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REPORT – VOLUME 4, STUDY 2

CNOOC UGANDA LIMITED

KINGFISHER OIL PROJECT, HOIMA DISTRICT, UGANDA - SURFACE WATER SPECIALIST REPORT

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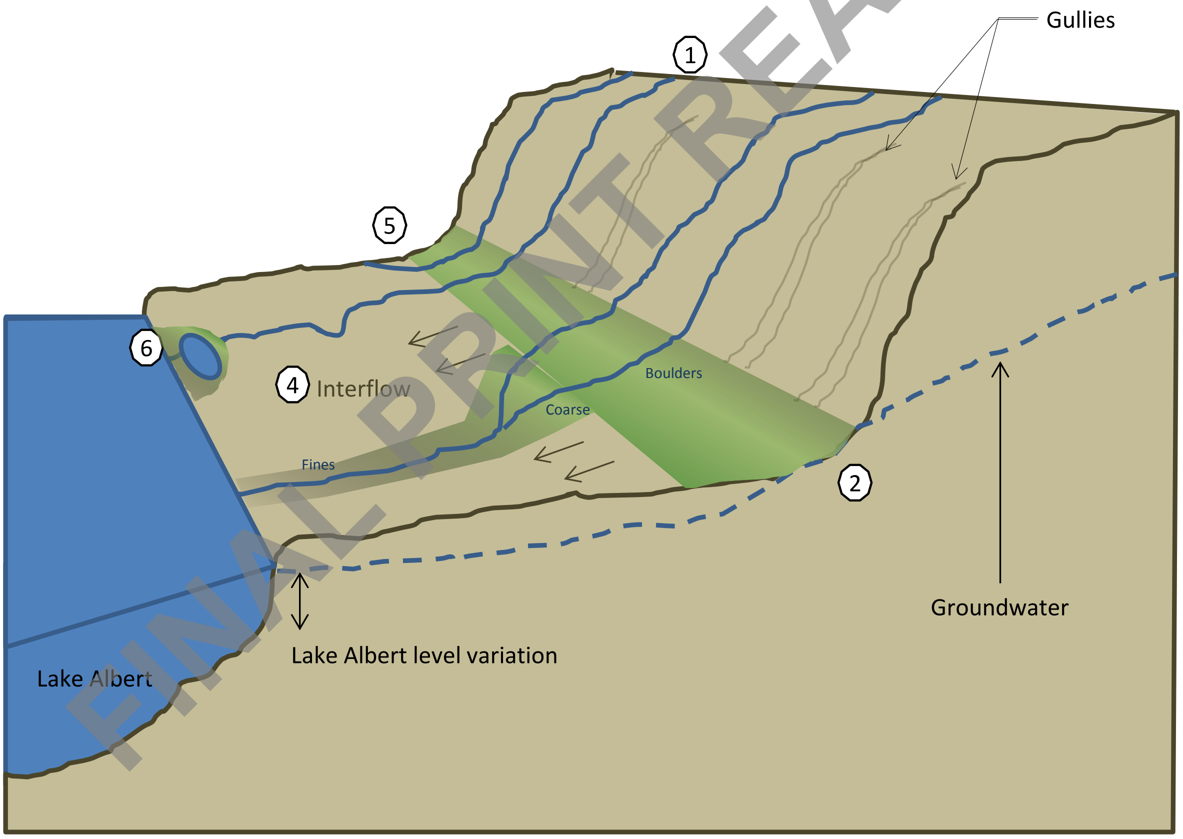
Golder Associates

EXECUTIVE SUMMARY

This report presents hydrology baseline information and an impact assessment of surface water hydrology affected by the Project. An understanding of surface water hydrological conditions prior to mine oil and gas development is essential to assess changes in water availability that could affect local users. Changes in hydrology can also affect water quality and other resources such as fish habitat, vegetation and wildlife. Hydrological data is further required to design mine oil and gas facilities (e.g. culverts, channels and storage ponds).

The regional climate in the area is described as tropical with a distinct wet and dry season. Rainfall over the study area catchment varies between 700 mm and 1 400 mm/ annum. Results of Global Climate Change models indicate that Uganda is likely to experience more extreme periods of intense rainfall and drought, while the rainfall seasons become more erratic and/or infrequent.

The project site is located within the Kingfisher catchment and drains westwards into the south eastern embankments of Lake Albert. Kingfisher catchment is associated with a very high western rift escarpment that drains into Lake Albert via several scattered streams and wetlands flowing westwards. Streams within the project zone of influence include the Kamansinig and Masikia Rivers. With the exception of these rivers, the area below the escarpment (approximately 13 km^2) is characterised by relatively spread out wetlands at an elevation associated with most project infrastructure (628 mamsl). The water system of the Flats is a localised system and a conceptual model of the Flats hydrological system is shown below.



The model shows that in the rainy season, runoff is discharged onto the Flats from the catchment (65 km^2). Water is conveyed through ravines on the steep slopes of the escarpment (1). Water energy is high when it reaches the Flats but it dissipates quickly as the slope Flattens and encounters bushy vegetation at the bottom of the escarpment. This is a zone of recharge where water infiltrates into the soil.

During the dry season, the Flats still receive some water from the upstream catchment through soil moisture stored during the rainy season and groundwater seepage (2). Evidence of groundwater seepage is given by a 100 m high band of green vegetation visible on the lower part of the escarpment during the dry season. Some smaller streams disappear from the surface a few hundred metres away from the bottom of the escarpment, indicating that the bottom of the escarpment is an important zone of recharge of water into the soil. Water contributes to recharging the aquifer, and also moves through the soil towards Lake Albert (4), while the rest is evaporated. Streams that are large enough slowly make their way through densely vegetated wetlands.

An important feature within the Flats system is a pond near the jetty (‘Luzira’) (6). Little is known about the hydrological behaviour of this system. During the dry season, the water level in the pond was measured to be lower than the level of Lake Albert. No water inflow was visible on the surface. It is very likely that the pond receives influx of water during the dry season while it overspills into Lake Albert through a large channel during the wet season.

Overall, water quality during the dry season is generally good. A concern could be during the wet season where humic acids from surrounding land areas such as wetland systems may possibly increase pH levels and introduce metals into Lake Albert

Impact Assessment

The potential impacts of the project during the construction phase and operation phases are listed and ranked in tables below.

Potential impacts during the construction phase.

No.	Potential Impact	Pre-Mitigation	Post- Mitigation
		Impact severity	
C1	Increased erosion and runoff volumes	Moderate	Minor
C2	Increased dust and sedimentation in drainage streams	Moderate	Minor
C3	Altering the banks and beds of streams by the construction of the pipeline	Moderate	Minor
C4	Spillage of oils, fuel and chemicals polluting water resources	Major	Moderate
C5	Discharge of poor quality effluent from the sewage works at the temporary camp	Moderate	Minor

Potential impacts during the operational phase.

No.	Potential Impact	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity
O1	Reduction in catchment area	Low	Low	Minor	Very Low	Very Low	Negligible
O2	Increased erosion, dust and sedimentation	Low	Low	Minor	Very Low	Very Low	Negligible
O3	Discharge of poor quality storm water from CPF	Medium	High	Major	Low	Medium	Moderate
O4	Spillage of crude oil from Well pads and CPF	Medium	High	Major	Low	Low	Minor
O5	Infrastructure crossing natural drainage lines	Medium	High	Major	Low	Low	Minor
O6	Oil leaks around pipeline	Medium	High	Major	Low	Medium	Moderate
O7	Rise in water level of Lake Albert	High	High	Major	Low	Medium	Moderate
O8	Decrease in Lake Albert levels	Very low/ negligible	High	Minor	Very low	Very Low	Negligible
O9	Discharge of poor quality effluent from the sewage works at the CPF (permanent camp)	Medium	Low	Moderate	Low	Low	Minor

Mitigation measures proposed for the Construction phase include:

- **Prevention of obstruction of water flow:** Impediments to natural water flow shall be avoided, or, if unavoidable, be allowed for in the design by means of appropriately sized and positioned drains, culverts etc.
- **Prevention of surface water pollution by effluent management:** Appropriate use of soak-ways and seepage fields will be put in place to prevent contamination of surface water.
- **Storm water management:** Potentially contaminated storm water shall be kept separate from other drainage at camp sites. Potentially contaminated storm water shall, if necessary, be tested and treated to remove contaminants before being released into the environment.
- **Flood management:** To avoid obstruction to storm water flows, culverts, drains and other means shall be used as necessary.
- **Dust Suppression:** Biodegradable chemical suppression or the use of water sprayers is required to keep the dust levels low and avoid sedimentation in the local surface waters.

- **Sewage water management:** Any discharge from sewage works should meet the IFC Environmental, Health and Safety (EHS) Guidelines for treated sanitary sewage discharge quality.
- **Storm water Management:** Any storm water that has been contaminated by oil, grease or other chemicals from site activity needs to be treated to the discharge standards
- **Process Water Management:** Management of process water to prevent spillages into the environment

Mitigation measures proposed for the Operations phase include:

- **Prevention of obstruction of water flow:** Impediments to natural water flow shall be avoided, or, if unavoidable, be allowed for in the design by means of appropriately sized and positioned drains, culverts etc.
- **Storm water management:** Potentially contaminated storm water shall be kept separate from other drainage at Base camp and other drilling activity sites. Potentially contaminated storm water shall, if necessary, be tested and treated to remove contaminants before being released into the environment.
- **Flood management:**
  - The location of areas prone to flooding relative to the well sites, campsites and access roads shall be confirmed and any consequences of this for drilling programme shall be determined and minimised as soon as possible.
  - Every effort shall be made to ensure the maintenance of the natural flow of water following storm events.
  - No works shall increase the risk of erosion during storm events. Should this be unavoidable specific erosion control measures shall be implemented for the duration of the risk.
- **Sewage water management:** Any discharge from sewage works should meet the IFC Environmental, Health and Safety (EHS) Guidelines for treated sanitary sewage discharge quality.

Acronyms / Abbreviations

Acronym	Description
ARI	Annual recurrence interval
AWM	Albert Water Management
CNOOC	China National Offshore Oil Corporation
CPF	Central Processing Facility
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DRC	Democratic Republic of Congo
DWRM	Directorate of Water Resources Management
EA	Exploration Areas
EBS	Environmental Baseline Study
EC	Electrical Conductivity
EFOs	Environmental Field Officers
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
EPH	Extractable Petroleum Hydrocarbons
ESIA	Environmental and Social Impact Assessment
ESIS	Environmental and Social Impact Statement
ESMP	Environmental and Social Management Plan
GRO	Gasoline Range Organics
IFC	International Finance Corporation
IPIECA	International Petroleum Industry Environment and Conservation Association
KF	Kingfisher
NEMA	National Environment Management Authority
PAH	Polyaromatic Hydrocarbons
POC	Potentially oil contaminated
SOW	Scope of Work
SPT	Sewage treatment plant
SW	Surface Water
TDS	Total Dissolved Solids
WHO	World Health Organization
WRMD	Water Resource Management Directorate

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1.0 INTRODUCTION

Golder Associates Africa (Pty) Ltd. (hereafter 'Golder') was contracted by China National Offshore Oil Corporation (hereafter 'CNOOC') to conduct a baseline assessment of the surface water hydrology associated with the proposed well field development for Kingfisher, Hoima District in Uganda. The assessment was conducted as a technical study to inform the Environmental and Social Impact Assessment (ESIA) being conducted by Golder for the Kingfisher Development Area.

This report presents the hydrology baseline and impact assessment for the Project. An understanding of baseline hydrological conditions prior to oil and gas development is essential to assess changes in water availability that could affect local users. Changes in hydrology can also affect water quality and other resources such as fish habitat, vegetation and wildlife. Hydrological data is further required to design oil and gas facilities including culverts, channels and storage ponds.

2.0 SCOPE OF WORK

The baseline and impact assessment components of surface water address the following aspects:

- Description of the annual and seasonal climatic regimes using parameters such as mean annual temperature, mean monthly rainfall, annual and monthly evaporation for the study area based on regional and local climatic data;
- Development of a surface water monitoring network;
- Management of baseline monitoring data;
- Development of stage-discharge curves;
- Description of the annual and seasonal surface water regimes for the study area based on monitoring data;
- Management of water quality monitoring data; and
- Description of water quality monitoring data and analysis.

3.0 METHODOLOGY

3.1 Documentation review

Available reports and studies supplied by the client as well as those found as part of a literature survey were used to provide a description of the baseline. A comprehensive reference list can be found in section 8.0.

3.2 Field investigations

In December 2013 the following monitoring procedure was set up:

- During site visits, general observations in terms of the site condition should be made and recorded. The observations included changes in channel form at the gauge cross-section, and upstream and downstream conditions. Observations also included vegetation changes. The extent of vegetation and channel sedimentation/erosion was noted. All changes between site visits resulting from catchment development and/or local activities were recorded;
- Flow measurement must be performed consistently in the same way, according to the Golder flow measurement procedure supplied to the monitoring team;
- Sampling of surface water must be done at key locations within the study area;
- It is crucial that measured monitoring data is processed and checked on the same day, so that any errors can be identified to prevent loss of monitoring data; and
- Training on surface water monitoring data collection was provided to the monitoring team.

4.0 PROJECT SUMMARY

4.1 CPF, wells flowlines and associated infrastructure

Wells, The Kingfisher development is an upstream project comprising wells, flow lines, central processing facility (CPF) and associated infrastructure and an oil product line, the feeder pipeline, to distribute oil to the tie in point with the export pipeline at Kabaale. This infrastructure is summarised in more detail below.

The wells, flowlines, central processing facility (CPF) and supporting infrastructure are situated on the Buhuka Flats in the Kingfisher Development Area (KFDA), on the south-eastern shores of Lake Albert. The project entails the drilling of wells from four onshore well pads, namely Pad 1, Pad 2, and Pad 3 (where exploration wells have already been drilled) together with Pad 4A (where no drilling has yet taken place). A total of 31 wells are planned to be drilled and commissioned as part of the development, 20 of which will be production wells and 11 to be used as water reinjection wells.

The produced well fluids will be conveyed to the CPF through buried infield flow lines connecting each well pad to the CPF. Well fluids will be separated at the CPF to yield produced water, sand, salts and associated gas (together with small quantities of other material) and crude oil of a quality that will meet the crude oil export standard. At the CPF the associated gas will be utilised for production of power or LPG for local market. Power will serve the requirements of the Kingfisher development but in later years is likely to be in excess of project requirements and will be exported to the national grid. No gas flaring is contemplated except in cases of emergency.

Supporting infrastructure associated with the production facility will include in-field access roads and flowlines, a jetty, and a water abstraction station on Lake Albert, a permanent camp, a material yard (or ‘supply base’), and a safety check station at the top of the escarpment (Figure 1).

4.2 Feeder pipeline

A feeder pipeline exits from the CPF and extends to the north running from the CPF storage tanks to a delivery point near Kabaale. The feeder pipeline exits the CPF on the east side, running almost due north to the base of the escarpment, where the alignment turns to the East climbing the escarpment. The average gradient in this section of the route is 1:3 (Vertical: Horizontal), rising from roughly 650 to 1040 mamsl. within a horizontal distance of 740 m. From the point at which the feeder pipeline crests the escarpment, the pipeline route runs to the north-east through gently undulating terrain that is extensively cultivated. This landscape includes a number of rural settlements. The route passes south-east of Hohwa and Kaseeta villages and passes immediately north of the planned Kabaale Airport, turning eastward to the terminal point at the proposed Kabaale Refinery. The total length of the pipeline is 46.2 km.

At Kabaale, the Government of Uganda is planning an industrial park which, among other facilities, will include a refinery, associated petrochemical processing plants, an international airport and related supporting infrastructure.

At the delivery point, there will be metering of the crude oil, which will be piped either to the industrial park to feed the refinery and associated petrochemical industry or exported through the East African Crude Oil Pipeline (EACOP), planned from Kabaale to the Tanga sea port in Tanzania. The EACOP will be a public - private partnership between the governments of Uganda, Tanzania and oil company(s).

The Feeder Pipeline ends at the delivery point in Kabaale. The industrial park and the EACOP are independent projects that do not feature further in the FD-ESMP (Figure 2).

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Figure 1: Project infrastructure to be developed on the Buhuka Flats

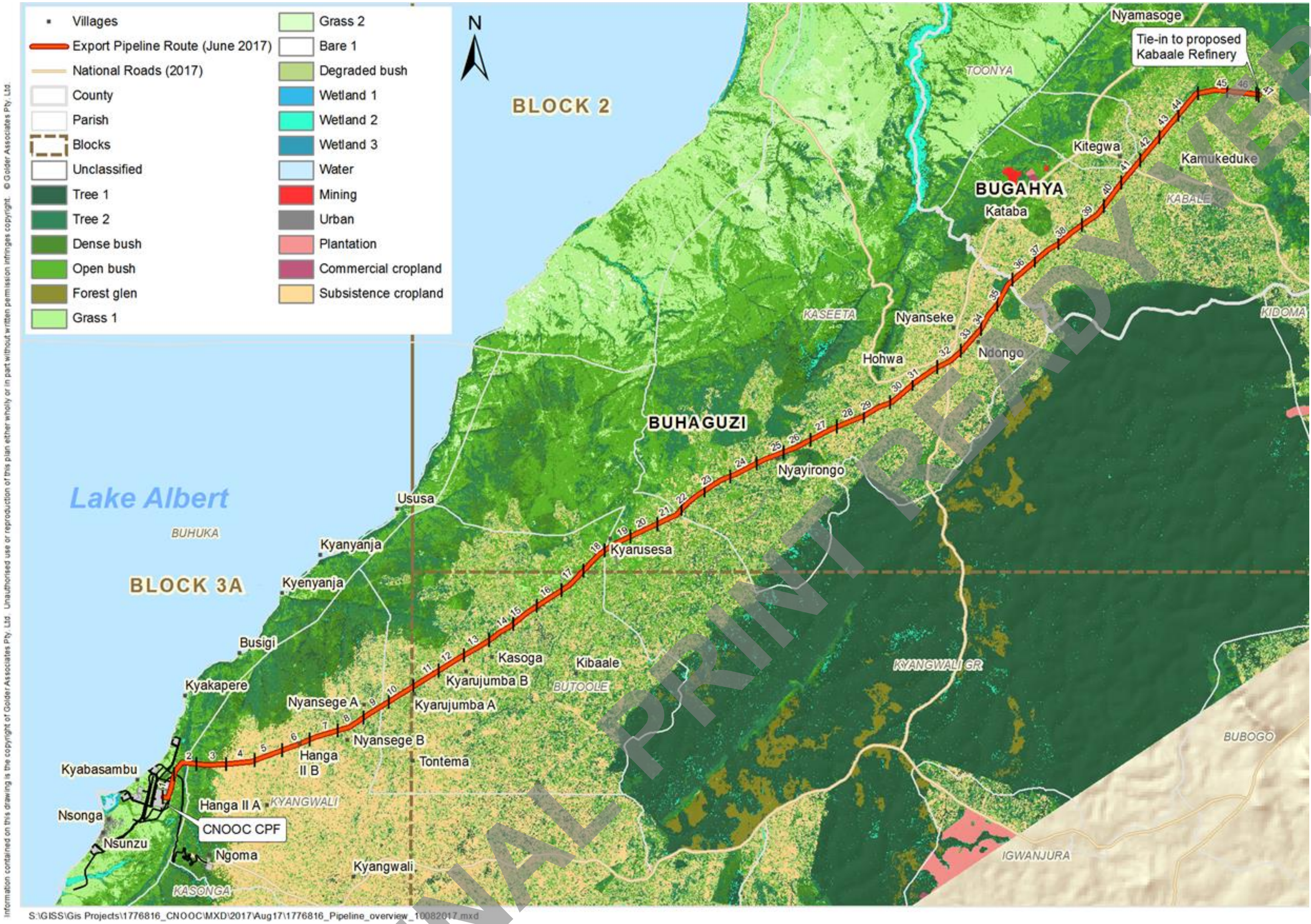

Figure 2: Project site location and feeder pipeline route

5.0 BASELINE INVESTIGATION

5.1 Objectives of Baseline investigation

The key objective of the baseline surface water investigation was to provide a description of the current hydrological conditions on site. This was achieved by:

- Collating available information in terms of meteorological and hydrological data;
- Setting up a hydrological monitoring network to collect information on baseline flows and water quality; and
- Describing flow patterns in the affected catchments in order to assess the potential impact the drilling could have on the catchment.

5.2 Regional Setting

5.2.1 Climate

5.2.1.1 Historic climate

The Köppen Climate Classification system was used to determine the regional climate for Uganda. The classification divides type of climates into different groups and sub-groups. The study area falls within the Aw group in the classification system. The regional climate is thus described as tropical with a distinct wet and dry season. The dry season coincides with the summer months with higher temperatures as presented in Figure 3. Temperature differentials are minimal in the area with average temperatures ranging from 22.4℃ to 25.6℃. A mean annual rainfall of approximately 1 140 mm was recorded between 1991 and 2015.

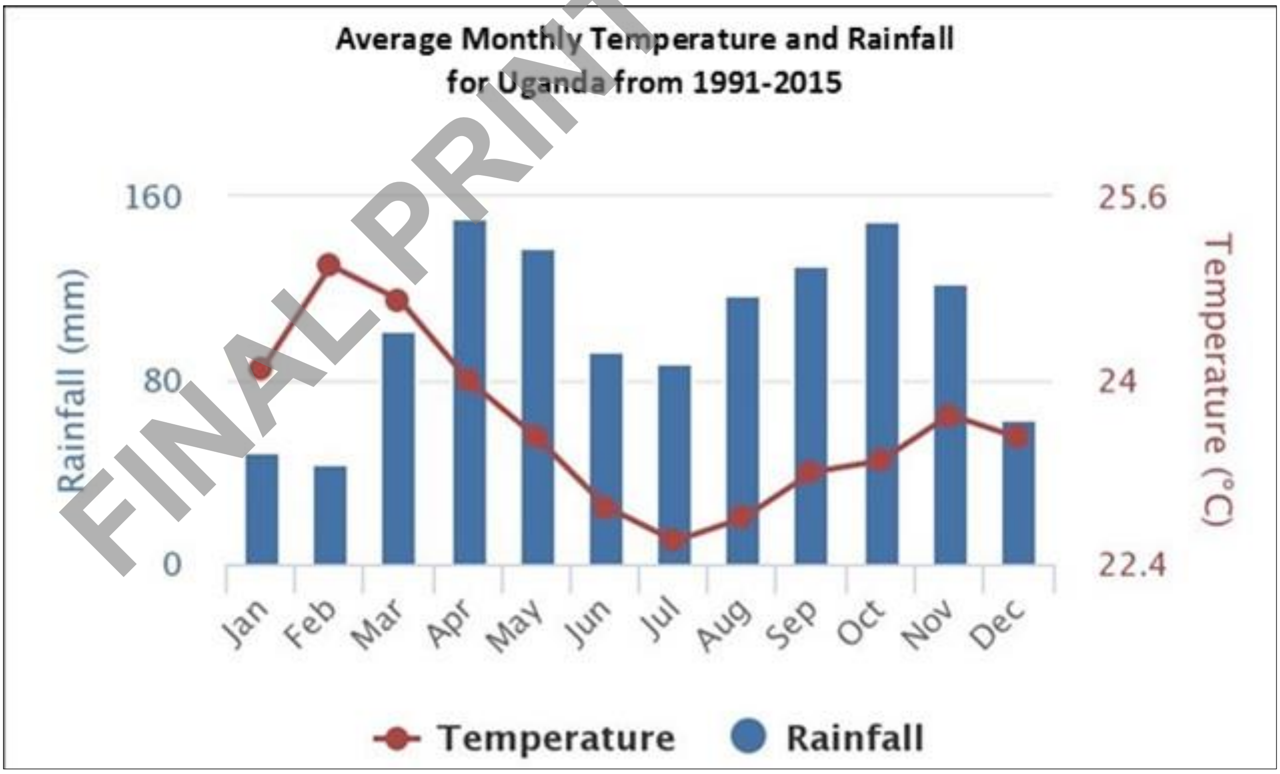

Figure 3: Rainfall data – Uganda (The World Bank Group, 2017)

The peak rainfall periods are between March-May and August-November. In general, the second peak rainfall (August to November) is higher than the early peak. The rainfall and in turn river runoff is important for agricultural development. Western areas bordering the rift valley are the driest and hottest.

5.2.2 Rainfall

Rainfall over Lake Albert catchment is lowest over the Lake (700 mm), gradually increasing outwards towards the escarpments on both sides to over 1 400 mm (Savimaxx Limited, 2006) as shown in Figure 4. The escarpment is likely creating an orographic effect, whereby rainfall increases due to the convection of air as altitude increases.

Rainfall over the Lake is approximately 700 mm/a and gradually increases towards the escarpments to 1 400 mm/a.

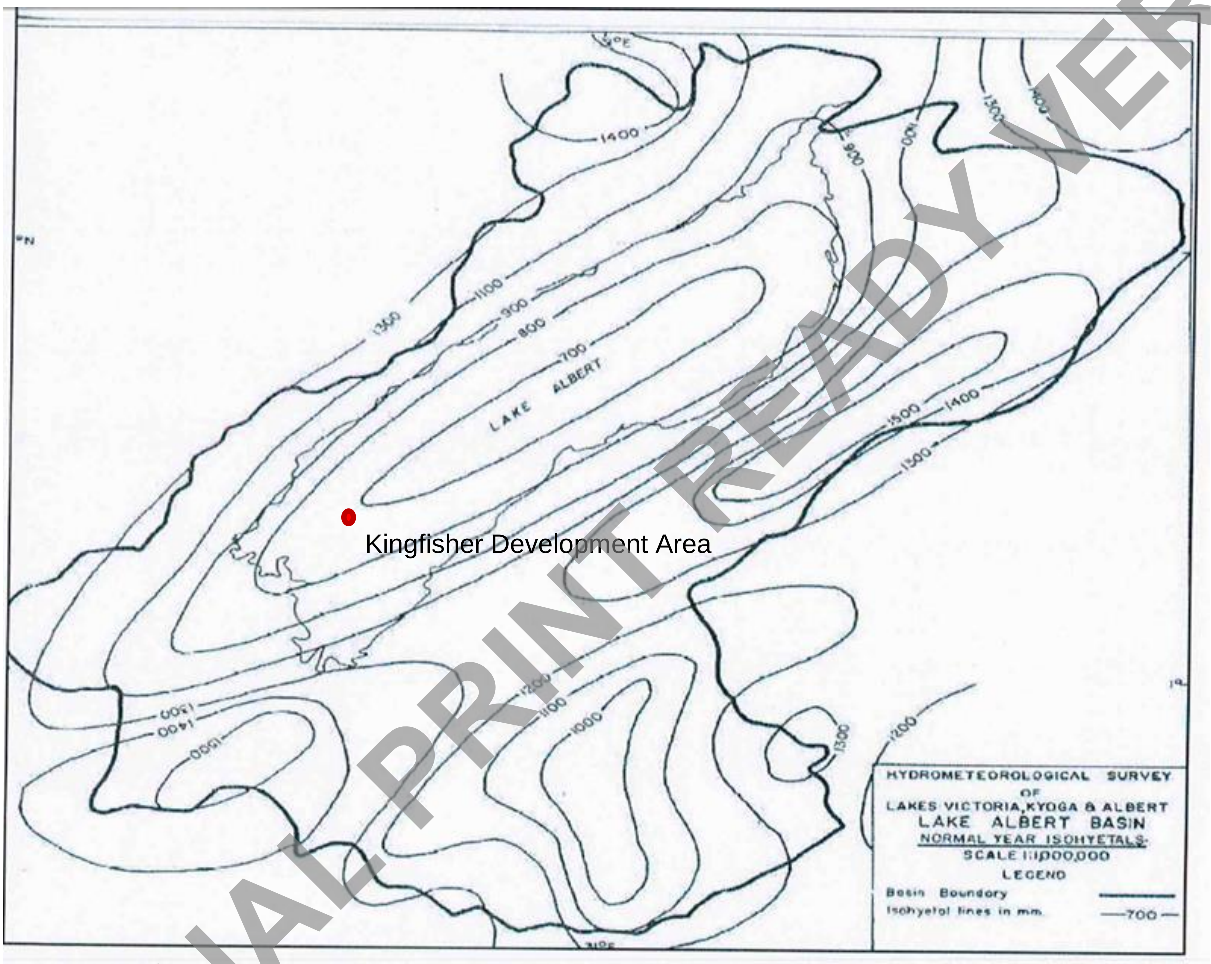

Figure 4: Rainfall distribution over the Lake Albert Basin (WSS Services (U) Ltd, 2012)

Rainfall data for the actual site was not available. Two rainfall stations were set up, one on the Flats and one on the escarpment to monitor the difference in rainfall regimes.

Rainfall data was obtained from neighbouring towns and existing reports and studies on predicting east African storms. The peak design storm that was used in the floodlines and baseline modelling is also presented in this section.

Design rainfall was calculated using a method reported in The Prediction of Storm Rainfall in East Africa, Fiddes et al (1974). According to the report, for much of East Africa a station on or close to a study area cannot be found or if available often has limited records that would give unreliable estimates of rainfall peaks. In order to address this limitation all available published records were analysed to produce maps of storm rainfall from which individual catchments could be interpolated.

The Karira network was selected as the closest representative rainfall region for the study. The mean regression equation for the network was applied.

Mean equation Y= 53.06 t 13.95 X

Y = Maximum expected daily point rainfall in T years (mm)

X = – (0.834 + 2.303 log log T) where T is the return frequency (yrs)

For comparative purposes, rainfall data was extracted from the KNMI Climate Explorer webpage. The closest town with available rainfall data was Masindi which is 87.5 km away from the CNOOC Kingfisher Development Area. The Masindi rainfall data record is 59 years in length, with 647 days of missing data. The maximum 24 hour rainfall depths each year were calculated and a statistical projection was plotted to calculate the various return period design rainfall depths. The Log Pearson 3 and Log Extreme value type 1 distribution were well suited to the data. A comparison between the design rainfall depths extrapolated from these two distributions and the interpolated rainfall depth from the east Africa report is shown in Table 1.

Table 1: Comparison of Calculated 24 hour ARI Peak Rainfall depths

Return Periods	Log extreme value type 1 distribution from KNMI data	Interpolated from Design storms in East Africa
1 in 2	57	58
1 in 5	-	74
1 in 10	81	84
1 in 20	92	94
1 in 50	109	107
1 in 100	124	117
1 in 200	141	162

The length of the Masinidi rainfall record is relatively short for calculations of extreme events such as the 1 in 200 year design storm. This can be seen by the difference in the extreme event depths produced using different methods.

5.2.3 Evaporation

The site area does not have long-term potential evaporation records. The Lake evaporation was taken from the hydro meteorological survey of the Lake's catchments report and is presented in Table 2.

Table 2: Monthly Evaporation for Masindi Town (UNDP and WMO, 1974)

	Date Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Monthly evaporation (mm)	1962-1968	149	135	146	128	137	121	116	117	127	131	119	131

5.2.3.1 Climate change

Several studies have indicated that Uganda is vulnerable to climate change. Climate change impacts can result in significant changes to water management measures. For this reason, a high level climate change overview was included in this report. The CGCM3.1 Model presented on the Climate Change Portal (The World Bank Group, 2017) was used for the discussion.

Results indicate that Uganda is likely to experience more extreme periods of intense rainfall, an erratic onset and cessation of the rainy seasons and more frequent episodes of drought. (Global Climate Change Alliance, 2012).

Monthly Rainfall

The CGCM3.1 model predicts an increase in monthly rainfall averages with an increase of up to 30 mm in November as presented in Figure 5. A decrease of 1.5 mm was noted for August. An overall increase of approximately 180 mm per annum is predicted. This will result in a mean annual rainfall of 1 320 mm.

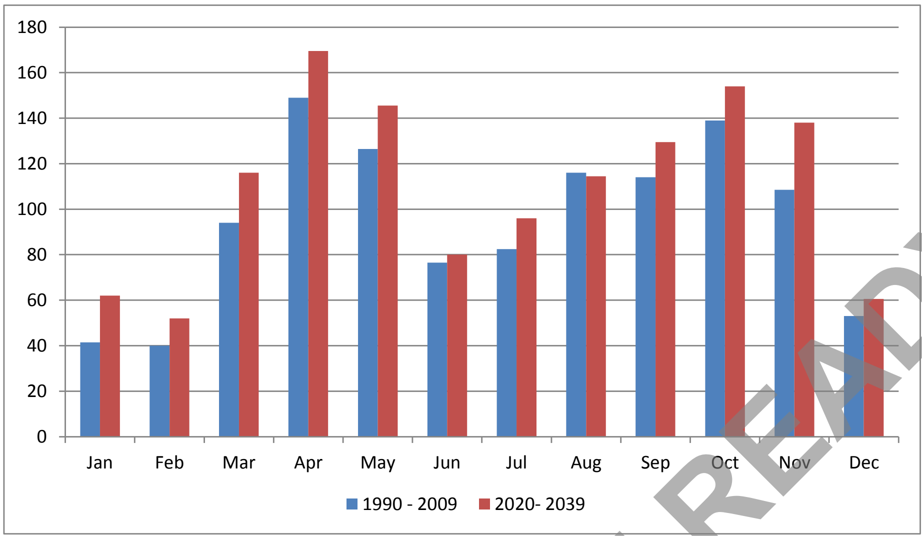

Figure 5: Projected change in rainfall based on the CGCM3 model for the period 2020 to 2039

An increase in rainfall intensity is also anticipated. Figure 6 presents the number of days with extreme rainfall predicted as compared to the historical data available.

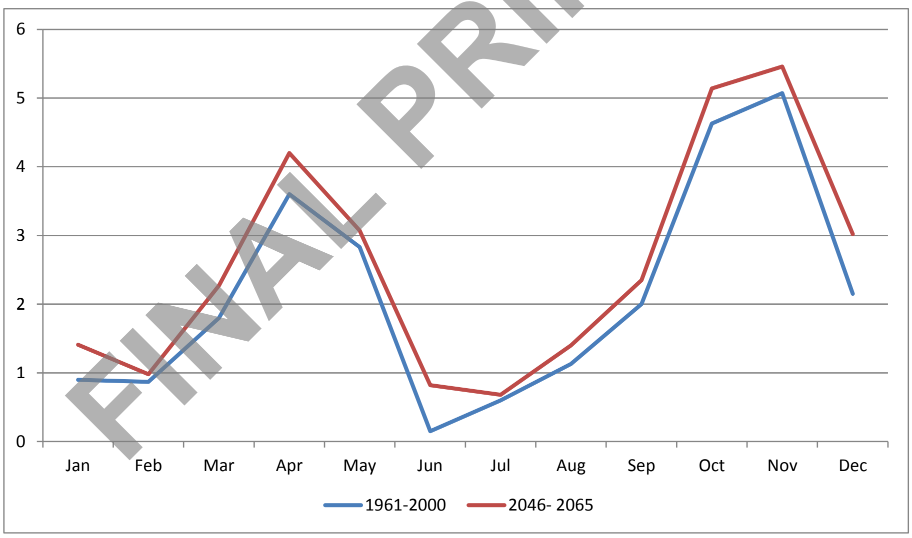

Figure 6: Days of extreme rainfall

5.2.4 Topography

The Lake Albert catchment falls within the Western Rift Valley. The landscape ranges from the low-lying Rift Valley floor to the rift escarpment and the raised hill ranges. The topography of Hoima District is part of a divided central African surface characterized by broad, flat-topped ridges of about 1 000 to 1 100 meters in height, whose formation is given as upper *Cretaceous* (65 - 135 million years ago). The surface rises to a plateau, which ranges between 600 - 800 metres above sea level. The topography around the edge of the Lake ranges from the broad plateau further inland, dipping down abruptly to the low-lying lake's edge which is flat and characterized by wetlands and intertwining rivers (International Lake Envrionment Committee Foundation, 1999).

The Kingfisher Development Area is located in an area that is commonly known as the Buhuka Flats in the Hoima District. Figure 7 shows the drainage lines of the Kingfisher Development Area, as well as the wetland delineation and the multiple rivers that flow over the sunken Flats on which the project is situated.

The water system drains northwards from the site. Lake Albert and its surrounding catchment form part of the source of the Nile. The main sources of water that feed Lake Albert are the Semliki River and the Victoria Nile. The Semliki River enters Lake Albert in the southern tip and drains from Lake Edward. The Victoria Nile enters into Lake Albert at the north, next to the outflowing point of Albert Nile. The Victoria Nile drains Lake Kyoga which in turn is fed from Lake Victoria, which is the largest fresh water Lake in Africa. The Victoria Nile regulates the levels in Lake Albert, but because it does not enter lower down in the Lake, it does not influence the salinity or ecology. Lake Albert is a saline Lake with a pH of approximately 9 (International Lake Envrionment Committee Foundation, 1999). There are other smaller rivers that enter into the Lake from Uganda and the DRC shores, some of these are highly seasonal and of little importance to the hydrology of the Lake.

Much of Hoima District is occupied by sedimentary beds of the Bunyoro geological series mainly represented by tillites and phyllites with subsidiary amounts of sandstones and conglomerates as basal members. These rocks are generally classified under Precambrian era, which are part of the dissected African surface.

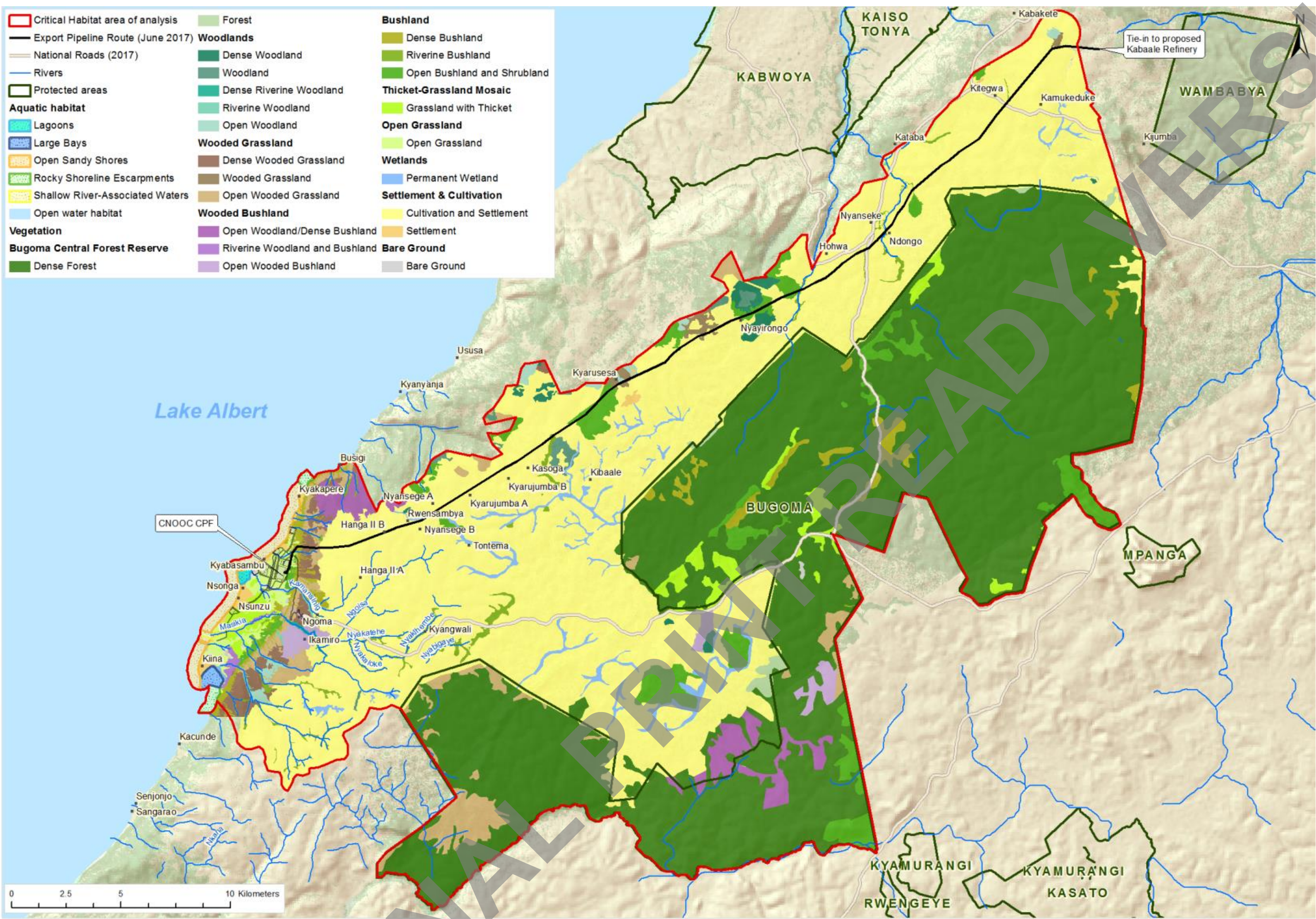

Figure 7: Regional land uses map indicating drainage lines and wetlands within the regional study area of the Kingfisher Development

5.2.5 Regional description

The proposed oil and gas well-field site is located on the eastern border of Lake Albert shores, in Uganda, in the Hoima District. Lake Albert forms a border between the Democratic Republic of Congo and Uganda. The Kingfisher Development Area is situated within exploration area block 3A. Figure 9 illustrates the site location in relation to the lake.

Figure 8 indicates the location of the Kingfisher Development Area within the exploration area block 3A and surroundings and the tie-in to the proposed Kabaale Refinery.

The Albertine Graben region stretches from Sudan in the north to Lake Edward in the south. The Lake Albert region is remote, land-locked and approximately 1 200 km from the nearest sea port. The region has rich biodiversity and significant surface water resources. The rivers and streams originate on the high elevated areas of the escarpment, flow down the escarpment into the valley and drain into Lake Albert. A series of erosion valleys and gullies cut the escarpment and discharge runoff from the escarpment to the valley.

The seasonal streams and rivers are flooded by runoff from the catchment areas after heavy rainfall events. The water drains quickly into Lake Albert and the discharge in the run-off channels ceases. The perennial rivers (Hohwa and Wambabya) flow continuously with peak flow during the rainy season.

All of Uganda drains towards the Nile. Most of the rivers originating on the highlands surrounding this area drain into the Lakes which in turn, drain into the Nile via Lake Albert. The River Semliki, which drains from Lake Edward is the most significant of these rivers (Uganda National Environmental Management Authority, 2010).

Water Use

Lake Albert is used mainly for fishing and tourist industries, with a high number of the protected areas being in the Albertine Rift and specifically in the area around Lake Albert. A number of people live in fishing villages on the shores of lakes Albert, Edward and George with fisheries activities providing an important source of livelihoods for the people in the Albertine Graben. The region contributes 18.7% of the total national fish catch, of which 15% is contributed by Lake Albert. Fish processing has become an important activity on the lake, both at artisanal and industrial level (NEMA, 2008). In terms of the fish biodiversity Lake Albert is the richest of the lakes in the region having approximately 53 fish species, about ten of which are endemic.

The local communities choose to use water from rivers and streams for agricultural purposes as the soils on the rift valley floor are predominantly sandy, making the area moisture deficient and unsuitable for agriculture. The clay soils in the Semliki flats are saline which also limits their agricultural potential. Therefore, the largest proportion of the rift valley area is of low agricultural potential, partly explaining its conservation area status.

The main settlements are sparse and rural with the majority of inhabitants being indigenous pastoral communities whose livelihoods depend on cattle. They include the Batuku in the Semliki flats and Basongora in Kasese to the south-west. The main towns in the area include Masindi, Hoima, Fort Portal, Hima and Kasese-Kilembe. Urbanization is taking place along the road system in the region and is likely to intensify due to the oil production activities in the region, which may pose new challenges of environmental management and development.

There is a small pocket of water called Luzira (RS03 in the Cultural Heritage Impact Assessment Report) that is a body of water with significant cultural features and is located near the Lake shore, about 200 m from the Jetty. For more information on this feature, please refer to the Cultural Heritage report. Lake Albert is the seventh largest in Africa, with a surface area of 5 300 km^2. The Lake surface has an elevation of 615 masl and its' deepest point is 58 m, with a median depth of 25 m. The water level fluctuations in the past have been recorded as an annual change of 0.5 m, but this range of fluctuation has increased due to climate change and the levels rising in Lake Albert (International Lake Envrionment Committee Foundation, 1999).

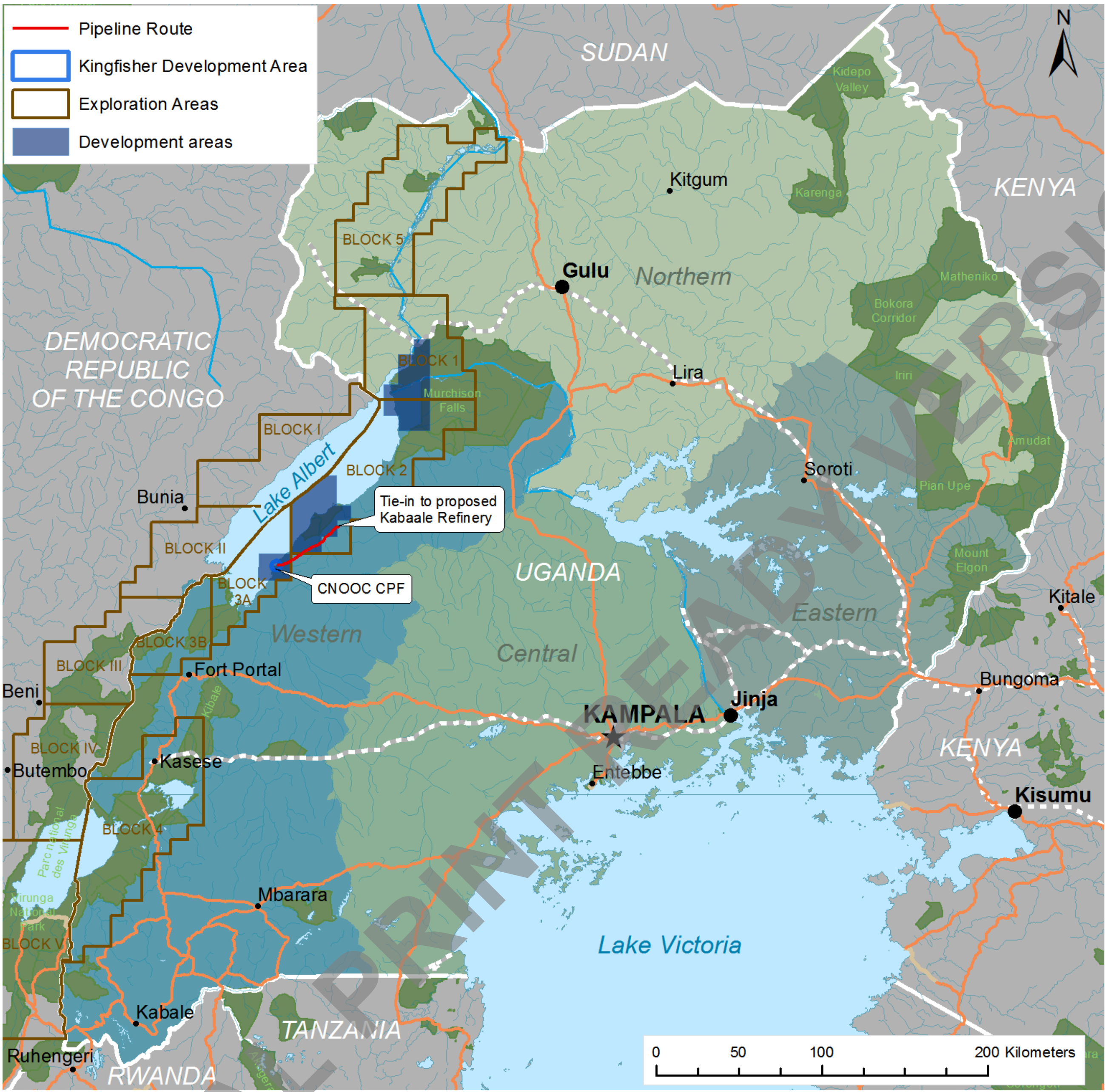

Figure 8: Location of the Kingfisher Development Area within the exploration area

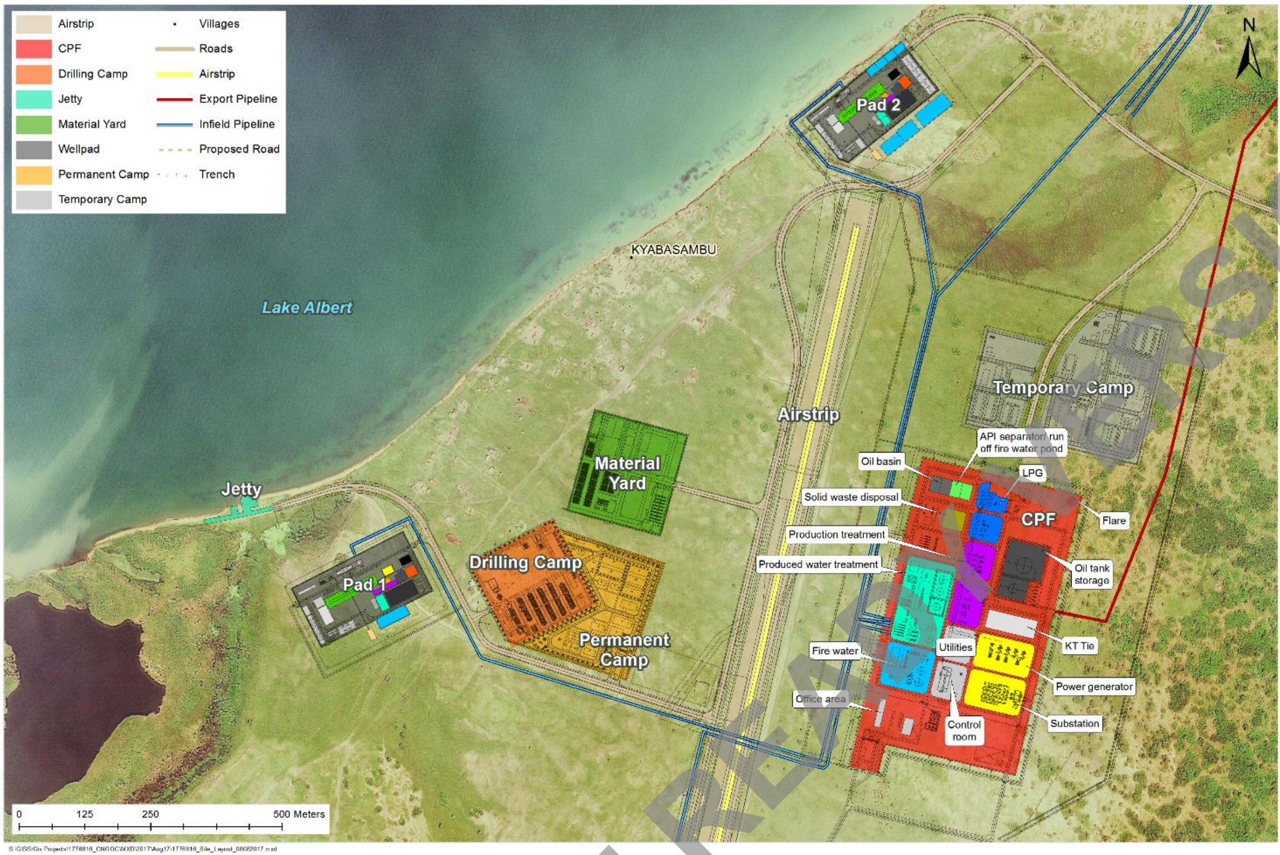

Figure 9: Site layout map

5.3 Hydrological description

5.3.1 System overview

The project area regionally forms part of the Hoima District, a Ugandan District that is bordered by Lake Albert in the west, Bundibugyo and Kibaale Districts in the south, Masindi District in the northeast and Kiboga District in the east. It is also hydrologically located within the Albert Water Management (AWM) Zone (Figure 10).

The AWM Zone is made up of catchments discharging into Lake Edward and Lake George; and catchments downstream of Lake Edward discharging into Lake Albert. Lake Albert occupies the majority of the approximately 2 270 km^2 area of the District covered by water bodies[1]. The Rivers Howa, Wambabya, Hoima and Waki all drain into Lake Albert. Hoima has substantial surface water resources which account for about 38% of the total area of the District.

In the western fringes of Lake Albert Basin lies the Western Rift Valley, an area that is largely covered by the Semliki Flats, Lake Albert and the Escarpment (NEMA, 1996). Road construction to the Lakeshores in Hoima District (project district) is reported to remain a big challenge due to the rift valley terrain.

Local Context

Hydrologically, the project site is located within the Kingfisher Development Area catchment and drains westwards into the south eastern embankments of Lake Albert. Kingfisher Development Area catchment is associated with a very high western rift escarpment that drains into Lake Albert via several scattered streams

[1] Other water bodies in the district include River Kafu which forms a boundary with Kibaale District and drains into Lake Kyoga (Kyoga WM Zone), east of Albert WM Zone.

and wetlands flowing westwards. Streams within the project zone of influence include the Kamansinig and Masika Rivers.

The Kamansinig River flows south west from above the escarpment, drains north west over the escarpment and then passes just south adjacent to where the majority of the proposed project infrastructure will be located below the escarpment into Lake Albert. The Masika River drains its tributaries, the Ngoisa, Nyakatehe and an unnamed tributary, also from above the escarpment. The Masika River drains then flows south west between Pad 3 and 5 into Lake Albert below the escarpment. Various other streams also flow over the escarpment and either join the main Rivers mentioned above (such as Masika) or gradually and independently feed Lake Albert.

The area below the escarpment is approximately 13 km^2 and, besides the rivers mentioned, is characterised by relatively scattered wetlands at an elevation level associated with most project infrastructure (628 mamsl). These plains, because of their close relationship with Lake Albert, may have significant water quality implications (see section 5.3.4).

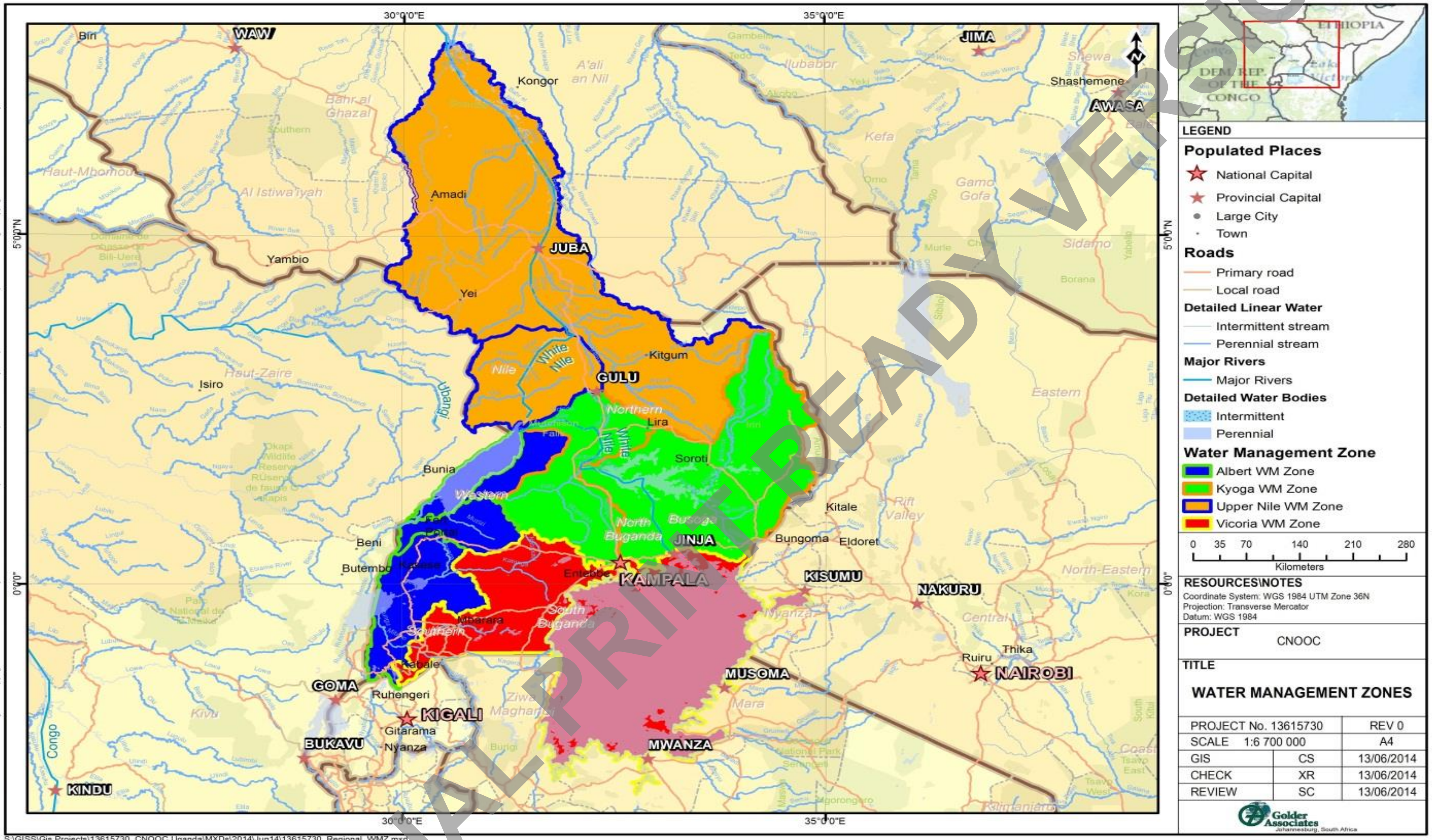

Figure 10: Regional water management zones for the site

5.3.2 Lake Albert

Lake Albert lies between two parallel escarpments in the Western Rift Valley.

Lake Albert covers a surface area of approximately 5 300 km^2. The Lake is approximately 150 km long, with an average width of 35 km and a maximum depth of 56 m. The principle influent streams to the Lake are the Semliki and Victoria Nile (Ramsar, 1992) (International Lake Environmental Committee, n.d.).

Lake Albert has a catchment area of 18 223 km^2 and includes Semliki, Muzizi and the west-ward flowing component of Kufu. The Semliki and Victoria Nile inflows account for approximately 83 % of the total inflow to the Lake, direct rainfall, approximately 10 % and inflow from local catchments account for the remaining 7 %. Evaporation accounts for approximately 26 % of the outflow from the Lake and the Albert Nile is the largest output (WSS Services (U) Ltd, 2012).

Rainfall over the Lake is approximately 700 mm/a and gradually increases towards the escarpments to 1 400 mm/a. Water levels at Butiaba on Lake Albert (approximately 90km north of the project site) have been recorded since January 1948. Analysis of the records shows annual variations of approximately 4 m. The monthly variations are shown in Figure 11.

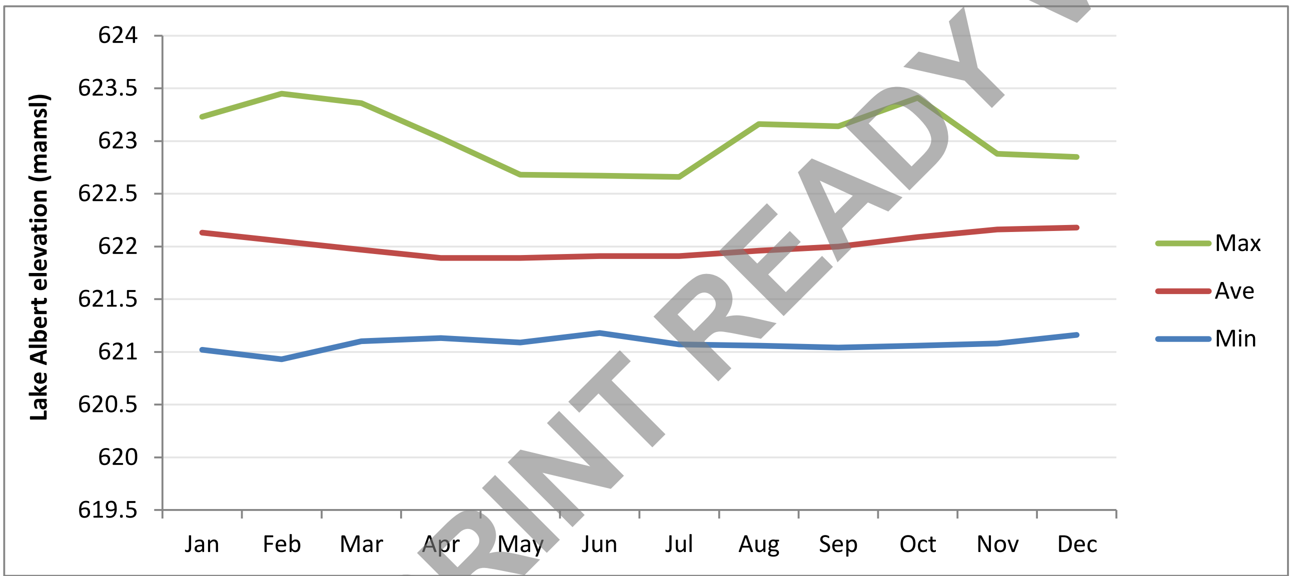

Figure 11: Lake Albert surface water elevation at Butiaba

It is to be noted that the surface water elevation trends do not depend solely on the hydrology of the Lake. It is also dependent on the dam release operations and the wind waves. Wind blowing over the calm Lake surface produces an effect that may appear as a widely varying and fluctuating ruffling of the surface. These small wind-induced waves can be observed at the Flats. These are quite transient, dissipating rapidly if the wind dies away. However due to the extent of the Lake it is also likely that more persistent gravity waves affect the water level. It is likely that a difference of several metres can be observed at different location on the Lake. A water level logger was installed on the Flats to monitor the more localised water level of Lake Albert.

The impact of these naturally occurring waves on the geomorphology of the Flats is noticeable as shown in Figure 12. At several locations along the Flats shoreline, the soil is being exposed as waves erode the shoreline. This is a naturally occurring process and it is being compensated to some extent by the rate of sediment material transported from the Flats upstream catchments and discharged into Lake Albert.

Figure 12: Wave erosion occurring on the shoreline of the Flats

5.3.3 Conceptual hydrological understanding

The water system of the Flats is very different from the rest of its upstream catchment. A conceptual model of the Flats' hydrological system is presented in Figure 13.

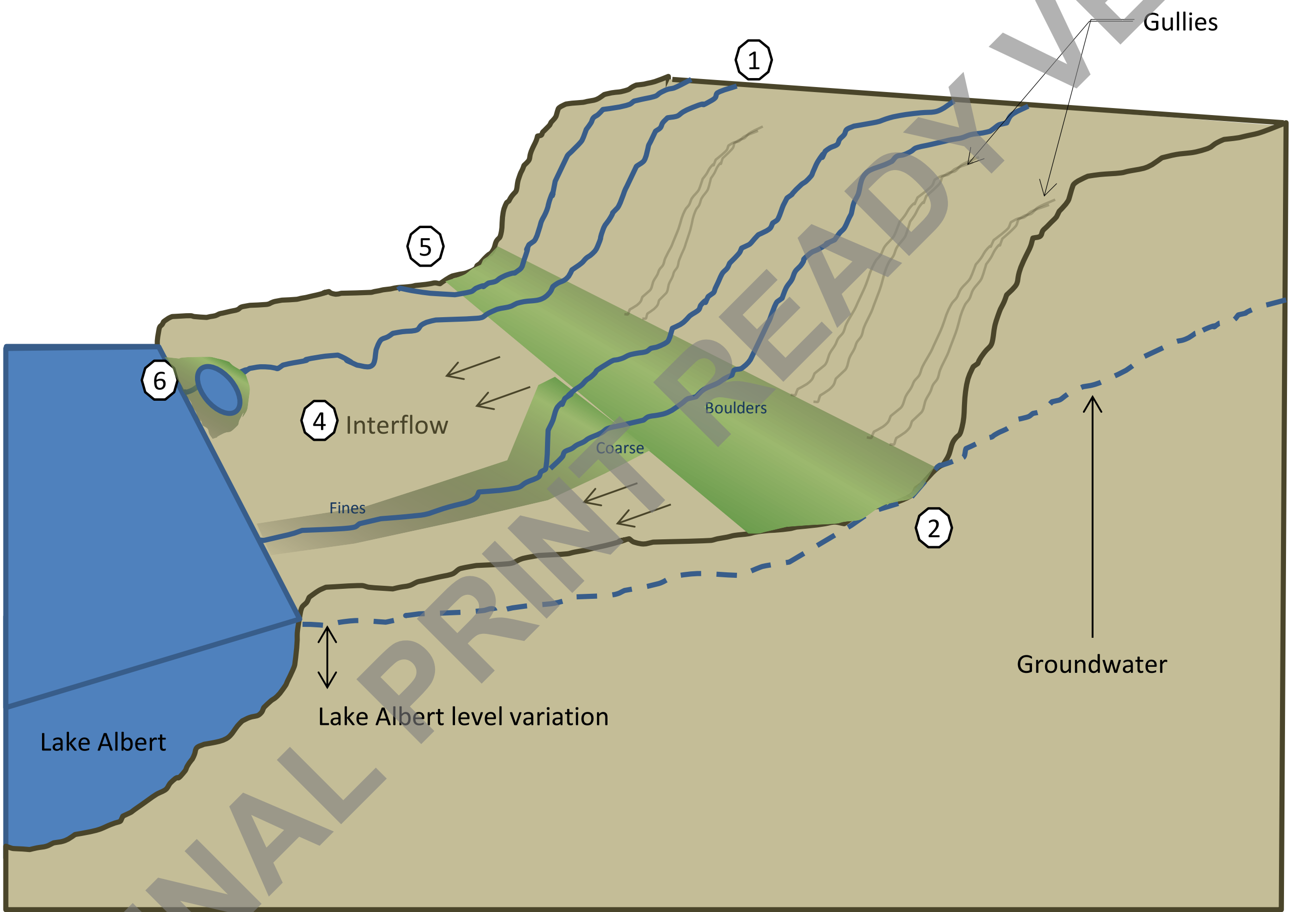

Figure 13: Hydrological Conceptual Model

A total catchment of 65 km^2 generates runoff during the rainy season that discharges onto the Flats. Water is conveyed through ravines on the steep slopes of the escarpment (1). Water has a strong energy when it reaches the Flats as evidenced by the large boulders within the river bed (see Figure 14a) and by the large gullies that divides the northern shorter sections of the Flats (5) (see Figure 16). Apart from the short section of the Flat in the North, the energy of the discharged water seems to get dissipated very quickly as the slope becomes very Flat and the losses generated by the bushy vegetation visible at the bottom of the escarpment slow down the flow of water. This is a zone of recharge where water infiltrates into the soil (see Figure 14c & Figure 17).

During the dry season, the Flats still receive some water from its upstream catchment. This water is coming from both the soil moisture stored during the rainy season in the catchment and the groundwater seepage as the steep slopes of the escarpment intercept the groundwater (2). Evidence of the groundwater seepage is given by a 100m high bandwidth of green vegetation visible on the lower section of the escarpment during the dry season. Some of the smaller streams disappear from the surface a few hundred metres away from the bottom of the escarpment. This shows that the zone at the bottom of the escarpment is an important zone of recharge of water into the soil.

Some of this water contributes to recharging the aquifer, some will move through the soil towards Lake Albert (4) and the rest is evaporated. Evidence of the water pathway through the soil is shown by the road shown in Figure 15 intercepting the interflow due to the compaction of the soil. The streams that are large enough slowly make their way through densely vegetated wetlands.

An important feature within the Flats system is a pond near the jetty also referred to as 'Luzira' (6). Little is known about the hydrological behaviour of this system. During the dry season, the water level in the pond was measured to be lower than the level of Lake Albert. No water inflow was visible on the surface. It is very likely that the pond receives influx of water during the dry season while it overspills into Lake Albert through a large channel during the wet season.

(a) Boulders (b) Coarse (c) Fine

Figure 14: River bed material

Figure 15: Interflow interception due to soil compaction

Figure 16: Gullies observed on the escarpment and plain

Figure 17: Wetland

5.3.4 Water quality

In order to obtain a reasonable water quality baseline, twenty two (22) monitoring stations were pre-selected for possible sample collection and analyses. The metadata for the surface water monitoring sites are given in Table 3. From these sites, ten (10) were assessed in detail with *in situ* measurements and grab sampling, while the remaining sites were monitored *in situ* only. Sites where grab samples were collected and analysed are highlighted in Table 3 and illustrated in Figure 18.

Table 3: Surface water quality monitoring points for the Kingfisher Development Area

Monitoring Point ID	Name or Description	Coordinates		Elevation (m)
		Latitude	Longitude	
SW1*	Tributary associated with proposed road cross section 3 (Kyakapere)	N 01°15'53.6"	E 30°45'27.5"	641
SW2*	Upstream of cross section 3 - Kyakapere (upstream)	N 01°15'50.6"	E 30°45'35.7"	677
SW3	Cross section 2	N 01°16'04.7"	E 30°45'30.7"	639
SW4*	Further upstream of SW5	N 01°15'16.4"	E 30°45'33.0"	676
SW5	Upstream of Spoil Area A(Quarry and Asphalt Plant) (Kowet)	N 01°15'17.2"	E 30°45'27.8"	649
SW6*	On Kamansinig river upstream SW7 (Kachasambo)	N 01°14'24.9"	E 30°45'26.1"	681
SW7	Kamansinig river upstream of the airstrip	N 01°14'20.7"	E 30°45'07.2"	656
SW8	Culvert on Kamansinig river western side of the proposed airstrip	N 01°14'19.5"	E 30°44'45.0"	642
SW9*	river upstream of proposed Spoils Area B - Reservoir (Nyakateke)	N 01°13'40.9"	E 30°45'10.0"	660
SW10	river downstream of proposed Spoils Area B (Nyakateke)	N 01°13'43.8"	E 30°45'03.5"	651
SW11	river below the escarpment and upstream of wetland sensitive areas	N 01°13'42.5"	E 30°44'42.7"	630
SW12*	Kamansinig river inflow to Boguma Lagoon and adjacent to Jetty (associated with Pad 1)	N 01°14'51.3"	E 30°44'21.0"	620
SW13	Small non-perennial stream 70 m upstream of proposed Pad 5	N 01°13'01.0"	E 30°43'27.3"	619
SW14*	Downstream of prior to entering Lake Albert	N 01°13'13.9"	E 30°43'23.1"	624
SW15	Stream from escarpment flowing towards South End Fishing Village (Mugera)	N 01°12'27.0"	E 30°44'04.6"	665
SW16	Downstream of SW15 (Mugera)	N 01°12'27.7"	E 30°44'01.6"	649

Monitoring Point ID	Name or Description	Coordinates		Elevation (m)
		Latitude	Longitude	
SW17	Tributary of river on escarpment	N 01°12'43.7"	E 30°44'18.5"	662
SW18	Kamansinig river between SW7 and SW8 (equidistance)	N 01°14'21.30"	E 30°44'55.90"	641
SW21	Site along the pipeline 35 km from the CPF site (east of pipeline)	N 01°24'12.11"	E 31°00'35.24"	1031
SW22	Site along the pipeline 35 km from the CPF site (west of pipeline)	N 01°24'06.02"	E 31°00'39.38"	1023

* - Site initially sampled for metals during December 2013

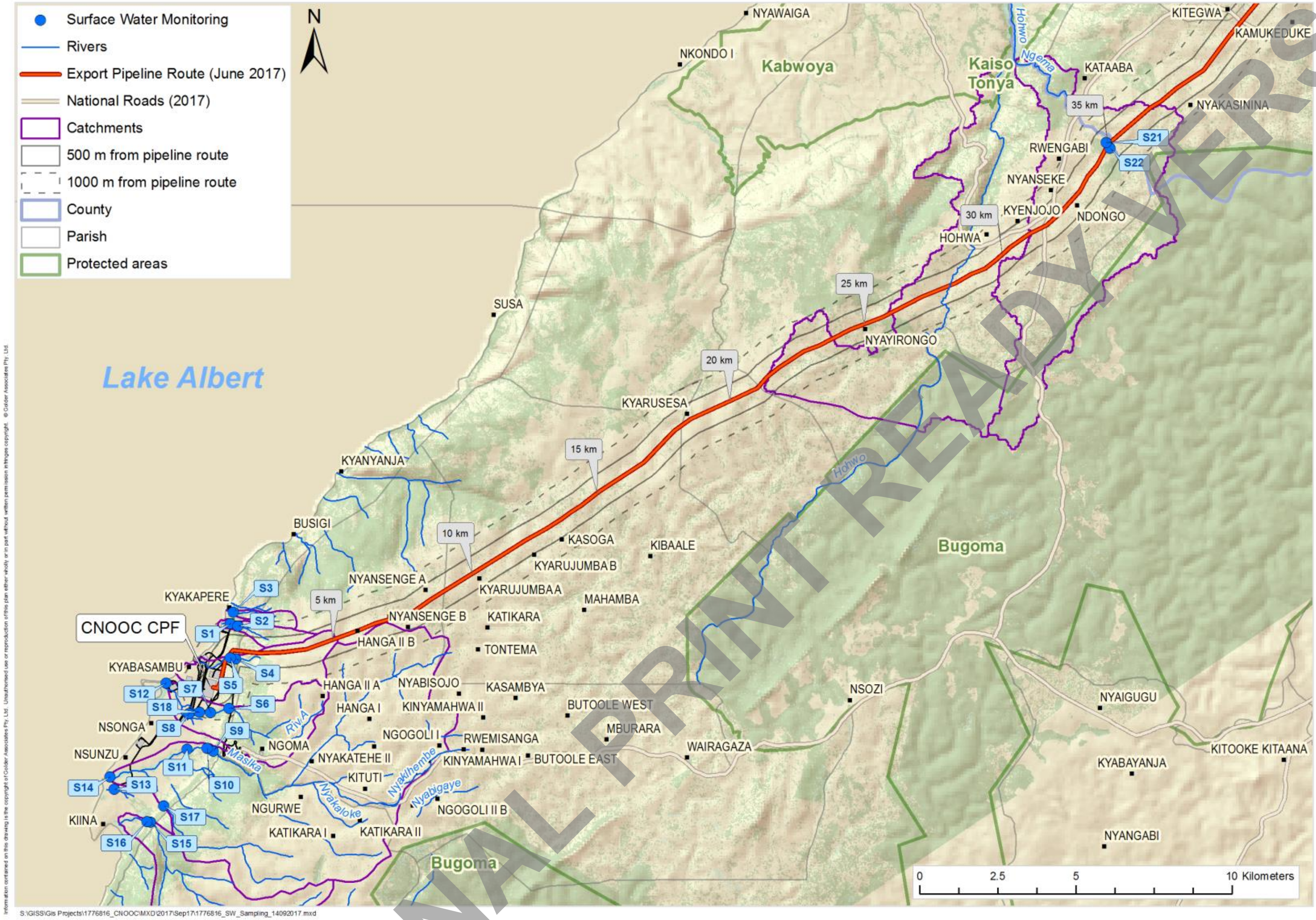

Figure 18: Surface water quality sample sites

5.3.5 *In situ* Water Quality

Two (2) sampling site visits were conducted during the dry season. The first site visit commenced on December 23, 2013 and the second on March 20, 2014. Flow measurements were taken at the sites on the major streams where flow and site conditions allowed measurements to be taken. The measured flows are listed in Table 4.

Table 4: Flow rates measured at four (4) surface water monitoring stations on 20 March 2014

Monitoring Sites	Average Flow (m^3/s)
SW10	0.75
SW11	0.66
SW16	0.43
SW12	1.15

Compact field instruments were used to measure the following parameters:

- pH;
- Electrical Conductivity (EC);
- Dissolved Oxygen (DO);
- Total Dissolved Solids (TDS);

The pH and EC spatial analysis of *in situ* measurements are illustrated in Figure 16, and have been grouped by the general location within the site (north, central and south) in Table 5 below.

Table 5: Surface water in situ measurements for selected sites (December 2013)

Monitoring Point ID	TDS (mg/l)	EC (µs/cm)	pH (pH Units)	DO (mg/l)
SW1	730	1030	7.73	3.73
SW2	554	824	8.92	7.3
SW4	390	558	9.06	8.45
SW5	390	-	8.90	-
SW6	351	515	9.01	6.5
SW7	513	742	7.93	4.48
SW12	914	1312	7.30	1.49
SW9	172	250	8.68	6.19
SW13	621	875	7.79	3.12
SW14	214	323	6.70	0.3
SW15	244	325	8.19	-
SW17	291	420	8.53	-

Green (South) represents the southern areas that are predominantly wetlands, south of the river. *Blue (North)* represents streams north of the majority of the project facilities. Orange represents streams located centrally and associated with the majority of site facilities.

Water quality has a direct influence on aquatic life, soil quality if irrigated (small scale farming) and human health when used for various domestic purposes including consumption. Although these measurements only provide a "snapshot", they can provide valuable insight into the characteristics and interpretation of a specific sample site at the time of the sample collection.

5.3.6 Water Quality Analysis

Initial samples were collected by Eco & Partners and sent to the National Water Quality Reference Laboratory in Uganda (Certificate of Analysis in APPENDIX C).

The second round of sampling (27 March 2014) focused on a more detailed analysis. In addition to the *in situ* water quality parameters, a range of constituents were selected for further assessment. Water samples were collected in various sample collection vials, stored at 4°C and delivered to Jones Environmental Laboratory in the United Kingdom where the following variables were evaluated (Certificate of Analysis in APPENDIX D):

- Physico-chemical:
  - pH, TDS, total alkalinity as $CaCO_3$ (Talk), EC @ 25°C and total dissolved hardness as $CaCO_3$ (THard) and silica (SiO_2);
- Major Ions:
  - Calcium (Ca), magnesium (Mg), sodium (Na), fluoride (F), sulphate (SO_4) and chloride (Cl);
- Nutrients
  - Ortho-phosphate (PO_4), Nitrate as N (NO_3-N) and Ammoniacal Nitrogen as N (NH_3-N);
- Inorganics and Trace Metals:
  - Dissolved Metals: Aluminium (Al), Barium (Ba), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Potassium (K), Vanadium (V), Zinc (Zn);
  - Metalloids: Arsenic (As); and
  - Halogens: Fluoride (F)
- Organics and Oils:
  - Extractable Petroleum Hydrocarbons (EPH) and Gasoline Range Organics (GRO)
- Polyaromatic Hydrocarbons (PAH)

The water quality results are discussed below.

Lake Albert

Sampling took place on the 26 May 2014 along the shores of Lake Albert at the shore points described in Table 6 and illustrated in Figure 19, as part of the aquatic biodiversity survey led by Dr T Kairania.

Table 6: Sampled sites in nearshore waters of Lake Albert along Kingfisher flats (aquatic biodiversity survey led by Dr T Kairania)

Parameter	Name of Transect			
	Pad 1	Pad 2	Pad 3	Pad 4A
Shoreline features	High eroded banks; just to north of Lagoon; soils - sandy; Hinterland: seasonal wetland with eroded *Miscathedium* and patches of *Typha* plus *Phragmites*	Close to seasonal stream; high eroded banks of sandy clay; hinterland – heavily grazed grassland; big community at a distance	Fairly high eroded banks, soils -sandy clay; immediate shore lined with low thickets. Shoreline waters lined with clumps of *Cyperus laevigatus*	Pad 4-2 just north of village settlement in short scattered woodland; Shoreline few meters from escarpment,

Parameter	Name of Transect			
	Pad 1	Pad 2	Pad 3	Pad 4A
Inshore (10 m)				
Coordinates	**1°14'55.02"N 30°44'21.69"E**	**1°15'18.80"N 30°44'52.07"E**	**1°13'53.74"N 30°43'47.34"**	**1°16'46.38"N 30°45'32.99"E**
Water depth & bottom type (Dry season)	1.1 m; sandy bottom with plant debris	2.6 m; clay mixed with shells	1.8 m; Sandy with live plant material	4.9 m; Soft mud
Water depth & bottom type (Wet season)	1.5 m; sandy bottom with plant debris	4.4 m; clay mixed with shells	2.5 m; Sandy with live plant material	3.3 m; Soft mud
Offshore (2 km)				
Coordinates	**1°15'47.25"N 30°43'41.68"E**	**1°16'14.81"N 30°44'14.74"E**	**1°14'27.86"N 30°42'51.99"E**	**1°17'34.44"N 30°44'47.33"E**
Water depth & bottom type (Dry season)	24.6 m; fine clay mixed with shells	14.0 m; Rocky with crushed shells	27.3 m; Very fine dark, smooth sand	28.6 m; Not determined
Water depth & bottom type (Wet season)	26.9 m; fine clay mixed with shells	13.5 m; Rocky with crushed shells	27.3 m; Very fine dark, smooth sand	28.1 m; Not determined

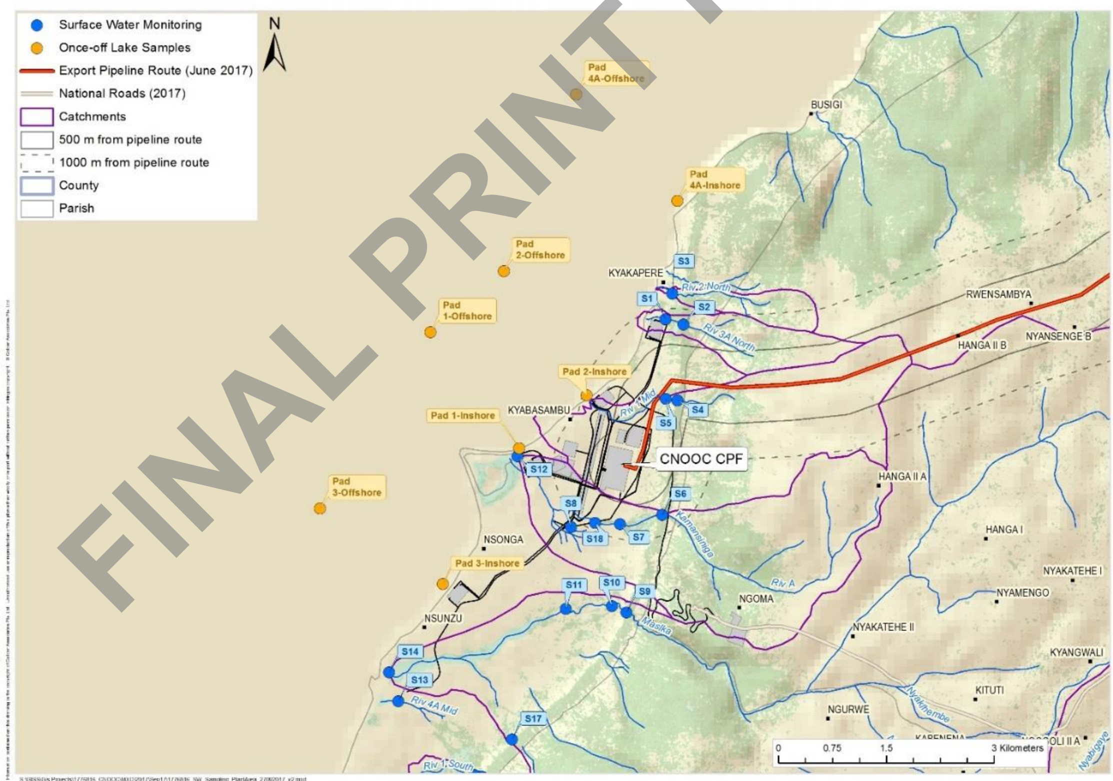

Figure 19: Lake Albert water quality sites (aquatic biodiversity survey led by Dr T Kairania, May 2014)

5.3.6.1 Results and Discussion

The results for the samples collected in December 2013 for SW 1, 2, 4, 6, 9, 12 and 14 were analysed for the following metals only: cadmium, chromium, lead, mercury, iron, aluminium, arsenic, copper, manganese, zinc, cobalt, nickel and selenium. In cases the limits detected were well below the Uganda National Standard (NEMA, 1995). The data is included as Appendix C.

The water quality results for samples collected during March 2014 are tabulated in Table and are grouped (colour coded) according to general areas of impacts. The water quality results were compared to the local Ugandan Acceptable Standards for drinking (NEMA, 1996), and the World Health Organisation (WHO) for Drinking Water (WHO, 2011). For each parameter, the more stringent of the two standards was used as a basis for comparison. The red cells indicate points where results exceed the defined limit and those underlined indicate that levels detected were less than the detection limit.

For the pre-development phase, the assessment of the baseline water quality results during the dry season (March 2014) revealed the following:

- The pH of the waters measured at the sites seem to fall within the upper limit of the standards range and exceeding this limit at five of the sampled sites with the maximum pH recorded at SW03 (lab pH 8.88) and SW04 (in situ pH 9.06);
- The pH at SW14 is lower than the majority of the sites. The lower pH conditions could result in an increase in trace metals as is shown by the elevated Fe and Mn concentrations at SW14, 4.28 and 0.8 mg/l, respectively. This area has also been reported to have elevated Ti levels, which might explain the occurrence of Fe in addition to possible re-suspension of sediments during rainy days (see Soils study). The shoreline closer to SW14 is typically characterised by total iron concentration of approximately 1 mg/l, and as a result the Fe concentrations cannot be attributed to Lake water intrusions onto the wetland. The dissolved oxygen concentration (0.3 mg/l *in situ*) at SW14 further supports these reducing conditions. Continuous monitoring is necessary;
- TDS and EC levels on site for SW01 were relatively high (TDS 730 mg/l and EC 1030 µS/cm). This may have been due to high concentrations of organic matter associated with the wetland system upstream of this site or contributions from the upstream villages; and
- Various traces of PAHs were also detected, however not at levels that cause concern. These are also constituents of concern that should be monitored for throughout the construction, operation and closure phases of any oil and gas project.

Overall, water quality during the dry season is generally good. A concern could be during the wet season where there is potential for humic acids (from surrounding land areas such as wetland systems) to increase pH levels and introduce metals into Lake Albert.

The water quality of Lake Albert (**Error! Reference source not found.**) as indicated by grab samples taken in May 2014, shows that the lake pH is strongly alkaline, and falls outside of the Uganda National Standards, however except for faecal coliform count which indicated low levels of faecal contamination at both the inshore and offshore sites, the other parameters measured are within the Uganda National Standards.

The list of proposed variable to be measured must also be included for those samples taken in the lake during the construction and operational phases of the project.

Table 7: Baseline surface water monitoring results for the dry season (March 2014)

Water Quality Variable	Units	WHO drinking water Standards	Ugandan Standards (NEMA, 1996)	Surface water monitoring points									
				SW02	SW03	SW09	SW17	SW14	SW15	SW19	SW20	SW21	SW22
				20/03/2014	20/03/2014	21/03/2014	23/03/2014	23/03/2014	23/03/2014	22/03/2014	23/03/2014	24/03/2014	24/03/2014
Physico-chemical													
pH	pH units	6.5 to 8.5	6.5 to 8.5	8.79	8.88	8.48	8.55	6.76	8.36	8.72	8.87	7.32	7.03
Total Alkalinity as $CaCO_3$	mg/l	-	500	416	308	146	232	178	160	274	302	134	136
Electrical Conductivity @25C	µS/cm	-	2500	853	621	274	469	377	330	517	648	319	320
Total Dissolved Solids	mg/l	600	1200	506	363	158	231	217	183	302	326	187	176
Silica	mg/l	-	-	27.6	26.8	32.9	13.8	27.1	28	30	2.4	33.3	21
Total Hardness as $CaCO_3$	mg/l	500	500	242	178	100	153	133	113	174	138	112	122
Major Dissolved Ions													
Sulphate as SO_4	mg/l	250	200	47.92	16.75	4.65	0.2	0.27	0.34	5.92	11.38	7.43	7.75
Chloride as Cl^-	mg/l	-	-	11.7	7.4	1.4	4.5	14.7	2.6	4.6	19.9	5.8	7.7
Ortho Phosphate as PO_4	mg/l	-	-	2.11	1.18	0.17	0.7	0.09	0.36	0.88	0.03	0.75	0.31
Nitrate as NO_3-N	mg/l	-	5	0.19	0.29	0.15	0.27	0.025	0.09	0.23	0.025	0.21	0.15
Ammoniacal Nitrogen as NH_3-N	mg/l	-	1	0.22	0.47	0.25	0.5	0.59	0.09	0.19	0.08	0.44	0.56
Fluoride as F^-	mg/l	1.5	-	1.3	1.2	0.5	0.8	0.5	0.7	1	0.5	0.15	0.15
Magnesium as Mg^{2+}	mg/l	-	-	31.1	20.3	11.6	18.7	15.2	14.6	21.5	26.1	13	12.5
Sodium as Na^+	mg/l	200	-	108.1	77.1	17.1	36.7	25.4	26.5	50.5	64.5	16.3	11.3
Potassium as K^+	mg/l	-	-	5.2	2.9	2	3.2	3.9	1.7	2.5	40.4	7.6	8
Calcium as Ca^{2+}	mg/l	-	-	44.5	37	20.5	29.7	27.7	20.8	33.6	11.4	22.9	27.9
Trace Metals (Dissolved)													
Aluminium as Al	mg/l	0.1	0.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Arsenic as As	mg/l	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barium as Ba	mg/l	0.7	-	0.046	0.049	0.065	0.042	0.101	0.05	0.042	0.093	0.079	0.051
Beryllium as Be	mg/l	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boron as B	mg/l	-	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.02
Cadmium as Cd	mg/l	0.003	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chromium as Cr	mg/l	-	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Copper as Cu	mg/l	-	1	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035	0.0035
Iron as Fe	mg/l	0.3	0.03 to 3.5	0.01	0.01	0.094	0.01	4.28	0.052	0.01	0.01	0.111	0.121
Lead as Pb	mg/l	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.01
Manganese as Mn	mg/l	0.1	0.1 to 0.5	0.005	0.004	0.01	0.003	0.849	0.007	0.001	0.001	0.026	0.183
Mercury as Hg	mg/l	0.006	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Nickel as Ni	mg/l	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Selenium as Se	mg/l	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vanadium as V	mg/l	-	-	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Water Quality Variable	Units	WHO drinking water Standards	Ugandan Standards (NEMA, 1996)	Surface water monitoring points									
				SW02	SW03	SW09	SW17	SW14	SW15	SW19	SW20	SW21	SW22
				20/03/2014	20/03/2014	21/03/2014	23/03/2014	23/03/2014	23/03/2014	22/03/2014	23/03/2014	24/03/2014	24/03/2014
Zinc as Zn	mg/l	-	3	0.02	0.04	0.07	0.02	0.04	0.05	0.02	0.04	0.05	0.04
Polyaromatic Hydrocarbons (Organics)(PAH)													
Naphthalene	µg/l	-	-	0.007	0.007	0.007	**0.184**	0.007	0.007	0.007	0.007	0.007	0.007
Acenaphthylene	µg/l	-	-	0.0065	**0.03**	**0.05**	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065
Acenaphthene	µg/l	-	-	0.0065	**0.04**	**0.07**	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065
Fluorene	µg/l	-	-	0.007	**0.05**	**0.06**	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Phenanthrene	µg/l	-	-	0.02	**0.05**	**0.06**	**0.07**	**0.02**	**0.03**	**0.03**	**0.02**	**0.02**	**0.03**
Anthracene	µg/l	-	-	0.0065	**0.02**	**0.02**	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065	0.0065
Fluoranthene	µg/l	-	-	0.006	**0.02**	**0.02**	**0.02**	0.006	0.006	0.006	0.006	**0.02**	0.006
Pyrene	µg/l	-	-	0.0065	**0.02**	**0.02**	**0.03**	0.0065	0.0065	0.0065	0.0065	**0.02**	0.0065
Benzo(a)anthracene	µg/l	-	-	0.0075	**0.02**	**0.02**	**0.03**	0.0075	**0.02**	0.0075	0.0075	**0.02**	**0.02**
Chrysene	µg/l	-	-	0.0055	**0.02**	**0.02**	**0.02**	0.0055	0.0055	0.0055	0.0055	**0.02**	0.0055
Benzo(bk)fluoranthene	µg/l	-	-	0.009	**0.02**	0.009	**0.03**	0.009	0.009	0.009	0.009	0.009	0.009
Benzo(a)pyrene	µg/l	-	-	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Indeno(123cd)pyrene	µg/l	-	-	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
Dibenzo(ah)anthracene	µg/l	-	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Benzo(ghi)perylene	µg/l	-	-	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055
PAH 16 Total	µg/l	-	-	0.0975	**0.29**	**0.34**	**0.384**	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975
Benzo(b)fluoranthene	µg/l	-	-	0.005	**0.01**	0.005	**0.02**	0.005	0.005	0.005	0.005	0.005	0.005
Benzo(k)fluoranthene	µg/l	-	-	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Oil and Grease													
EPH (C8-C40)	µg/l	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
GRO (>C4-C8)	µg/l	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
GRO (>C8-C12)	µg/l	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
GRO (>C4-C12)	µg/l	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Green indicates southern areas that are predominantly wetlands, south of the river. *Blue* are streams north of most of the project facilities. *Purple* are streams located outside the immediate site.

Table 8: Water quality data for samples taken at sites in nearshore waters along Kingfisher Flats, Lake Albert (May 2014)

Parameters	Units	Pad 1		Pad 2		Pad 3		Pad 4A		*Nat Std
		I/S	O/S	I/S	O/S	I/S	O/S	I/S	O/S	
Total Depth	m	1.5	24.3	2.6	13.5	1.8	27.3	3.3	28.1	
Secchi Depth	m	0.7	0.93	0.81	0.92	0.71	0.95	1.01	0.96	
Dissolved Oxygen	mg/L	7.53	7.80	7.03	7.94	7.56	7.72	7.50	7.95	**NS**
Temp	°C	28.4	28.1	27.8	28.1	28.5	28.1	27.8	27.8	**20-35***
Conductivity	µS/cm	634	633	633	633	632	634	633	633	**2500**
pH	--	9.60	9.62	9.61	9.61	9.45	9.63	9.66	9.66	**6.5-8.5**
Alkalinity	mg/L	316	332	316	360	324	320	240	320	**500**
Hardness	mg/L	180	200	160	240	180	200	180	160	**500**
TDS	mg/L	304	313	317	312	310	312	304	313	**1200**
TSS	mg/L	3	2	1	1	2	1	1	1	**0**
Turbidity	NTU	2	2	2	3	4	2	2	2	**10**
Calcium: Ca^{2+}	mg/L	20.8	10	24	40	24	24	24	24	**75.0**
Magnesium: Mg^{2+}	mg/L	30.7	38.4	24	33.6	28.8	33.6	28.8	24	**50.0**
Fluoride: F^-	mg/L	1.2	1.3	1.2	1.2	1.1	1.3	1.1	1.3	**1.5**
Iron	mg/L	0.01	0.01	0.02	1.01	0.04	0.01	0.00	0.06	**5**
Sulphate	mg/L	11	11	10	10	11	11	10	10	**200**
Chloride: Cl^-	mg/L	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	**500**
BOD_5 at 20°C	mg/L	0.0	0.6	0.9	0.4	0.5	0.2	0.3	0.6	**30***
COD	mg/L	11	10	11	15	7	15	14	12	**100***
SRP	mg/L	0.003	0.000	0.001	0.002	0.002	0.002	0.003	0.000	**5000***
TP	mg/L	0.026	0.034	0.029	0.031	0.044	0.036	0.034	0.034	**10**
Nitrate	mg/L	0.023	0.024	0.095	0.031	0.055	0.032	0.035	0.024	**4.5**
Nitrite	mg/L	0.008	0.007	0.010	0.010	0.002	0.001	0.001	0.007	**3**
Ammonia	mg/L	0.008	0.020	0.022	0.029	0.015	0.010	0.012	0.020	**1**
Total Nitrogen	mg/L	0.32	0.122	0.185	0.372	0.122	0.140	0.122	0.122	**10**
Chlorophyll a	µg/L	2.1	2.1	2.1	1.0	1.0	2.1	3.1	3.1	**NS**
Faecal coliform	CFU/100mL	50	25	2	2	10	5	7	3	**0**

I/S: inshore; O/S: offshore; Nat Std: Uganda National Standard

5.4 Hydrological modelling

5.4.1 Peak calculation

The rational method was used to calculate peak rainfall for the 1 in 50 and 1 in 100 year annual storm recurrence interval for each catchment area. A Mean Annual Precipitation of 1 200 mm was used in the peak calculation as reported by UNDP&WMO, (1974). The 24 hour storm rainfall was calculated using the method described in section 5.2.2. Catchments for five rivers namely; Mid 1, North 2, Mid 2, North1, Mid 3 Masika were delineated for floodline analysis while catchments for rivers crossing the pipeline namely Pipeline River 1, Pipeline River 2 were also delineated. In order to account for flood contribution from the south most river (South 1) the peak flow of both Mid 3 Masikia and South 1 was also calculated. The catchments are shown in Table 9.

Table 9: Catchment properties used in the Rational method

Catchment Name	Area (km^2)	Stream length (m)	Elevation at 10% of Slope	Elevation at 85% of Slope	Slope (m/m)	Time of Concentration (hrs)
Mid 1	6.99	1422	621.6	646.5	0.023	0.4
North 2	1.38	565	621.9	648.3	0.062	0.1
Mid 2	7.63	2645	624.5	644.8	0.010	0.8
North1	0.74	527	626.2	674.4	0.122	0.1
Mid 3 Masikia	46.36	1937	614.7	636.7	0.015	0.6
Pipeline Rivier 1	42.26	11434	697.2	1035	0.039	1.5
Pipeline River 2	76.95	5688	778.8	979.9	0.047	0.8
Mid 3 Masikia and South 1	61.12	1937	614.7	636.7	0.015	0.6

The properties of each of the catchment as applied in the rational method are shown in Table 9. Considering the topography for the study area, the elevation at 10% of 85% of the slopes was calculated for both the lower and upper section of the rivers separately. The lower section of the river stretched up to the edge of the escarpment while the Upper section extended from the edge of the escarpment to the head waters of each catchment as shown in the catchment map (Figure 20).

Table 10: 50 year and 100 year Peak flows calculated using the Rational Method

River Name	1 in 50 Flood Peak (m^3/s)	1 in 100 Flood Peak(m^3/s)
North1	14.7	18.0
North 2	25.9	34.1
Mid 1	82.9	109.2
Mid 2	55.9	73.6
Mid 3 Masikia	395.6	518.7
Pipeline River 1	175.8	230.6
Pipeline River 2	457.0	598.0
Mid 3 Masikia and South 1	474.0	620.8

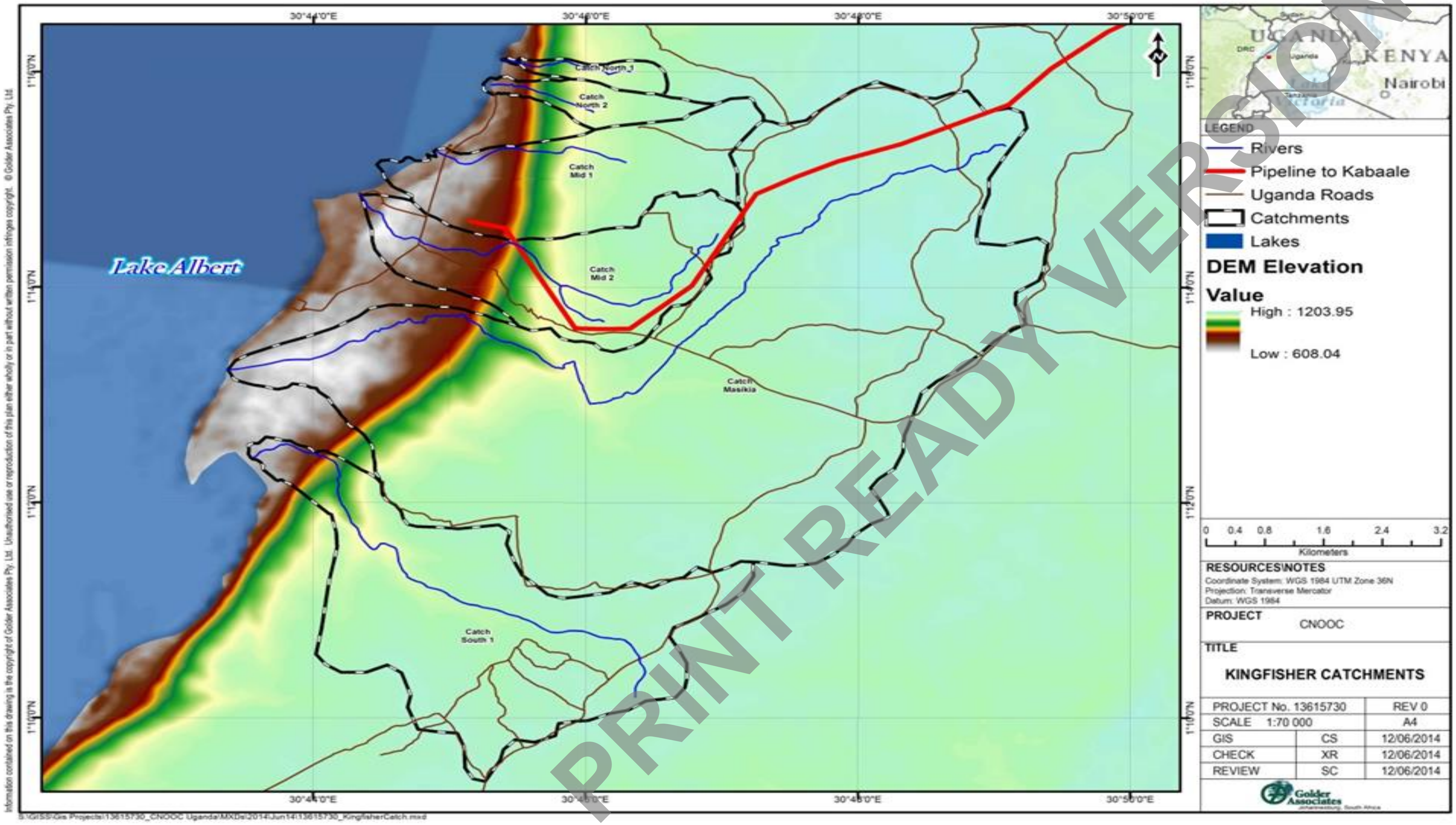

Figure 20: Site specific catchments

5.4.2 Floodlines

The HEC-RAS program was used to route the peak discharge for each of the rivers under study. Cross sections were generated using 1m x 1m Digital Elevation Model (DEM). The peak flows calculated using the rational method was applied in the model. Slope was used as boundary conditions with the exception of the downstream cross section (chainage 672.8m) of Mid River 2 where a critical depth was applied. The reason for choice is explained in the assumptions and recommendations section. A roughness coefficient (Manning n) of 0.035 was applied for both channel and overland flow as the area fitted the floodplain with pasture and farmland description according to data published by (Munson, Young, Okiishi , & Huebsch, 2009) Munson, R. *et al* (1990). The 1 in 50 years and 1 in 100 floodline was generated and plotted as seen in Figure 21 and Figure 22.

Assumptions and Limitations

The area where the proposed site lies is generally flat and as a result the river line is not always well defined. Even though the resolution of the DEM was high, the accuracy was low. The low accuracy of the DEM combined with varying depression storages meant the river could not always be defined accurately. As a result assumptions had to be made concerning the river banks. In some cases for example River Mid 2, according to the DEM data the elevation was higher downstream which according to observations from our site visit is not the case hence critical flow was applied as the downstream boundary condition. A decision was then made to extend the probable floodline based on the available result and there was no more accurate topographical data as the rivers emptied into the Lake. This information is shown with a dotted line in the floodline map as shown in Figure 21 and Figure 22.

It is recommended to adhere to the 1 in 100 year floodline limit for construction or keep a 100 m buffer along the rivers as per the IFC standards (International Finance Corporation, 2007). According to the IFC report it is advised to “avoid construction of facilities in a floodplain, whenever practical, and within a distance of 100 m of the normal high-water mark of a water body or water well used for drinking or domestic purposes.”

As shown in Figure 21 the following structures fall within the 1 in 100 floodline. It is recommended that these structures are relocated where possible:

- Mid 1 - Pad 2, Material yard and Spoil area C
- Mid 2 – Pad 1 and Spoil Area A/Burrow pit
- Masikia – Spoil Area B
- South 1 – Pad 5 (proposed)

The airstrip also runs through both the 1 in 50 and 1 in 100 year floodline. A bridge or culvert is required to mitigate against the risk of flooding.

A higher level of certainty of the flooding risk could be further achieved if more reliable local rainfall were to be obtained amongst other essential more accurate data inputs. It is for this reason coupled with the low lying nature of the of the Kingfisher Development Area that over and above relocating structures according to the determined floodline it is recommended that all structures be raised in order to mitigate against the risk of flooding. Based on the floodline results, it is recommended that proposed structures that fall within the 1 in 100 year floodline be raised by 1 metre.

Figure 21: 1 in 50 and 1 in 100 year flood lines for the Flats

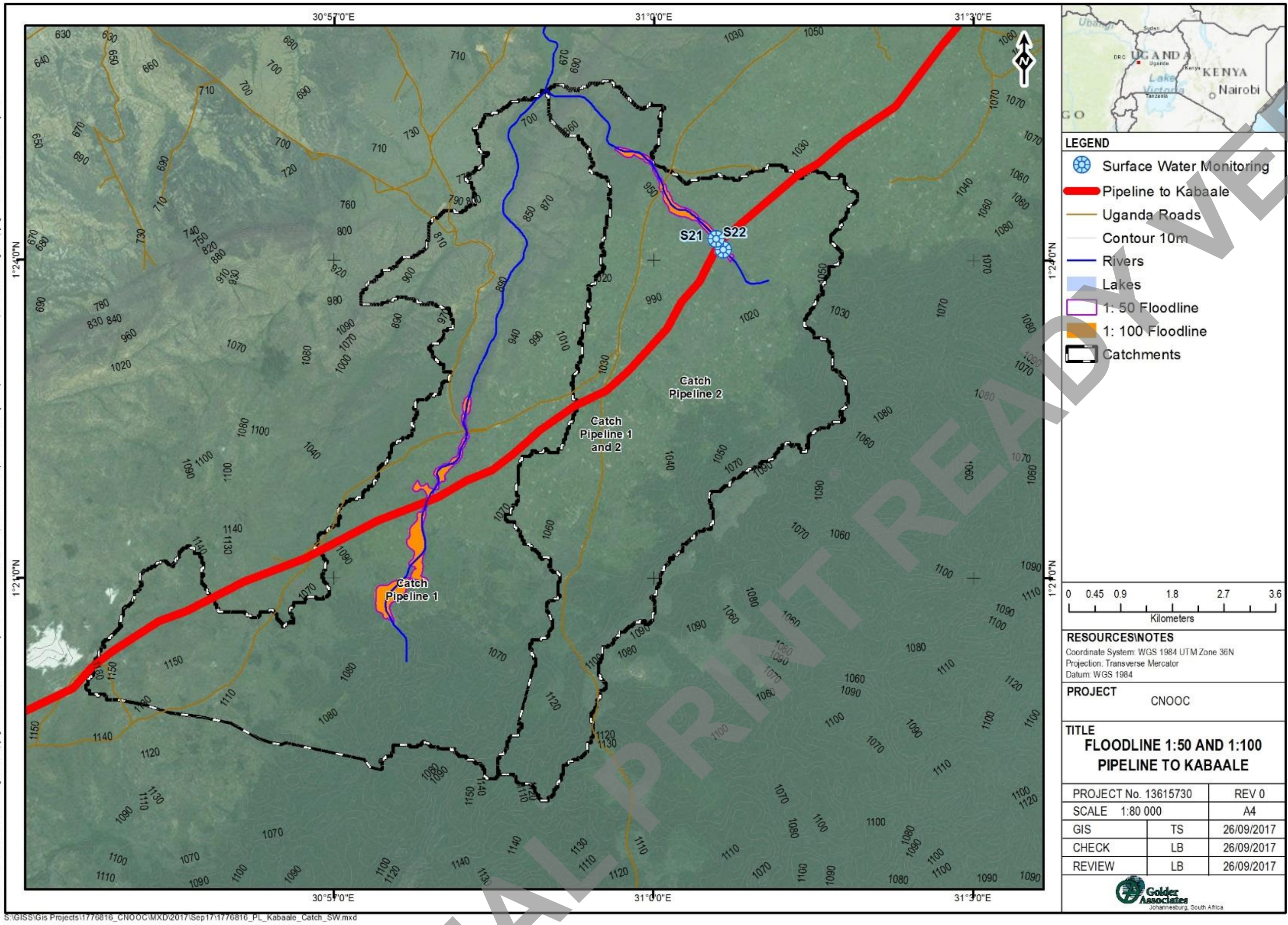

Figure 22: 1:100 floodlines along the pipeline routing

6.0 IMPACT ASSESSMENT

6.1 Major areas of concern for surface water impacts

The major areas of concern for the surface water impacts are water quality and quantity (flow) impacts on the rivers and streams draining to the lake in relation to (Figure 23):

- The construction camps and associated activities;
- Well pads and associated activities;
- Central processing facility and associated activities; and
- Pipelines and associated activities.

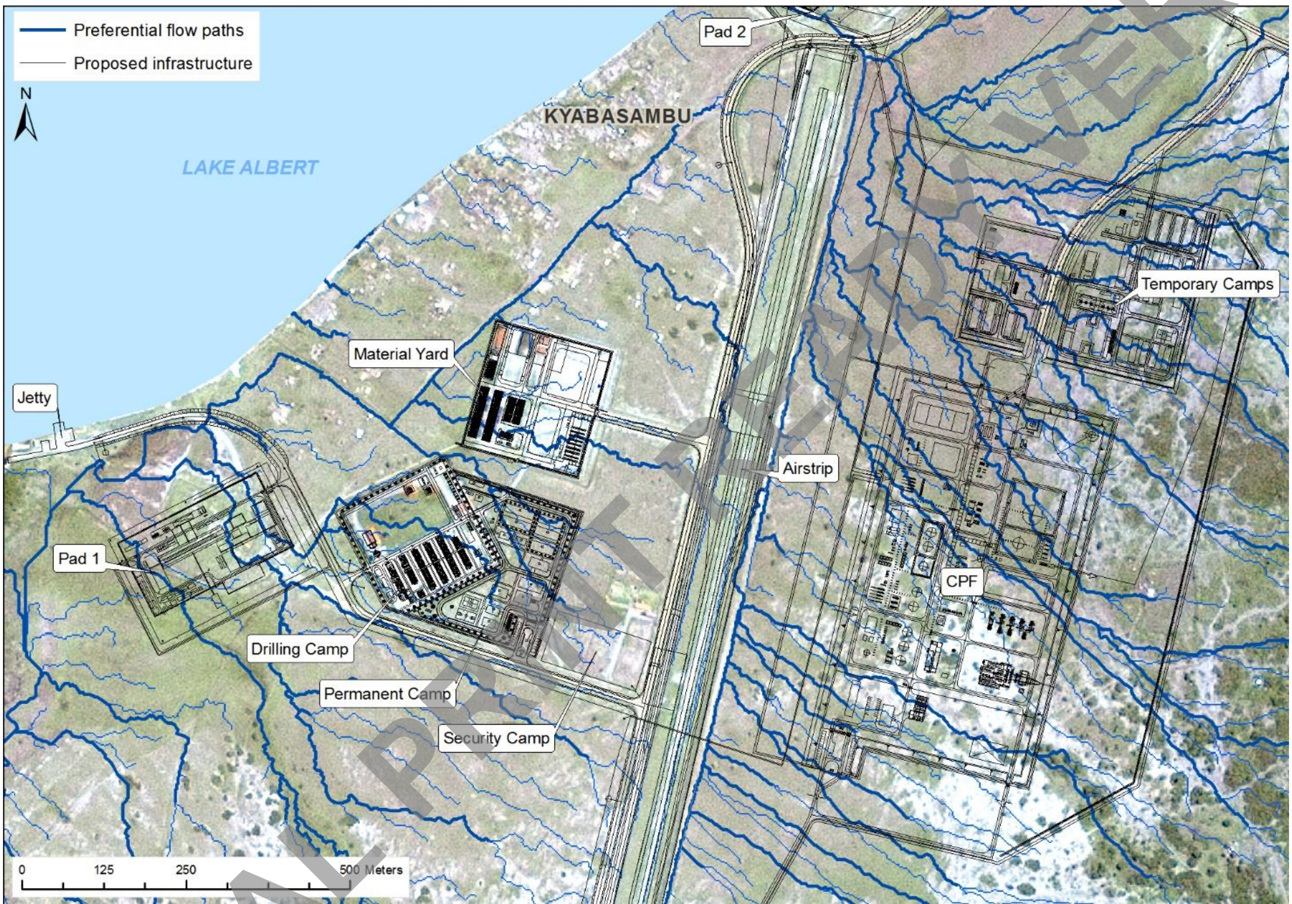

Figure 23: Proposed infrastructure in relation to preferential flow paths

The impacts are further elaborated in the sections to follow.

6.1.1 Camps (temporary and permanent)

The major activities around the camps that could have a negative impact on the surface water resources include erosion and sedimentation from areas that have been cleared of vegetation, domestic sewage treatment and small oil and chemical spills from equipment.

6.1.2 Well pads

All development and production wells in the Kingfisher Development Area will be drilled from four well pads on the eastern shores of Lake Albert. Three of these well pads currently exist and will be upgraded to meet requirements for oil production. The well-fluids will be transported to a Central Processing Facility (CPF) via separate flowlines from each of the four well pads. The final development is expected to consist of 20 production wells (producers) and 11 water injection wells (injectors). The well depth will be approximately 1700 m below the floor of Lake Albert. Horizontal departure of the well from the well pad location will typically be around 3 800 m.

After well completion, the rig and the auxiliary facilities will be removed and the well will be connected to a manifold combining well fluids from all of the wells on the well pad into a single flowline to the CPF. Each production well pad is expected to comprise:

- Production well heads and manifolds;
- Water injection wells and manifolds;
- Utility Systems;
- Production and test flow meters;
- Pig Launcher/ Receiver;
- Chemical injection system;
- Closed drain system; and
- Equipment room to accommodate instrumentation, telecom, and electrical equipment.

Simultaneous production and drilling on the well pads will occur for the first 7 years, until the project reaches full production. The design will allow for the drilling rig to move between different slots without shutting down production on the well pad.

Drilling waste

Once drilling commences, drilling fluid (otherwise known as 'mud') is continuously circulated down the drill pipe and back to the surface equipment. The main functions of drilling mud are to remove rock cuttings to the surface, generated by the drill bit, maintain wellbore stability, cool and lubricate the drill bit, seal permeable formations and transmit hydraulic energy to the drilling tools and bit. The risk of uncontrolled flow from the reservoir to the surface is further reduced by using blowout preventers, a series of hydraulically actuated steel rams that can close around the drill string or casing to quickly seal off a well. Steel casing is run into completed sections of the borehole and cemented into place. The casing and cement provide structural support to maintain the integrity of the borehole, isolate underground formations and protect useable underground sources of groundwater.

The waste produced during drilling will include:

- Hazardous Solids (used chemical containers, fuel storage containers, oil-contaminated rags, used batteries, used filters, fluorescent tubes, power unit/transport maintenance wastes, paint waste);
- Hazardous solids (potentially contaminated cement slurry);
- Hazardous Liquids (used oil, waste chemicals, rinsate, thinners, viscofiers, solvents, acids, treating chemicals, other used chemicals in drums);
- Non Hazardous Liquids (sewage effluent, grey water);
- Non Hazardous Solids (construction materials, packaging wastes, paper, scrap metal, plastics, glass);
- Drilling Cuttings (solids), coarse and fine particles - aqueous (water based);
- Drilling Cuttings (solids), coarse and fine particles – synthetic;
- Drilling Liquids (including clear liquids from dewatering of aqueous drill cuttings); and

- Completion Fluids (solids, residual drilling fluids, hydrocarbons, acids, glycol, methanol, other).

Produced Water Injection

A total of 11 water injection wells are planned on the well pads. Water injection is intended to meet two objectives - disposal of large quantities of produced water, removed from the well fluids at the CPF, in a safe and environmentally responsible manner; and assisting to maintain reservoir pressures throughout the life of the project. Injection water will consist of a combination of produced water, water from potentially oil contaminated (POC) areas at the CPF and make up water from Lake Albert. Injection of chemical additives at the well pad will not be required. A wide variety of additives will be required but these will be injected in different areas of the produced water circuit at the CPF, prior to delivery to the wells

Production Waste Generated on the Well pad

In order to handle oily drainage from pipelines and equipment, each well pad will be provided with an underground closed drain system leading to a sump with a submersible pump. The levels will be monitored and the sump periodically emptied into a mobile tanker for handling at the CPF.

Only small quantities of solid waste will be generated, once drilling is completed. The wells are unmanned and will be remotely operated from the CPF over extended periods, without intervention on the well pad. During maintenance, small quantities of potentially oil contaminated and non-hazardous waste will be generated. These will be separated into non-hazardous and hazardous components, delivered to the CPF for temporary storage and then recycled, where possible, or earmarked for disposal by a certified hazardous waste contractor. CNOOC indicates that NORM is not expected in the pigging wastes. Estimated quantities of potentially hazardous waste are less than 0.5 t/well/year.

The surface water impacts from the well pads are therefore related to contaminated run-off from the well pads due to the drilling waste produced, and may be both related to water quality and aesthetics of poorly disposed solid waste. Once drilling has ceased there are likely to be small amounts of potentially oil contaminated and non-hazardous waste generated.

6.1.3 Central Processing Facility

The well-fluids from the CNOOC Kingfisher wells will be sent to a Central Processing Facility (CPF) on the Buhuka flats. Figure illustrates the CPF and associated infrastructure. Nearly three quarters of the total volume of fluids from the wells over the 25-year period will be formation water. The well-fluids will be processed in the CPF to separate formation water and associated gas from the oil phase. The oil will be stabilized, desalted and dehydrated to meet the export specification. Associated gas will be separated and utilized as fuel gas for power generation, the heating system and other utilities. Combined power generation with LPG recovery is proposed to utilize excess associated gas.

Produced water from the separators will be treated to achieve the injection water specification. Produced water, along with treated lake water from the CPF, will be injected into the reservoir. Lake water will be pumped to the CPF via a dedicated flow line running from the Lake Albert intake facilities ().

The CPF will comprise the following activities and areas:

- Oil Separation Flash Gas facilities;
- Gas Treatment & Compression facilities;
- Produced Water Treatment & Injection facilities;
- Oil Storage & Export facilities;
- Ground flare;
- Power Generation plant;
- Electrical substation;

- Water and wastewater (sewge) treatment plant;
- Fire water and pumps;
- Plant Utilities area;
- Control room and administrative buildings;
- Maintenance workshop;
- Gatehouse; and
- Perimeter fencing, lighting and internal access road system.

The CPF therefore has several clean and dirty areas, with the main areas of concern for potential surface water pollution linked to the following areas: oil separation flash gas facilities; produced water treatment and injection facilities; oil storage and export facilities; water and wastewater (sewage) treatment plant; and the maintenance workshop.

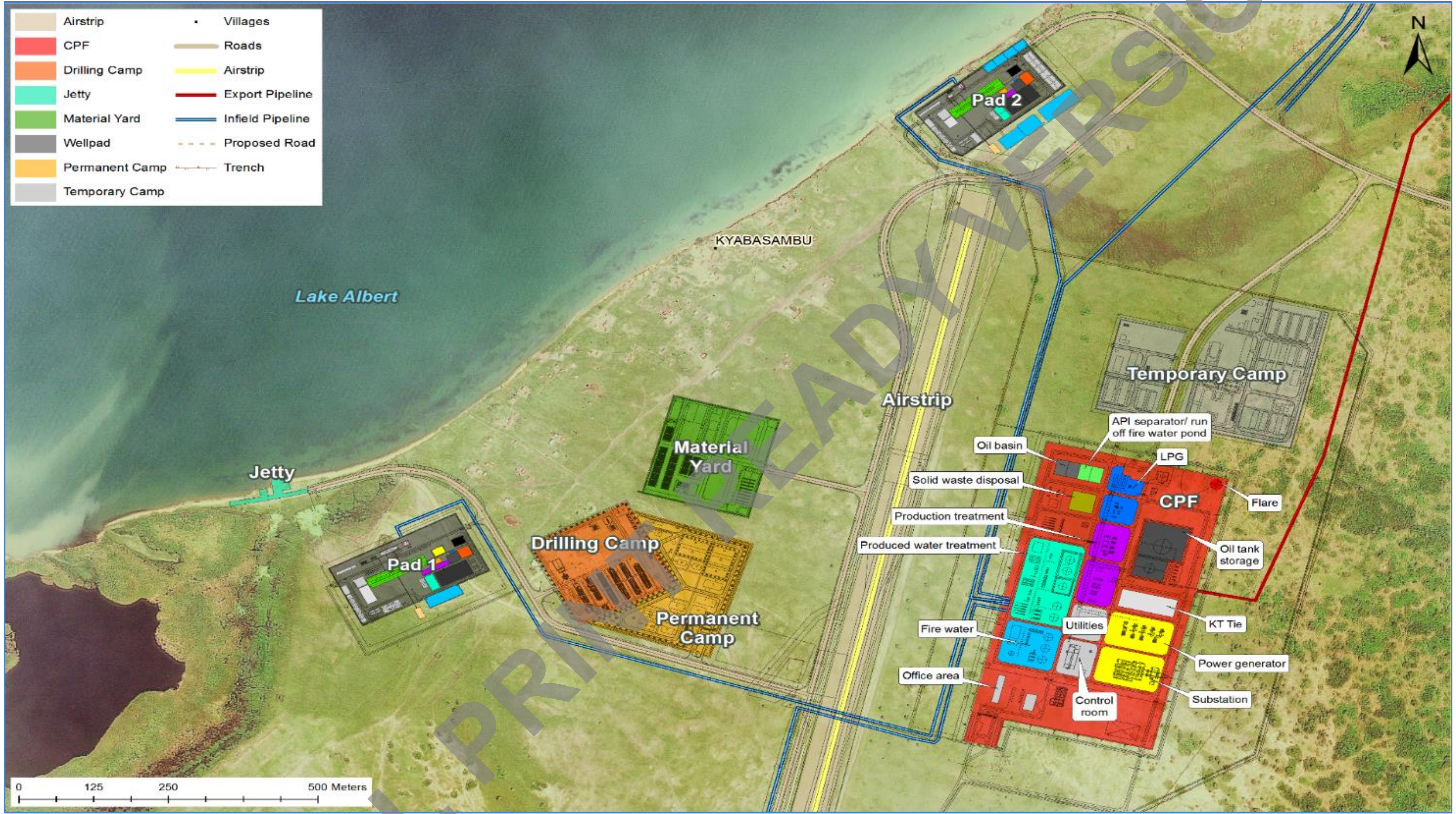

Figure 24: CPF and associated infrastructure

Water Supply

All project water requirements will be supplied from a water intake station on Lake Albert, roughly 1 km northwest of the CPF (Figure 2-4). The final location will be determined during the FEED and will be influenced by the findings of technical studies and the ESIA. A reinforced concrete chamber will be sunk close to the shore edge comprising a pump basin, a silt collection basin and a trash screen section. The depth of the structure will be set to cover the range of design lake water levels and the pump basin depth set to ensure pump performance at the minimum lake level.

Most of the planned intake capacity will be for make-up of produced water injection requirements (further detail on produced water make up is included below). Even in year 25, when produced water generation is high and make up water requirements are at their lowest (56 m^3/hr), this demand will still comprise about 89% of the total project water use.

The planned capacity of the intake station is 390 m^3/hr, which includes provision for the maximum make-up injection water demand (~301 m^3/hr in year 5), potable water demand of 52 m^3/d and incidental (unaccounted) water demand, estimated to be in the order of 37 m^3/hr, which takes into account water requirements for makeover of wells during operations which is an intermittent activity. The average daily water demand at the CPF, excluding domestic requirements is expected to be approximately 100 m^3/day.

Wastewater

The following wastewater streams will be generated at the CPF:

- Produced water - removed from the well fluids and delivered to the water treatment plant before injection down one of 11 injection wells on the well pads;
- Process effluent routed to the Closed Drain system;
- Drainage (mainly storm water) routed to the Open Drain system; and
- Domestic effluent - treated in a sewage treatment plant at the permanent camp.

Figure 27 illustrates the handling of clean and POC water at the CPF.

Produced water

Discharge of produced water outside the boundary of the production facilities will not be considered owing to the sensitivity of the receiving environment. Produced water will be treated to meet the injection water specification, combined with lake water to make up the required quantity, and injected back into the oil reservoir to maintain reservoir pressures. Produced water will increase sharply in the first few years of the project while ramping up to full production in year 6 (415 m^3/h). The steep annual increase continues until around year 11 (679 m^3/h) after which the curve flattens, and from year 17 onward annual increases in produced water generation are slight. At year 25 end-of-life of the field, produced water reaches a peak of 756 m^3/h.

The expected produced water chemistry is set out in Table 11. Table 12 sets out specific requirements that need to be achieved prior to reinjection. These parameters are not measured in the produced water because of the high level at which they would be present or rate of corrosion that they would produce.

Table 11: Properties of CNOOC produced water

Physical Parameters		Anionic Parameters	Concentration (mg/l)	Cationic Parameters	Concentration (mg/l)
pH@25ºC (pH units)	7.32	Chloride	3 969	Lithium	0.2
Resistivity @25ºC ohm.m	0.805	Sulphate	105	Barium	2.3

Density@20ºC (kg/l)	1.004	Bromide	49.8	Strontium	4.7
Elements	Concen-tration (mg/l)	Nitrate	0.15	Calcium	268
		Phosphate	<1	Magnesium	5.8
		Bicarbonate	257	Sodium	1 724
		Carbonate	0	Potassium	1760
		Hydroxide	0	Iron	<0.5
Total Iron	4.2	Formate	5.2	Copper	<0.5
Phosphorous	<2	Acetate	697	Zinc	2.2
Silicon	27	Propanoate	51	Manganese	0.6
Sulphur	38	Butyrate	20	Aluminium	<1
Total Cl equivalent (mg/l)	4 676	Iso-Valerate	5.7		
Total Na equivalent (mg/l)	3 083	Boron	<3		
Total NaCl equivalent (mg/l)	7 758	Cl: Br	80		
Cation/Anion Balance %	101.67				
Cation/Anion Bias (%)	1.67				

Disposal Standard

The stringent requirement to remove oil from the produced water (Table 12) is mainly to prevent clogging of the injection system. The produced water stripped from the oil in the primary and secondary separators will be delivered to the water treatment plant for further cleaning.

Table 12: Specification for injection of produced water

Specification Unit Value	Unit	Value
Suspended Solids	mg/l	< 5.0
Particle Size	mm	< 3.0
Oil cut	mg/l	< 15.0
Average corrosion rate	mm/a	<0.076
Dissolved Oxygen	mg/l	0.1
Sulphate Reducing Bacteria	unit/ml	25
Ferrobacteria	unit/ml	< n X 10^3 (1<n<10)
Metatrophic bacteria	unit/ml	< n X 10^3 (1<n<10)

Produced Water Treatment Plant

The produced water treatment plant will consist of three treatment stages: primary, secondary and tertiary. The specification for produced water quality is stringent, and the basis of design requires a multi staged produced water treatment plant, comprising primary, secondary and tertiary treatment. A number of options have been considered for each stage with the following being selected by the FEED team:

- Skim tanks (Primary treatment). This provides a surge capacity of 4 hours for any upsets in the downstream systems. Skim tanks also ensure coarse separation of oil from water to less than 100 mg/l and TSS to less than 30 mg/l, which is sufficient for secondary and polishing stages of separation.

- Spray-induced gas flotation (Secondary treatment). This treatment system has the advantage of light weight, reduced power consumption, low cost and reliability. Oil in water will be reduced to less than 30mg/l and TSS to less than 20 mg/l.
- Walnut shell filtration (Tertiary treatment). This technology is capable of polishing the water to reliably meeting the 15mg/l oil specification (typically achieve less than 10 mg/l for oil in water and TSS. Five 250 m^3/hr filters will be provided, supported by two backwash pumps.
- Provision for an on line oil concentration monitor at the water injection point buffer tank outlet. Provision for other sampling points in the circuit will also be made to monitor oil in water through the treatment system.

Filter aids, reverse demulsifiers and biocides may be added at various points in this treatment process.

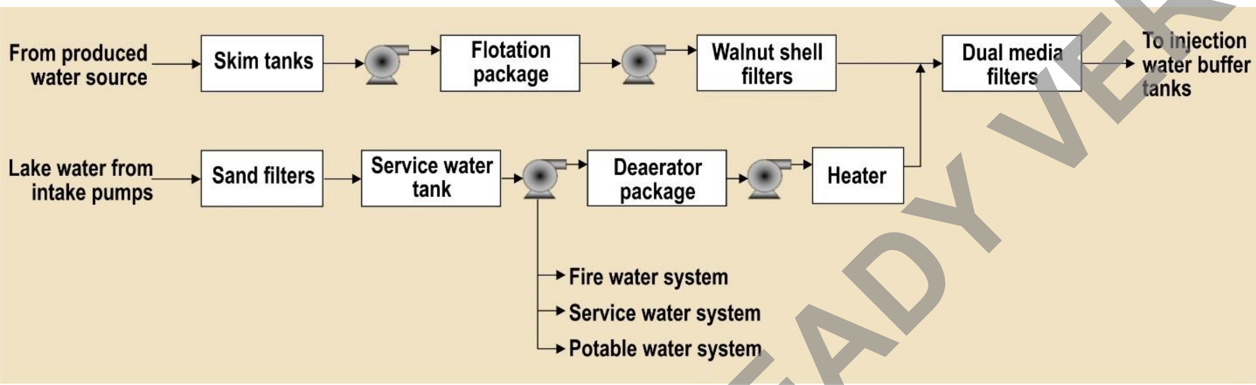

Figure 25: Produced water injection (including make-up water)

Addition of Make-Up Water

The produced water from the CPF will be combined with lake make-up water to meet water injection requirements in the Kingfisher Field (Figure). Lake water will be pumped to the CPF via a dedicated flowline running from the Lake Albert intake facilities. The demand for make-up water will increase sharply up to year 3, to meet the initial shortfall for water injection, after which demand will level off, staying more or less constant until year 9, and then gradual declining. After year 6, the amount of make-up water will be outstripped by produced water generation and by year 25, the usage will only be 34% of the earlier peak requirement, and 7% of the total water injected (Figure 2-6).

At the CPF, the make-up water will be deoxidized by a vacuum deaerator and heated to 87°C. It will then be mixed with the produced water from the walnut shell filters and routed to the dual media filters for fine filtration to reduce TSS to less than 5mg/l, with a particle size average diameter of less than 5 microns.

Backwash Water/ Oil Recovery/ Sludge Disposal

Large quantities of filter backwash water will be generated at the produced water and lake make up water treatment plant.

- The backwash water for the lake water sand filters will be supplied from the service water tank. Dirty backwash water will be discharged into a water recycle tank which is cylindrical, carbon steel tank, designed with a conical bottom to trap sediment. Solids trapped in the bottom will flow into a sludge settling drum for further separation of solids and water. Clarified water will be returned to the inlet of the sand filters. Solids will be drummed and removed by a third party contractor for disposal
- The backwash water for walnut shell filters and dual media filters will be supplied from the water injection buffer tank by backwash pumps. Dirty backwash water will be discharged into a foul water tank. Foul water will be pumped back into the inlet header of the skim tanks.

- Oil skimmed from the skim tanks, flotation vessels, surge tank, walnut shell filters and water injection buffer tanks will be contained in a foul oil recovery drum which will be pumped back to the oil treatment system.
- One sludge settling drum will be provided for the produced water and lake water settled solids. The sludge settle drum will be a vertical cylindrical tank fabricated in lined carbon steel and designed with a conical bottom into which slurry will be discharged from the following sources:
  - water recycle tank conical bottom
  - drain from skim tanks
  - drain from flotation vessels
  - drain from surge tank
  - drain from foul water tank
  - Drain from buffer tanks

The foul oil will be discharged from the sludge settling drum to the sludge dewatering package via a bucket type weir on the side of the drum. Solids will settle in the conical bottom and be discharged by sludge transfer pumps to the sludge dewatering package for further dehydration. Clarified water will be pumped back into the inlet header of the skim tanks by water transfer pumps.

The sludge dewatering package will use a spiral sludge dehydrator which will be fully automatic for easier operation and maintenance, with lower energy consumption and low noise. The effluent through the spiral sludge dehydrator will be pumped back into the inlet header of the skim tanks, while the dewatered sludge will be transferred to the waste disposal areas for disposal by a third party waste contractor.

Storage and Delivery to the Injection Wells

The produced water and make up water will be stored in two 2,000 m^3 buffer tanks at the CPF, at a temperature of 80ºC. The tanks will have a retention time of 4 hours of storage. Produced water from the tanks will be pressurized by booster pumps (to 199.8 bar) and delivered by flowline to the injectors on the well pads. Provision will be made for dosing with corrosion inhibitor, scale inhibitor, oxygen scavenger and biocide on delivery into the pressurized flowlines to the well pads.

Process Effluent (routed to the Closed Drain System)

Process effluent is generated by equipment operated under pressure, equipment containing toxic fluids and equipment containing highly volatile hydrocarbon liquids which may need to be drained for maintenance or inspection. All of the effluent is route through fully contained closed drains and is either pumped back to the oil processing plant or to the produced water plant.

Potentially oil contaminated (POC) water

Potentially oil contaminated (POC) water will be removed in the open drain system. POC water is managed in three ways (illustrated in Figure 27):

- Open drain system 1 (OD1): from permanently oil contaminated areas during normal operations, or other routine events that could release significant quantities of hydrocarbon liquids. These areas include storm water and wash water collected underneath oil processing equipment likely to produce drips and spillages in routine operations (pumps, compressors, separators, vessels, manifolds, all equipment with non-welded fittings); water collected from beneath oil loading areas; drainage from oil sampling points, water draw off from oil storage tanks, produced water skim tanks, injection water tank bottoms. OD1 effluent is routed through buried pipes to a first flush sump (15 minutes), connected to an oil-water interceptor (example illustrated in Figure 26) for primary treatment and then pumped to the produced water treatment plant for produced water disposal. A maximum 15-minute storm water runoff value of 120 m^3 (equivalent to runoff of 478 m^3/hr) is provided for. Storm water from this area after the first fifteen minutes will be collected and tested before release into the environment.

- Open drain system 2 (OD2): from accidentally oil-contaminated areas during normal operations, or other routine events that are could release very small quantities of hydrocarbon liquids; or areas that are normally clean but could release hydrocarbons as a result of a leak, such as a piping weld puncture or a rare event such as storm flooding and cross contamination of normally clean areas. These areas include storm water collected from paved areas near process units, from bunded areas designed to collect accidental spillages. First flush (15 minutes) OD2 storm water is not discharged directly to the environment – as a minimum, floating oil will be collected from an observation basin and tested before discharge; and
- Open drain system 3 (OD3): from oil-free areas of the plant where the risk of contamination with hydrocarbons or other oily products is negligible and can be disregarded. These areas include undeveloped areas, building roofs and green spaces. OD3 storm water may be discharged directly to the environment through a pipe or ditch without testing.

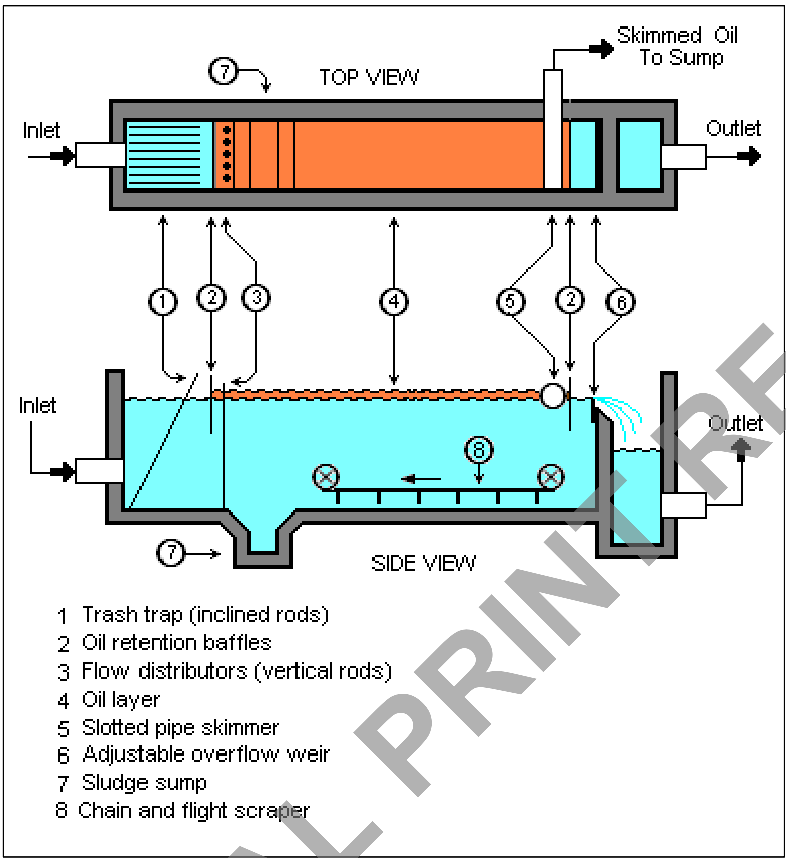

Figure 26: Typical API oil separator (Source: API, 1990)

Laboratory water

Potentially chemically polluted effluent released into the laboratory sinks will be piped into a separate, vented, tank. This will be treated using secondary treatment such as neutralisation; or diluted with water in a controlled manner to prevent hazard to the environment, before release into the open drains (normally the OD 2 drains); or contained in sealed drums, labelled with appropriate hazard warnings and stored for onward transport to a hazardous waste disposal facility.

Storm water impacts from the CPF

Figure 28 illustrates the storm water flow direction and various discharge points and drainage to the lake.

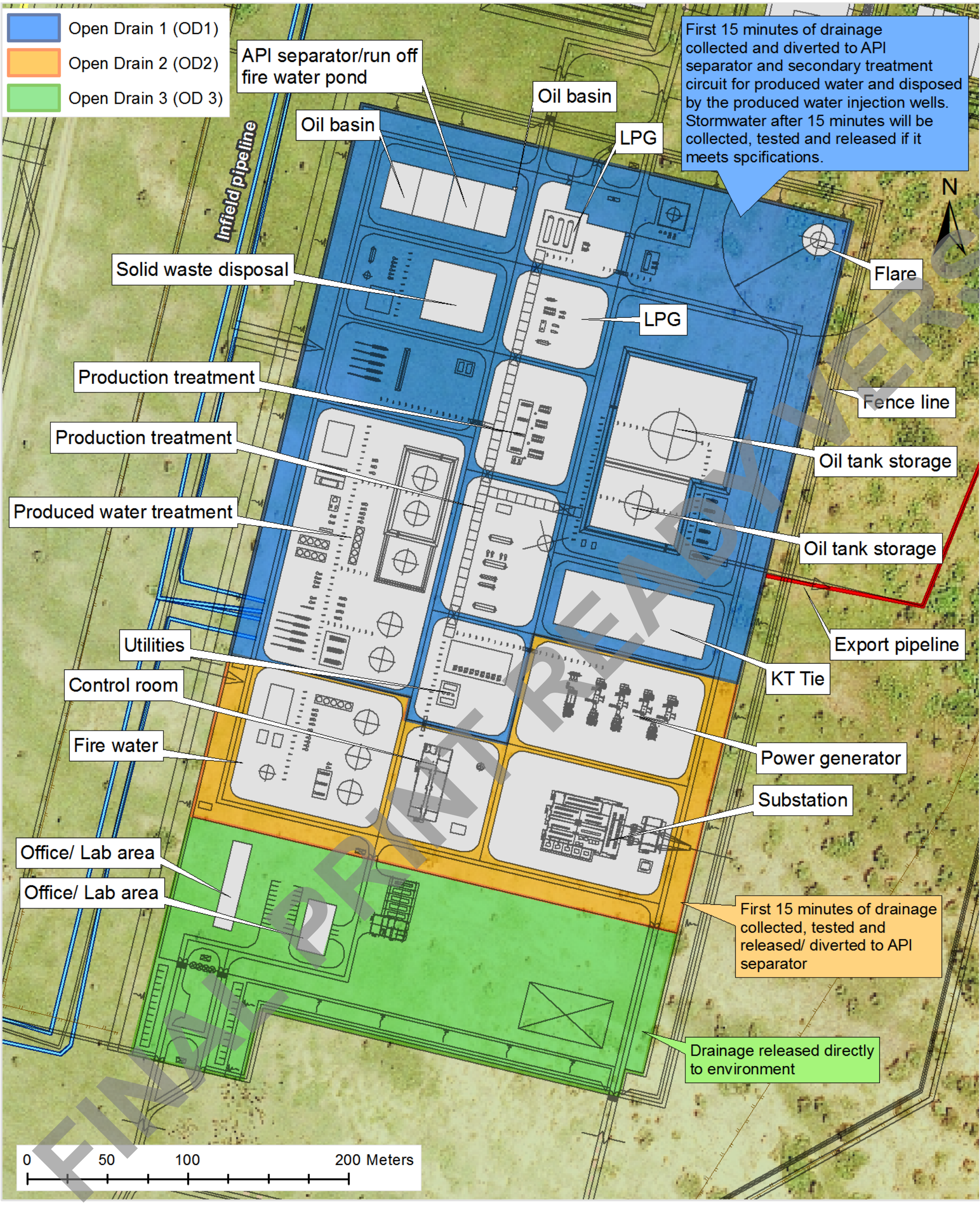

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Figure 27: Handling of clean and POC water at the CPF

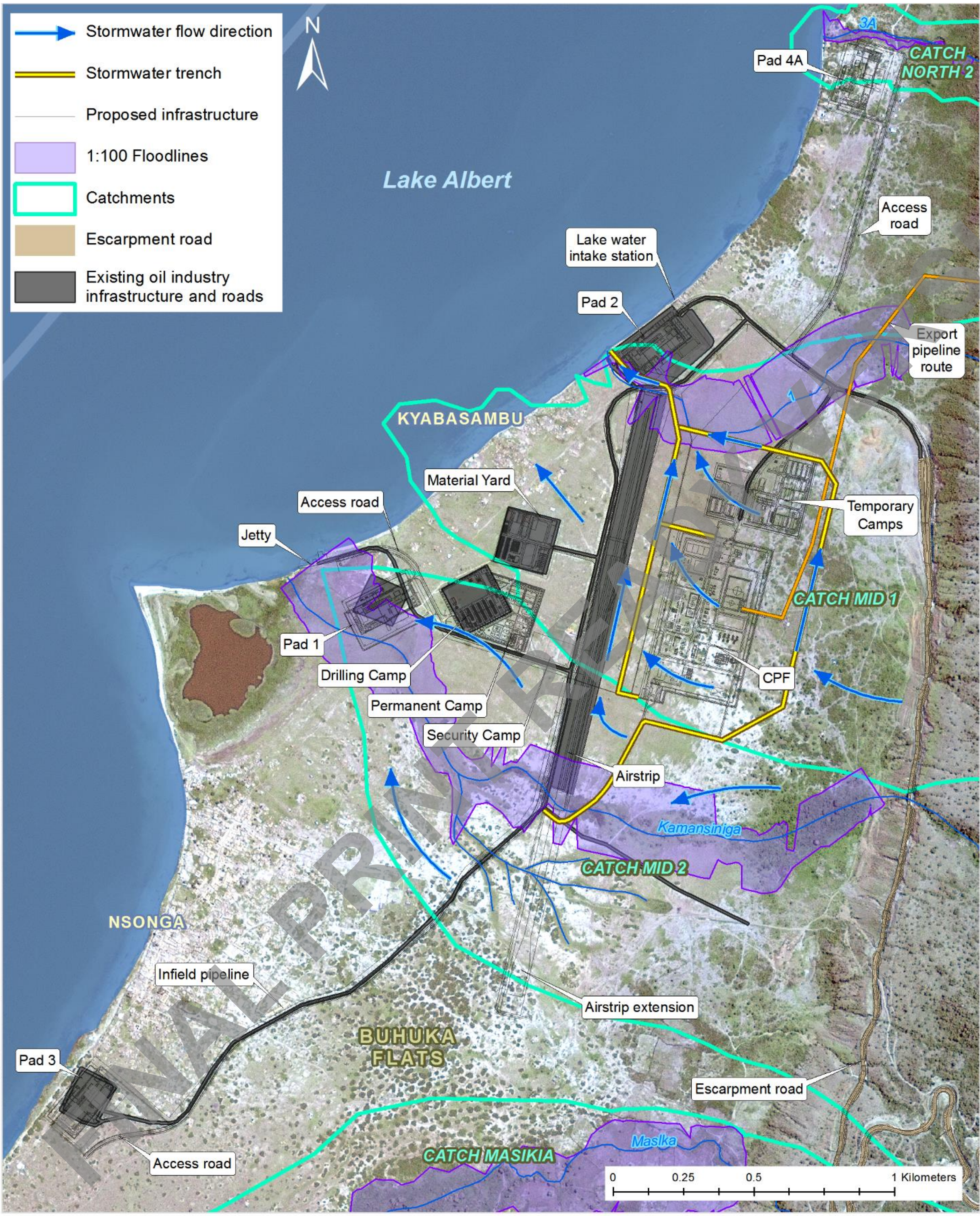

Figure 28: KDA drainage to the lake

Using the floodline model the CPF was divided into a northern (Figure) and southern catchment. The contour elevations fall towards the north-west. Left to its own devices the runoff will channelize parallel to the runway into the stream on the north. The recommendation would be to channelize runoff and pass it under the runway (Figure). The total flow from the CPF catchment leaves the site at 5.8 $m^3.s^{-1}$ with a velocity of 2.7 $m.s^{-1}$ in a concrete lined channel with trapezoidal cross-section 1 m deep and 2 m wide at the base. A culvert across the runway conveys the flow 550 mm deep at 0.91 $m.s^{-1}$, using 6 x 2 m wide x 1 m high culverts.

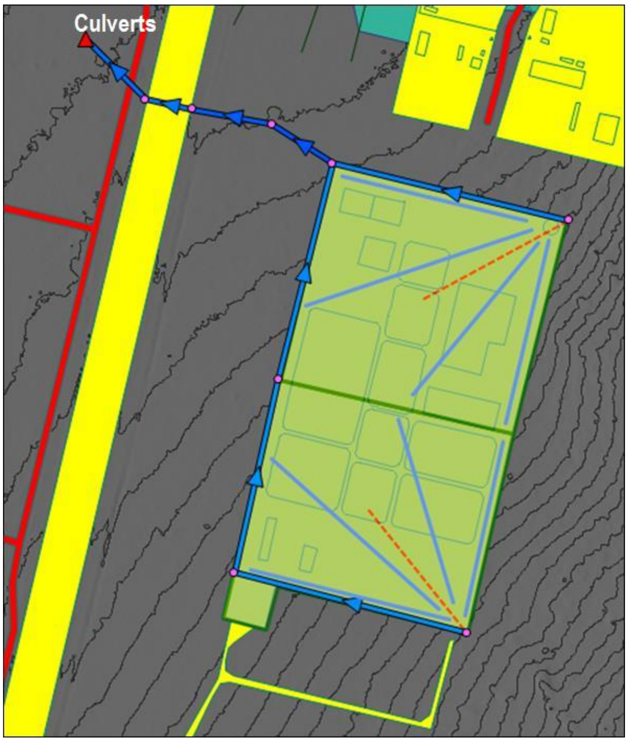

Figure 29: Northern drainage

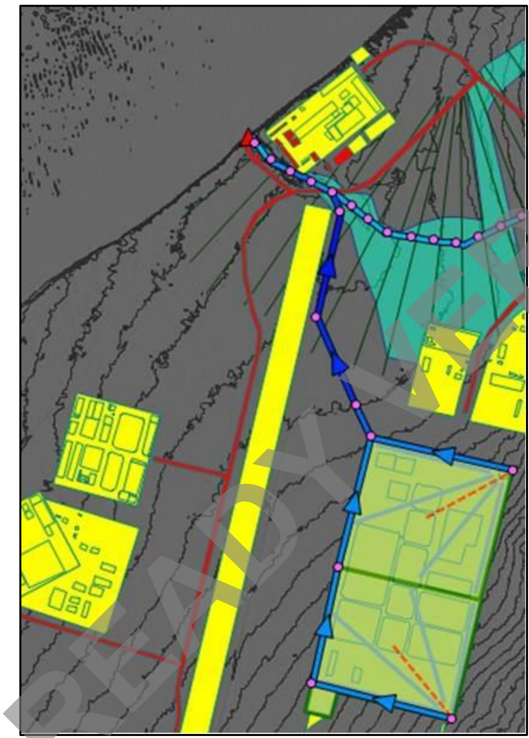

Figure 30: CPF hydrograph

When injecting the flow hydrograph from the entire CPF into the northern stream (considering the 1:100 peaks), the increase in velocity is greater than the sum of their parts, likely because of the channel geometry. The peak flood in the channel from normal runoff is already likely to cause scour at 3.49 $m.s^{-1}$ flow velocity. After addition of the CPF runoff hydrograph as per the image in Figure 30, inflow velocity increases to 7.4 $m.s^{-1}$ which will cause substantial erosion once in-channel. If a constant inflow of 5.762 $m^3.s^{-1}$ at the upstream node (in lieu of the hydrograph, because it will not necessarily be routed as per below) is introduced, the velocity only increases to 5.52 $m.s^{-1}$, which is still substantial for an unlined condition and will certainly cause erosion.

Domestic Wastewater

During construction a temporary 300 m^3/d Sewage Treatment Plant (STP) will be constructed at the temporary camp and a 50m^3/d plant at the drilling camp. Both of these discharges will enter the lake via drainage line 1, just south of drilling pad 2.

For the operational phase the planned capacity of the domestic wastewater treatment plant (sewage works) is 45 m^3/day, making provision for an estimated 135 personnel plus contingency. Treated sewage effluent will meet the more stringent of the Ugandan and IFC treated sewage effluent requirements (Appendix 1). The sewage treatment plant will be located at the permanent camp. Backup sewage treatment capability will be provided by the sewage treatment plant built to supply the drilling camp, which has spare capacity for an additional 90 people. The two sewage plants will be linked to allow for maintenance shutdowns of either plant. After drilling is completed in year 6, the drilling sewage plant will be maintained as a backup.

Sewage from the CPF will be routed via conservancy tanks to a regulating tank at the permanent camp from where it will be treated in a Membrane Bioreactor treatment works.

The primary option for final disposal of treated sewage effluent will be by irrigation of the green spaces around the facilities including the camp and the CPF, on roads to suppress dust and also the wider community grazing areas in the Flats. This will be done using 5m^3 water trucks fitted with spray / irrigation jets. The backup option will be discharge of the treated domestic wastewater into the channel leading to Lake Albert. Combining the final sewage effluent with the produced water is not a viable option due to the risk of bacterial contamination in the reinjection wells.

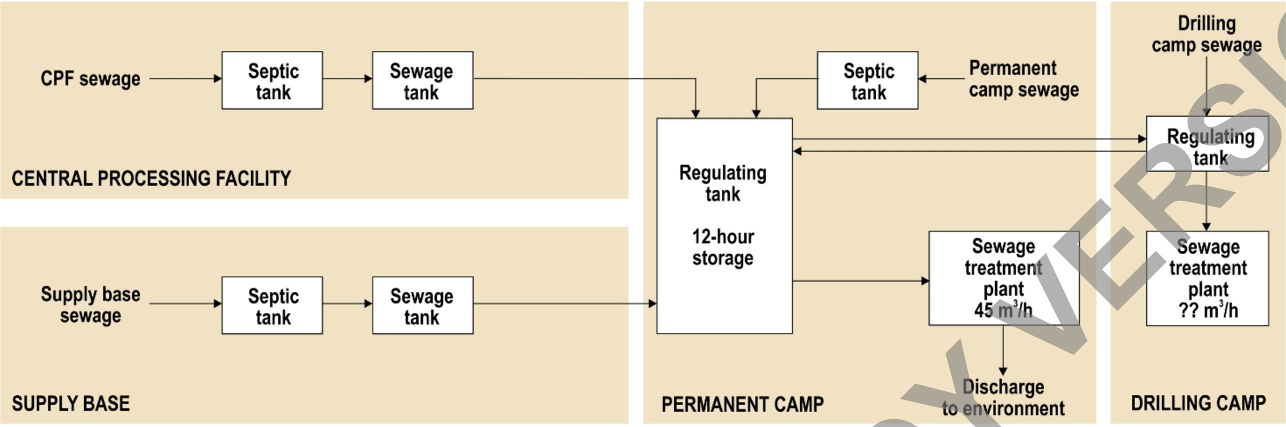

Figure 31: Schematic of sewage treatment capacity for the CPF, supply base and permanent camp

6.1.4 Pipelines

The Kingfisher well fluids, consisting of a mixture of crude, gas and water, will be delivered to the CPF via buried flowlines from each of the four well pads.

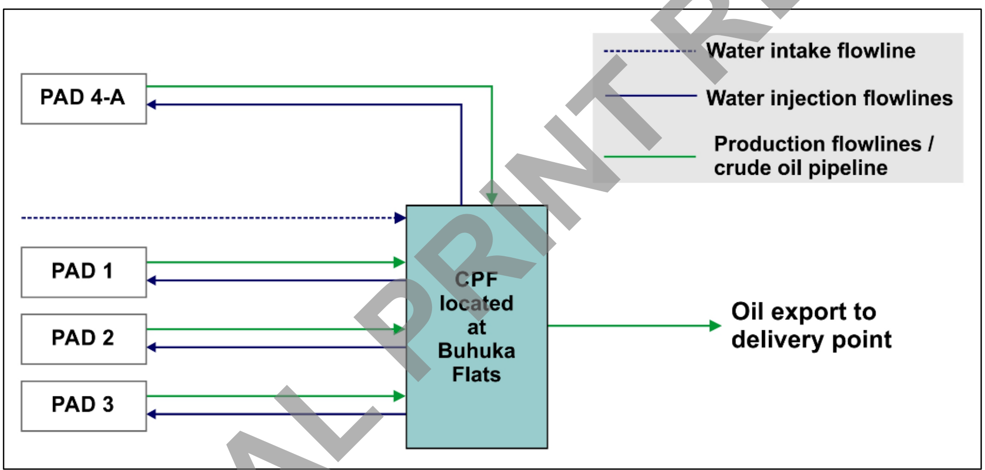

Figure 32: Schematic of production and water injection flowlines

The flowlines will cross minor drainage lines from the escarpment near Pad 2 and south of the airstrip en route to Pad 3. The flowlines will be buried beneath the maximum scour depth of the river course as illustrated in Figure 33. The flowlines will be rated to cater for overpressure conditions.

Soil tests in the Bugoma flats show moderate to high corrosivity. The outer surface of the flowlines is likely to be encased in an FBE coating in order to inhibit corrosion. Welded joints will be protected using a heat shrink wrap sleeve, applied after the weld is completed.

An impressed current Cathodic Protection System will be used to apply a small electrical current to the metal surface of the pipeline. Combined with a sacrificial anode, this minimises external corrosion of the pipe. There is no risk to humans or animals caused by the system. Taking into account current methods of pipe manufacture, pipeline construction and maintenance and cathodic protection, the design life of a pipe buried according to these specifications is likely to exceed 30 years.

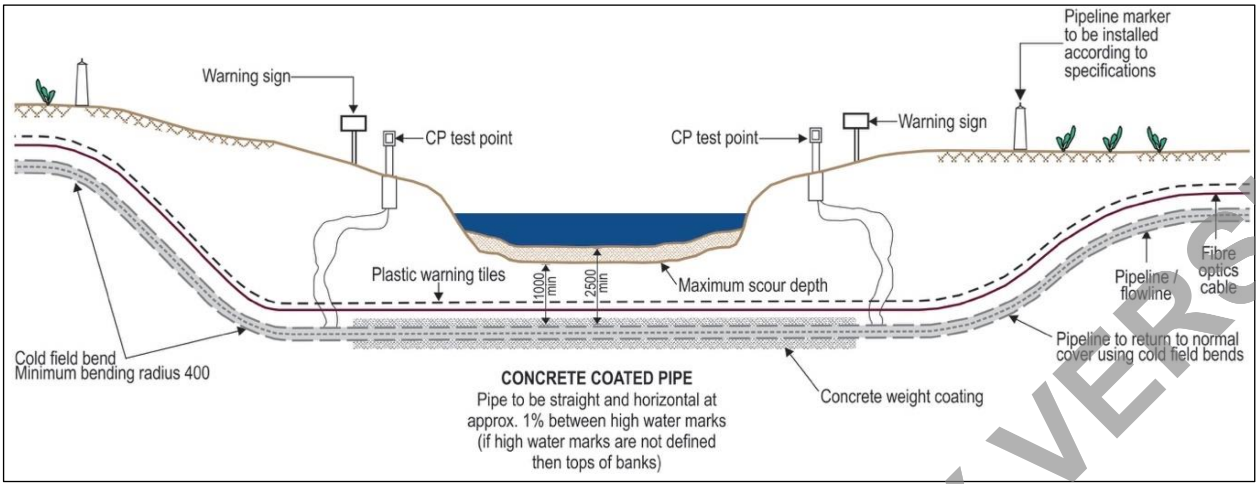

Figure 33: Cross section of a flowline crossing of a typical drainage line

The flowlines require little maintenance on a day to day basis. The right of way will be monitored regularly for any signs of human activity (for example, excavation) that could create a risk, and for any leaks. A major flowline failure would be picked up by a pressure drop in the line, recorded in the control room at the CPF. Minor leaks would typically manifest as a small patch of dying vegetation at the surface. In some instances, leaks can be heard and are reported by third parties. Leaks are very rare.

The main surface water concerns are therefore related to potential leaks from the pipeline at surface water crossings.

6.2 Impact Assessment Methodology

The impact assessment process compares the magnitude of the impact with the sensitivity of the receiving environment. This method relies on a detailed description of both the impact and the environmental or social component that is the receptor. The magnitude of an impact depends on its characteristics, which may include such factors as its duration, reversibility, area of extent, and nature in terms of whether positive, negative, direct, indirect or cumulative.

Once the magnitude of the impact and the sensitivity of the receiving environment have been described, the severity of the potential impact can be determined. The determination of significance of an impact is largely subjective and primarily based on professional judgment.

To provide a relative illustration of impact significance, it is useful to assign numerical descriptors to the impact magnitude and receptor sensitivity for each potential impact. Each is assigned a numerical descriptor of 1, 2, 3, or 4, equivalent to very low, low, medium or high. The significance of impact is then indicated by the product of the two numerical descriptors, with significance being described as negligible, minor, moderate or major, as in Table 13. This is a qualitative method designed to provide a broad ranking of the different impacts of a project.

Table 13: Determination of impact severity

			Sensitivity of receptor			
			Very low	Low	Medium	High
			1	2	3	4
Magnitude of Impact	Very low	1	1 Negligible	2 Minor	3 Minor	4 Minor
	Low	2	2 Minor	4 Minor	6 Moderate	8 Moderate
	Medium	3	3 Minor	6 Moderate	9 Moderate	12 Major
	High	4	4 Minor	8 Moderate	12 Major	16 Major

Table 14: Impact assessment criteria and rating scale

Criteria	**Rating scales**
Magnitude (the expected magnitude or size of the impact)	**Negligible**- where the impact affects the environment in such a way that natural, and /or cultural and social functions and processes are negligibly affected and valued, important, sensitive or vulnerable systems or communities are negligibly affected.
	Low- where the impact affects the environment in such a way that natural, and/or cultural and social functions and processes are minimally affected and valued, important, sensitive or vulnerable systems or communities are minimally affected. No obvious changes prevail on the natural, and / or cultural/ social functions/ process as a result of project implementation
	Medium - where the affected environment is altered but natural, and/or cultural and social functions and processes continue albeit in a modified way, and valued, important, sensitive or vulnerable systems or communities are moderately affected.
	High - where natural and/or cultural or social functions and processes are altered to the extent that they will temporarily or permanently cease, and valued, important, sensitive or vulnerable systems or communities are substantially affected. The changes to the natural and/or cultural / social-economic processes and functions are drastic and commonly irreversible
Sensitivity of the Receptor	**Low** – where natural recovery of the impacted area to the baseline or pre-project condition is expected in the short-term (1-2 years), or where the potentially impacted area is already disturbed by non-project related activities occurring on a scale similar to or larger than the proposed activity
	Medium – where natural recovery to the baseline condition is expected in the medium term (2-5 years), and where marginal disturbance or modification of the receiving environment by existing activities is present.
	High – where natural recovery of the receiving environment is expected in the long-term (>5 years) or cannot be readily predicted due to uncertainty over the nature of the potential impact, and where unique or highly valued ecological, social or cultural resources could be adversely affected.

6.3 Construction and decommissioning phase impacts

The anticipated impacts are expected to be similar for both the construction and decommissioning phases, and will occur over a similar period of approximately 2 years. Therefore, for the intents of this impact assessment, the decommissioning phase impacts have been included with the construction phase impacts in their assessment.

This section presents an assessment of the possible interactions of the drainage lines and rivers with the production facility infrastructure and activities including the camps, well pads and Central Processing Facility, as well as the pipelines; and the resulting impacts during the construction and decommissioning phases of the Project.

The predicted impacts on the surface water environment can be broadly categorised as:

- Impacts on water quality:
  - Sedimentation due to erosion;
  - Pollution from spillages; and
  - Discharge of poorly treated domestic wastewater.
- Impacts on/ from water quantity:
  - Disturbance of the flow lines in the Buhuka Flats;
  - Inadequate storm water management
- Impacts on the bed and banks of rivers/ streams:
  - Pipeline crossings; and
  - Construction activities in rivers/ streams.

The potential impacts of the project during the construction and decommissioning phase are listed and ranked in Table 15 and discussed in the sections to follow.

Table 15: Potential impacts in the construction and decommissioning phase

No.	Potential Impact	Pre-Mitigation			Post- Mitigation		
		Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity
C1	Increased erosion and runoff volumes	Medium	Medium	Moderate	Low	Low	Minor
C2	Increased dust and sedimentation in drainage streams	Medium	Low	Moderate	Low	Low	Minor
C3	Altering the banks and beds of streams by the construction of the pipeline	Medium	Low	Moderate	Low	Low	Minor

No.	Potential Impact	Pre-Mitigation			Post- Mitigation		
		Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity
C4	Spillage of oils, fuel and chemicals polluting water resources	Medium	High	Major	Low	Medium	Moderate
C5	Discharge of poor quality effluent from the sewage works at the temporary camp	Medium	Low	Moderate	Low	Low	Minor

6.3.1 Increased erosion and runoff volumes

Impact Assessment

Due to the expansive network of drainage lines on the Buhuka Flats (Figure 23) the removal of vegetation and topsoil for the construction of the infrastructure, as well as the compaction of surfaces during construction, will result in increased runoff and erosion from the site, particularly given the steep slopes leading into the Flats from the escarpment and high rainfall in the area. Sediment generated during construction of the CPF itself and other onshore infrastructure will enter the lake during storm flows over the approximately three year construction period, peaking during site establishment when vegetation is being cleared and civil earthworks is ongoing.

The soils of the Buhuka Flats are dispersive (Golder Associates 2014d), and cleared areas will be prone to scour, and high sediment loads may be expected. River 1, which flows north of the temporary camps and proposed CPF, is likely to receive the drainage from the CPF earthworks and temporary camp. Additional sediment will also be contributed from the expansion of well pad 2 to its full size. While the materials yard falls within River 1 catchment, its construction activities are likely to impact Lake Albert directly.

The sediment from the construction activities at the permanent camp are likely to impact the Kamansiniga River, South of the CPF, and potentially also the lake directly. This river, as well as the papyrus lagoon (Luzira) and lake, will also be impacted by any construction activities at Pad 1 (Figure 34). The Luzira is an important area as it is an active place of worship and the historic center of cultural activity. The biodiversity study (Golder Report number: 1776816_D.0) has however indicated that the seasonal wetland will provide efficient attenuation of sediment, and a significant increase in sediment concentrations in the lake or in the lagoon are unlikely.

While the water courses of the study area support dense emergent vegetation that will assist in reducing flow velocities and sediment, it is still expected that increased turbidity will be measurable in the nearshore environment during and after storms, where the rivers discharge into the lake, and specifically at River 1 where there are no attenuating wetlands.

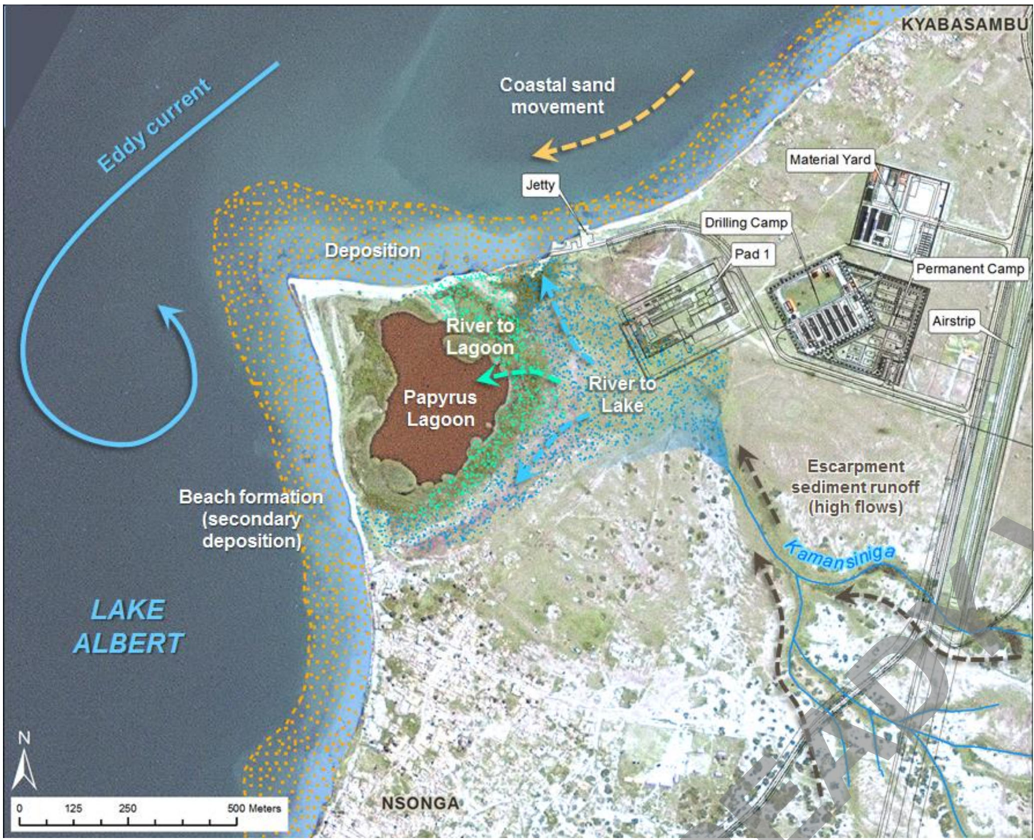

Figure 34: Likely drainage path to the Papyrus Lagoon

Impact Classification

The impacts caused by erosion and sedimentation on the rivers, lake and lagoon are expected to be mostly on River 1 where no wetland attenuation can be expected and the largest load will report to, although there is likely to be some impact on the Kamansiniga River, Luzira and Lake Albert directly. It has been scored with a medium magnitude where the affected environment is altered but natural, and/ or cultural and social functions and processes continue albeit in a modified way, and valued, important, sensitive or vulnerable systems (such as the Luzira) or communities are moderately affected. The sensitivity of the receptor has been scored as medium where natural recovery to the baseline condition is expected in the medium term (2-5 years), and where marginal disturbance or modification of the receiving environment by existing activities is present.

The **impact severity** is therefore scored as **moderate**, as the impacts can be reversed however may take some time.

Mitigation

Mitigation should include:

- Limiting the area that is cleared at all the sites where additional construction may occur (expansion of well pads, materials yard and camps), and specifically the proposed CPF area which is yet to be constructed;
- At all sites, ensuring that soil is not placed where it can easily be washed in to the river;
- Construction and maintenance of storm water channels/ trenches around the sites so that sediment is collected as far as possible on the site and stored in sediment control dams prior to release. The dams will allow the sediment to settle prior to discharge of runoff to the environment. It is recommended that

the storm water from around the CPF is channelled under the runway to prevent scour that would very like occur if all the water was to exit to the river at the run-way.

- Construction of a storm water management berm system on the perimeter of each development area so that clean storm water run-off is directed away from the site.

Should erosion and sediment control mitigation be put in place, the **impact severity** could be reduced to a **minor,** as the majority of sediment would not reach the rivers, lagoon or lake in one flush.

6.3.2 Increased dust and sedimentation in drainage streams

Impact Assessment

The removal of vegetation and topsoil, as well as the movement of vehicles during construction, specifically during construction of the CPF, and expansion of the well pads will result in increased dust levels and further sedimentation in the surface waters near the Kingfisher Development Area. This may result in an increase in sediment load in the runoff reporting to the rivers and Lake Albert, as described in Section 6.3.1.

Impact Classification

It is expected that the impact would have a medium magnitude where where the affected environment is likely to be altered but natural, and/ or cultural and social functions and processes (specifically at the Luzira) will continue, and valued, important, sensitive or vulnerable systems or communities are moderately affected.

The sensitivity of the receptor however has been scored as low, where natural recovery of the impacted areas to the baseline or pre-project condition is expected in the short-term (1-2 years) as cleared areas are revegetated and buildings are erected.

The **impact severity** is therefore scored as **moderate**, as the impacts will still be of medium magnitude, however, can be reversed within a fairly short (1-2 year period).

Mitigation

Mitigation should include:

- Dust suppression using biodegradable chemicals or water abstracted from Lake Albert during the construction phase;
- Avoidance of construction activities during times when the communities may be holding the rituals/ cultural activities to lessen the dust at a specific time.

Implementing mitigation should reduce the impact to low magnitude where the impact is likely to affect the environment in such a way that natural, and/or cultural and social functions and processes are minimally affected and valued, important, sensitive or vulnerable systems or communities are minimally affected. In this respect no obvious changes will prevail on the natural, and/ or cultural/ social functions/ processes as a result of project implementation and sensitivity, so that an overall minor impact significance is recorded. The sensitivity of the receptor will remain low where natural recovery of the impacted areas to the baseline or pre-project condition is expected in the short-term (1-2 years) as cleared areas are revegetated and buildings are erected.

The **impact severity** is therefore reduced to minor.

6.3.3 Altering the banks and beds of streams due to excavation for infield and export pipelines

Impact assessment

The construction of the pipeline crossings may alter the river banks and bed. While the pipeline will be below ground, there is the potential for erosion at the excavation site when digging the trench for the flowline. This may have impacts downstream of the crossings, backwater upstream of the crossings during the excavation when water cannot flow through, and erosion once the water in the rivers starts to flow again. This will have direct impacts on the lake between Pads 3A and 2 and River 1 where trenching would need to take place to lay the infield flowlines; as well as the Hohwo and Ngema rivers which are crossed by the export pipeline at about 27 and 35 kilometres respectively.

Impact Classification

The impact on the drainage lines and River 1 where the infield pipeline from Pad 3A connects to the line at Pad 2 would have a medium magnitude and low sensitivity, resulting in a **moderate impact severity** during construction.

The reason being that the affected environment would be altered during the trenching activity, however natural, and/or cultural and social functions and processes would continue and natural recovery of the impacted area to the baseline or pre-project condition is expected in the short-term (1-2 years).

Similarly the impact on the Hohwo and Ngema rivers by the excavation for the export pipeline is also expected to result in a **moderate impact severity** during construction, as the impacted areas would be of short duration.

Mitigation

The protocols to be applied while constructing the crossings should be developed and documented in the Environmental Management Plan (EMP). The mitigation needs to include:

- Excavating during times when high rainfall is not expected to limit wash down of excavated material into the lake and rivers, and to limit the volume of water that will need to be dammed to allow the trench to be dug and the pipes laid;
- Rehabilitation of the bed and banks of the river as soon as the pipe has been laid ensuing that the compaction is adequately done to avoid scour as water flow commences.

Implementing mitigation will reduce the impact to low magnitude and sensitivity with an overall **minor impact severity** because the risk of soils being washed down will be limited,

6.3.4 Spillage of oils, fuel and chemicals polluting water resources

Impact Assessment

Small quantities of oil and chemicals from vehicles and other mechanical equipment during construction into storm water draining from construction areas could increase the concentrations of these pollutants in River 1 and consequently in Lake Albert south west of well pad 2, as well as to a lesser extent into the Kamansinig River. In the day to day construction activities this is considered to be likely, although concentrations should be low. In addition the contamination will be short term over a small geographical area in the near-shore environment. Minor spillages and rain wash from oily construction equipment that is working on the jetty and water intake station may also contribute to pollution loads in these areas, particularly as the deposition would be directly into the near-shore lake environment.

Impact Classification

The overall magnitude is considered to be medium where the affected environment will be slightly altered and the natural and cultural activities of the communities in the sensitive areas are expected to be marginally impacted in most cases.

However, a further and more severe risk will result from the construction and drilling of the wells. While control systems are proposed to manage contaminated storm water and wash water from the well pads, the presence of drilling crews on site for nearly a year using potentially hazardous drilling fluid; and the absence of a buffer between the well pads and the lake (and in the case of well pad 1, the seasonal wetland and the lagoon); makes it likely that occasionally contaminated drainage will reach the lake unless there is a very high level of control of day to day activities.

This must be assessed in the context of the sensitivity of the near-shore environment to oil and chemical spills. The concentration of hydrocarbons and other pollutants in the lake water is currently below levels that could cause harm in the lake environment (Golder Associates 2014b), however in the absence of mitigation, the overall impact severity of chemical and oil pollution to Lake Albert may be **major,** where natural and/or cultural or social functions and processes are altered to the extent that they will temporarily or permanently cease while for example, a spill is cleaned up resulting in a medium rated magnitude and the sensitivity of the receptor is rated as high, where natural recovery of the receiving environment is expected in the long-term (>5 years) however, cannot be readily predicted due to uncertainty over the nature of the potential impact, and where unique or highly valued ecological, social or cultural resources (The Luzira) could be adversely affected.

Mitigation

The protocols that should be applied during the construction phase should be developed and documented in the EMP. The protocols should address the following:

- Compliance to the requirements of the Ugandan National Environment (Waste Management) Regulations, S.I. No 52/1999 or other relevant International Waste guidelines;
- Storage of new and used oils in demarcated bunded areas;
- Storage of other hazardous or toxic substances securely and controlled use thereof;
- The construction of covered drilling waste pits to contain hazardous waste prior to collection for safe disposal at a certified hazardous waste facility;
- Construction of an evaporation pond at each well pad to contain the liquid drilling wastes; and associated dewatering pumps to pump liquids for safe disposal by a certified hazardous waste contractor at a certified hazardous waste facility;
- No co-handling of reactive liquids or solids;
- Creation and monitoring of an inventory of chemicals held on site;
- Availability and accessibility of HAZOP sheets of all chemicals; and
- The immediate clean-up of spills and temporary storage at the CPF of any hazardous material before being disposal by a certified hazardous waste contractor.

If the recommended construction protocols are followed, then impact during construction will be reduced to low magnitude and medium sensitivity, with an overall **moderate severity**.

6.3.5 Discharge of poor quality effluent from the sewage works at the temporary camp

Impact Assessment

During construction a temporary 300 m^3/d Sewage Treatment Plant (STP) operate at the temporary camp and a 50m^3/d plant at the drilling camp. Both of these discharges will enter the lake via drainage line 1 (probably canalised), just south of drilling pad 2. Should poor quality effluent be discharged to the environment this may have an impact on the ecosystems as well as human health.

Impact Classification

The impact is rated with a medium magnitude where the affected environment is altered because of specific impacts related to bacterial contamination. The receptor sensitivity is recorded as low as the natural recovery of the impacted area to the baseline or pre-project condition is expected in the very short-term, resulting in a **moderate** impact severity.

Mitigation

The treatment process needs to be of a type that will meet the Uganda and IFC standards in terms of BOD, N, P and SS. Chlorine should be considered as a disinfection step, either in tablet form (1st choice due to stability and ease of transport) or in solution form (2nd choice since sodium hypochlorite loses efficiency with storage duration). Gaseous disinfection is not recommended due to the potential explosive safety risks.

It is recommended that the effluent be irrigated rather than discharged directly back into a water resource, or a man-made wetland be constructed upstream of the discharge to act as a buffer.

Treated sewage effluent would need to comply with the values set out in Table 16.

Table 16: Treated sewage effluent discharge limits (EFC standards)

Variable	Guideline Value
pH pH	6 – 9
BOD mg/l	30
COD mg/l	125
Total nitrogen mg/l	10
Total phosphorus mg/l	2
Oil and grease mg/l	10
Total suspended solids mg/l	50
Total coliform bacteria MPN/ 100 ml	400

Notes: MPN = Most Probable Number

If the recommended construction protocols are followed and the systems are maintained, then impacts during construction will be reduced to low magnitude and sensitivity, resulting in an overall **moderate** impact severity.

6.4 Operational phase

The potential impacts during the operational phase identified for the surface water study are presented in Table 17.

Table 17: Potential impacts related to the Operational phase

No.	Potential Impact	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity
O1	Reduction in catchment area	Low	Low	Minor	Very Low	Very Low	Negligible
O2	Increased erosion, dust and sedimentation	Low	Low	Minor	Very Low	Very Low	Negligible
O3	Discharge of poor quality storm water from CPF	Medium	High	Major	Low	Medium	Moderate
O4	Spillage of crude oil from Well pads and CPF	Medium	High	Major	Low	Low	Minor
O5	Infrastructure crossing natural drainage lines	Medium	High	Major	Low	Low	Minor
O6	Oil leaks around pipeline	Medium	High	Major	Low	Medium	Moderate

No.	Potential Impact	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity	Magnitude (the expected magnitude or size of the impact)	Sensitivity of the Receptor	Severity
O7	Rise in water level of Lake Albert	High	High	Major	Low	Medium	Moderate
O8	Decrease in Lake Albert levels	Very low/ negligible	High	Minor	Very low	Very Low	Negligible
O9	Discharge of poor quality effluent from the sewage works at the CPF (permanent camp)	Medium	Low	Moderate	Low	Low	Minor

6.4.1 Catchment reduction

Impact Assessment

The infrastructure development at the Kingfisher Development Area will only marginally reduce the runoff volume reporting to the local streams. The major rivers reporting to the lake will not be impacted in respect of reduced flow. The drainage lines will be impacted by the construction of the CPF and the well pads, however the storm water that would report via the drainage lines to the lake, will now be channelled around the CPF and well pads and other infrastructure to either River 1 or to Kamanasinig River, so that the volume of water reporting to the lake will only be marginally reduced. There is however the concern that the storm water emanating from the site may be slightly polluted so some volume may be lost as the water will first pass through sediment control dams, sediment traps or oil and grease traps before the water can be released to the environment.

The infrastructure will be required to stand at a raised elevation from the actual ground level due potential flooding over the Buhuka Flats, which will reduce the impact on the runoff volumes.

Impact Classification

The impact has been ranked with a low magnitude which means that the impact affects the environment in such a way that natural, and /or cultural and social functions and processes are negligibly affected, and valued, important, sensitive or vulnerable systems or communities are negligibly affected. In this respect the receptor sensitivity is also rated as low as there is almost no impact to the lake. This relates to an overall **minor** impact severity.

Mitigation

The storm water that is potentially contaminated on the site infrastructure areas, will be collected by the storm water channels and channelled to sediment control dams, sediment traps or oil and grease traps before the water can be released to the environment, if it meets the Uganda Standards as discussed under section 6.4.3. This will result in minimal impact on the natural runoff volumes, without contaminating the surface water.

With mitigation, the impact will be reduced to a negligible magnitude, very low sensitivity, and **negligible** impact severity.

6.4.2 Erosion, dust and sediment collection

Impact Assessment

With open roads and removal of vegetation around the Kingfisher Development Area and along the access road that runs parallel to the export pipeline to Kabaale, there could be an increase in erosion and dust leading to an increase in sedimentation in the runoff water. This could result in a deterioration of land capability and increased sediment loading in the natural water courses. Erosion around cleared areas around the site could lead to the accumulation of sediment upstream of the points where the infrastructure crosses the drainage paths. It is however expected that those areas that are cleared of vegetation during the construction phase and where no infrastructure is located, will have been revegetated. The dust and erosion is therefore likely to be mostly along the access road, so will be limited.

Impact Classification

During the operational phase it is expected that those areas that are cleared of vegetation during the construction phase and where no infrastructure is located, will have been revegetated so that erosion will be limited and sedimentation impacts will decrease compared to that of the construction phase.

The impact has therefore been ranked with a low magnitude which means that the impact affects the environment in such a way that natural, and /or cultural and social functions and processes are negligibly affected, and valued, important, sensitive or vulnerable systems or communities are negligibly affected. In this respect the receptor sensitivity is also rated as low as there is almost no impact to the lake. This relates to an overall **minor** impact severity due to dust and erosion leading to sedimentation during the operational phase.

Mitigation

Dust suppression along the access road would reduce the excess dust that might contribute to sedimentation. The dust suppression methods should be limited to using bio-degradable, eco-friendly suppression chemicals or water extracted from Lake Albert. Effective storm water management measures will be installed as mentioned previously to separate dirty areas. Sediment traps should also be installed where appropriate to allow for flow of water while preventing the accumulation of sediment when the water is released from site.

With mitigation, the impact will be reduced to a negligible magnitude, very low sensitivity, and **negligible** impact severity.

6.4.3 Discharge of poor quality storm water

Impact Assessment

Potentially Oil Contaminated (POC) storm water generated in the defined hazardous areas of the plant will be collected in the open drain system for delivery to an API oil separator. API separators are designed to separate gross amounts of oil and suspended solids from the water. The first 15 minutes of any storm will be captured and routed through the API separator before being delivered to the secondary treatment section of the produced water treatment system for further treatment and disposal with produced water. A maximum 15-minute storm water runoff value of 120 m^3 (equivalent to runoff of 478 m^3/hr) is provided for. The balance of any storm water will be captured in a storm water pond, tested and released into the environment, if it meets the discharge specification. All storm water from designated non-hazardous areas of the plant will be released directly from the open drains, without testing.

Clean storm water will be kept separate from potentially oil contaminated water in order to reduce the volume of wastewater to be treated prior to discharge. Storm water upslope of the plant will be diverted around it. Storm water from clean areas of the plant such as building roofs or roads will be allowed to soak-away or be reused as a resource, where possible.

Chemical and other potential small spillages will be contained in the closed drain system, collected, drummed and disposed by an accredited hazardous waste contractor appointed to manage transport and disposal of wastes leaving the site.

Poor quality storm water released to the environment could have a significant impact on the aquatic ecosystems health in the wetland as well as lake areas, and particularly in the Luzira area, and if left unchecked could have human health impacts.

Impact Classification

The overall magnitude is considered to be medium where the affected environment will be slightly altered and the natural and cultural activities of the communities in the sensitive areas are expected to be marginally impacted in most cases.

This must be assessed in the context of the sensitivity of the near-shore environment to oil and chemical spills. The concentration of hydrocarbons and other pollutants in the lake water is currently below levels that could cause harm in the lake environment (Golder Associates 2014b), however in the absence of mitigation, the overall impact severity of chemical and oil pollution to Lake Albert may be **major,** where natural and/or cultural or social functions and processes are altered to the extent that they will temporarily or permanently cease while for example, a spill is cleaned up resulting in a medium rated magnitude and the sensitivity of the receptor is rated as high, where natural recovery of the receiving environment is expected in the long-term (>5 years) however, cannot be readily predicted due to uncertainty over the nature of the potential impact, and where unique or highly valued ecological, social or cultural resources (such as the Luzira) could be adversely affected.

Mitigation

The storm water management system in place, including oil separators, needs to be optimally operated and maintained to ensure that water released to the environment has an oil and grease content of less than 10 mg/L.

Water released to the environment should be analysed for TDS, oils and grease and in the event that this water does not meet the discharge standards for TDS or oil and grease, additional treatment will be required before this water can be released.

Implementation of these measures would mean that the magnitude would be reduced to a low rating and the sensitivity of the receptor to a medium. The overall impact severity would be **moderate.**

6.4.4 Crude oil spills

Impact assessment

Simultaneous production and drilling on the well pads will occur for the first 7 years, until the project reaches full production. The design will allow for the drilling rig to move between different slots without shutting down production on the well pad.

In order to handle oily drainage from pipelines and equipment, each well pad will be provided with an underground closed drain system leading to a sump with a submersible pump. The levels will be monitored, and the sump periodically emptied into a mobile tanker for handling at the CPF.

Only small quantities of solid waste will be generated, once drilling is completed. The wells are unmanned and will be remotely operated from the CPF over extended periods, without intervention on the well pad. During maintenance, small quantities of potentially oil contaminated and non-hazardous waste will be generated. These will be separated into non-hazardous and hazardous components, delivered to the CPF for temporary storage and then recycled, where possible, or earmarked for disposal by a certified hazardous waste contractor. CNOOC indicates that NORM is not expected in the pigging wastes. Estimated quantities of potentially hazardous waste are less than 0.5 t/well/year.

During the operational phase, oil spills at the wells, as well as spillage of other on-site chemicals, could result in the pollution of water resources if the spill is not contained or the sump is not well maintained and emptied adequately.

Impact Classification

While control systems are proposed to manage contaminated storm water and wash water from the well pads, the presence of drilling crews on site when drilling is taking place at a particular well pad, using potentially hazardous drilling fluid; and the absence of a buffer between the well pads and the lake (and in the case of well pad 1, the seasonal wetland and the lagoon); makes it likely that occasionally contaminated drainage will reach the lake unless there is a very high level of control of day to day activities.

The concentration of hydrocarbons and other pollutants in the lake water is currently below levels that could cause harm in the lake environment (Golder Associates 2014b), however in the absence of mitigation, the overall impact severity of chemical and oil pollution to Lake Albert may be **major,** where natural and/or cultural or social functions and processes are altered to the extent that they will temporarily or permanently cease while for example, a spill is cleaned up resulting in a medium rated magnitude and the sensitivity of the receptor is rated as high, where natural recovery of the receiving environment is expected in the long-term (>5 years) however, cannot be readily predicted due to uncertainty over the nature of the potential impact, and where unique or highly valued ecological, social or cultural resources (such as the Luzira) could be adversely affected.

This will result in a medium magnitude and high receptor sensitivity, an overall **major** significance.

Mitigation

Measures for containment of oil spills and warning systems for leaks must be included in the design of the abstraction wells. The protocols that should be applied in the event of an oil spill in the operational phase should be developed and documented in the EMP and maintenance of the control systems must be done so that all aspects remain optimal. A clean-up plan should be prepared and carried out in this event. No contaminated storm water should be released from the well pads due to their proximity to the lake. All contaminated water should be pumped and contained at the CPF until collected by an accredited waste removal contractor for safe disposal at an accredited hazardous waste site.

After mitigation the impact severity decreases to **moderate**, based on a low magnitude and medium receptor sensitivity.

Closely related to both discharge of poor quality storm water and crude oil and other chemical spills, is the aspect of surface water monitoring. In this respect other contaminants of concern (associated with crude oil production), listed in Table 18 should be measured in samples from all the surface water sampling points indicated in Table 3 on a monthly basis, as well as at sites identified in Lake Albert. Monitoring will allow trends to be developed so that additional mitigation can be implemented as necessary to limit impacts to human and aquatic ecosystems health.

Table 18: Variables to be measured for surface water

Variable	Unit	Variable	Unit
pH		Total Phenols	µg/l
Total Suspended Solids	mg/l	Naphthalene	µg/l
Nitrogen (inorganic)	mg/l	Acenaphthylene	µg/l
Aluminium	µg/l	Acenaphthene	µg/l
Arsenic	µg/l	Fluorene	µg/l
Cadmium	µg/l	Phenanthrene	µg/l
Chromium III	µg/l	Anthracene	µg/l
Chromium VI	µg/l	Fluoranthene	µg/l
Copper	µg/l	Pyrene	µg/l
Lead	µg/l	Benz(a)anthracene	µg/l
Mercury	µg/l	Benzo(a)pyrene	µg/l
Manganese	µg/l	Sulfides	mg/l
Zinc	µg/l		

6.4.5 Infrastructure crossing natural drainage lines

Impact assessment

The airstrip and a road lie across the Kamansiniga River and its associated wetland area. This may lead to decreased flows as the water is dammed upstream and could lead to negative impacts in the downstream wetlands, and potentially the lagoon which is a sensitive area that communities use for various rituals.

Impact Classification

In terms of reduced flows to the wetlands this has been recorded as having a medium magnitude where the affected environment is altered, but natural, and/or cultural and social functions and processes continue albeit in a modified way, and valued, important, sensitive or vulnerable systems or communities are moderately affected. If the Luzira is affected then it would be rated as high receptor sensitivity, where natural recovery of the receiving environment is expected in the long-term (>5 years) or cannot be readily predicted due to uncertainty over the nature of the potential impact, and where unique or highly valued ecological, social or cultural resources could be adversely affected.

In this case the overall impact severity is rated as **major**.

Mitigation

Where roads and the airstrip have already been constructed, inspection should be undertaken to assess whether the drainage lines have been impacted in such a manner that is leading to decreased flows and erosion downstream, and if so, an adequately designed culvert will need to be put in place to allow the peak design flood with minimum backwater to pass.

The entrances and exits from the culvert must be protected to prevent erosion and collection of debris, which would block the flow. Should the mitigation be in place, or put in place if necessary, the impact will be reduced to low magnitude receptor sensitivity with and overall **low** impact severity.

6.4.6 Oil leaks along the pipeline

Impact Assessment

The Kingfisher well fluids, consisting of a mixture of crude, gas and water, will be delivered to the CPF via buried flowlines from each of the four well pads. The flowlines will cross minor drainage lines from the escarpment near Pad 2 and south of the airstrip en route to Pad 3. Flowlines will be buried 1 m below ground to top-of-pipe and may be less in constrained locations, however it is noted that this is rarely if ever the case in the study area.

The export pipeline stretches along a 48 km area from the CPF to the Kabaale and crosses the Hohwo and Ngema rivers at about 27 and 35 kilometres respectively. At these crossings the flowlines will be buried beneath the maximum scour depth of the river course as illustrated in Figure 33.

Oil leaks could occur, which would cause contamination of the run-off water into the groundwater and surface water systems at the drainage lines.

The depth of burial is based on the ISO 13623 standard and is intended to minimise the risk of pipeline exposure due to erosion gulleys or accidental excavation. The pipeline will be buried with a surrounding cushion of frictionless material, typically a well-graded sand without rocks or large stones in it, to prevent damage to the pipe coating during the process of pipe-laying or during operation.

Impact Classification

This impact is ranked with a medium magnitude and high receptor sensitivity should a leak occur where the pipeline underlies a river or drainage line and where the resources could be impacted to such an extent that a body of water cannot be used by the communities for a period of time and the ecology is considerably damaged. In this respect there is a rating of an overall **major** impact severity.

Mitigation

The flowlines require little maintenance on a day to day basis, however the right of way will be monitored regularly for any signs of human activity (for example, excavation) that could create a risk, and for any leaks. A major flowline failure would be picked up by a pressure drop in the line, recorded in the control room at the CPF. It is therefore of utmost importance that the control systems are maintained. Minor leaks would typically manifest as a small patch of dying vegetation at the surface or as a sheen of oil at a river crossing or in a downstream water body.

There are several design specifications that must be strictly adhered to including:

- Flowlines will be rated to cater for overpressure conditions;
- Corrosion protection (cathodic protection);
- Lifespan of 25 years.

With mitigation in place the impact would be of a low magnitude, however the receptor would still be of medium sensitivity resulting in an overall **moderate** impact significance.

6.4.7 Rise in water level of Lake Albert

Impact Assessment

During the operational phase and with the expected change in climatic conditions over the next decades (see section 5.2.1), a rise in the water level could lead to an increase in erosion of the shoreline, thereby reducing the width of the Flats. Flooding of the Flats could occur and would have a large impact on infrastructure with potential for pollution, specifically from the pads that are located close to the lake. This could have a potential disastrous impact on eth environment and risk to human lives.

Impact Classification

Without mitigation this aspect is scored as a high magnitude where natural and/or cultural or social functions and processes may be altered to the extent that they will temporarily or permanently cease, and valued, important, sensitive or vulnerable systems or communities are substantially affected – this could be specific to the Luzira and are of the lake around the well pads should contamination due to erosion occur. The changes to the natural and/or cultural / social- economic processes and functions could be drastic. The receptor sensitivity is therefore rated as high, with an overall **major** impact severity.

Mitigation

Measures for erosion prevention around the drill pads should be put in place so that should erosion start occurring, timeous action can take place. The protocols that should be applied in the event of a significant raise in water level should be developed and documented in the EMP. A management plan should be prepared and carried out in this event.

Mitigation will result in the impact being ranked with a medium magnitude and low receptor sensitivity, an overall **moderate** impact severity.

6.4.8 Impact on Lake Albert volume due to abstraction for the project

Impact Assessment

A high level water balance for the Lake Albert was determined using an average rainfall over the Lake of 750 mm/annum and is presented in Table 19.

Table 19: Conceptual water balance over Lake Albert

Sources/sinks	Percentage of total	Volume (Million Ml/a)
Sources		
Direct rainfall	10	3 975
Semliki and Victoria Nile	83	32 993
Runoff from catchments	7	2 283
Total inflow	***39 750***	
Sinks		
Evaporation	26	10 335
Abstractions	4	1 590
Albert Nile	70	27 825
Total	***39 750***	

During the operational phase, the Kingfisher Development Area will require between 520 m^3/day and 7 315 m^3/day which equates to between 191 260 Ml/annum and 2 669 245 Ml/annum. This equates to between 0.00048% and 0.00654 % of the average inflow into Lake Albert. This is much less than the monthly variations observed naturally at Lake Albert so will have a negligible impact.

Impact Classification

Based on the negligible impact scenario the rating is ranked as a low magnitude and very low receptor sensitivity, with an overall **negligible** impact severity.

Mitigation

Monitoring of the Lake water level should be put in place, and monitoring of the abstracted volumes recorded daily.

There is currently no trans-boundary agreement between countries legislating the conjunctive management of the Nile River Basin. However, due to the high sensitivity of this trans-boundary resource, part of the Nile River, proactive engagement with the relevant authorities over the course of the operations should take place.

The impact significance should not change.

6.4.9 Discharge of poor quality effluent from the sewage works

Impact assessment

The planned capacity of the domestic sewage treatment plant is 45 m^3/day, making provision for an estimated 135 personnel plus contingency. Treated sewage effluent will meet the more stringent of the Ugandan and IFC treated sewage effluent requirements. The sewage treatment plant will be located at the permanent camp. Backup sewage treatment capability will be provided by the sewage treatment plant built to supply the drilling camp, which has spare capacity for an additional 90 people. The two sewage plants will be linked to allow for maintenance shutdowns of either plant. After drilling is completed in year 6, the drilling sewage plant will be maintained as a backup.

Sewage from the CPF will be routed via conservancy tanks to a regulating tank at the permanent camp from where it will be treated in a Membrane Bioreactor sewage treatment works.

Options for final disposal of treated sewage effluent include:

- the base case (discharge into perimeter drains around the CPF, which discharge into small drainage lines leading to Lake Albert);

- irrigation onto land in the buffer area around the CPF and at the personnel camp lawns and gardens; and
- discharge into an artificial wetland.

Should poor quality effluent be discharged to the environment this may have an impact on ecosystems as well as human health.

Impact Classification

The impact is rated with a medium magnitude where the affected environment is altered because of specific impacts related to bacterial contamination, and potentially nutrient enrichment from nitrates and phosphates. The receptor sensitivity is recorded as low as the natural recovery of the impacted area to the baseline or pre-project condition is expected in the very short-term, resulting in a **moderate** impact severity.

Mitigation measures

The design will provide for secondary containment around storage tanks of hazardous liquids, so as to minimize the risk of spillages due to accidents or leaks. Secondary containment shall consist of berms, dykes or walls capable of containing the larger of 110% of the largest tank or 25% of the combined tank volumes in areas with above-ground tanks with a total storage volume equal to or greater than 1 000 litres and will be made of impervious, chemically resistant material.

Treated sewage effluent needs to comply with the values set out in Table 16. It is recommended that the effluent be irrigated on the green areas around the CPF and camps as well as to eth environment behind the CPF, rather than discharged directly back into a water resource, or a man-made wetland be constructed upstream of the discharge to act as a buffer.

The disposal and storage of sludge from the sewage works will need to be handled in a manner that will render the sludge stable and safe to use as a soil ameliorant or collected and disposed of at an accredited waste site: disposed of in accordance with the local regulatory requirements. If there are no local requirements, the disposal methods should be in keeping with the protection of public health and safety and conservation of the environment and the natural water and land resources.

If the recommended construction protocols are followed and the final effluent discharged as recommended and sludge is disposed of safely, then impacts during the operational phase will be reduced to low magnitude and sensitivity, resulting in an overall **minor** impact severity.

7.0 RECOMMENDED MITIGATION MEASURES

7.1 Construction

Mitigation measures proposed for the construction phase are presented in Table 20.

Table 20: Surface Water Impacts during Construction Phase

Mitigation Measures	Monitoring Indicators	Monitoring Frequency	Responsible Entity	Training Necessary
Prevention of obstruction of water flow: Impediments to natural water flow shall be avoided, or, if unavoidable, be allowed for in the design by means of appropriately sized and positioned drains and culverts.	No damming of water or obstructions to water flow (natural or during storm events).	At all times	**CNOOC Contractor All contractors**	None.
Prevention of surface water pollution by chemicals management: Appropriate designs and measure in place to collect and	Water quality analysis water bodies in the receiving environment.	Monthly	**CNOOC Contractor All contractors**	None.

Mitigation Measures	Monitoring Indicators	Monitoring Frequency	Responsible Entity	Training Necessary
manage spills and prevent contamination of surface water.				
Storm water management: Potentially contaminated storm water shall be kept separate from other drainage at camp sites. Potentially contaminated storm water shall, if necessary, be tested and treated to remove contaminants before being released into the environment.	Identification of areas where activities could cause contamination and evidence of measures taken to avoid these. Runoff water quality (records). Links to surface water monitoring	As required before discharge is to be considered	**CNOOC Contractor All contractors**	None.
Flood management: To avoid obstruction to storm water flows, culverts, drains and other means shall be used as necessary.	Details of measures implemented in designs.	Prior to commencement of construction activities.	**CNOOC Contractor All contractors**	None.
Dust Suppression: Biodegradable chemical suppression or the use of water sprayers is required to keep the dust levels low and avoid sedimentation in the local surface waters.	Sedimentation of the water courses	At all times.	**CNOOC Contractor All contractors**	None
Sewage water management: Any discharge from sewage works should meet the IFC Environmental, Health and Safety (EHS) Guidelines for treated sanitary sewage discharge quality.	Water quality analysis on treated water	Monthly	**CNOOC Contractor All contractors**	None
Storm water Management: Any storm water that has been contaminated by oil, grease or other chemicals from site activity needs to be treated to the discharge standards	Spill volumes	Continuously	**CNOOC Contractor All contractors**	None
Process Water Management: Management of process water to prevent spillages into the environment	Spill volumes	Continuously	**CNOOC Contractor All contractors**	None

7.1.1.1 Sewage management

Any discharge from sewage works should meet the IFC Environmental, Health and Safety (EHS) Guidelines for treated sanitary sewage discharge quality as presented in Table 21.

Table 21: Indicative Values for Treated Sanitary Sewage Discharges (International Finance Corporation, 2007)

Pollutants	Units	Guideline Value
pH	pH	6 to 9
BOD	mg/l	30
COD	mg/l	125
Total Nitrogen	mg/l	10
Total Phosphorus	mg/l	2
Oil and Grease	mg/l	10
Total Suspended Solids	mg/l	50
Total Coliform Bacteria	MPN*/100 ml	400
* Most Probable Number		

7.1.1.2 Storm water management

The IFC guidelines specify that a storm water management plan needs to be in place from the construction phase right through to the operational phase in order to reduce the impact on the natural surface water. Any storm water that has been contaminated by oil, grease or other chemicals from site activity needs to be treated to the discharge standards listed in Table 22 before it can be released to the environment (International Finance Corporation, 2007). The key principles need to be applied during construction in order to manage surface runoff resulting from precipitation or drainage (International Finance Corporation, 2007):

- Plan construction activities to avoid sensitive times of the year, like heavy rain seasons.
- Minimize areas to be cleared, and use hand cutting tools where possible to avoid unnecessary increases in erosion in the area and sedimentation in the surface waters.
- Avoid construction of facilities in a floodplain and within a distance of 100 m of the normal high-water mark of bodies of water used for drinking and domestic purposes.
- Consider the use of existing roads for access in order to reduce the impact of erosion, sedimentation and obstruction to the natural surface water flow. Try to construct pipelines along existing infrastructure and roads.
- Install temporary erosion, sediment control measures and slope stabilization measures at all times where necessary.
- The peak discharge rate should be reduced in areas of development in order to reduce the potential erosion of the flow paths and sedimentation of downstream surface waters.
- Storm water should be kept separate from other process and sanitation wastewater streams to reduce the volume of wastewater to be treated.
- Runoff from process areas should be kept separate from less contaminated (or sediment heavy) runoff areas so as to not further contaminate more water. Storm water from process areas needs to be treated to the discharge standards listed in Table 22 before being released to the environment.
- Oil/water separators and grease traps should be installed and maintained at refuelling areas, workshops, parking areas and fuel storage areas.
- Runoff from areas with potential sources of contamination and sediment loading should be minimized where possible.

- Reuse of storm water and contaminated runoff should be done as much as possible. Storm water should be managed as a resource.

Table 22: Emissions, Effluent and Waste Levels from Onshore Oil and Gas Development (International Finance Corporation, 2007)

Parameter	Guideline Value
Produced Water and Hydrotest Water	For Discharge to surface waters or to land: Total hydrocarbon content 10 mg/l pH: 6 to 9 BOD: 25 mg/l COD: 125 mg/l TSS: 35 mg/l Phenols: 0.5 mg/l Sulfides: 1 mg/l Heavy metals* (total): 5 mg/l Chlorides: 600 mg/l average; 1 200 mg/l maximum
Completion and Well work-over fluids	For discharge to surface waters or to land: Total hydrocarbon content 10 mg/l pH: 6 to 9
Storm water Drainage	Storm water runoff should be treated through an oil/ water separation system able to achieve oil and grease concentration of 10 mg/l
Cooling Water	The effluent should result in a temperature increase of no more than 3°C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge.

7.1.1.3 Process water management

In the construction phase, the only process water should be that of hydrostatic testing which is done on the pipelines to detect leaks and verify the integrity of the pipeline and the equipment. There are often chemical additives in the hydrostatic testing water like corrosion inhibitors, oxygen scavengers and dyes. Due to these chemical additives, it is important that this water does not adversely affect the natural surface water in the area. The following principles should be considered when dealing with hydrostatic testing water:

- Test manifolds installed into sections of newly constructed pipeline should be located outside of riparian zones and wetlands;
- The source of water used for hydrostatic testing purposes should not negatively impact the water levels or flow rates of the natural water body, and the volume (or rate) of withdrawal should not exceed 10% of the stream volume (or flow);
- Erosion control measures and fish screens should be in place when withdrawal from the water source is carried out;
- Disposal alternatives for the hydrostatic testing water include injection into disposal well or discharge to surface water or land;
- If disposal to the surface water or land is chosen, the use of chemicals should be minimized by reducing the time that the water spends in the pipeline. The chemicals used should be selected carefully so as to reduce the concentration of the additive, reduce the toxicity and increase the biodegradability and bioavailability;

- Reuse of the hydrostatic testing water should be done as far as possible;
- When discharging this water, the quality needs to be within the IFC EHS guidelines as set out in Table 22; and
- Break tanks or energy dissipaters and sediment controls should be used when discharging the water to the environment to avoid erosion and sedimentation in the downstream water bodies. If discharged to water, the discharge point should be selected carefully so that the quality of discharge does not negatively impact the water body. If discharge is onto the land, then the discharge site should avoid cultivated land, sensitive land or sites that might be prone to flooding or erosion.

7.2 Operational phase

Mitigation measures proposed for the operational phase are presented in Table 23.

Table 23: Surface Water Impacts during Operation Phase

Mitigation Measures	Monitoring Indicators	Monitoring Frequency	Responsible Entity	Training Necessary
Prevention of obstruction of water flow: Impediments to natural water flow shall be avoided, or, if unavoidable, be allowed for in the design by means of appropriately sized and positioned drains, culverts etc.	No damming of water or obstructions to water flow.	At all times.	**CNOOC Base camp management contractor**	None.
Stormwater management*: Potentially contaminated stormwater shall be kept separate from other drainage at Base camp and other drilling activity sites. Potentially contaminated stormwater shall, if necessary, be tested and treated to remove contaminants before being released into the environment.	Water quality monitoring records. Identification of areas where activities could cause contaminatio n and evidence of measures taken to avoid these.	At all times.	**CNOOC Base camp management contractor**	None.
Flood management: ▪ The location of areas prone to flooding relative to the well sites, campsites and access roads shall be confirmed and any consequences of this for drilling programme shall be determined and minimised as soon as possible. ▪ Every effort shall be made to ensure the maintenance of the natural flow of water following storm events. ▪ No works shall increase the risk of erosion during storm events. Should this be unavoidable specific erosion control measures shall be implemented for the duration that the risk exists.	No alterations to natural flows. Details of measures implemented to prevent erosion.	At all times	**CNOOC Base camp management contractor drilling sub-contractors**	None.

Sewage management: Any discharge from sewage works should meet the IFC Environmental, Health and Safety (EHS) Guidelines for treated sanitary sewage discharge quality.	Water quality analysis on treated water	Monthly	**CNOOC Contractor All contractors**	None

**The operational storm water management plan will be discussed in further detail.*

7.2.1.1 Sewage water management

The IFC General EHS guidelines for environmental wastewater and ambient water quality set out recommended sanitary wastewater management strategies. These include (International Finance Corporation, 2007):

- Keeping the waste produced by food services, laundry, laboratories, medical infirmaries and sewage waste separate in order to ensure that the treatment for each is specific and efficient;
- If treated sewage is to be released to the environment then the discharged effluent needs to meet the local or national standards for sanitary wastewater. If there are no standards in place, the guidelines set out in the IFC EHS general guidelines should be used (Table 21).
- The sludge from sanitary wastewater treatment systems should be disposed of in accordance with the local regulatory requirements. If there are no local requirements, the disposal methods should be in keeping with the protection of public health and safety and conservation of the environment and the natural water and land resources.

7.2.1.2 Storm water management plan

The proposed infrastructure on the Kingfisher Development Area will be built on a higher elevation in order to avoid flooding in the Buhuka Flats. The clean water runoff that would report to the infrastructure will be diverted around the elevated edge of the infrastructure. It is assumed that the infrastructure will be raised high enough to prevent the 1 in 100 year ARI flood from infiltrating the elevated working area. In light of this design, no diversion berms or channels are required to divert the clean water away from contaminated areas. The dirty water within the working areas needs to be contained and channelled to settling tanks, treatment and oil and grease separation tanks before the water is released to the environment due to the sensitivity of the Lake Albert water resource. The following recommendations are made in order to comply with the IFC EHS Oil and gas development guidelines (International Finance Corporation, 2007):

- The storm water should be kept separate from process and sanitary wastewater streams so that the volume of water to be treated to a higher degree is reduced;
- All process areas should be bunded to ensure storm water flows into the closed drainage system and that uncontrolled surface runoff is avoided;
- If there is a point where clean runoff might enter into a site work area, a system of diversion conduits should be used to prevent clean surface water runoff from the catchments upstream side entering the work area according to international requirements. The diverted clean runoff should be diverted to the local drainage channels;
- Drip trays and other control measures should be used to collect runoff from areas that are not contained within the bunded drainage areas. These collection points should be directed to the closed drainage system;
- Monitoring of storm water and impoundments should begin as soon as possible once drilling commences;
- When final infrastructure plans become available, a more accurate delineation of clean and dirty areas should be compiled;

- Sediment settlement basins and erosion control structures should be constructed down slope of all spoils stock pile areas, the crusher plant and bitumen storage area and areas of exposed terrain in order to manage the increase in sedimentation in the natural water bodies;
- Local runoff is collected and treated to remove sediments to acceptable levels prior to release to the natural environment. Bunds and drainage diversion works should be constructed around the perimeter of all infrastructure areas, designed to divert and prevent natural runoff waters originating outside the development sites from mixing with internal site runoff;
- Sediment settlement basins should generally be located at low points, by forming earth bunds. Storage volume consists of a permanent pool settling zone and sediment storage zone. The trap size is calculated to match the settling velocity of the target sediment size with the design flow. A target of medium sized silt particles of >0.02 mm (20 µm) is generally adopted. Hence the sediment basin is expected to be effective in removing sand and medium to coarse silt, and less effective in removal of fine silt and clay for the design event;
- After a storm event, the water in the basin slowly infiltrates/evaporates or is pumped out for recycling. Prior to the commencement of the wet season, the sediment basins are cleaned out. A ramp into the basin is included so that sediment removal may be undertaken by front end loader (or similar). The removed sediments should be contained in an area where they cannot be transported in the next storm event back into the sediment trap, or to the downstream environment;
- Where possible the storm water should be reused in the oil and gas works operations and treated as a resource;
- Oil separators and grease traps should be installed and maintained at refuelling stations, workshops, in parking areas, at fuel storage areas and containment areas. The oil/water separation process should be able to achieve an oil grease concentration of 10 mg/l as noted in Table 22;
- Sludge and sedimentation that build up in the storm water drainage system may contain contaminants and should be disposed of according to local regulation. If there are no regulations, then disposal should be consistent with protection of public health and safety and the conservation of water and land resources;
- Potential chemical and/ or oil and grease contamination could occur at the following areas of infrastructure: the CPF, the material yard (for drilling and production), and the well pads. Due to the potential contamination of surface runoff water in these areas, it is recommended that appropriate local treatment and/or oil and grease traps are installed and maintained downstream of the collection channels around these sites. The areas and total runoff volume that can be expected for the 1 in 2, 10, 30, 50 and 100 year 24 hour ARI storm events is presented in Table 24;
- These runoff volumes were calculated based on the peak rainfall events. The dirty catchment areas were based on the layout of the proposed site provided to Golder Associates and would need to be updated when more accurate layout dimensions are determined. The areas were assumed to be 90% impermeable, with a CN number of 98. The overland flow on these surfaces was assumed to have a Mannings n value of 0.012 for the impermeable surfaces, and 0.13 for the permeable surfaces.

Table 24: Total Runoff Volumes Expected in Potentially Contaminated Areas for the 1 in 2, 10, 20, 50 and 100 year 24 hour Storm Events

Infrastructure	Catchment area (ha)	Return Period				
		1 in 2	1 in 10	1 in 20	1 in 50	1 in 100
		Volume of water (m^3)				
Pad 1	2.1675	1230	1800	2020	2300	2510
Pad 2	4.2101	2400	3490	3920	4460	4880
Pad 3	0.7777	440	650	720	820	900

Infrastructure	Catchment area (ha)	Return Period				
		1 in 2	1 in 10	1 in 20	1 in 50	1 in 100
		Volume of water (m^3)				
Pad 4-2	0.2173	120	180	200	230	250
Pad 5	0.4665	270	390	430	490	540
Material Yard (for drilling only)	3.6748	2090	3050	3420	3900	4260
Material Yard (For production only)	5.457	3110	4530	5070	5780	6330
CPF	28.0787	16000	23310	26120	29770	32580

7.2.1.3 Process water management

Process water contains a complex mixture of inorganic and organic compounds including dissolved salts, trace metals, suspended particles, hydrocarbons and organic acids. Process water may also contain chemical additives such as scale and corrosion inhibitors. Because of this, the disposal of process water needs to be carefully planned in order to prevent negative impacts on the surface water. The disposal method set out for the Kingfisher Development Area is the injection of the process water into the reservoir to enhance oil recovery. It should be noted that other possible uses of the process water could be in irrigation or dust control if the quality of the water is suitable for these activities.

The IFC EHS guidelines on Onshore Oil and Gas Development state that the process water needs to meet the quality limits presented in Table 22 before the water can be discharged to the environment. Other recommendations set out by these guidelines include (International Finance Corporation, 2007):

- The reduction of the volume of process water for disposal by:
  - Good well-management during well completion activities to minimize water production;
  - Recompletion of high water producing wells;
  - The use of downhole fluid separation techniques and water shutoff techniques where possible; and
  - Shutting in high water producing wells.
- The selection of additive chemicals should be done carefully, taking into account the toxicity, volume and bioavailability of the additive.
- If cooling or heating systems are required, the discharge from these systems should ensure that the water released to the environment is within 3°C of ambient water temperatures at the edge of the defined mixing zone or within 100 m of the discharge point.

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Water Resource Scientist

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APPENDIX A

Document Limitations

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APPENDIX B

Constants used in the Rational method for the calculation of flood lines

Lower Catchments

Percentage Coverage of Surface Slopes

Surface slope	Percentage Coverage
Vleis and pans	51%
Flat areas	19%
Hilly	27%
Steep areas	3%

Permeability of Land Surface

Permeability	Percentage Coverage
Very permeable	45%
Permeable	45%
Semi-permeable	50%
Impermeable	5%

Percentage Coverage of Different Vegetation Types

Vegetation	Percentage Coverage
Thick bush and plantation	0%
Light bush and farm-lands	3%
Grass lands	90%
No vegetation	7%

Pipeline Catchments

Percentage Coverage of Surface Slopes

Surface slope	Percentage Coverage
Vleis and pans	21%
Flat areas	25%

Surface slope	Percentage Coverage
Hilly	50%
Steep areas	4%

Permeability of Land Surface

Permeability	Percentage Coverage
Very permeable	45%
Permeable	50%
Semi-permeable	5%
Impermeable	1%

Percentage Coverage of Different Vegetation Types

Vegetation	Percentage Coverage
Thick bush and plantation	5%
Light bush and farm-lands	55%
Grass lands	30%
No vegetation	10%

APPENDIX C

Results obtained from initial water quality sampling run

Republic of Uganda

Form A

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

CERTIFICATE OF ANALYSIS

Name of client : Golder Associates
Date of sampling : 23rd Dec 2013
Serial no : LIMNO/2014/03

Sampled by: Eco & Partner
Date received : 23rd Dec 2013
Date of reporting: 3 March 2014

Source name		CNOOC SW 12	CNOOC SW 14	CNOOC GW 1	CNOOC GW 2	Acceptable Standard NEMA, 1995
Source location/GPS	Eastings	N01°14'51.3"	N01°13'13.9"	N01°14'31.6"	N01°13'56.1"	
	Northings	E30°44'21.0"	E30°43'23.1"	E30°44'17.4"	E30°43'38.8"	
Parameters	**Units/Lab No**	E22166	E22167	E22168	E22169	
Cadmium (Cd)	mg/L	<0.0005	<0.0005	0.0561	<0.0005	**0.01**
Chromium (Cr)	mg/L	0.0006	0.0004	0.0633	0.0008	**0.05**
Lead (Pb)	mg/L	0.0044	<0.0004	0.0693	0.0059	**0.01**
Mercury (Hg)	mg/L	0.001	<0.001	0.0032	0.001	**0.001**
Iron (Fe)	mg/L	<0.002	1.5887	0.3983	<0.002	**0.03-3.5**
Aluminium (Al)	mg/L	<0.006	<0.006	0.527	<0.006	**0.2**
Arsenic (As)	mg/L	<0.003	<0.003	<0.003	<0.003	**0.01**
Copper (Cu)	mg/L	<0.0004	<0.0004	0.0581	0.0024	**1**
Manganese (Mn)	mg/L	0.0013	0.5524	0.0628	0.0046	**0.1-0.5**
Zinc (Zn)	mg/L	<0.001	<0.001	0.0815	<0.001	**3**
Cobalt (Co)	mg/L	0.0018	0.0015	0.0607	<0.001	**NS**
Nickel (Ni)	mg/L	<0.005	<0.005	0.0615	<0.005	**0.02**
Selenium (Se)	mg/L	0.0274	0.0085	0.0707	0.0416	**0.01**

NOTE:

1. The type of sample container and sample holding time affect the integrity of the sample and hence the results of analysis
2. Values lower than the detection limit reported as <DL
3. DL stands for Detection Limit

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Name of client : Golder Associates
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Serial no : LIMNO/2014/03

Sampled by: Eco & Partner
Date received : 23rd Dec 2013
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Source name		CNOOC SW1	CNOOC SW 2	CNOOC SW 4	CNOOC SW 6	CNOOC SW 9	Acceptable Standard NEMA, 1995
Source location/GPS	Eastings	N01°15'53.6"	N01°15'50.6"	N01°15'16.4"	N01°14'24.9"	N01°13'40.9"	
	Northings	E30°45'27.5"	E30°45'35.7"	E30°45'33.0"	E30°45'26.1"	E30°45'10.0"	
Parameters	Units/Lab No	E22161	E22162	E22163	E22164	E22165	
Cadmium (Cd)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.01
Chromium (Cr)	mg/L	0.0002	0.0005	0.0004	0.0006	0.0004	0.05
Lead (Pb)	mg/L	0.0042	<0.0004	<0.0004	<0.0004	<0.0004	0.01
Mercury (Hg)	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	0.001
Iron (Fe)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	0.03-3.5
Aluminium (Al)	mg/L	0.201	<0.006	<0.006	<0.006	<0.006	0.2
Arsenic (As)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	0.01
Copper (Cu)	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	1
Manganese (Mn)	mg/L	0.001	0.0015	<0.0004	0.0004	0.0011	0.1-0.5
Zinc (Zn)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	3
Cobalt (Co)	mg/L	<0.001	<0.001	<0.001	0.001	<0.001	NS
Nickel (Ni)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	0.02
Selenium (Se)	mg/L	0.0309	0.0217	0.0255	0.0181	0.008	0.01

NOTE:

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Name of client : Golder Associates
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Sampled by: Eco & Partner
Date received: 23rd Dec 2013
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Source name		Kachunde stream	Ususa BH (shallow well)	L. Albert	Senjojo stream	Nsonga shorelines	Acceptable Standard NEMA, 1995
Source location/GPS	Eastings	245312E	257853E	244514E	243427E	248343E	
	Northings	130206N	148016N	130739N	127536N	138448N	
Parameters	Units/Lab No	E22156	E22154	E22149	E22153	E22150	
Cadmium (Cd)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.01**
Chromium (Cr)	mg/L	0.0004	0.0007	0.0004	<0.0002	0.0003	**0.05**
Lead (Pb)	mg/L	<0.0004	<0.0004	0.0025	<0.0004	0.0025	**0.01**
Mercury (Hg)	mg/L	<0.001	<0.001	0.001	<0.001	0.0011	**0.001**
Iron (Fe)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	**0.03-3.5**
Aluminium (Al)	mg/L	0.168	<0.006	0.193	<0.006	0.034	**0.2**
Arsenic (As)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	**0.01**
Copper (Cu)	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	**1**
Manganese (Mn)	mg/L	0.0007	0.1633	0.0008	<0.0004	0.0007	**0.1-0.5**
Zinc (Zn)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	**3**
Cobalt (Co)	mg/L	0.001	<0.001	0.001	<0.001	0.001	**NS**
Nickel (Ni)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	**0.02**
Selenium (Se)	mg/L	0.0134	0.0027	0.0244	0.011	0.0141	**0.01**

NOTE:

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Serial no : LIMNO/2014/03

Sampled by: Eco & Partner
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Source name		Kyabasambu stream	Kyenyanja BH	Busigi BH	Busigi stream	Ususa spring	Kina BH	Kina shores	Acceptable Standard NEMA, 1995
Source location/GPS	Eastings	250301	253969	252471	252682	257901	246306	246408	
	Northings	137495	144783	143039	142819	147698	133757	133715	
Parameters	Units/Lab No	E22157	E22160	E22158	E22159	E22155	E22152	E22151	
Cadmium (Cd)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.01
Chromium (Cr)	mg/L	<0.0002	0.0003	0.001	0.0002	0.0006	<0.0002	0.0002	0.05
Lead (Pb)	mg/L	<0.0004	<0.0004	<0.0004	0.0006	<0.0004	<0.0004	0.0004	0.01
Mercury (Hg)	mg/L	0.001	0.001	<0.001	0.0011	<0.001	<0.001	0.0012	0.001
Iron (Fe)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	0.0303	<0.002	0.03-3.5
Aluminium (Al)	mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.2
Arsenic (As)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.01
Copper (Cu)	mg/L	<0.0004	0.0009	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	1
Manganese (Mn)	mg/L	0.0016	0.001	0.0068	0.0013	0.0005	0.1189	0.0004	0.1-0.5
Zinc (Zn)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.2079	<0.001	3
Cobalt (Co)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.0011	0.001	NS
Nickel (Ni)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02
Selenium (Se)	mg/L	0.01	0.0133	0.016	0.0158	0.0131	<0.001	0.0121	0.01

NOTE:

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APPENDIX D

Results obtained from second water quality sampling run

Jones Environmental Laboratory

Registered Address : Unit 3 Deeside Point, Zone 3, Deeside Industrial Park, Deeside, CH5 2UA. UK

Unit 3 Deeside Point
Zone 3
Deeside Industrial Park
Deeside
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Golder Associates Africa Ltd
12 Steven Street
Universitas
Bloemfontein
Free State
9301
South Africa

UKAS TESTING 4225

Attention :	Jennifer Pretorius
Date :	3rd April, 2014
Your reference :	CN00C 12614848
Our reference :	Test Report 14/4273 Batch 1
Location :	Kingfisher
Date samples received :	27th March, 2014
Status :	Final report
Issue :	1

Ten samples were received for analysis on 27th March, 2014. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

Compiled By:

Paul Lee-Boden BSc
Project Manager

Bob Millward BSc FRSC
Principal Chemist

Client Name: Golder Associates Africa Ltd
Reference: CN00C 12614848
Location: Kingfisher
Contact: Jennifer Pretorius
JE Job No.: 14/4273

Report : **Liquid**

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50			
Sample ID	SW02	SW03	SW09	SW14	SW15	SW17	SW19	SW20	SW21	SW22			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	20/03/2014	20/03/2014	21/03/2014	23/03/2014	23/03/2014	23/03/2014	22/03/2014	23/03/2014	24/03/2014	24/03/2014			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014			
Dissolved Aluminium #	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	ug/l	TM30/PM14
Dissolved Barium #	46	49	65	101	50	42	42	93	79	51	<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Boron	<12	<12	<12	<12	<12	<12	<12	42	<12	16	<12	ug/l	TM30/PM14
Dissolved Cadmium #	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Calcium #	44.5	37.0	20.5	27.7	20.8	29.7	33.6	11.4	22.9	27.9	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	6.3	<1.5	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	<20	<20	94	4280	52	<20	<20	<20	111	121	<20	ug/l	TM30/PM14
Dissolved Lead #	6	7	7	6	5	<5	5	<5	6	5	<5	ug/l	TM30/PM14
Dissolved Magnesium #	31.1	20.3	11.6	15.2	14.6	18.7	21.5	26.1	13.0	12.5	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	5	4	10	849	7	3	<2	<2	26	183	<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	ug/l	TM30/PM14
Dissolved Nickel #	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Potassium #	5.2	2.9	2.0	3.9	1.7	3.2	2.5	40.4	7.6	8.0	<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	ug/l	TM30/PM14
Dissolved Sodium #	108.1	77.1	17.1	25.4	26.5	36.7	50.5	64.5	16.3	11.3	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	3.7	5.2	<1.5	<1.5	2.4	2.5	2.0	3.5	3.1	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	23	42	68	37	45	20	22	38	46	37	<3	ug/l	TM30/PM14
Total Hardness Dissolved (as CaCO3)	242	178	100	133	113	153	174	138	112	122	<1	mg/l	TM30/PM14
PAH MS													
Naphthalene #	<0.014	<0.014	<0.014	<0.014	<0.014	0.184	<0.014	<0.014	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Acenaphthylene #	<0.013	0.030	0.050	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Acenaphthene #	<0.013	0.040	0.070	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluorene #	<0.014	0.050	0.060	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Phenanthrene #	0.020	0.050	0.060	0.020	0.030	0.070	0.030	0.020	0.020	0.030	<0.011	ug/l	TM4/PM30
Anthracene #	<0.013	0.020	0.020	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluoranthene #	<0.012	0.020	0.020	<0.012	<0.012	0.020	<0.012	<0.012	0.020	<0.012	<0.012	ug/l	TM4/PM30
Pyrene #	<0.013	0.020	0.020	<0.013	<0.013	0.030	<0.013	<0.013	0.020	<0.013	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.015	0.020	0.020	<0.015	0.020	0.030	<0.015	<0.015	0.020	0.020	<0.015	ug/l	TM4/PM30
Chrysene #	<0.011	0.020	0.020	<0.011	<0.011	0.020	<0.011	<0.011	0.020	<0.011	<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<0.018	0.020	<0.018	<0.018	<0.018	0.030	<0.018	<0.018	<0.018	<0.018	<0.018	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	<0.016	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	ug/l	TM4/PM30
PAH 16 Total #	<0.195	0.290	0.340	<0.195	<0.195	0.384	<0.195	<0.195	<0.195	<0.195	<0.195	ug/l	TM4/PM30
Benzo(b)fluoranthene	<0.01	0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	90	90	91	96	95	91	92	90	89	91	<0	%	TM4/PM30
EPH (C8-C40) #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM30

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Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: CN00C 12614848
Location: Kingfisher
Contact: Jennifer Pretorius
JE Job No.: 14/4273

Report : **Liquid**

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

Please see attached notes for all abbreviations and acronyms

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Sample ID	SW02	SW03	SW09	SW14	SW15	SW17	SW19	SW20	SW21	SW22			
Depth													
COC No / misc													
Containers	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G	H HN P G			
Sample Date	20/03/2014	20/03/2014	21/03/2014	23/03/2014	23/03/2014	23/03/2014	22/03/2014	23/03/2014	24/03/2014	24/03/2014			
Sample Type	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water	Surface Water			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014	27/03/2014			
GRO (>C4-C8) #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
GRO (>C8-C12) #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
GRO (>C4-C12) #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
Fluoride	1.3	1.2	0.5	0.5	0.7	0.8	1.0	0.5	<0.3	<0.3	<0.3	mg/l	TM27/PM0
Sulphate #	47.92	16.75	4.65	0.27	0.34	0.20	5.92	11.38	7.43	7.75	<0.05	mg/l	TM38/PM0
Chloride #	11.7	7.4	1.4	14.7	2.6	4.5	4.6	19.9	5.8	7.7	<0.3	mg/l	TM38/PM0
Ortho Phosphate as PO4 #	2.11	1.18	0.17	0.09	0.36	0.70	0.88	<0.06	0.75	0.31	<0.06	mg/l	TM38/PM0
Nitrate as N #	0.19	0.29	0.15	<0.05	0.09	0.27	0.23	<0.05	0.21	0.15	<0.05	mg/l	TM38/PM0
Ammoniacal Nitrogen as N #	0.22	0.47	0.25	0.59	0.09	0.50	0.19	0.08	0.44	0.56	<0.03	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	416	308	146	178	160	232	274	302	134	136	<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	853	621	274	377	330	469	517	648	319	320	<2	uS/cm	TM76/PM0
pH #	8.79	8.88	8.48	6.76	8.36	8.55	8.72	8.87	7.32	7.03	<0.01	pH units	TM73/PM0
Silica	27.60	26.80	32.90	27.10	28.00	13.80	30.00	2.40	33.30	21.00	<0.01	mg/l	TM52/PM0
Total Dissolved Solids	506	363	158	217	183	231	302	326	187	176	<10	mg/l	TM20/PM0

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NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 14/4273

SOILS

Please note we are only MCERTS accredited for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary. If we are instructed to keep samples, a storage charge of £1 (1.5 Euros) per sample per month will be applied until we are asked to dispose of them.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

WATERS

Please note we are not a Drinking Water Inspectorate (DWI) Approved Laboratory . It is important that detection limits are carefully considered when requesting water analysis.

UKAS accreditation applies to surface water and groundwater and one other matrix which is analysis specific, any other liquids are outside our scope of accreditation

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

ABBREVIATIONS and ACRONYMS USED

#	UKAS accredited.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance.
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to a Jones Environmental approved laboratory.
CO	Suspected carry over
OC	Outside Calibration Range
NFD	No Fibres Detected
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS

JE Job No: 14/4273

Test Method No.	Description	Prep Method No. (if appropriate)	Description	UKAS	MCERTS (soils only)	Analysis done on As Received (AR) or Air Dried (AD)	Reported on dry weight basis
TM4	16 PAH by GC-MS, modified USEPA 8270	PM30	In-house method based on USEPA 3510. Liquid samples are mixed with solvent and agitated with an automatic magnetic stirrer with a stir bar for 15 minutes to extract organic molecules. ISO 17025 accredited extraction method. All accreditation is matrix specific				
TM4	16 PAH by GC-MS, modified USEPA 8270	PM30	In-house method based on USEPA 3510. Liquid samples are mixed with solvent and agitated with an automatic magnetic stirrer with a stir bar for 15 minutes to extract organic molecules. ISO 17025 accredited extraction method. All accreditation is matrix specific	Yes			
TM5	In-House method based on USEPA 8015B. Determination of Extractable Petroleum Hydrocarbons (EPH) in the carbon chain length range of C8-40 by GC-FID. Accredited to ISO 17025 on soil and water samples and MCERTS (carbon banding only) on soils. All accreditation is matrix specific.	PM30	In-house method based on USEPA 3510. Liquid samples are mixed with solvent and agitated with an automatic magnetic stirrer with a stir bar for 15 minutes to extract organic molecules. ISO 17025 accredited extraction method. All accreditation is matrix specific	Yes			
TM20	TDS, TSS and TS - gravimetric	PM0	No preparation is required.				
TM27	In-House method based on USEPA 9056. Analysis of samples using a Dionex Ion-Chromatograph instrument.	PM0	No preparation is required.				
TM30	Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry) using Thermo iCAP 6000 series instrument. Accredited to ISO 17025 for soils and waters and MCERTS accredited for Soils. All accreditation is matrix specific.	PM14	In-house method based on USEPA 3005A. Acid digestion of water samples and analsyis by ICP-OES as per method TM030W.ISO 17025 accredited extraction method. All accreditation is matrix specific				
TM30	Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry) using Thermo iCAP 6000 series instrument. Accredited to ISO 17025 for soils and waters and MCERTS accredited for Soils. All accreditation is matrix specific.	PM14	In-house method based on USEPA 3005A. Acid digestion of water samples and analsyis by ICP-OES as per method TM030W.ISO 17025 accredited extraction method. All accreditation is matrix specific	Yes			
TM36	In-House method based on USEPA 8015B. Determination of Gasoline Range Organics (GRO) in the carbon chain range of C5-12 by headspace GC-FID. Accredited to ISO 17025 on soil and water samples and MCERTS accredited (carbon banding only) on soils. All accreditation is matrix specific.	PM12	In-house method based on USEPA 5021. Preparation of solid and liquid samples for headspace analysis. Samples are spiked with surrogates to facilitate quantification. ISO 17025 accredited extraction method. All accreditation is matrix specific	Yes			
TM38	Ionic analysis using the Thermo Aquakem Photometric Automatic Analyser. Accredited to ISO17025 and MCERTS for most analytes. All accreditation is matrix specific.	PM0	No preparation is required.	Yes			
TM52	Silica by Spectrophotometer	PM0	No preparation is required.				

JE Job No: 14/4273

Test Method No.	Description	Prep Method No. (if appropriate)	Description	UKAS	MCERTS (soils only)	Analysis done on As Received (AR) or Air Dried (AD)	Reported on dry weight basis
TM73	pH in by Metrohm	PM0	No preparation is required.	Yes			
TM75	Alkalinity by Metrohm	PM0	No preparation is required.	Yes			
TM76	Electrical Conductivity by Metrohm	PM0	No preparation is required.	Yes			

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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