.

4.2 Brine Supply

It has been estimated (Morton 1973) that Lake Katwe has a salt reserve of 22.5 million tonnes, of which 2.0 million tonnes are NaCl, the most soluble of the salts present. However, no information is available on the amount of liquid brine present or its hydrological dynamics; the reservoir is simply referred to as 'big'. The feasibility study makes reference to the probability

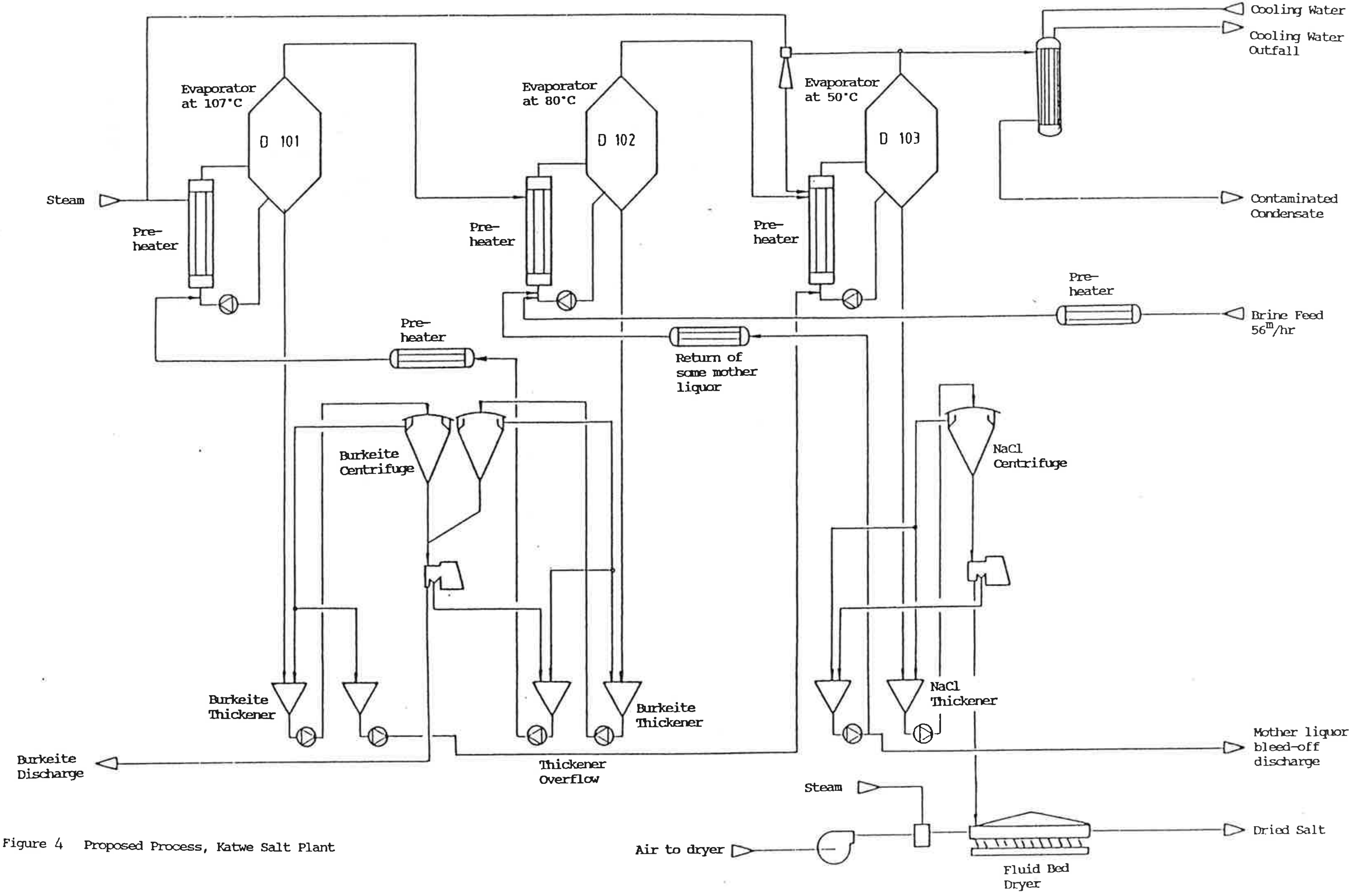


Figure 4 Proposed Process, Katwe Salt Plant

of slow changes in the NaCl concentration of the interstitial brine over time and the possible need to drill additional wells. It must therefore have been assumed that other groundwater will replace the brine pumped out. (It is not known whether there is any hydraulic connection between Lake Katwe and the higher Lake Edward). The feasibility study makes passing reference to the possibility of the dilution of Lake brine by the introduction of water. Presumably, therefore, some thought has been given to water injection in the event that groundwater inflow does not equal the proposed brine pumping rate. (There is a definite proposal to return some de-salted liquor from the process to Lake Katwe).

The half metre depth of brine at the surface of the lake represents a very small proportion of the total brine reservoir. No estimate has been made of the likely effect of pumping on the availability of surface brine.

4.3 Solid Wastes

As presently proposed, dissolved Burkeite would be pumped to Lake Munyanyange for disposal. The exact quantity has not been predicted but is estimated to be in the region of 20,000 tonnes/year. About 9,000 tonnes per annum could probably be utilised by the Kasese cobalt plant process (see Kasese report) if it was implemented. This, however, would still leave 11,000 tonnes/year to be dumped in Lake Munyanyange, a proposition that is least acceptable.

4.4 Liquid Wastes

It has been proposed that brine from which Burkeite and much of the NaCl has been removed will be pumped back into Lake Katwe for disposal (and ultimate re-use).

The cooling water system is a circuit which includes a cooling tower. It is therefore not expected that there will be a continuous discharge of heated water to Lake Edward. However, all cooling water systems and steam generation systems discharge water from time to time due to blowdown, bleed-off, overflows, maintenance operations, de-scaling, etc. Since the water in circuit would be dosed with chemicals to prevent fouling (e.g. $CuSo_4$, Cl_2) and corrosion (e.g. zinc), these losses would be contaminated. It has been proposed that these waste waters would drain to the former hot water basin whence they would be pumped at intervals to Lake Munyanyange for discharge. The quantity and quality of such discharges is not known.

Non-condensable gases from the evaporators will be pumped to the atmosphere via water seal vacuum pumps. Since these gases include H_2S, the seal water will become contaminated with dissolved H_2S. No proposal has yet been made for the treatment or disposal of this contaminated water. Similarly, no disposal method has been proposed for the liquid effluent arising from the vent gas scrubber, which again would contain H_2S.

4.5 Emissions to Air

Scrubber

As previously mentioned, gases arising from the process will be scrubbed before venting to the atmosphere. The H_2S concentration in the final emission will depend upon the efficiency of the scrubber which has not been stated. No estimate has been provided of the volume flow or temperature of vent gases. No proposal has been made for the height of the scrubber vent stack or the diameter of its outlet.

Boilers

The boilers will burn 1125 l/hour of fuel oil. The sulphur content of the fuel has not been stated and the expected emissions of SO_2, NO_X, HC_S and suspended particulates have not been specified. Stack height has not been specified. On the basis of pollution factors, it can be estimated that the emission will comprise:

Particulates	2.87 kg/hr
SO_2	19 x S kg/hr (where S = % sulphur content by weight)
NO_X	7.5 kg/hr
HC	0.37 kg/hr
CO	0.52 kg/hr

Generator

A diesel power generator will consume 440 l/hr of diesel fuel. No estimate has been made of the resulting emissions to air. However, it can be anticipated on the basis of pollution factors that the emission will comprise:

Particulates	1.0 kg/hr
SO_2	7.6 x S kg/hr (where S = % sulphur content by weight)
NO_X	4.4 kg/hr
HC	1.04 kg/hr
CO	17.4 kg/hr

4.6 Transport

Brine will be piped direct from Lake Katwe to the saltworks and wastes will be piped out. All other materials and products will be carried by road, but it is assumed that most of the bulk goods will be transhipped to the railway at Kasese. The main materials to be transported will be:

Boiler fuel	approx	7,500 t.p.a.
Diesel fuel	approx	3,000 t.p.a.
Salt product		40,000 t.p.a.

In addition, about 9,000 t.p.a. of Burkeite might be transported to the Kasese cobalt works if it is established.

4.7 Safety

No information has been provided on hazardous processes and activities within the plant and how employees will be protected from them.

5. ENVIRONMENTAL IMPACT OF PROPOSED INDUSTRY

5.1. Impact Identification

Figure 5 is a network diagram which demonstrates the main environmental impacts expected from the proposed salt industry. Briefly, they are as follows:

(i) The industry will generate and disperse into the atmosphere toxic gases, including H_2S and engine exhaust fumes, thus creating the risk of air pollution.

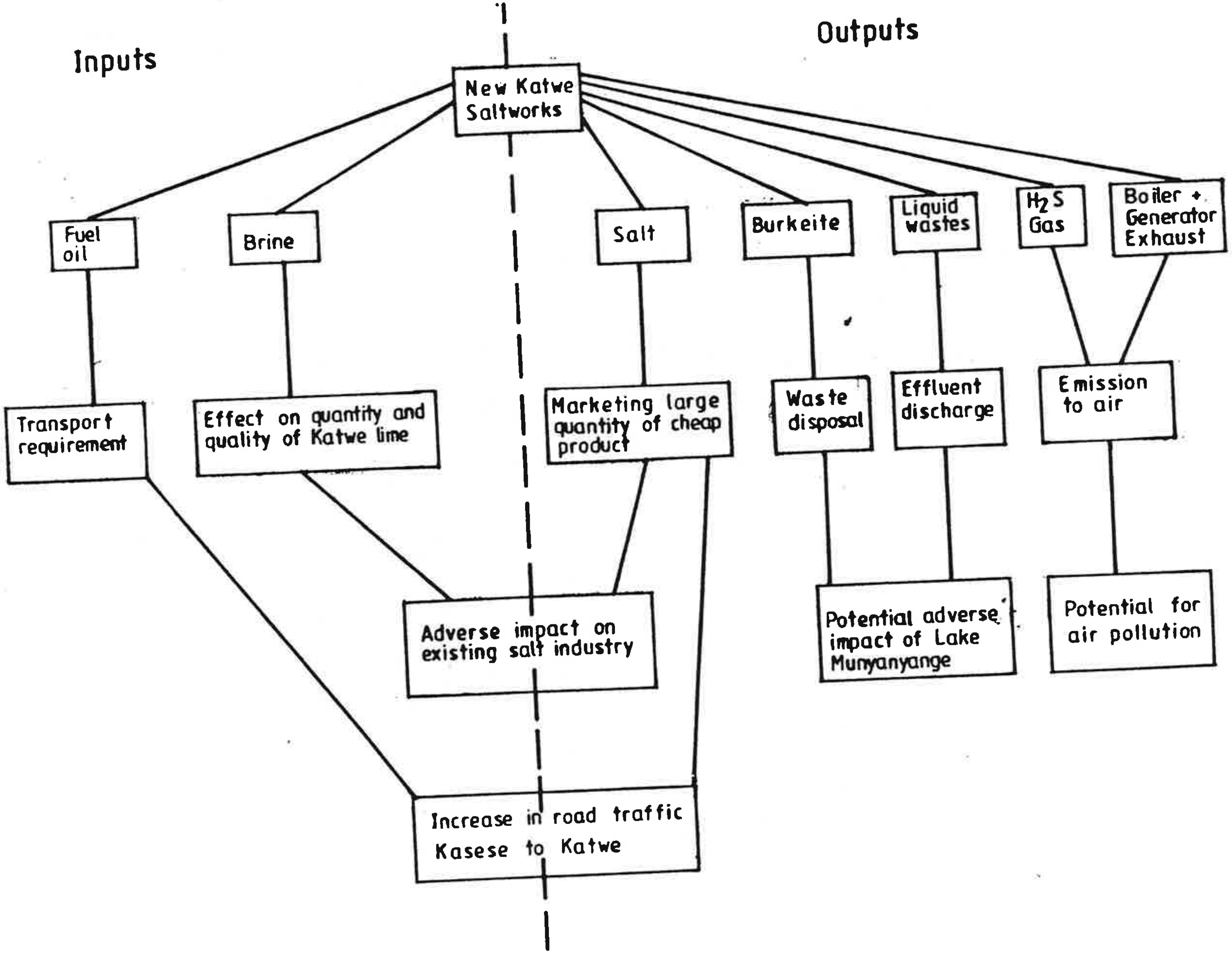
(ii) Solid and liquid wastes from the industry are expected to be disposed of in Lake Munyanyange. As noted earlier, Lake Munyanyange is home to a diversity of animals, particularly birds; for some, such as the Flamingos and Avocets, this is by far the most important site in the whole of Uganda. Disposing wastes into the lake will severely affect the habitat and therefore destroy the animals and birds' existence in the crater. Furthermore the site is very convenient for bird-watchers and other visitors, whose numbers are expected to rise considerably in the future.

(iii) Also as noted earlier, the Munyanyange crater is home of a rare and interesting plant species, *Odyssea jaegari*, which would in all probability become extinct as a consequence of disposing wastes into the crater.

(iv) The proposed industry will conflict with the existing artisan industry in that it will market large quantities of cheap salt. This will no doubt kill the artisan industry, thus rendering a large number of people jobless and disrupting the social and economic fabric of the entire community.

(v) Most of the salt produced by the industry is expected to be transported by rail from Kasese to markets in Kampala and beyond. This will cause an increase in road traffic, especially of trucks transporting the salt from Katwe to Kasese. Because the road passes through Queen Elizabeth National Park, the increased volume of traffic will create noise and environmental disturbance which will adversely affect the behaviour of animals and the character of the park.

Figure 5: The main environmental impacts expected from the rehabilitated Lake Katwe salt factory.



5.2 Quantification and Evaluation of Impacts

5.2.1. Impact of Construction

There would be little impact except for disposal of large quantities of scrap materials from the old factory as it is replaced by a new plant. The scrap will need to be disposed of properly.

5.2.2 Impact of Operations

Brine Supply: A major question is the likely impact of brine pumping on the quantity and quality of brine at the surface of Lake Katwe. It has been suggested that the artisan salt industry could co-exist with the modern industry since the latter will be using sub-surface interstitial brine while the local industry uses the surface lake brine. This suggestion is tantamount to saying that the surface and interstitial brine reservoirs are completely separate. Indeed, we were not able to find any information on the relationship between the two. However, there is such a relatively small reservoir of surface brine (approximately 2,500,000 m^3) that if there is any significant physical link between the two, then the proposed pumping rate of 56 m^3 per hour could, over time, adversely affect the amount of brine available for traditional salt production.

Assuming that the surface lake brine is the only constant source of recharge to the underlying closed aquifer system, it has been estimated that a year's pumping at the proposed rate would reduce the lake level by 5 cm (Lissanu and Ayele 1987), assuming that other factors like evapotranspiration and precipitation remain constant. The depth of the lake generally varies between 15 cm (at the end of the dry season) and 60 cm (at the beginning of the dry season). Extrapolating the assumptions over a few years makes it clear that the lake could become permanently dry within a few years, which would mean the end of the local salt industry.

The flow rate of the de-salted liquor to be returned to the lake has not been estimated. This is a question that demands more information on the part of the salt company.

It would be interesting to know how pumping affected the lake level during the brief period in which the original plant was in operation.

Solid Waste Disposal

Lake Munyanyange is the habitat of a diversity of animals, particularly birds. For some, such as Flamingos, this lake is by far the most important habitat for them in the whole of Uganda. Many other rare species have been recorded there. Also as noted earlier, the Munyanyange crater provides the specialised habitat for at least one very rare plant *(Odyssea jaegari)*. The proposed disposal of wastes into Lake Munyanyange is therefore environmentally unacceptable. Furthermore, it would destroy a potentially valuable tourist site.

In the circumstances, it is suggested that, since Burkeite will arise from the production process as a cake, it could be disposed of in solid form. The solid could be taken back to Lake Katwe (possibly by conveyor) and stacked along one shore of the lake. Since it is relatively insoluble, it should not unduly affect the quality of salt produced by traditional evaporation methods. (Even if the Burkeite were used by the proposed cobalt plant at Kasese, the plant would consume less than half of the waste arising from the salt factory).

Liquid Waste Disposal

Liquid wastes from the factory may well be contaminated with metals or other pollutants, and should not therefore be returned to the Lake Katwe brine reservoir which ultimately is used for human consumption. It is suggested that the washdown water spillages, etc, from the factory which will constitute liquid wastes should be evaporated and the solid remains co-disposed in a tailings dam with solid wastes from the cobalt processing plant at Kasese.

The plant as presently constructed is well contained. However, any site licence on planning permission issued should specify that no discharges of any kind are to be allowed into Lake Edward, and that all fuel and chemical storage tanks must be bunded. To further safeguard the lake against accidental spillage, there should be an interceptor on the factory's southern boundary.

Emissions to Air

As described in Section 4.5, emissions from the salt factory will mainly comprise of H_2S. In addition, exhaust gases from boilers and the generator will include SO_2, NO_x, HC, CO and particulates. The waste gas scrubber vent will need to be controlled with an H_2S

emission standard. There should also be a gas sampling port on the vent and a monitoring programme to ensure that the emission standard is maintained. For the exhaust gases, a sufficiently high stack will have to be erected.

Impact on Existing Industry

At the peak of activities in the dry season, well over 12,000 persons are employed in the salt-winning industry alone. As pointed out earlier, the industry is responsible for an annual turn-over of at least Shs 100 million.

In assessing the impact of a revived Katwe Salt factory, therefore, one must focus on the diverse social and economic implications of this revival.

It was not apparent from interviews with salt workers that they were unduly worried by a revived factory. This is not to say that the factory would not affect the social and economic well-being of Katwe people. There are indications, for example, that in time, the artisan salt production would be phased out even as a result of competition for the market. The targeted annual production from the factory of 40,000 tonnes would be enough to flood the market, thereby diminishing the economic significance of artisan production.

According to the factory manager, there is no intention of giving priority to Katwe locals in job opportunities at the factory. Moreover, its labour force, from management to group employees, would be a mere 250 people, recruited on merit. With the characteristic lack of formal education in Katwe, the only job opportunities available for the locals are group employment. To this end, the salt factory has little to offer to the local people when compared with the artisan salt-winning.

The only other viable alternative for the people would be fishing. But given that the capacity of the fishing industry is presently controlled to ensure sustainability, the industry is unlikely to absorb the thousands of people that would be made redundant from the traditional salt industry.

Paradoxically, the recommissioned salt factory might have a negative impact on the fishing industry in its present form. Since salt-winning employs the majority of the people, it has a bearing on the demand for fish. With no more salt-winning, the local demand for fish will decline, thereby jeopardising some employment within the fishing industry itself.

The recommissioned salt factory would similarly have a negative impact on employment opportunities in other economic service sectors such as restaurants, shops and bars.

Impact of Transportation

As indicated in Section 4.6, there will be about 10,500 tonnes of fuel per annum to be ferried between Kasese and Katwe, and about 40,000 tonnes per annum of the salt product. In addition, there might be a further 9000 tonnes per annum of Burkeite transported to Kasese cobalt plant if it is established. Altogether these will represent about 5950 lorry loads per annum at 10 tonnes each or about 500 per month between Katwe and Kasese. The increased volume of traffic may adversely affect the animals in Queen Elizabeth National Park, thereby undermining the attractiveness of the park for tourism.

Impact of Expansion of Katwe Population on Queen Elizabeth National Park

Initially, the existing artisan and proposed industries will co-exist, and during that time the resident population of Katwe will increase. Such an increase in population will escalate poaching activities in the park, such as gathering of fuelwood, killing of animals, etc. These are activities that will undermine the status of the park.

Furthermore, increasing numbers of bird-watchers are coming to the park, and include Lake Munyanyage in their visit. The Lake is part of an Animal Sanctuary and there are therefore legal implications arising from any activities harmful to wildlife.

The above impacts and their classification are summarised in Table 6.

Table 6: **SUMMARY TABLE OF IMPACTS AND THEIR CLASSIFICATION**

Potential Impact of Proposed Development	Classification of Impact	Description of Potential Impact
Diminution of brine in Lake Katwe.	EI ELt I	Pumping of brine out of Lake Katwe at the proposed rate of 56cm^2 per hour will. over a few years, diminish the amount and quality of brine available for traditional salt production.
Destruction of Lake Munyanyange, a unique habitat in the region for Flamingos, and for rare plant Odyssea jaegari.	EI ELt I D	Disposing solid waste (Burkeite) in Lake Munyanyange will fill up the crater lake and its shoreline. This will destroy the unique aquatic habitat on which birds such as Flamingos thrive, and the rare plant Odyssea jaegari only found on the Lake's shoreline will be destroyed.
Production of contaminated liquid waste pollutants.	EE ELt D C I	Liquid wastes from the factory will be contaminated with pollutants (such as metals), which will pose a risk of pollution of aquatic systems.
Emission into the air of gaseous pollutants.	EE ELt I D C	Emissions to air will mainly be comprised of pollutant gases such as H_2S, SO_2, NO_x, HC and CO. (Note classification would change substantially if recommended air pollution controls are involved in the plant design).
Loss of employment opportunities.	EE ELt I D Sn	The traditional salt industry currently employs well over 12,000 persons; and the industry has an annual turn-over of about Shs.100 million. In addition, it supports many other people in fishing and other service sectors such as bars, restaurants and shops. The proposed industry will employ only about 250 persons, thus curtailing employment opportunities for many people.

..../continued

Table 6: **SUMMARY TABLE OF IMPACTS AND THEIR CLASSIFICATION (continued)**

Potential Impact of Proposed Development	Classification of Impact	Description of Potential Impact
Increased volume of traffic through QENP.	EE ELt R I C	The industry will require annually about 10,500 tonnes of fuel to be ferried from Kasese railway terminus to Katwe. It will also produce about 40,000 tonnes of salt to be shipped to Kasese. There may also be a further 9000 tonnes of Burkeite transported to Kasese cobalt works. Altogether these will represent about 5950 lorry loads per year through the park, which may adversely affect game viewing.
Increased resident population of Katwe town.	EI EL ESt R D	Initially the traditional and proposed industries will co-exist, and for that period, the population of Katwe will increase. This will escalate poaching activities in QENP.

KEY TO TABLE 6

EI = Exposure Intensive
EL/EE = Exposure limited/extensive
ELT = Exposure long-term
EST = Exposure short-term
R = Reversible
I = Irreversible
D = Direct
ID = Indirect
C = Cumulative
Sn = Synergistic

6. PROPOSED AMELIORATIVE MEASURES

The following measures are recommended to ameliorate the environmental impacts due to the proposed industry:

- the solid wastes (Burkeite) should be stacked around Lake Katwe.
- liquid wastes should be evaporated and the solids disposed of in the Kasese cobalt plant tailings dam.
- emission standards should be established for the scrubber (H_2S).
- stacks of adequate height for dispersion of gases from the generator and boilers should be erected (heights to be calculated by designers).
- a gas sampling port should be provided on the vent to the waste gas scrubber.
- all fuel and chemical storage tanks should be bunded.
- there should be an interceptor on the factory's southern boundary to prevent spillage of contaminated liquids into Lake Edward.
- discharges of any kind into Lake Edward should be forbidden.
- compensation for loss of employment by traditional salt workers should be instituted by, for example:

    giving them priority for jobs in the new factory.

    expansion of the fishing industry to the optimum allowable for sustainable fishing.

    instituting resettlement schemes to allow people to start new lives elsewhere.

    establishment of other job-creating industries in the area, such as fish processing.

- designation of Lake Munyanyange as a Site of Special Scientific Interest.

7. PROPOSED MONITORING SCHEME

There will be need to institute a number of monitoring schemes in order to detect any unpredictable changes, viz:

- return of the de-salted liquor may alter the quality of brine in Lake Katwe. Brine quality should therefore be monitored continuously.
- continuous pumping of brine out of Lake Katwe may actually reduce the amount of brine in the lake. Brine level in the lake should also be monitored continuously.
- the water quality in areas of Lake Edward nearest the factory should be monitored for early detection of any kind of contamination.
- There should be a gas monitoring system to ensure that gaseous emission standards are maintained

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APPENDIX : SCIENTIFIC NAMES OF BIRDS AND MAMMALS FOUND AT LAKE MUNYANYANGE ON 25 OCCASIONS BETWEEN 1984 AND 1985

Pink-backed Pelican *Pelecanus rufescens*
Grey Heron *Ardea cinerea*
Black-headed Heron *Ardea melanocephala*
Cattle Egret *Bubulcus ibis*
Little Egret *Egretta grazetta*
Hamerkop *Scopus umbretta*
Open-billed Stork *Anastomus lamelligerus*
Marabou *Leptoptilos crumeniferus*
Yellow-billed Stork *Mycteria ibis*
Hadada *Bostrychia hagedash*
* Glossy Ibis *Plegadis falcinellus*
Sacred Ibis *Threskiornis aethiopica*
* African Spoonbill *Platalea alba*
* Lesser Flamingo *Phoeniconaias minor*
* Greater Flamingo *Phoenicopterus ruber*
Egyptian Goose *Alopochen aegyptiacus*
Red-billed Teal *Anas erythrorhynonchos*
\+ * Garganey *A querquedula*
Yellow-billed Duck *A undulata*
Tawny Eagle *Aquila rapax*
Red-necked Spurfowl *Francolinus afer*
\+ Ringed Plover *Charadrius hiaticula*
Kittlitz's Sandplover *C pecuarius*
Wattled Plover *V senegallus*
Spur-winged Plover *V spinosus*
\+ * Curlew *Numenius arquata*
\+ * Whimbrel *N phaeopua*
\+ * Wood Sandpiper *Tringa glareola*
\+ Greenshank *T nebularia*
\+ Marsh Sandpiper *T stagnatilis*
\+ * Redshank *T totanus*
\+ Curlew Sandpiper *C ferruginea*
\+ Little Stint *C minuta*
\+ * Black-tailed Godwit *Limosa limosa*
\+ Ruff *Philomachus pugnax*
Black-winged Stilt *Himantopus himantopus*
* Avocet *Recurvirostra avosetta*
\+ * Phalarope sp, prob Grey *Phalaropus* sp prob *flulicaris*
Water Thicknee *Burhinus vermiculatus*
Grey-headed Gull *Larus cirrocephalus*
\+ Lesser Black-backed Gull *L fuscus*
\+ * Black-headed Gull *L ridibundus*
White-winged Black Tern *Chlidonias leucopterus*
\+ * Gull-billed Tern *Gelochelidon nilotica*
White-browed Coucal *Centropus superciliosus*
Little Swift *Apus affinis*
Red-capped Lark *Calandrella cinerea*
Mosque Swallow *H senegalensis*
White-headed Rough-wing *Psalidoprocne albiceps*
Common Bulbul *Pycnonotus barbatus*

Grey-backed Camaroptera *Camaroptera brachyura*
Trilling Cisticola *Cisticola woosmani*
Plain-backed Pipit *Anthus leucophrys*
+ Yellow Wagtail *Matacilla flava*
Black-headed Gonolek *Laniarius barbarus*
Tropical Boubou *L ferrugineus*
Scarlet-chested Sunbird *N senegalensis*

+ Indicates a migrant from the Palearctic Region

* Indicates a species which is uncommon or rare in QENP

MAMMALS

Spotted Hyena *Crocuta crocuta*
Lion *Felis leo*
Elephant *Loxodonta africana*
Hippopotamus *Hippopotamus amphibius*
Bushbuck *Tragelphus scriptus*
Bohor Reedbuck *Redunca redunca*
Uganda Kob *Kubus kob*
Defassa Waterbuck *K ellipsiprymnus*