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CNOOC UGANDA LIMITED

KINGFISHER OIL PROJECT, HOIMA DISTRICT, UGANDA - GROUNDWATER SPECIALIST STUDY

REPORT – VOLUME 4, STUDY 3

Submitted to:
The Executive Director National Environment Management Authority, NEMA House, Plot 17/19/21 Jinja Road, P. O. Box 22255 Kampala, Uganda

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Executive Summary

The **objectives** of the groundwater investigation are to:

- Understand the baseline groundwater regime at the proposed facility from available information;
- Establish the baseline groundwater quality profile; and
- Use the available groundwater information to predict potential groundwater impacts during construction, operation, and decommissioning.

The specialist study was based on available groundwater information and a hydrocensus around the area. The approach is designed to give a broad overview of the site conditions and available information as well as to identify gaps in the understanding of the current geohydrological regime. In the event that insufficient information is available, or that the data sets are not applicable to the area under investigation, additional work may be required. The study included the following tasks:

- Site Familiarisation and client liaison
- Desk study.
- Hydrocensus and water sampling
- Data Processing and Evaluation

During the desk study several reports (provided by CNOOC) were used for background information to the project. These included numerous standards, guidelines and existing and approved EIA's relevant to the project area. Government groundwater database data was also accessed to fill information gaps and provide regional level input.

Field investigations in this case were limited to a site familiarisation visit and two hydrocensus surveys for the project site. No other field investigations were performed. The hydrocensus was completed in two stages during December 2013 and March 2014. The first field trip involved the collection of groundwater, spring, stream, and lake water samples along the lake front of Lake Albert in the area directly affected by the Kingfisher project. During the March 2014 field trip, duplicate water samples were taken from the groundwater wells along the lake front to include petroleum hydrocarbon analyses for the establishment of a water quality baseline for these parameters. In addition a hydrocensus was completed along the pipeline route and through all communities that could potentially be affected by the activities and groundwater samples were taken from wells. A total of 14 samples were taken at the lake front, and another 15 were taken on the escarpment along the pipeline route. Water level measurements were limited to two unused wells near the camp site.

The Kingfisher field is formed by a structural trap, which comprises a southwest-northeast trending 3-way dip-closed hanging-wall anticline that seals against basement to the south-east along the main bounding fault of the Albert Basin. The field is about 10km by 2km and provided the drilling sites for 3 wells and 3 side-tracks (CNOOC, 2014). The sedimentary succession of Kingfisher is composed of intervals of Late Miocene and Pliocene age. The sequence comprises a series of interbedded sandstones and shales, representing a mixture of low-stand events, during which sedimentation was dominated by fluvial processes and flood or high-stand events when lacustrine deposition predominated.

The **groundwater resources** at the Kingfisher Project site and associated pipeline infrastructure can be summarised as followed:

- On the Buhuka flat and lake front villages (only 5 out of the 10 villages) the groundwater is utilised as a source of domestic water through shallow wells and deeper installed wells. Most are equipped with hand pumps and sealed at surface;

- Wells are prone to fail due to corrosive properties of the groundwater (i.e. often the pipes are corroded away, if not maintained). The villagers conveyed that wells often do not yield enough water or that water quality is to poor for use. As an alternative, villagers augment their water supply with lake water and/or springs or streams against the escarpment;
- The groundwater is assumed to be associated with the bedrock formations consisting of granite, gneiss or quartzite formations on the escarpment and with sediments such as sandstone down at the lake front;
- Water level elevations were interpolated for the area, and static water levels showed great variation between 1m to 63m below ground level. The variability in water levels confirms the fractured and thus heterogeneous character of the aquifers;
- General groundwater flow direction in the KP area is towards Lake Albert in a north-westerly direction;
- Water quality on the Buhuka flats are very poor and characterised by very high salinity (and corrosive character) caused by accumulation of salts from evapotranspiration and seasonal water fluctuations;
- Water quality along the escarpment villages was generally acceptable with some trace metals exceeding the drinking water guidelines;
- No organic (petroleum) hydrocarbons were detected in any of the samples; and
- Microbial water quality was very poor and most of the water sources including the lake water tested positive for Coliforms and E.coli. The cause of this is most likely due to poor or non-existing sanitation practices.

The **potential impacts** on the groundwater systems were determined for the construction and operational phases of Kingfisher Well Field Development, with a significance rating for each impact before and after mitigation

The **construction phase activities** that could potentially impact on the groundwater resource include activities associated with materials handling, water demand, and waste generation during the construction of the various components of the project (i.e. residential camps, CPF, pipeline and well pads). All these activities can result in pollution of groundwater resources. The following table summarises the potential construction impacts:

Receptor	Description	Type of Impact	Pre-mitigation			Post-mitigation		
			Sensitivity	Magnitude of Impact	Impact Significance	Sensitivity	Magnitude of Impact	Impact Significance
Groundwater	Pollution from domestic waste water discharge	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from sanitation waste - well pads and pipeline construction	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from accidental spills from	Direct	High	Medium	12 Major	Low	Low	4 Minor

Receptor	Description	Type of Impact	Pre-mitigation			Post-mitigation		
			Sensitivity	Magnitude of Impact	Impact Significance	Sensitivity	Magnitude of Impact	Impact Significance
	materials handling							
Groundwater	Pollution from waste generated during vehicle maintenance	Direct	High	Medium	12 Major	Low	Low	4 Minor
Groundwater	Pollution from domestic waste disposal	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from drill wastes - management and disposal	Direct	Medium	Medium	9 Moderate	Low	Medium	6 Moderate
Groundwater	Pollution from well blow-out	Direct	High	High	16 Major	Medium	Medium	9 Moderate

The **operational phase** of the Kingfisher project covers the Kingfisher production and transmission system from outlet of the well Christmas choke valves; to inlet flange of delivery point; and include the following elements:

- Well pads;
- Flowlines;
- Central Process Facilities (CPF);
- Crude oil Pipeline;
- Lake Water Extracting Station; and
- Infrastructure (camps, roads, buildings, etc.).

The impacts associate with these elements will be groundwater pollution caused by generation of domestic waste and waste water discharge; waste generation during the maintenance of equipment and machinery; hazardous waste; accidental spills of materials stored and handled, inadequate drainage management; well drilling; pipeline or flowline failure; and well blow out. The impacts associated with a catastrophic well blow out or pipeline failure poses potentially the largest risk to the groundwater resources. However, incidents of that nature are unlikely under good operational conditions and mitigation measures will be in place to prevent such incidents. Potential impacts are summarised in table below:

Receptor	Description	Type of Impact	Pre-mitigation			Post-mitigation		
			Sensitivity	Magnitude of Impact	Impact Severity	Sensitivity	Magnitude of Impact	Impact Severity
Groundwater	Pollution from domestic waste water discharge	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from accidental spills from materials handling	Direct	High	High	16 Major	High	Low	8 Moderate
Groundwater	Pollution from waste generated during flow line and CPF maintenance activities	Direct	Medium	Medium	9 Moderate	Medium	Low	6 Moderate
Groundwater	Inadequate drainage/stormwater management	Indirect	Medium	Medium	9 Moderate	Medium	Very Low	3 Minor
Groundwater	Pollution from solid waste generation	Direct	High	Medium	12 Major	Medium	Low	6 Moderate
Groundwater	Production Waste Generated on the Well pad	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from Produced Water Injection	Direct	High	High	16 Major	Medium	Medium	9 Moderate
Groundwater	Pollution from pipeline/flowline failure	Direct	High	High	16	Medium	Medium	9 Moderate
Groundwater	Pollution from well blow-out	Direct	High	High	16 Major	Medium	Medium	9 Moderate

The severity and occurrence of the impacts expected on groundwater resources can be reduced o minor in most cases with applied **mitigation measures**. All mitigation measures recommended, takes cognisance of the IFC Standards, together with the relevant Ugandan legislative requirements, CNOOC's in-house environmental specifications and acceptable industry best practice.

Impacts are mostly related to waste water and solid waste generation during the construction phase and mitigation measures typically consist of management plans to handle hazardous materials, waste and waste water to reduce the impacts.

Pipeline failures can be prevented by choosing the right materials suited to the product transported, equipment and appropriate maintenance and testing of the pipeline. Hydrostatic testing by which the pipeline is subjected to pressure above the operating pressure, to blow out defects before they reach a critical size in service should also be used to detect corroded pipe before it fails in service. A pipeline integrity strategy should be compiled; to guide inspection and preventive maintenance to ensure the integrity of the pipeline

The drilling fluid is the primary safeguard against blow-out of hydrocarbons from a well and its density can be controlled to balance any anticipated formation pressures. The drilling mud will be tested from time-to-time during the drilling process and its composition adjusted to account for any changing down-hole conditions. The mud density will be adjusted as required by an on-site chemist. The likelihood of a blow-out will be further minimized by using a specially designed blow-out preventer (BOP). When installed on top of the well-bore, a BOP will close the well automatically in case of a blowout. A management plan needs to be in place in case of a catastrophic well blow-out and or pipeline failure. Such a management plan needs to include measures to clean-up soils and groundwater.

The most important mitigation measure for potential impacts to groundwater will be monitoring of the groundwater systems. This will only be accomplished by installation of dedicated groundwater monitoring wells. The monitoring network should be concentrated at the KP area and should include community wells. The installation of the network should be done during the construction phase of the project. The spatial distribution, depth, and construction of the wells will be dependent on the identified waste sources and final infrastructure distribution. The monitoring system needs to be designed to monitor all identified potential sources of groundwater contamination on the Kingfisher Project area (CPF, well pads, flow lines and accommodation camps). This will ideally include the installation of monitoring wells up- and down-gradient of all activities/sources that could result in potential groundwater pollution. Frequencies of sampling and required analytical parameters need to be discussed with the relevant Regulatory Authority. It is recommended, based on similar project experience, to sample wells quarterly, and to analyse for all the parameters included in the hydrochemical evaluation of this report.

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Table 1: Terminology and Acronyms

Acronym	Description
BOP	Blow-out preventer
BVS	Block Valve Station
CLOs	Community Liaison Officers
CNOOC	China National Offshore Oil Corporation
CPF	Central Processing Facility
DRC	Democratic Republic of Congo
DWRM	Directorate of Water Resources Management
EA	Exploration Areas
EBS	Environmental Baseline Study
EC	Electrical Conductivity
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ESIA	Environmental and Social Impact Assessment
ESIS	Environmental and Social Impact Statement
ESMP	Environmental and Social Management Plan
IFC	International Finance Corporation
KF	Kingfisher
LPG	Liquefied Petroleum Gas
LSA	Local Study Area
mamsl	Metres above mean sea level
mbgl	Metres below ground level
MD	Maximum Depth
MEMD	Ministry of Energy and Mineral Development
NEMA	National Environment Management Authority
MPN	Most Probable Number
NGO	Non-governmental Organisations
NTU	Nephelometric Turbidity Units
OGP	International Association of Oil and Gas Producers
PAH	Poly aromatic hydrocarbons
PEPD	Petroleum Exploration and Production Department
PLDS	Pipeline Leak detection System
PPE	Personal Protective Equipment
PS	Performance Standards
PSAs	Production Sharing Agreements
RTU	Remote Terminal Unit
SBM	Synthetic Based Drilling Mud
SOP	Standard Operating Procedures
SOW	Scope of Work
SPT	Sewage treatment plant
TDS	Total dissolved Solids

Acronym	Description
TPH	Total Petroleum hydrocarbons
TSS	Total Suspended Solids
TVD	Total vertical depth
VOC	Volatile Organic Compounds
VOIP	Voice over Internet Protocol
WBM	Water Based Mud
WHCP	Hydraulic Wellhead Control Panel
WRMD	Water Resource Management Directorate

1.0 INTRODUCTION

Golder Associates was appointed by China National Offshore Oil Corporation (CNOOC) to undertake a baseline and ESIA for its proposed Oil production operations in the Albertine Rift Valley in Western Uganda. This report represents the Groundwater Baseline Study for the Block EA 3A exploration area.

1.1 Background

The petroleum potential of Uganda was first documented by A.J. Wayland in 1925, based on oil seepages he mapped at that time. The first well, Waki-B1, was drilled in the Butiaba area in 1938 (NEMA, 2010). The Albertine Graben, the area with potential for petroleum accumulation, has since been subdivided into ten Exploration Areas. The Exploration Areas include blocks 1 and 5 located to the north of Lake Albert, blocks 2, 3A, 3B, 3C and 3D on and around Lake Albert, while blocks 4A, 4B and 4C are located around lakes Edward and George in the southern part of the Graben. Five out of these ten Exploration Areas are licensed to oil exploration companies for exploration, development and production.

Oil exploration and production activities so far indicate that the oil potential in this area is promising. For example, out of the 34 oil and gas wells that have been drilled, only 2 have been found without oil. The estimated reserves in the Albertine Graben as a whole are about 2 billion barrels. The size of the reserves is enough to sustain production for 20 years (NEMA, 2010).

CNOOC will operate the Kanywataba license and the Kingfisher production licence within EA-3A, Figure 1. Kingfisher discovery has three drilled wells, Kingfisher 1, 2 & 3 while Kanywataba prospect was recently drilled but found to be a dry well that was plugged and abandoned. There is a future plan to drill a fourth well, Kingfisher 4, to further appraise the Kingfisher oil field. The Kanywataba prospect will most likely be relinquished back to government in the last quarter of this year upon expiry of the license.

The Kingfisher oil field lies within the Kingfisher Development Area (KDA), mostly beneath Lake Albert, in a 15 km x 3 km area. The project will consist of the following components, located within two main areas:

1) The wells, flowlines, central processing facility (CPF) and supporting infrastructure. These will be situated on the Buhuka Flats in the Kingfisher Development Area (KDA), along the south-eastern side of Lake Albert. The subsurface construction will include a total of 31 wells, made up of 20 production wells and 11 produced water injection wells. The CPF will also produce fuel gas, used to supply all of the project's power requirements in the first 10 years, and LPG, which will be sold into the local market.

2) The export pipeline, which will transport the stabilised crude oil from the CPF to Kabaale, roughly 52 km to the northeast, to tie in at the site of a proposed oil refinery, planned by the Ugandan Government.

Project components that are excluded from this ESIA or which will be considered only as a part of the cumulative assessment of impacts, or as a due diligence assessment of a third-party supplier, are those that have already been permitted or are the responsibility of other parties:

- Waste sites for disposal of petroleum wastes.
- Transmission lines and substation infrastructure to export and import power.
- The pipeline linking the Kaiso - Tonya field to the CPF. This oil field is to be developed by Tullow Oil, but will be processed by the CPF. The environmental permitting for all aspects of Kaiso – Tonya are the responsibility of Tullow Oil.
- Some of the ancillary project infrastructure has already been licensed and built.

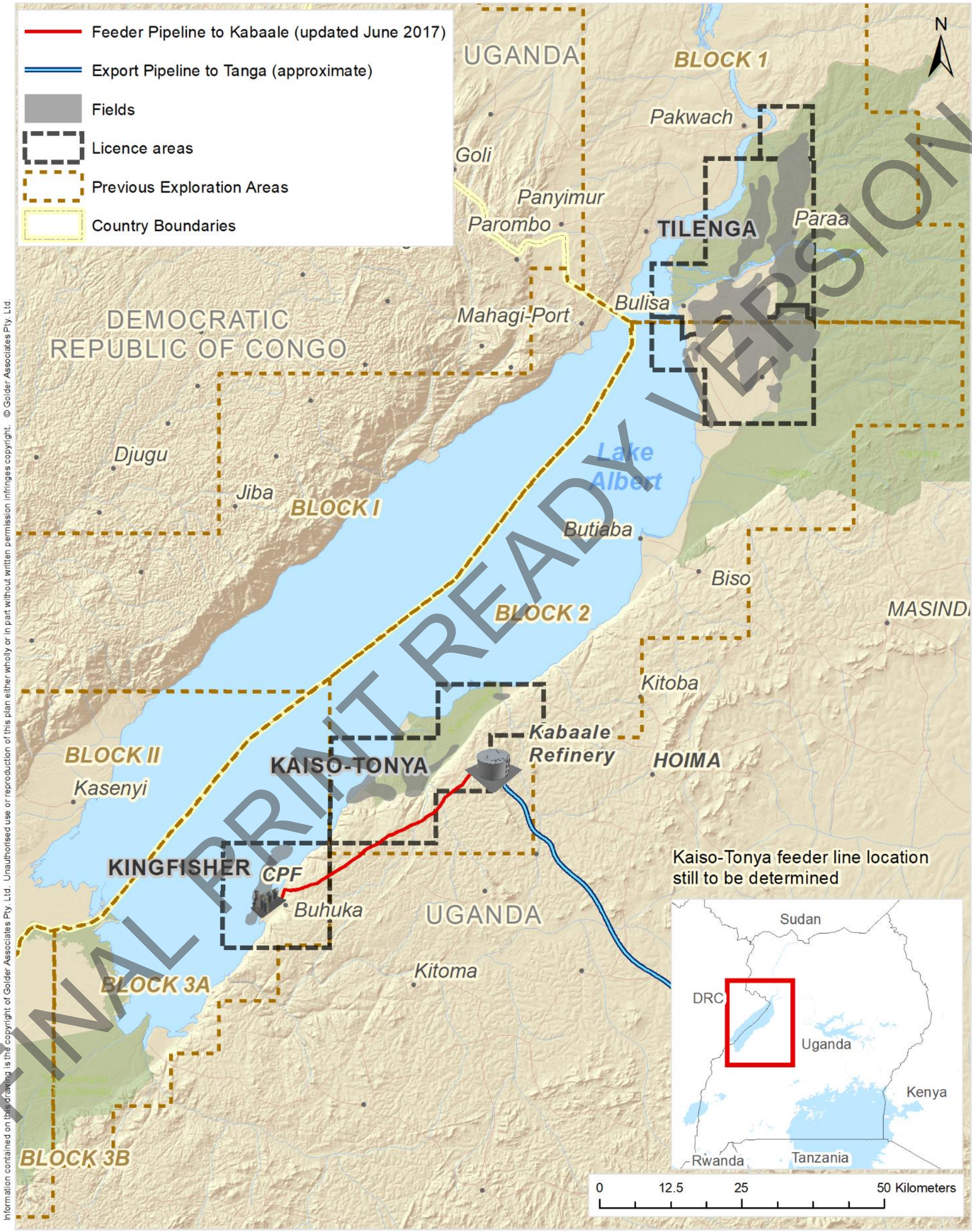

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Figure 1: Regional Location of the Kingfisher Project Site

1.2 Objectives of the study

Generally, groundwater is the most important source of potable water in Uganda, and most especially in the rural areas, providing 80% or more of the water supply (British Geological Survey, 2001). Availability of data for groundwater in an aggregated format for different parts of the country is limited, resulting in a dearth of information for Hoima District in general and Buhuka Parish in particular. Nevertheless, villages on the Buhuka Flats do make use of groundwater from wells, although the larger villages receive water from the escarpment by a gravitational pipeline installed by the previous concession holders. In either case, the water is not treated and villagers express concern about the poor quality of domestic water.

The objectives of the groundwater investigation are to:

- Understand the baseline groundwater regime at the proposed facility and along the pipeline route from available information;
- Establish the baseline groundwater quality profile; and
- Use the available groundwater information to predict potential groundwater impacts during construction, operation, and decommissioning.

2.0 LEGAL FRAMEWORK

This section presents the summary of the international and national policy framework relevant to this *groundwater specialist study*. Other policies, laws, regulations, standards and guidelines relevant to the full ESIA may not be listed here and the reader is referred to the ESIA report. This section also identifies agencies, departments and institutions responsible for the monitoring and enforcement of legal requirements.

3) **National environmental legislation relevant to groundwater is listed below:**

- The Constitution of the Republic of Uganda, 1995;
- The National Environment Act, Cap 153, 1995;
- The National Environmental Impact Assessment Regulations, 1998 made under the National Environment Act, Cap 153;
- The National Environmental (Audit) Regulations, 2006 under the National Environment Act, Cap 153 of 1995;
- The Mining Act, 2003;
- Petroleum (Exploration and Production) Act Cap 150;
- Petroleum (Conduct of Exploration Operations Regulations, 1993 under the Petroleum exploration and production Act. Cap 150, 1985;
- The draft Petroleum Exploration, Development and Production Bill of 2012;
- The Water Act Cap 152;
- The National Environment (Waste Management Regulations 1999) under the National Environment Act Cap 153, 1995;
- The National Environment (Standards for Discharge of Effluent into Water or on Land) Regulations 1999 under the National Environment Act Cap 153, 1995;
- The Uganda Bureau of Standards (US 201) specification for Drinking (Potable Water) 1994; and
- Environmental Impact Assessment Guidelines for the Energy Sector, 2004.

4) **National policies and guidelines relevant to groundwater are listed below:**

- The Oil and Gas Policy 2008;
- The National Environment Management Policy 1994;
- The National Water Policy 1999; and
- The National Energy Policy 2002.

5) **Several institutions are relevant stakeholders in the Kingfisher Discovery Area Project. The major ones include (but are not limited to) the following:**

- The Ministry of Water and Environment;
- Ministry of Justice and Constitutional Affairs;
- The National Environment Management Authority (NEMA); and
- The Water Resources Management Authority (WRMA).

6) **International Finance Corporation (IFC):**

CNOOC is committed to the International Finance Corporation (IFC) performance standards (PS) on social and environmental sustainability. These were developed by the IFC and were last updated on 1st January 2012. The PS comprise of eight performance standards namely:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 2: Labour and Working Conditions;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety and Security;
- Performance Standard 5: Land Acquisition and Involuntary Resettlement;
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- Performance Standard 7: Indigenous Peoples; and
- Performance Standard 8: Cultural Heritage.

Performance Standard 1 establishes the importance of:

(i) integrated assessment to identify the social and environmental impacts, risks, and opportunities of projects;
(ii) effective community engagement through disclosure of project-related information and consultation with local communities on matters that directly affect them; and
(iii) the management of social and environmental performance throughout the life of a project through an effective Environmental and Social Management System (ESMS).

PS 1 is the overarching standard to which all the other standards relate. The ESMS should be designed to incorporate the aspects of PS 2 to 8 as applicable.

The Equator Principles (EPs) constitute a credit risk management framework for determining, assessing and managing environmental and social risk in Project Finance transactions. Project Finance is often used to fund the development and construction of major infrastructure and industrial projects. The EPs are adopted by financial institutions and are applied where total project capital costs exceed US$10 million. The EPs are primarily intended to provide a minimum standard for due diligence to support responsible risk decision-making. The EPs are based on the International Finance Corporation Performance Standards on social and environmental sustainability and on the World Bank Group Environmental, Health, and Safety Guidelines (EHS Guidelines).

IFC General Environmental Health and Safety (EHS) Guidelines (World Bank Group, 2007) are technical reference documents with general and industry specific examples of Good International Industry Practice (GIIP). Reference to the EHS guidelines is required under IFC PS 3. The EHS Guidelines contain the performance levels and measures normally acceptable to the IFC and are generally considered to be achievable in new facilities at reasonable cost. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever standard is more stringent.

7) Applicable CNOOC Internal Procedures and Specifications:

The following internal CNOOC Procedures and Specifications were considered during the compilation of this Baseline and Impact Assessment.

- Lake Region Operations Management Specification - The purpose of this specification is to guide the delivery of site and activity specific environmental and social impact assessments, environmental management plans for Company's activities in the Albertine Graben.
- Environmental Management Procedure - The purpose of this procedure is to ensure that all environmental issues are managed properly to avoid adverse impacts on environment or human health during all operations. The specification applies to the Company's activities during exploration operations and construction activities.
- Environmental Monitoring Management Specification - The purpose of this specification is to track environmental performance; assess implementation and effectiveness of operational controls; monitor discharges and emissions to ensure compliance with relevant standards and Company's environmental objectives; and provide a basis for continuous review and improvement to the operational monitoring program.
- Spill Prevention and Control Specification - The purpose of this specification is to undertake necessary measures to prevent accidental spills or releases of hazardous materials such as petroleum, acid or alkali.
- Waste Management Specification - The purpose of this specification is to assure that the Company will properly and safely manage all non-hazardous and hazardous waste, from its generation to ultimate disposition, to prevent/minimize risks to human health and the environment. Terms of Reference

2.1 Approach and Methodology

As described in detail in the RFP document supplied by CNOOC, the requirement to undertake the requested baseline study and subsequent ESIA is essential to provide sufficient understanding of the groundwater environment and potential impact on this environment surrounding the proposed operational areas. To undertake this during the feasibility stages of the project at a time when the findings and recommendations of the ESIA are still able to influence design decisions and mitigation measures is essential given the environmental value of the area.

The specialist study was based on available groundwater information and a hydrocensus around the area. The approach is designed to give a broad overview of the site conditions and available information as well as to identify gaps in the understanding of the current hydrogeological regime. In the event that insufficient information is available, or that the data sets are not applicable to the area under investigation, additional work may be required.

The study included the following tasks:

2.1.1 Site Familiarisation

The project kick-off comprised of a site familiarisation visit by the hydrogeology team. The site visit provided the opportunity to make contact with the relevant role players for the project and to identify the correct contacts to obtain relevant existing information.

2.1.2 Client Liaison

Discussions were held with the client to confirm the focus of the groundwater investigation and to gather available information for the desk study.

2.1.3 Desk Study

All available groundwater data were collected, collated and scrutinised. This included reports from previous work undertaken including the wells drilled in and around the area, well logs, test data, water quality data, monitoring data, climatic data, maps, stereo pair black and white air photography, etc. Government database data was also accessed for larger region around the Kingfisher site.

The desk study and data collection are the two essential components of any investigation. The information and findings of the desk study was integrated with the data and findings from the primary (field) data collection and analysis.

Several reports were provided by CNOOC as background information to the project. These included numerous standards, guidelines and existing and approved EIA's relevant to the project area. Table 2 lists the main reports, papers and documents; used as sources for this baseline investigation.

Table 2: Information sources - Reports

Author	Date	Title	Type
CNOOC	2014	Introduction to the Kingfisher field Geological Background	Presentation presented by Ronald Kaggwa to Golder 26/02/2014
CNOOC	2013	Kingfisher-4 Pre-Development Well ESIA	Presentation presented to Golder September 2013
CNOOC	2013	Injection water supply for the Kingfisher Development area	Internal Document
GAA	2013	Scoping report for the environmental and social impact assessment for Kingfisher discovery area in Hoima district, Uganda by CNOOC Uganda ltd.	Report submitted to CNOOC December 2013
Environmental Assessment Consult Ltd	2013	The Environmental Audit for the drilling operations of Kingfisher 1, 2 and 3	March 2013
Environmental Assessment Consult Ltd	2013	EIA for 2D Seismic testing Kingfisher Area	June 2013
NEMA	2010	Environmental Sensitivity Atlas for the Albertine Graben	Report, 2nd Edition 2010
NEMA and PEPD	2013	Strategic environmental assessment (sea) of oil and gas activities in the Albertine graben, Uganda	Draft SEA Report

Author	Date	Title	Type
Heritage Oil	2006 to 2013	EIAs for drilling of Kingfisher KF1,2,3 and 4	Completed Drilling EIA's
Tobias Karp, Christopher A. Scholz, and Michael M. McGlue	2010	Structure and Stratigraphy of the Lake Albert Rift, East Africa: Observations from Seismic Reflection and Gravity Data	AAPG Memoir 95, p. 299 – 318
Total	2013	Proposed Appraisal Drilling: Mpyo Field (south area) Environmental and Social Impact Statement	Rev 0 – February 2013
Tullow Oil	2012	Report on the Environmental Baseline Exploration Area 2	Volumes1, 2, and 3
Directorate of Water Development, Ministry of Water & Environment	2010	Hoima District Domestic Water Supply Report	Available at www.mwe.go.ug
Directorate of Water Resources Management, Ministry of Water & Environment	2012	Albert Water Zone, hydrogeological map series	PDF, with detail borehole data for Block 3A

The data set collected from the Directorate of Water Resources Management, Ministry of Water & Environment comprised of data for more than 200 boreholes drilled in the Block EA 3A and surrounding areas. The data was interpreted together with the Hydrogeological Map series produced in 2012 by the directorate.

The data set included information for:

- Coordinates;
- Depth to water strikes;
- Depth to bedrock;
- Well depth;
- Water level; and
- Lithological logs.

Actual data points in Block EA 3A was approximately 25 points (Figure 2). The several of these points were surveyed and investigated during the hydrocensus completed for the Kingfisher area (Figure 3).

Data was very limited in the south-western border of Lake Albert. It should be noted that groundwater data is limited to areas that is inhabited; the south western shore area of Lake Albert is mostly protected areas and very few communities reside in these areas, hence the scarcity of data.

This is however not seen as a limitation on the interpretation of the hydrogeological systems, since the regional geology is relative uniform – thus the hydrogeological properties from one area can be extrapolated to other areas. The majority of the aquifer systems exploited in the area is generally associated with the hard rock formations gneiss, granite and or quartzite – all of which are considered to be fractured type aquifers.

Hydrocensus

A hydrocensus was carried out to capture direct and updated information on existing groundwater points.

The main outcomes from the hydrocensus are as follows:

- Capture up to date water level data; and
- Capture up to date water quality data.

Data Processing and Evaluation

Data gathered during the desk study and hydrocensus were used to characterise the hydrogeological situation in the area. The interpretation and assessment of the available data identified information gaps. The impacts of these gaps in the context of the available information were quantified and pertinent recommendations were prepared and presented to the ESIA project team.

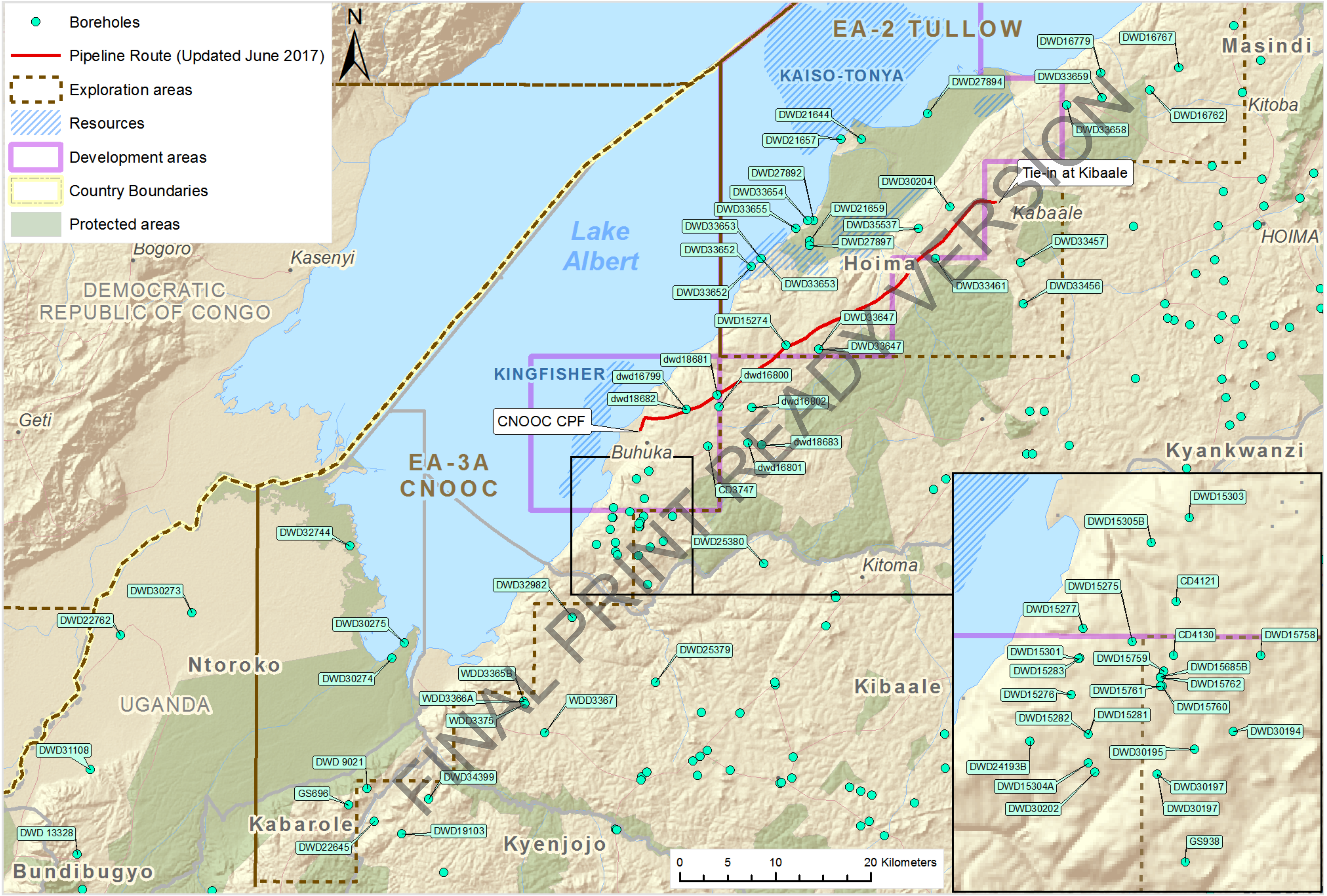

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Figure 2: Distribution of data points – well/boreholes locations, Golder (2013) Groundwater Baseline Report for Kingfisher Block 3A

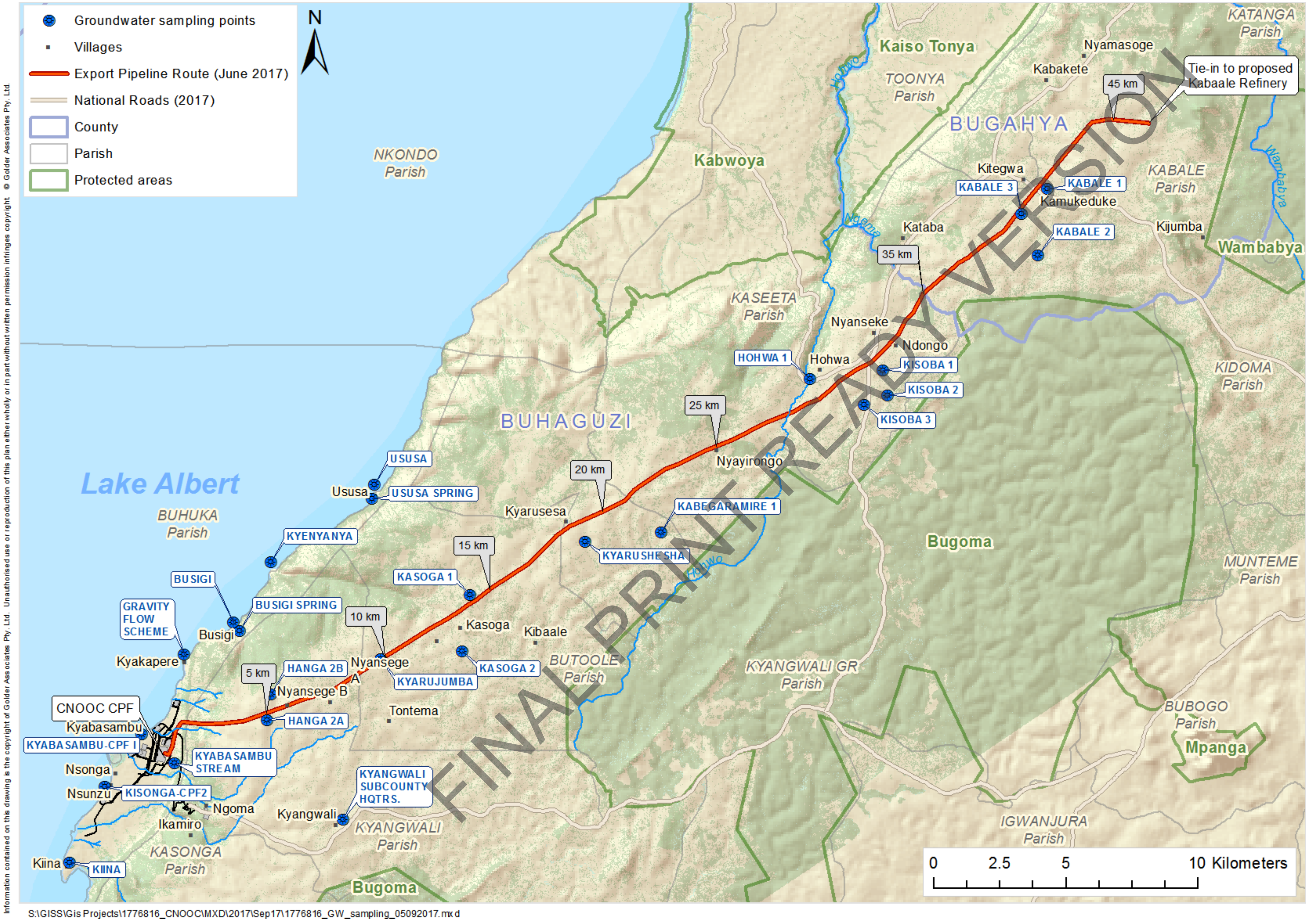

Figure 3: Location of the hydrocensus points surveyed

3.0 PROJECT SUMMARY

3.1 CPF, wells flowlines and associated infrastructure

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 4).

3.2 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 5).

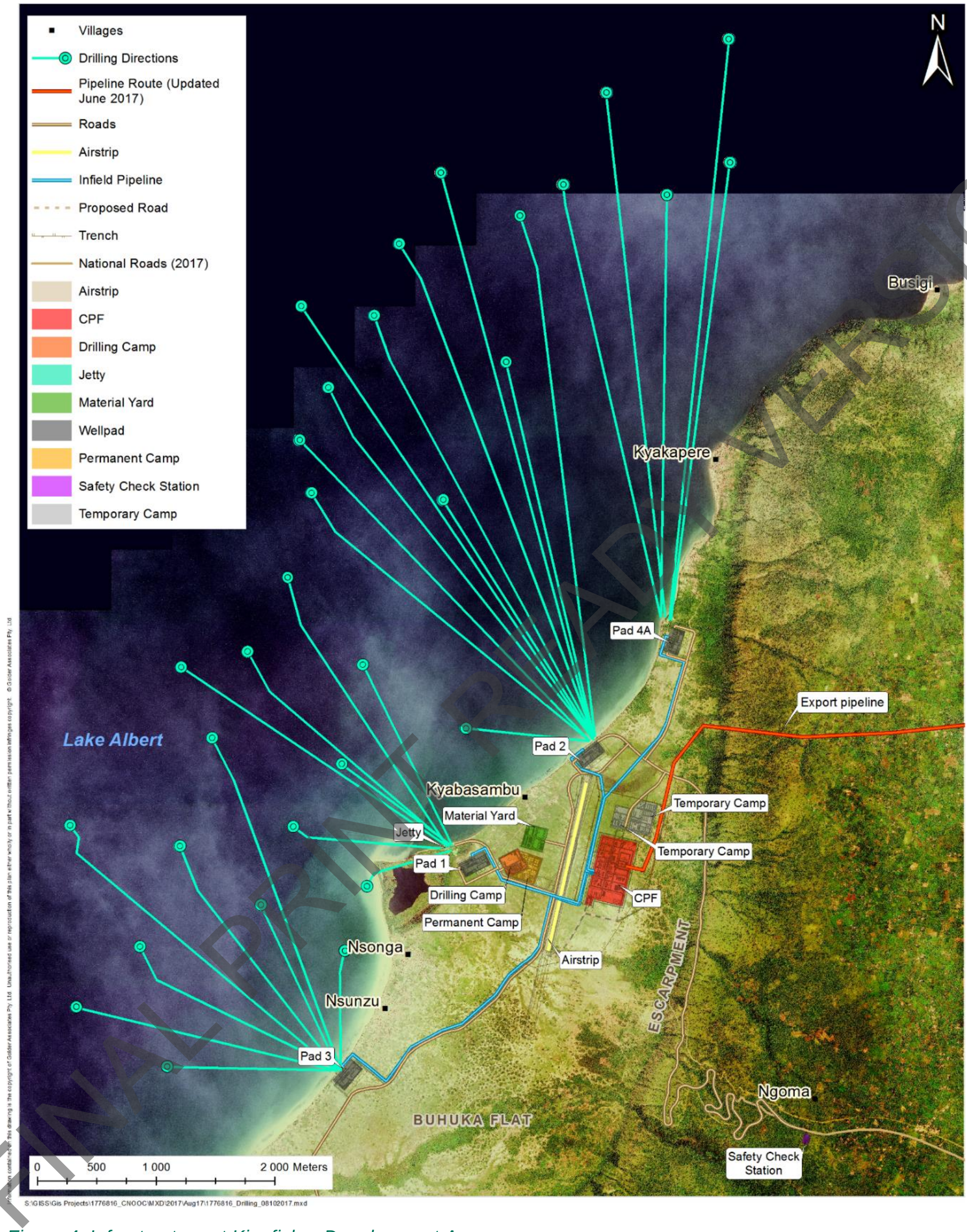

Figure 4: Infrastructure at Kingfisher Development Area

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4.0 FIELD INVESTIGATIONS

Field investigations in this case were limited to a site familiarisation visit and two hydrocensus surveys for the project site. No other field investigations were performed.

The groundwater team carried out a hydrocensus to capture direct and updated information on existing groundwater points both down at the lake front and up on the escarpment.

The main outcomes from the hydrocensus are expected to be as follows:

- Capture of up to date water quality data; and
- Determination of the extent of groundwater use by local communities.

The hydrocensus was completed in two stages during December 2013 and March 2014. The first field trip involved the collection of groundwater, spring, stream, and lake water samples along the lake front of Lake Albert in the area directly affected by the Kingfisher project. During the March 2014 field trip, duplicate water samples were taken from the groundwater wells along the lake front to include petroleum hydrocarbon analyses for the establishment of a water quality baseline for these parameters. In addition, a hydrocensus was completed along the pipeline route and through all communities that could potentially be affected by the activities and groundwater samples were taken from wells.

A total of 14 samples were taken at the lake front, and another 15 were taken on the escarpment along the pipeline route. Water level measurements were limited to two unused wells near the camp site. A summary of the information collected is provided in Table 3 and the locations of surveyed points are shown on Figure 3.

Microbial sampling was undertaken in June 2014 from the hydrocensus sampling points. Personal communication and observations made in the villages clearly indicate that that faecal contamination of water sources is typically due to poor sanitation practiced in the area. From the hydrocensus, the general practices regarding groundwater use and water quality distribution has been established for the areas directly affected by the project activities.

Limitations to the data collections that should be noted were:

- The major information gap identified from the field data is the lack of water level data. The community wells are all sealed with hand pump head gear, and there is no access to measure water levels. Water level measurements were limited to two wells in the villages Kyabasambu and Kisonga on the flats. Both wells had handpumps that were no longer working, and the headgear was physically removed to take samples and measure the water level depth. Therefore, no piezometric groundwater maps can be produced to infer the general groundwater flow direction and/or gradient from field data;
- On the flats there are no functioning wells left with the exception of one at Kina, where the water is too saline for potable use. The main water sources are the gravity flow, non-perennial streams, and the lake;
- The first round of samples were analysed for inorganic parameters only, and the second round of samples included organic hydrocarbon analyses; and
- Microbial analyses could not be done at a laboratory due to the short time period that is required (less than 24hours) between sampling and analysis. Colitag™ test kits were used for the microbial analyses of the hydrocensus points. Colitag™ is a Presence/Absence and MPN enzyme substrate test that detects as few as 1 MPN of total coliform and *E. coli* bacteria per 100mL water sample. Results can be read any time between 16 and 48 hours. Colitag™ is US EPA approved for use as a presence absence test and in the Most Probable Number (MPN) format as specified in Standard Method 9221 for compliance monitoring of total coliforms and *E. coli* in drinking water.

Table 3: Hydrocensus summary

Date	Site name	Type	Water level (mbgl)	Sample y/n	Depth in metres	Community comments
12/12/2013	Nsonga	No well		n		Gravity flow scheme, Pipes are corroded pump not working
12/12/2013	Nsunza	Gravity flow scheme		n		Gravity flow scheme, Pipes are corroded pump not working
12/12/2013	Ususa (BH)	Deep well		y		3.5 pipes, close to lake
12/12/2013	Ususa (Spring)	Spring		y		Source where rock face cuts the sediments on escarpment
12/12/2013	Kyenyanja	Deep well		y		One working well, and spring/stream
13/12/2013	Kyakapere	Gravity flow scheme		n		No working wells, Gravity flow/lake water
13/12/2013	Senjonjo (spring/stream)	Stream		n		No wells, villagers complain WQ is affected by upstream village on escarpment
13/12/2013	Kacunde	Deep well		y		Wells, but use gravity flow or lake
13/12/2013	Kina	Deep well		y		Saline as observed from ground surface and comments from villagers
13/12/2013	Busigi	Deep well		y		Well and stream
13/12/2013	Kyabasambu stream			n		One of the sources of the Buhuka flat
13/12/2013	Lake Albert			n		Lake sample
01/02/2014	Kyangwalisubcounty HQ	Deep well		y		Refugee camp
28/02/2014	Kyabasambu (CPF1)	Deep well	5.3	y		Pump broken - removed headgear to measure water level
28/02/2014	Kisonga (CPF2)	Deep well	6.66	y		Pump broken - removed headgear to measure water level
28/02/2014	Ususa	Motor drilled shallow well		y		

Date	Site name	Type	Water level (mbgl)	Sample y/n	Depth in metres	Community comments
28/02/2014	Kyenyanya	Motor drilled shallow well		y		
28/02/2014	Gravity flow scheme	Gravity flow scheme		n		
28/02/2014	Kiina	Deep well		y		Saline as observed from ground surface and comments from villagers
02/03/2014	Kabale1	Deep well		y	39	Saline water
02/03/2014	Kabale2	Protected dug well		y		
02/03/2014	Kabale3	Protected dug well		y	4.5	
02/03/2014	Kisoba 1	Protected dug well		y	4.5	
02/03/2014	Kisoba 2	Protected dug well		y	3	Dries up with continues pumping
02/03/2014	Kisoba 3	Deep well		y	42	High population
02/03/2014	Hohwa 1	Protected dug well		y	3	Seasonal well
03/03/2014	Kabegaramire 1	Deep well		y	33	
03/03/2014	Kyarushesha	Protected dug well		y		Broken down
03/03/2014	Kasoga 1	Deep well		y	27	Bad smell
03/03/2014	Kasoga 2	Protected dug well		y	3	
03/03/2014	Kyarujumba	Deep well		y	33	
03/03/2014	Hanga 2B	Deep well		y	24	
03/03/2014	Hanga 2A	Deep well		y		

A follow up survey of villages where boreholes or hand dug wells are used for water supply was undertaken during May and June 2015. The aim of this survey was to ground truth the government data collected, and fill information gaps. The villages to the south of Lake Albert were visited and groundwater abstraction points were recorded where possible. More than 30 villages were visited with details of wells recorded for 24 wells; of which 10 were sampled (Figure 5).

The Government database data set was used as a reference point, however several of the sites from the database could not be found; were destroyed or not in working condition.

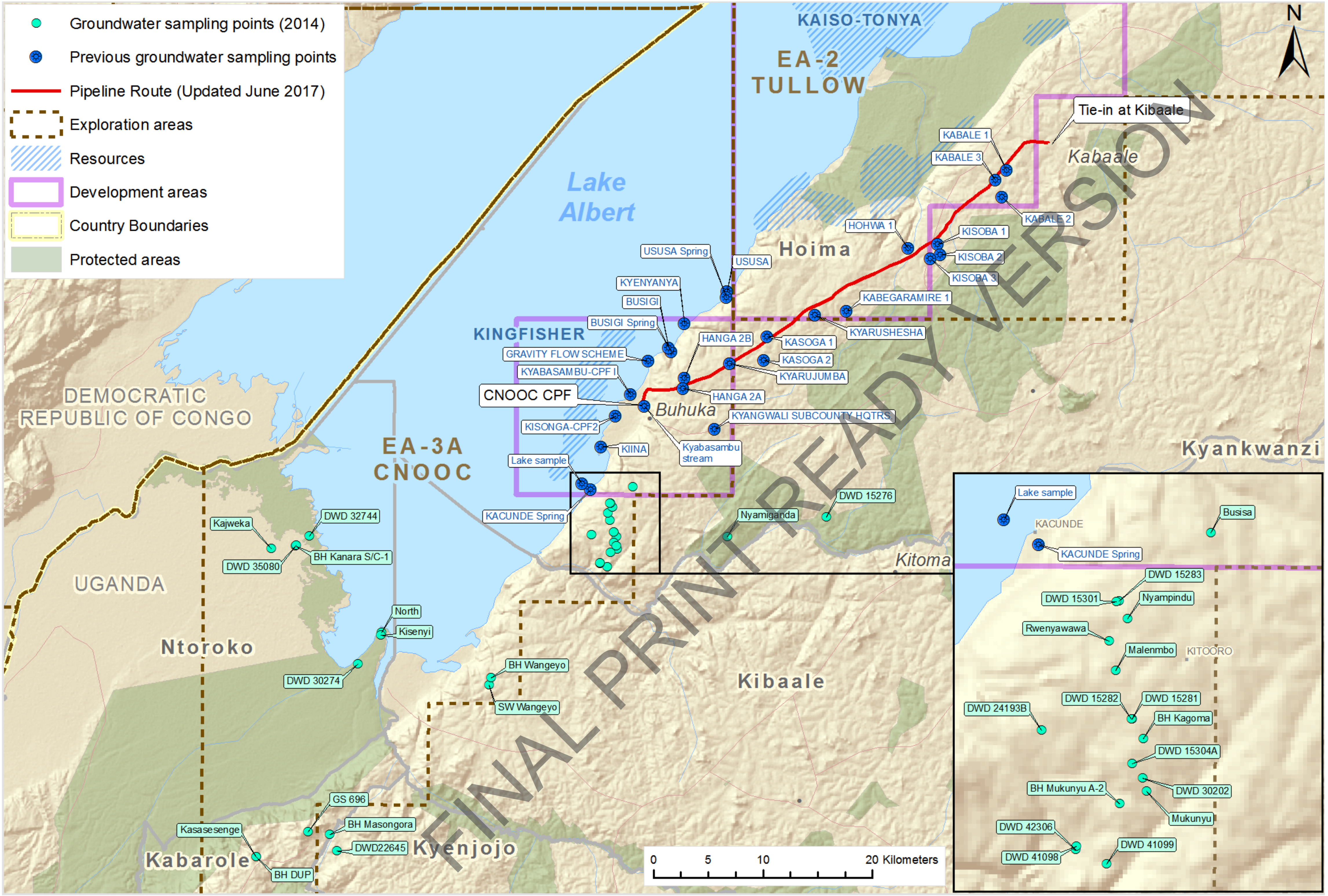

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Figure 5: Follow up survey of wells in villages, indicated on the original baseline map backdrop to indicate clearly which boreholes were revisited

Table 4: Follow up field survey results

Date	ID	Coordinate 36N		Village	Remark
		N	E		
02/06/2015	BH Mukunyu	0247762	0124391	Mukunyu	Sampled
02/06/2015	BH Nyamiganda	0257815	0125558	Nyamiganda	Sampled
02/06/2015	BH Malenmbo	0247084	0127078	Malenmbo	Sampled
02/06/2015	BH Rwenyawawa	0246944	0127728	Rwenyawawa	Sampled
02/06/2015	BH Nyampindu	0247354	0128225	Nyampindu	Sampled
02/06/2015	BH Busisa	0249187	0130129	Busisa	Sampled
03/06/2015	BH Kasasesenge	0214793	0096310	Kasasesenge	Sampled
04/06/2015	BH Kajweka	0216159	0124471	Kajweka	Sampled
04/06/2015	BH Ntoroko North	0226248	0116790	Ntoroko North	Correspond with government number DWD 30275; sampled
04/06/2015	BH Kisenyi	0226164	0116579	Kisenyi	Sampled
28/05/2015	DWD 30274	0224076	0113932		Not in working condition
29/05/2015	BH Kanara S/C-1	0218395	0124718		Not in working condition
29/05/2015	DWD 35080	0218449	0124766		Not in working condition
30/05/2015	BH Masongora	0221470	0098349	Masongora	Not in working condition, in Village Masongora
30/05/2015	DWD22645	0222154	0096811	Byeya	Working condition; installed Apr-2006, out of Block 3A
31/05/2015	SW Wangeyo	0236094	0111991	Wangeyo	Working condition; installed Apr-13, depth 7m, pump installation depth 1.8m,funded by Land Rover and IFRC
31/05/2015	BH Wangeyo	0236229	0112672	Wangeyo	Working condition; installed Mar-13, BH depth 81.57m, pump installation depth 21m, funded by Land Rover and IFRC
02/06/2015	BH Kagoma	0247692	0125562	Kagoma	Working condition; installed Mar-13, funded by The Church of Jesus Christ of Latter-day Saints"
02/06/2015	BH Mukunyu A-2	0247166	0124124	Mukunyu	Working condition; installed Jan-15
02/06/2015	DWD 41099	0246879	0122785	Mukunyu	Working condition; funded by UHCR.
02/06/2015	DWD 42306	0246198	0123110	Mukunyu	Working condition; funded by UNICER
02/06/2015	DWD 41098	0246213	0123173	Mukunyu	Working condition; funded by UNHCR

5.0 BASELINE ENVIRONMENT

5.1 Climate

5.1.1 Rainfall

The Albertine Graben has sharp variations in rainfall amounts, mainly due to variations in the landscape. The landscape ranges from the low lying Rift Valley floor to the rift escarpment and the raised mountain ranges. The Rift Valley floor lies in a rain shadow of both the escarpment and mountains, and has the least amount of rainfall; averaging less than 875mm per annum (much lower than that of the highland area).

Rainfall records by Directorate of Water Resources Management (NEMA, 2013) indicate that Moyo in the extreme north-east received an annual rainfall mean of 1174.8mm over a seven year period (between 2003 and 2009). During this period the highest annual mean rainfall was in 2006 (1593.9mm) while the lowest was in 2004 (623.6mm) indicating a high range in the mean annual rainfall received. Butiaba around Lake Albert in the centre north-east receives 750mm, while Kasese in the central part of the Graben receives a slightly higher mean rainfall of 970mm. On the highland areas of the rift escarpment, rainfall averages increase largely due to orographic influences. For example, Masindi receives an annual average rainfall of 1359mm, while Hoima receives 1435mm (NEMA, 2013).

5.1.2 Temperature and humidity

The Albertine Graben region lies astride the equator. The region experiences small annual variations in air temperatures; and the climate is generally hot and humid, with average monthly temperatures varying between 27°C and 31°C. Maximum temperatures are consistently above 30°C and sometimes reach 38°C. Average minimum temperatures are relatively consistent and vary between 16°C and 18°C. High air temperatures result in high evaporation rates causing some areas to have a negative hydrological balance.

The relative humidity in the Albertine Graben is higher during rain seasons with maximum levels prevalent in May. The lowest humidity levels occur in dry seasons with minimum levels occurring in December and January. The average monthly humidity is between 60% and 80% (NEMA, 2013).

5.1.3 Wind

Wind speed and direction records indicate a high incidence of strong winds especially in the Rift Valley (NEMA, 2013). The prevailing winds commonly blow along the valley floor in a north-east to south-west direction or vice versa. Winds also blow across the Rift Valley in an east to west direction. On the escarpment and mountain slopes, prevailing wind-directions are typically multi-directional. Overall, the area typically experiences moderate to strong and gusty winds, increasing in the afternoon. Both wind speed and direction have important implications on oil exploration and production activities particularly the dispersion potential for oil pollutants (NEMA, 2013).

5.2 Topography and Drainage

Lake Albert occupies the northernmost rift basin in the western rift valley. The lake is approximately 130km long and approximately 35km wide and is an open hydrologic system that receives its major input from the Semliki River to the southwest and the Victoria Nile to the northeast. Lake Albert is relatively shallow as most other large East African rift lakes, found to the south, have maximum water depths of approximately 58m.

Within the Albertine Graben, there are three main lakes: Lake Albert, Lake Edward, and Lake George. Most of the rivers and streams originating from the highlands surrounding this area drain into the lakes which, in turn, drain into the Nile via Lake Albert. Most significant of these rivers is River Semliki which comes from Lake Edward through the western edge of the great Ituri rain forest in DR Congo, and enters Uganda at a point close to the northern end of the Rwenzori range. The other is the Victoria Nile which enters Lake Albert at its northern most tip before draining out of the lake as the Albert Nile on its way to Nimule and onward to Sudan. Both rivers have built deltas into Lake Albert; Semliki being the largest. Ninety percent of the delta is created in Uganda. Although the Victoria Nile carries more water than the Semliki, it has little influence on the ecology of the lake, other than to maintain water levels. The Semliki on the other hand provides the primary supply of water into the lake system. The lake also has a large sedimentation potential from the

Victoria Nile. There are other numerous small streams entering the lake from both Uganda and DR Congo, some of which are highly seasonal and of only minor importance to the hydrology of the lake.

A series of erosion valleys and gullies cut the escarpment and discharge runoff from the escarpment to the valley. There are also seasonal streams and rivers which are flooded by runoff from the catchment areas after heavy rainfall events. In the Lake Albert area, water from these rivers drains quickly; either into Lake Albert or it seeps into the thick sediments of the Rift Valley floor. The seasonal rivers in this area include Sebugoro, Kabyosi, Warwire, and Nyamasoga.

Most of the rivers and streams have incised into the landscapes leading to a topographic pattern of narrow river valleys and sometimes gorge-like features. Due to the nature of rift escarpment landscape, the rivers and streams flowing into the Rift Valley often have a limited catchment size and this implies limited hydrological potential. Consequently, some of the scarps are drained by ephemeral (intermittent) flows to the extent that some of the river valleys are dry most of the time.

5.3 Geology

5.3.1 Regional Geology

The Albertine Graben is a 500 km-long rift basin of Mesozoic-Cenozoic origin that straddles the border of Uganda and the Democratic Republic of Congo. It is developed upon the Precambrian orogenic belts of the African Craton and is bordered by steep normal faults with uplifted flanks composed of Precambrian basement rocks such as gneisses, quartzites and matie intrusions (Byakagaba, 2004).

The geological sequence in the Albert Basin is of Miocene – Recent age, resting on metamorphosed pre-Cambrian basement. The oldest sediments so far encountered have been of Late Miocene age. It is thought that approximately 6,000m of section were deposited in the central part of the basin, with some 3,000m present in the area of Kingfisher Field. The sequence comprises a series of interbedded sandstones and shales, representing a mixture of low-stand events, during which sedimentation was dominated by fluvial processes and flood or high-stand events when lacustrine deposition predominated.

The high petroleum potential of the basin is due to the thickness (>5000m) of organic-rich sediments and the well-developed reservoir rocks which contain porous and permeable sands and conglomerates. There is a very high quartz content within the reservoir rocks (>75%) which makes them resistant to compaction and therefore contributes to the preservation of the porosity. It is also thought that the fractured and weathered basement may also act as a reservoir. Rifting within the basin caused the formation of several large-scale structural traps, whereas facies change, and unconformities lead to the development of stratigraphical and lithological traps.

Observations from seismic-reflection and gravity data sets reveal that the overall structural morphology of Lake Albert is that of a full Graben, which is a unique configuration in the western rift valley. The Bunia border fault bounds the entire basin along the western shore, and it is opposed on the eastern margin by a complex of several large basement involved faults, which created two structural sub-basins. Major basement-involved faults control the modern distributions of isobaths and the location of deep-water areas. The maximum thickness of the sedimentary section is 5km and dip on pre-rift basement is shallow (<18degrees) (Karp, et.al. 2010).

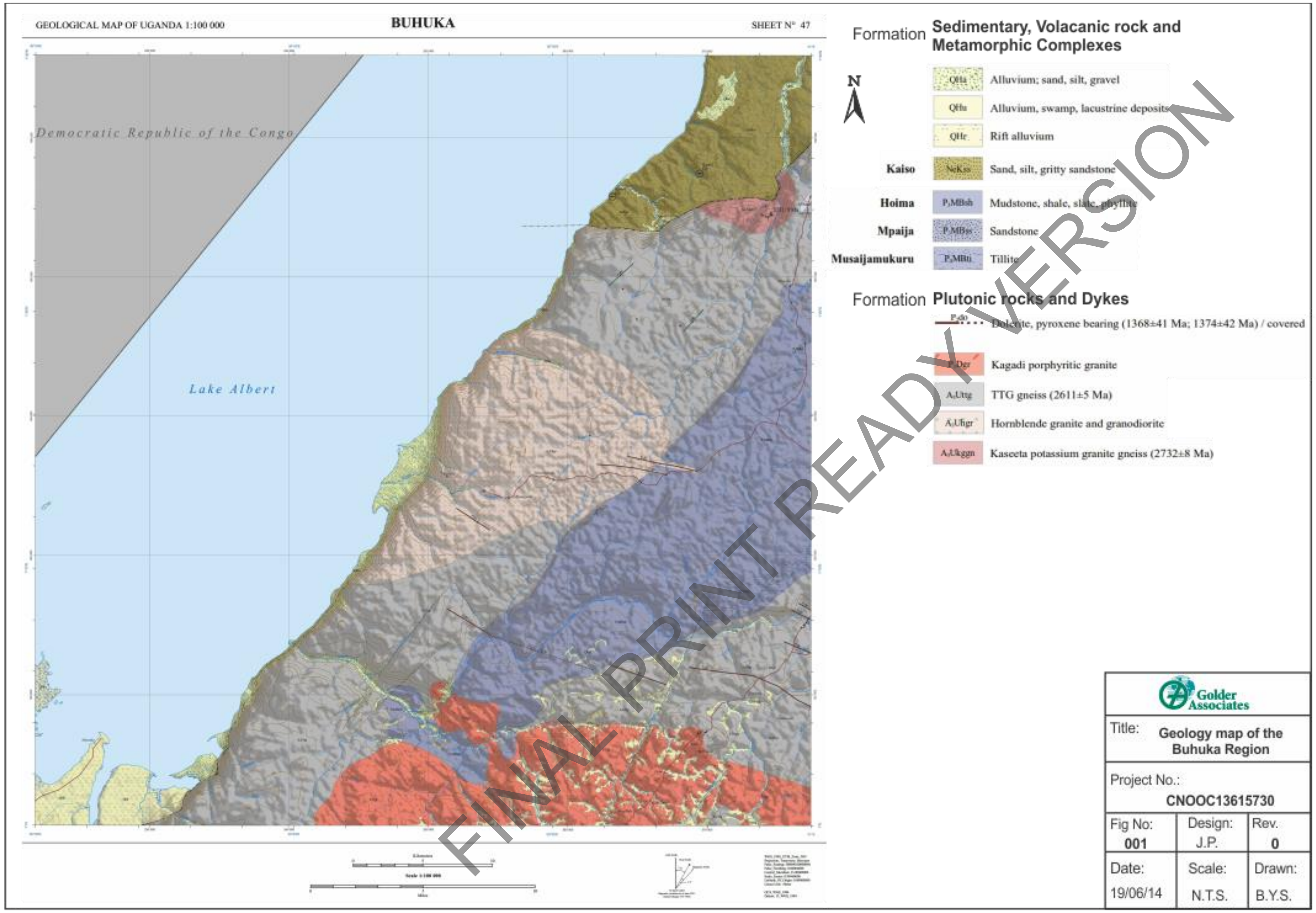

Figure 6: Regional Geological Map (adapted from Geological maps produced by Department of Geological Survey and Mines, 2012)

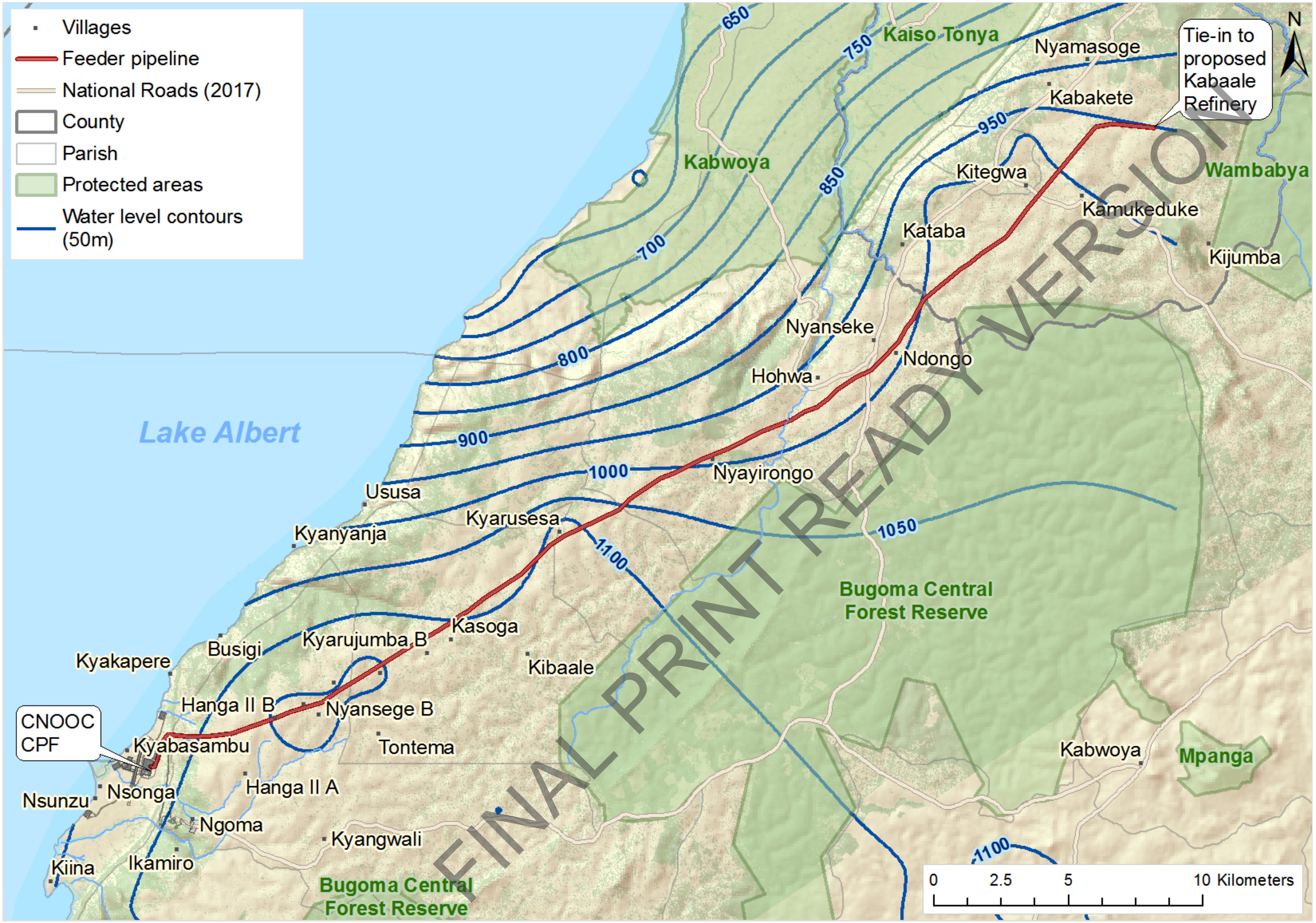

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Figure 7: Water elevation map for the Kingfisher Project area

5.3.2 Local Geology

The Kingfisher field is formed by a structural trap, which comprises a southwest-northeast trending 3-way dip-closed hanging-wall anticline that seals against basement to the south-east along the main bounding fault of the Albert Basin. The field is about 10km by 2km and provided the drilling sites for 3 wells and 3 side-tracks (CNOOC, 2014).

The sedimentary succession of Kingfisher is composed of intervals of Late Miocene and Pliocene age. The Late Miocene and Pliocene intervals can be subdivided into M5 and M6 unit of Late Miocene, P1 and P2 units of Early Pliocene, P3 and P4 units of Late Pliocene (See Figure 8).

Pick Name	Age	Kingfisher-1	Kingfisher-1A	Kingfisher-2	Kingfisher-3	Kingfisher-3A
P4	Late Pliocene	972.00m MD	973.00m MD 972.70m TVD	1018.00m MD 966.39m TVD	1027.00m MD 960.50m TVD	1021.00m MD 960.83m TVD
P3	Late Pliocene	1152.00m MD	1153.00m MD 1152.14m TVD	1296.00m MD 1171.73m TVD	1310.00m MD 1174.75m TVD	1259.00m MD 1163.11m TVD
P2	Early Pliocene	1407.00m MD	1435.00m MD 1418.80m TVD	1702.00m MD 1473.49m TVD	1807.00m MD 1546.68m TVD	1689.00m MD 1541.34m TVD
P1	Early Pliocene	1807.00m MD	1880.00m MD 1827.93m TVD	2257.00m MD 1890.82m TVD	2330.00m MD 1938.76m TVD	2065.00m MD 1876.34m TVD
M6	Late Miocene	Not present	2376.31m MD 2298.27m TVD	2800.74m MD 2306.58m TVD	2947.42m MD 2424.23m TVD	2546.38m MD 2347.65m TVD
M5	Late Miocene	Not present	2533.00m MD 2443.86m TVD	3012.00m MD 2468.34m TVD	3145.00m MD 2575.28m TVD	2676.00m MD 2476.64m TVD
Basement	Pre-Mesozoic	2066.00m MD	2830.00m MD 2719.84m TVD	3601.00m MD 2928.88m TVD	Not reached	Not reached
TD		2125.00m MD 2121.35m TVD	2962.40m MD 2847.40m TVD	3906.00m MD 3198.00m TVD	3200.00m MD 2619.19m TVD	2712.00m MD 2512.19m TVD

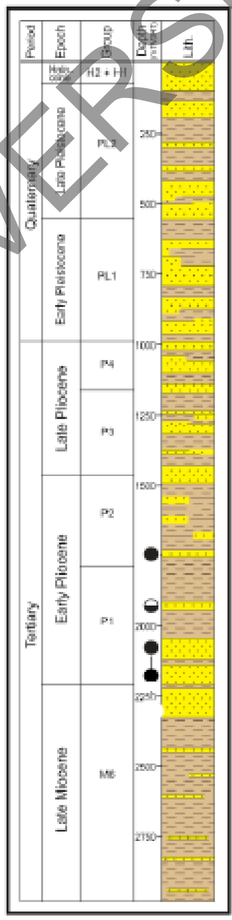

Figure 8: Sedimentary Sucession at Kingfisher (CNOOC, 2014)

The initial Kingfisher- well intersected a hydrocarbon-bearing interval from 1,783 - 1,795m MD (maximum depth). This upper interval has been termed “Zone 1”. The well subsequently intersected basement at 2,095m, significantly shallower than anticipated and was side-tracked to the northwest as Kingfisher-A. This encountered the Zone 1 sandstone interval about 250m from the original discovery location but found it to be water-wet, thereby showing the hydrocarbon reserve at this level to be very small. The Kingfisher-A side track subsequently discovered a lower hydrocarbon bearing interval from 2,259.5m to 2,372.5m which was denoted as “Zone 2”. The second side-track, Kingfisher-B, did not encounter any hydrocarbons at deeper levels. Subsequent appraisal drilling on the Kingfisher structure comprised wells Kingfisher-2, -3 and -3A, also deviated to the northwest. These focused exclusively on the Zone 2 reservoirs.

Preliminary results from the geotechnical drilling showed that Pad-2 is underlain by inorganic clays up to an average depth of 18m followed by a mixture of silty sandy clays to 30m.

5.4 Hydrogeology

5.4.1 Regional Hydrogeology

Data reviewed at the Directorate of Water Development (DWD, 2014) indicate that data for groundwater wells in the Kingfisher areas are limited to areas of inhabitation. The following is inferred from the data reviewed and the published hydrogeological maps for the region:

- The Hoima district area is covered by the basement rocks, with the main geological units in the basement are laterites, granites, clays and gneisses. Fractured granitic rocks form the main unit are considered to be a sustainable aquifer system.
- Analysed borehole lithology logs for Hoima district revealed that the basement had two water bearing zones; the weathered and fractured-rock zones.
- Wells are drilled to depths of between 23m and 152m, with the average being around 62m below ground level;
- The bedrock depths were provide to be on average 30m below surface, and were recorded to be either of from granitic and quartzitic origin. The upper lithologies are mainly described as interbedded clay and/or sand sediments of various thicknesses;
- The water strikes are mainly associated with fractured and weathered bedrock and it can therefore be concluded that the aquifer systems utilised will have a fractured character. Recorded yields varied between very low (0.1l/s) to high (20 l/s), with the average at 2.9l/s. 25% of boreholes recorded had yields higher than 4l/s. The variability in yields is typical of fractured bedrock type aquifers; and
- Water level data for the lake front villages showed that the water levels occurred between 5.37- 6.37m (this includes water levels measured during the hydrocensus) below surface. On the escarpment water levels were on average 18.1m below surface. 40% of the recorded water levels on the escarpment were deeper than 20m below surface. General groundwater flow direction in the KP area is towards Lake Albert in a north-westerly direction (Figure 7).

5.4.2 Site Hydrogeology

From the hydrocensus results it was seen that only 5 out of the 10 villages visited along the lake front had functioning wells from which potable water could be sourced. Wells are prone to fail due to corrosive properties of the groundwater (i.e. often the pipes are corroded away, if not maintained). The villagers conveyed that wells often do not yield enough water or that water quality is to poor for use. As an alternative, villagers augment their water supply with lake water and/or springs or streams against the escarpment.

As discussed earlier, measuring water levels in the wells was difficult due to the type of pump installations typical for the area, Figure 9.


Figure 9: Typical well installation in the Kingfisher project area

Field parameters measured during the hydrocensus along the lake front villages are shown in Table 5 . The wells at Busigi and Kiina were found to have high salinity and villagers therefore do not want to use the water.

Table 5: Field parameters measured at wells and springs along the lake front (2014)

Village	pH	EC (µS/m)	Redox (mV)	T ºC
Senjonjo (s)	7.34	1160	-55	24.1
Kacunde (s)	7.97	790	62	23.7
Kiina (w)	8.09	>2000	0	28.6
Busigi (w)	8.79	2970	106	28.4
Busigi (s)	8.93	893	83	25.8
Ususa (w)	9.34	256	50	28.2

s – spring or stream
w - well

It was observed that during the rainy season, the groundwater level in the Kingfisher area is less than 1mbgl in certain areas. These perched water table conditions are likely caused by the poorly-porous and slow draining clayey soils. Accordingly, it is probable that a limited perched aquifer beneath the site may be accessible as a water source through shallow hand dug wells. This source is however relatively unprotected from surface infiltration of contaminants and not reliable throughout the year. It is inferred that shallow groundwater in the area flows in a generally westerly direction towards the lake.

The hydrogeology along the pipeline route differed from that observed at the flats and lake front villages. Fifteen wells were recorded at the villages along the pipeline route (Table 3). These wells are the main source of water for the people living along the route. A small percentage of the wells recorded were shallow (<5mbgl) dug wells with hand pumps installed. However, users complained about poor quality of water and seasonality of the shallow wells. The deeper wells were found to be generally reliable source of water with occasional complaints regarding water quality.

During the follow up survey in 2015 water quality samples were taken south along the lake front and along the escarpment of the Kingfisher Project area and pipeline (Figure 5). Eleven of the wells surveyed were sampled and field water quality parameters were measured and recorded (Table 6). As with the previous hydrocensus all the functioning wells are equipped with hand pumps and no water level data could be recorded. Some of the installed wells did have date of installation and depth of installation recorded on the head gear which was noted. Two wells where installation depth was recoded also varied between 7m and 81m below ground surface. Once again, the variable water quality and water levels indicated that the aquifers utilised by local communities are highly heterogeneous.

Table 6: Field chemical parameters recorded for samples along the pipeline route (2015)

ID	DO mg/L	T ºC	EC us/cm	pH
* BH Mukunyu	2.95	25.4	370	7.9
* BH Nyamiganda	3.63	23.8	240	7.6
* BH Malenmbo	2.89	24.3	2.8	7.1
* BH Rwenyawawa	3.88	25.2	25.2	6.8
* BH Nyampindu	4	24.3	470	7.6
* BH Busisa	4.6	24.4	330	7.5
* BH Kasasesenge	6.11	23.9	136	8.3
* BH DUP (1)	6.11	23.9	136	8.3
* BH Kajweka	4.87	27.5	1600	8.1
* BH Ntoroko North	3.11	24.3	690	7.5
* BH Kisenyi	4.75	28.5	510	7.4

It can generally be inferred that the bedrock aquifer associated with the granite, gneiss, and quartzite formation can be utilised as a sustainable and reliable water source. The aquifer is characterised as a fractured rock aquifer and yield is generally dependant on structural properties of the formation. The heterogeneity is observed in the variable water level elevation observed of the system

The aquifer can be classified as moderately vulnerable due to the relative depth (~20mbgl) of water table and is the main source of potable water of villages in the study area. The exception is on the Buhuka flat where the water quality is poor and water properties corrosive to infrastructure. Shallow perched aquifers associated with weathered sediments are often utilised as a source of water but vulnerable to contamination and not sustainable throughout the drier months of the year.

5.4.3 Groundwater Quality

From the discussion above it is clear that there are water quality issues related to the groundwater sources within the study area. Samples were taken from various wells, springs, streams and the lake to determine the water quality baseline for the area. Historical or monitoring water quality data is very limited for the study area. For instance, some of the previous ESIAs for the oil field development have limited once off sample results and it is not always clear where the samples were taken and from what type of water source (RPS, 2006; AWE, 2008 and 2013; AECOM, 2012) .

The samples submitted for chemical analyses were analysed at either National Water Quality Reference Laboratory in Entebbe, Uganda or at Jones Environmental Laboratory in the UK. All results were compared to the Uganda National Bureau of Standards (UNBS) standard **US 201 (2008) for Drinking (potable) water** (2nd Edition).Only parameters that tested above detection limits are included in this discussion and full results are provided in Appendix B.

From the discussion above it is clear that there are water quality issues related to the groundwater sources within the Kingfisher Development Area and along the proposed pipeline route. Similar to the hydrogeological properties the water quality results can also be extrapolated from the KDA area to Block EA 3A.

Samples were taken from various wells, springs, streams and the Lake to determine the water quality baseline for the area. Historical or monitoring water quality data is very limited for the study area. Some of the previous ESIAs for the oil field development, has limited once off sample results, it is not always clear where the samples were taken and from what type of water source.

The samples submitted for chemical analyses were analysed at either National Water Quality Reference Laboratory in Entebbe, Uganda or at Jones Environmental Laboratory in the UK.

All results were compared to the Uganda National Bureau of Standards (UNBS) standard **US 201 (2008) for Drinking (potable) water** (2nd Edition).

5.4.3.1 Physical Parameters

The Physical parameters include: Electrical Conductivity (EC), pH, Total Dissolved Solids (TDS), Total suspended solids (TSS), Turbidity, Total Hardness, and Total Alkalinity, **Table 7**.

Generally, physical parameters are all well below the required standards, with the exception of pH and salinity along the lake front wells and surface water points. pH of surface water and groundwater sources along the lake front tend towards alkaline (pH values above 9). Kyangwali's borehole sampled at the escarpment had a pH of 5.99, the only site with a slightly acidic pH, this is typical of granitic type groundwater. Other sampled sites were well within the acceptable standards for pH. Boreholes on the Buhuka flats (Kina and Kyabasambu) were characterised with very high salinity (EC>3800 mS/m). Hardness and alkalinity for all sites are well within acceptable standards, except for Kina and Kyabasambu samples that have hardness in excess of a 1000 mg/L.

Based on the physical parameters it can be concluded that groundwater (and surface water) at the lakefront are not recommended for domestic use due to excessive salinity, hardness and elevated pH. The groundwater tested on the escarpment at community boreholes can generally be described as good quality water based on these parameters and suitable for domestic use.

Table 7: Physical parameters for the sites sampled (mg/L unless otherwise stated)

Site Name	Date	EC (mS/m)	pH	TDS	TSS	Turbidity (NTU)	Total Hardness Dissolved ($CaCO_3$)	Total Alkalinity
US 201 drinking potable water specification Class 2		**250**	**6.5-8.5**	**1200**	**-**	**10**	**-**	**500**
WHO drinking water (2011)		-	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	-	-	Not of health concern at levels found in drinking-water	-
Kyabasambu stream	10/12/2013	35.1	10.00	284	1	1	-	76
Busigi stream	10/12/2013	54.3	10.10	335	3	1	-	80
Ususa spring	10/12/2013	66.7	9.30	197.5	4	2	-	76
Senjojo stream	10/02/2014	29.3	9.68	373.8	3	2	-	36
Kachunde stream	10/02/2014	44	9.95	249	2	1	-	80
Kina shores	10/12/2013	63.4	10.10	326	0	0	-	84
Lake Albert	10/02/2014	57.6	9.96	390.4	0	1	-	48
Nsonga shorelines	10/02/2014	58.9	10.03	387.8	9	6	-	88
Ususa BH (shallow well)	06/03/2014	97.9	7.23	903	-	-	246	222
Ususa BH (shallow well)	10/02/2014	85	9.38	470	5	2	-	36
Kina BH	10/12/2013	4400	7.75	20100	24	1	-	48

Site Name	Date	EC (mS/m)	pH	TDS	TSS	Turbidity (NTU)	Total Hardness Dissolved ($CaCO_3$)	Total Alkalinity
US 201 drinking potable water specification Class 2		**250**	**6.5-8.5**	**1200**	**-**	**10**	**-**	**500**
WHO drinking water (2011)		-	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	-	-	Not of health concern at levels found in drinking-water	-
Kina BH	06/03/2014	3826.7	6.89	4477	-	-	7952	258
Kyenyanja BH	10/12/2013	67.1	10.10	906	0	1	-	88
Busigi BH	10/12/2013	176.6	10.20	307	0	1	-	100
Kyenyanja BH	06/03/2014	82	8.00	916	-	-	172	290
Kyabasambu (CPF1)	06/03/2014	719.3	7.13	4776	-	-	1362	304
KYANGWALI HQ	06/03/2014	19.9	5.99	1406	-	-	73	56
KABALE 1	02/03/2014	44.4	6.74	312	-	-	164	198
KABALE 2	02/03/2014	23.3	6.60	237	-	-	55	114
KABALE 3	02/03/2014	43.3	6.99	284	-	-	169	218
KISOBA 1	02/03/2014	29.8	6.83	236	-	-	102	146
KISOBA 2	02/03/2014	44.8	7.07	301	-	-	183	206
KISOBA 3	02/03/2014	24.7	6.64	183	-	-	97	118

Site Name	Date	EC (mS/m)	pH	TDS	TSS	Turbidity (NTU)	Total Hardness Dissolved ($CaCO_3$)	Total Alkalinity
US 201 drinking potable water specification Class 2		**250**	**6.5-8.5**	**1200**	**-**	**10**	**-**	**500**
WHO drinking water (2011)		-	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	-	-	Not of health concern at levels found in drinking-water	-
HOHWA 1	02/03/2014	64.3	7.53	554	-	-	244	336
KABEGARAIRE 1	02/03/2014	39.1	7.13	292	-	-	178	186
KYARUSHESHA 1	02/03/2014	27.7	6.96	222	-	-	85	100
KASOGA 1	02/03/2014	47.5	7.36	341	-	-	227	252
KASOGA 2	07/03/2014	17.4	6.57	150	-	-	57	90
KYARUJUMBA	07/03/2014	19.1	6.62	181	-	-	59	86
HANGA 2B	07/03/2014	58	7.22	388	-	-	225	266
HANGA 2A	07/03/2014	35.9	6.74	267	-	-	114	152

Table 8: Macro Constituents (units in mg/L unless otherwise stated)

Site Name	Date	Ca	Mg	Na	F	Cl	K	SO_4	NO_3
US 201 drinking potable water specification class 2		**75**	**50**	**400**	**1.5**	**500**	**100**		**5.00**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water		50	1.5	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	50
Kyabasambu stream	10/12/2013	48	19.2	-	1.2	0.03	-	-	1.3
Busigi stream	10/12/2013	48	110.4	-	1.2	0.03	-	-	1.49
Ususa spring	10/12/2013	72	28.8	-	1	0.03	-	-	0.03
Senjojo stream	10/02/2014	136	-	-	1	0.03	-	-	0.03
Kachunde stream	10/02/2014	40	19.2	-	1	0.03	-	-	0.03
Kina shores	10/12/2013	32	43.2	-	0.9	0.03	-	-	4.4
Lake Albert	10/02/2014	27.2	34.6	-	0.9	0.03	-	-	0.04
Nsonga shorelines	10/02/2014	16	48	-	0.9	0.03	-	-	0.11
Ususa BH	06/03/2014	57.6	24.4	81	0.3	81.3	8.4	47.9	133.47
Ususa BH	10/02/2014	112	24	-	0.7	0.03	-	-	1.43
Kina BH	10/12/2013	2000	186	-	1.1	3.30	-	-	1.64
Kina BH	06/03/2014	1587	948.7	5845	-	14979.4	16.8	692.33	14.65

Site Name	Date	Ca	Mg	Na	F	Cl	K	SO_4	NO_3
US 201 drinking potable water specification class 2		**75**	**50**	**400**	**1.5**	**500**	**100**		**5.00**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water		50	1.5	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	50
Kyenyanja BH	10/12/2013	56	33.6	-	1	0.03	-	-	0.43
Busigi BH	10/12/2013	56	33.6	-	1.2	0.03	-	-	1.33
Kyenyanja BH	06/03/2014	21.8	28	87.4	0.8	56.6	49	19.12	19.88
Kyabasambu (CPF1)	06/03/2014	262.4	168	858.9	0.3	2420.9	4.2	-	2.21
KYANGWALI HQ	06/03/2014	19.9	5.5	8.3	0.4	16	2.8	10.34	2.30
KABALE 1	02/03/2014	34.1	18.7	0.03	-	5.30	2.7	40.26	1.02
KABALE 2	02/03/2014	12.4	5.8	0.03	-	0.7	1.5	5.12	2.17
KABALE 3	02/03/2014	33.8	20	0.03	0.5	3	1	17.08	1.15
KISOBA 1	02/03/2014	21.7	11.4	0.02	1	1	2.1	6.24	4.29
KISOBA 2	02/03/2014	39.7	20	0.02	1.3	15.6	2.5	17.41	0.75
KISOBA 3	02/03/2014	21.7	10.2	0.01	0.6	0.5	2.7	6.99	2.04
HOHWA 1	02/03/2014	35.2	37.2	0.05	2.7	3.5	1.2	14.32	8.54

Site Name	Date	Ca	Mg	Na	F	Cl	K	SO_4	NO_3
US 201 drinking potable water specification class 2		**75**	**50**	**400**	**1.5**	**500**	**100**		**5.00**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water		50	1.5	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	50
KABEGARAIRE 1	02/03/2014	30	24.6	0.01	0.3	2.4	2.8	24.9	0.66
KYARUSHESHA 1	02/03/2014	18.2	9.4	0.02	-	1.7	2.1	36.38	5.89
KASOGA 1	02/03/2014	61.4	17.5	0.02	1.7	1.4	2.8	18.04	0.75
KASOGA 2	07/03/2014	13.9	5.4	13.7	0.3	0.7	0.5	0.32	0.75
KYARUJUMBA	07/03/2014	13.5	6	14.1	0.5	0.5	2.7	6.18	2.21
HANGA 2B	07/03/2014	58.5	18.8	35.3	1.4	18	3.0	31.18	0.62
HANGA 2A	07/03/2014	24.8	12.4	31.7	1.1	9	1.8	16.41	2.35
Kyabasambu stream	10/12/2013	48	19.2	-	1.2	0.03	-	-	1.3
Busigi stream	10/12/2013	48	110.4	-	1.2	0.03	-	-	1.49
Ususa spring	10/12/2013	72	28.8	-	1	0.03	-	-	0.03
Senjojo stream	10/02/2014	136	-	-	1	0.03	-	-	0.03
Kachunde stream	10/02/2014	40	19.2	-	1	0.03	-	-	0.03

Site Name	Date	Ca	Mg	Na	F	Cl	K	SO_4	NO_3
US 201 drinking potable water specification class 2		**75**	**50**	**400**	**1.5**	**500**	**100**		**5.00**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water		50	1.5	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	50
Kina shores	10/12/2013	32	43.2	-	0.9	0.03	-	-	4.4
Lake Albert	10/02/2014	27.2	34.6	-	0.9	0.03	-	-	0.04
Nsonga shorelines	10/02/2014	16	48	-	0.9	0.03	-	-	0.11
Ususa BH	06/03/2014	57.6	24.4	81	0.3	81.3	8.4	47.9	133.47
Ususa BH	10/02/2014	112	24	-	0.7	0.03	-	-	1.43
Kina BH	10/12/2013	2000	186	-	1.1	3.30	-	-	1.64
Kina BH	06/03/2014	1587	948.7	5845	-	14979.4	16.8	692.33	14.65
Kyenyanja BH	10/12/2013	56	33.6	-	1	0.03	-	-	0.43
Busigi BH	10/12/2013	56	33.6	-	1.2	0.03	-	-	1.33
Kyenyanja BH	06/03/2014	21.8	28	87.4	0.8	56.6	49	19.12	19.88
Kyabasambu (CPF1)	06/03/2014	262.4	168	858.9	0.3	2420.9	4.2	-	2.21
KYANGWALI HQ	06/03/2014	19.9	5.5	8.3	0.4	16	2.8	10.34	2.30

Site Name	Date	Ca	Mg	Na	F	Cl	K	SO_4	NO_3
US 201 drinking potable water specification class 2		**75**	**50**	**400**	**1.5**	**500**	**100**		**5.00**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water		50	1.5	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	50
KABALE 1	02/03/2014	34.1	18.7	0.03	-	5.30	2.7	40.26	1.02
KABALE 2	02/03/2014	12.4	5.8	0.03	-	0.7	1.5	5.12	2.17
KABALE 3	02/03/2014	33.8	20	0.03	0.5	3	1	17.08	1.15
KISOBA 1	02/03/2014	21.7	11.4	0.02	1	1	2.1	6.24	4.29
KISOBA 2	02/03/2014	39.7	20	0.02	1.3	15.6	2.5	17.41	0.75
KISOBA 3	02/03/2014	21.7	10.2	0.01	0.6	0.5	2.7	6.99	2.04
HOHWA 1	02/03/2014	35.2	37.2	0.05	2.7	3.5	1.2	14.32	8.54
KABEGARAIRE 1	02/03/2014	30	24.6	0.01	0.3	2.4	2.8	24.9	0.66
KYARUSHESHA 1	02/03/2014	18.2	9.4	0.02	-	1.7	2.1	36.38	5.89
KASOGA 1	02/03/2014	61.4	17.5	0.02	1.7	1.4	2.8	18.04	0.75
KASOGA 2	07/03/2014	13.9	5.4	13.7	0.3	0.7	0.5	0.32	0.75
KYARUJUMBA	07/03/2014	13.5	6	14.1	0.5	0.5	2.7	6.18	2.21

Site Name	Date	Ca	Mg	Na	F	Cl	K	SO_4	NO_3
US 201 drinking potable water specification class 2		**75**	**50**	**400**	**1.5**	**500**	**100**		**5.00**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water		50	1.5	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	Not of health concern at levels found in drinking-water	50
HANGA 2B	07/03/2014	58.5	18.8	35.3	1.4	18	3.0	31.18	0.62
HANGA 2A	07/03/2014	24.8	12.4	31.7	1.1	9	1.8	16.41	2.35

5.4.3.2 Macro Chemistry

The macro chemistry consists of the major cations and anions that contributed to the salinity of the groundwater, Table 8 . It can therefore be expected that the samples that showed elevated salinity will have corresponding elevated cations and anions. The major contributing cations to high salinity down at the lake from is Na and Ca, and to a lesser extent Mg. Cl and SO_4 is the major anion contributors to salinity and the Kina borehole have a very high Cl content of nearly 15 000mg/L. Nitrate (NO_3) is another anion that is problematic and is suspected to be sourced from poor sanitation practices. Bicarbonate is the major anion of the escarpment boreholes.

Piper diagrams are used to characterise the groundwater (Figure 10). The Piper plots include two triangles, one for plotting cations and the other for plotting anions. The cations and anion fields are combined to show a single point in a diamond-shaped field, from which inference is drawn on the basis of hydro-geochemical facies concept. These tri-linear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms than is possible with other plotting methods.

From the plotted Piper Diagram, it can be seen that most of the escarpment boreholes can be characterised as Ca/Mg bicarbonate type water, which is expected from the type of geology and recharge mechanisms (rapid recharge after rainfall events) occurring on the escarpment.

The groundwater character of the lake front boreholes is less distinct, and most can be classified as Na Mg – bicarbonate with enrichment of Cl that contribute to the elevated salinity. The source of the Cl in groundwater cannot be directly linked to the lake water since the lake water samples (Kina shores, Lake Albert, Nsonga shorelines) all had very low Cl values (0.03 mg/L). The build-up of salts on the lake front plains is the result of evapotranspiration and a seasonal water level fluctuation. It is assumed that the gradient of groundwater flow towards the lake on the flats is very low and this will also contribute to the salinization of the upper soil profiles.

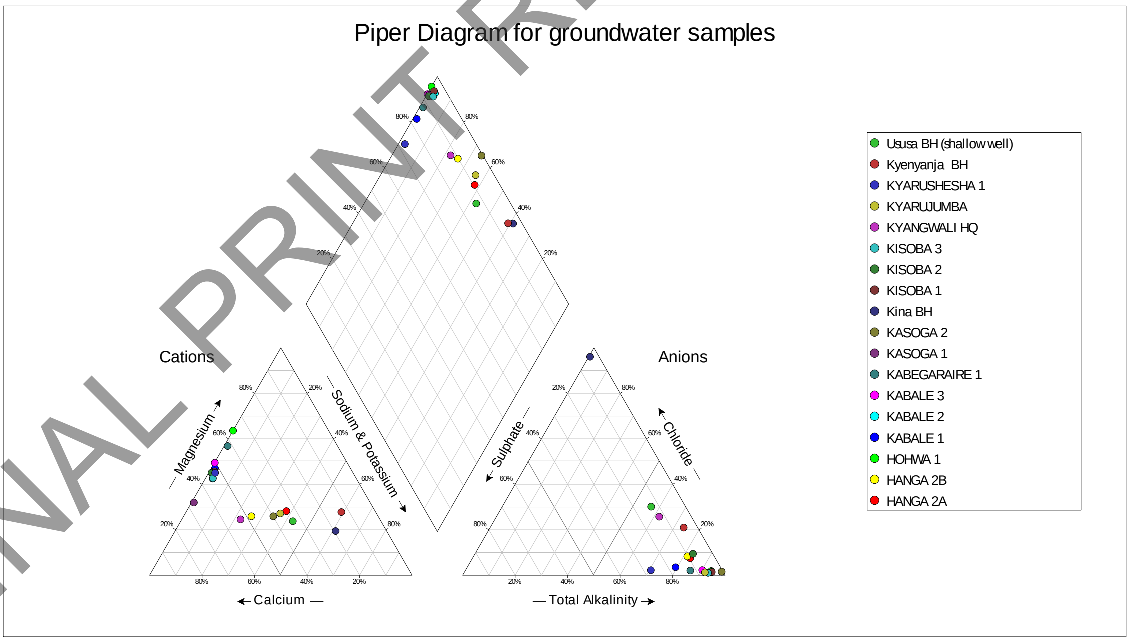

Figure 10: Piper diagram for the groundwater samples

5.4.3.3 Micro Chemistry

To determine the micro chemistry of the groundwater, a number of parameters were included in the analyses that include a wide range of trace metals. The trace metals that had positive detections are listed in Table 9.

Several trace metals exceed the set guidelines at a number of sampling points. These are: Mn, Fe, Al, Se, Pb and Hg. Pb and Hg is often associated with crude oil and natural gas occurrences but in this case the source is likely from natural groundwater leaching of the bedrock gneiss and granite. Mn, Al, Se, and Fe were also detected above guideline values at several of the sites. These elements are also associated with the gneiss and granite bedrock formations.

These elements are likely to pose a health risk in the long-term for users of the water resource.

5.4.3.4 Organic Chemistry

The samples taken during the March 2013 sample run were submitted or organic analyses consisting of Poly aromatic Hydrocarbons (PAH), Extractable Petroleum hydrocarbons (EPH), and Gasoline Range Organics. The analyses were *below detection for all the organic parameters tested in the submitted samples*.

Table 9: Micro constituents (units in mg/L unless otherwise stated)

Site Name	Date	NH_3	PO_4	Total P	Total N	Cr	Pb	Hg	Fe
US 201 drinking portable water		**1**		**10**	**10**	**0.05**	**0.01**	**0.001**	**0.03 - 3.5**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water	-	-	-	0.05	0.01	0.006	Not of health concern at levels found in drinking-water
Kyabasambu stream	10/12/2013	0.50	-	0.07	0.13	-	-	0.001	0.05
Busigi stream	10/12/2013	-	-	0.26	0.06	0.0002	0.0006	0.0011	0.01
Ususa spring	10/12/2013	0.20	-	0.15	0.29	0.001	-	-	0.01
Senjojo stream	10/02/2014	-	-	0.05	0.31	-	-	-	0.01
Kachunde stream	10/02/2014	-	-	0.10	0.28	0.0004	-	-	0.02
Kina shores	10/12/2013	-	-	0.05	0.37	0.0002	0.0004	0.0012	0.01
Lake Albert	10/02/2014	-	-	0.05	0.27	0.0004	0.0025	0.001	0.02
Nsonga shorelines	10/02/2014	-	-	0.15	0.12	0.0003	0.0025	0.0011	0.04
Ususa BH (shallow well)	06/03/2014	0.27	1.35	-	-	-	0.01	-	-
Ususa BH (shallow well)	10/02/2014	-	-	0.17	2.67	0.001	-	-	0.04
Kina BH	10/12/2013	-	-	0.04	1.18	-	-	-	0.06
Kina BH	06/03/2014	0.74	-	-	-	-	0.02	-	0.22
Kyenyanja BH	10/12/2013	-	-	0.55	0.42	0.0003	-	0.001	-

Site Name	Date	NH_3	PO_4	Total P	Total N	Cr	Pb	Hg	Fe
US 201 drinking portable water		**1**		**10**	**10**	**0.05**	**0.01**	**0.001**	**0.03 - 3.5**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water	-	-	-	0.05	0.01	0.006	Not of health concern at levels found in drinking-water
Busigi BH	10/12/2013	-	-	0.17	2.45	0.001	-	-	-
Kyenyanja BH	06/03/2014	0.44	2.48	-	-	-	-	-	-
Kyabasambu (CPF1)	06/03/2014	0.52	-	-	-	-	0.02	-	0.04
KYANGWALI HQ	06/03/2014	0.19	0.06	-	-	-	0.05	-	0.46
KABALE 1	02/03/2014	0.18	-	-	-	-	0.02	-	0.66
KABALE 2	02/03/2014	0.23	-	-	-	-	0.02	-	0.94
KABALE 3	02/03/2014	0.22	-	-	-	-	0.01	-	0.22
KISOBA 1	02/03/2014	0.86	-	-	-	-	0.02	-	0.85
KISOBA 2	02/03/2014	0.38	-	-	-	-	0.01	-	0.15
KISOBA 3	02/03/2014	0.36	-	-	-	-	0.01	-	0.03
HOHWA 1	02/03/2014	0.27	-	-	-	-	0.01	-	-
KABEGARAIRE 1	02/03/2014	0.30	-	-	-	-	0.02	-	2.06
KYARUSHESHA 1	02/03/2014	0.40	-	-	-	-	0.01	-	0.32
KASOGA 1	02/03/2014	0.41	-	-	-	-	0.01	-	0.98

Site Name	Date	NH_3	PO_4	Total P	Total N	Cr	Pb	Hg	Fe
US 201 drinking portable water		**1**		**10**	**10**	**0.05**	**0.01**	**0.001**	**0.03 - 3.5**
WHO drinking water (2011)		Not of health concern at levels found in drinking-water	-	-	-	0.05	0.01	0.006	Not of health concern at levels found in drinking-water
KASOGA 2	07/03/2014	0.40	-	-	-	-	0.01	-	1.09
KYARUJUMBA	07/03/2014	0.46	0.19	-	-	-	0.01	-	0.82
HANGA 2B	07/03/2014	0.40	-	-	-	0.009	0.02	-	1.00
HANGA 2A	07/03/2014	0.15	-	-	-	-	0.01	-	1.03

Site Name	Date	Al	Ba	Cu	Mn	Zn	Co	Ni	Se	Si	V
US 201 drinking portable water		**0.2**		**1**	**0.1 -0.5**	**3**		**0.02**	**0.01**	**-**	**-**
WHO drinking water (2011)		A health-based value of 0.9 mg/l could be derived, but this value exceeds practicable levels based on coagulation process in drinking-water plants	-	2	Not of health concern at levels causing acceptability problems in drinking-water	Not of health concern at levels found in drinking-water	-	0.07	0.04	-	-
Kyabasambu stream	10/12/2013	-	-	-	0.0016	-	-	-	0.01	-	-
Busigi stream	10/12/2013	-	-	-	0.0013	-	-	-	0.016	-	-
Ususa spring	10/12/2013	-	-	-	0.0005	-	-	-	0.013	-	-
Senjojo stream	10/02/2014	-	-	-	-	-	-	-	0.011	-	-
Kachunde stream	10/02/2014	0.17	-	-	0.0007	-	0.001	-	0.013	-	-
Kina shores	10/12/2013	-	-	-	0.0004	-	0.001	-	0.012	-	-
Lake Albert	10/02/2014	0.19	-	-	0.0008	-	0.001	-	0.024	-	-
Nsonga shorelines	10/02/2014	0.03	-	-	0.0007	-	0.001	-	0.014	-	-
Ususa BH (shallow well)	06/03/2014	0.17	0.19	-	0.598	0.06	-	-	-	27.4	0.02
Ususa BH (shallow well)	10/02/2014	-	-	-	0.16	0.00	-	-	0.0027	-	-
Kina BH	10/12/2013	-	-	-	0. 119	0.21	0.001	-	-	-	-

Site Name	Date	Al	Ba	Cu	Mn	Zn	Co	Ni	Se	Si	V
US 201 drinking portable water		**0.2**		**1**	**0.1 -0.5**	**3**		**0.02**	**0.01**	**-**	**-**
WHO drinking water (2011)		A health-based value of 0.9 mg/l could be derived, but this value exceeds practicable levels based on coagulation process in drinking-water plants	-	2	Not of health concern at levels causing acceptability problems in drinking-water	Not of health concern at levels found in drinking-water	-	0.07	0.04	-	-
Kina BH	06/03/2014	-	0.10	-	0.04	0.20	-	0.002	-	42.10	-
Kyenyanja BH	10/12/2013	-	-	0.0009	0.001	-	-	-	0.013	-	-
Busigi BH	10/12/2013	-	-	-	0.01	-	-	-	0.016	-	-
Kyenyanja BH	06/03/2014	0.05	0.09	-	0.01	0.02	-	-	-	6.2	0.02
Kyabasambu (CPF1)	06/03/2014	-	3.05	-	1.54	0.19	-	-	-	34.1	-
KYANGWALI HQ	06/03/2014	0.07	0.11	-	0.002	2.48	-	-	-	55.6	0.0017
KABALE 1	02/03/2014	-	0.09	-	0.01	0.07	-	0.002	-	53.1	0.01
KABALE 2	02/03/2014	1.10	0.08	0.01	0.06	0.03	-	0.002	-	61.8	0.003
KABALE 3	02/03/2014	-	0.18	-	0.13	0.05	-	-	-	25.9	-
KISOBA 1	02/03/2014	-	0.14	0.01	0.03	0.04	-	-	-	37.6	0.003
KISOBA 2	02/03/2014	-	0.17	0.04	0.13	0.07	-	-	-	36.7	-
KISOBA 3	02/03/2014	-	0.16	-	0.03	0.17	-	-	-	32.2	-

Site Name	Date	Al	Ba	Cu	Mn	Zn	Co	Ni	Se	Si	V
US 201 drinking portable water		**0.2**		**1**	**0.1 -0.5**	**3**		**0.02**	**0.01**	**-**	**-**
WHO drinking water (2011)		A health-based value of 0.9 mg/l could be derived, but this value exceeds practicable levels based on coagulation process in drinking-water plants	-	2	Not of health concern at levels causing acceptability problems in drinking-water	Not of health concern at levels found in drinking-water	-	0.07	0.04	-	-
HOHWA 1	02/03/2014	-	0.14	-	0.05	0.03	-	-	-	33.9	0.01
KABEGARAIRE 1	02/03/2014	-	0.04	-	0.10	0.13	-	-	-	33.4	-
KYARUSHESHA 1	02/03/2014	0.27	0.06	-	0.08	0.02	-	-	-	36.0	0.01
KASOGA 1	02/03/2014	-	0.20	-	0.35	0.01	-	-	-	46.9	-
KASOGA 2	07/03/2014	0.21	0.08	-	0.05	0.06	-	-	-	32.2	0.0018
KYARUJUMBA	07/03/2014	-	0.12	-	0.01	0.09	-	-	-	36.6	0.0048
HANGA 2B	07/03/2014	-	0.13	-	0.31	0.05	-	-	-	38.5	-
HANGA 2A	07/03/2014	-	0.13	-	0.10	0.03	-	-	-	49.4	0.004

5.4.3.5 Microbial Water Quality

As noted earlier, one of the complaints recorded by the communities was the water quality causing outbreaks of diarrhoea and cholera. It was suspected that the microbial water quality is poor in most of the water sources. To confirm this; the water had to be tested for bacteriological counts. Due to the distance from accredited laboratories, water samples at Kingfisher and along the pipeline could not be submitted for microbial testing at a laboratory. As an alternative the water was tested using Colitag™[1]. Colitag™ is a Presence/Absence and MPN (most probable number) enzyme substrate test that detects as few as 1 MPN of total coliform and *E. coli* bacteria per 100mL water sample. Results can be read any time between 16 and 48 hours. Generally, water is not considered potable if there are more than 1 MPN/100mL (or CFU/100mL) E.coli in a water sample.

Water pollution caused by faecal contamination is a serious problem contributing to diseases from pathogens (disease causing organisms). Frequently, concentrations of pathogens from faecal contamination are small, and the number of different possible pathogens is large. As a result, it is not practical to test for pathogens in every water sample collected. Instead, the presence of pathogens is determined with indirect evidence by testing for an "indicator" organism such as coliform bacteria. Coliforms come from the same sources as pathogenic organisms. Coliforms are relatively easy to identify, are usually present in larger numbers than more dangerous pathogens, and respond to the environment, wastewater treatment, and water treatment similarly to many pathogens. As a result, testing for coliform bacteria can be a reasonable indication of whether other pathogenic bacteria are present.

The most basic test for bacterial contamination of a water supply is the test for total coliform bacteria. Total coliform counts give a general indication of the sanitary condition of a water supply. Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. Faecal coliforms are the group of the total coliforms that are considered to be present specifically in the gut and faeces of warm-blooded animals. Because the origins of faecal coliforms are more specific than the origins of the more general total coliform group of bacteria, faecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms.

Escherichia coli (*E. coli*) is the major species in the faecal coliform group. Of the five general groups of bacteria that comprise the total coliforms, only *E. coli* is generally not found growing and reproducing in the environment. Consequently, *E. coli* is considered to be the species of coliform bacteria that is the best indicator of faecal pollution and the possible presence of pathogens. The results from the Colitag™, therefore gives an indication of the presence of Total coliform and *E. coli* bacteria in the water samples.

Samples were taken from all the hydrocensus boreholes, springs, the gravity flow system, and Lake Albert to test for the bacteria. Results are indicated in Table 10 and full results with photographs and site descriptions are provided in Appendix C.

Table 10: Colitag™ test results

	Total coliforms	*E. coli*
Kingfisher (Buhuka Flat)		
KYABASAMBU-CPF 1	yes	yes
KYABASAMBU-CPF 1	yes	yes
NSONGA-CPF2	yes	yes
LAKE-JETTY	yes	yes
GRAVITY FLOW-CPF	yes	yes

[1] Colitag™ is a Presence/Absence and MPN (most probable number) enzyme substrate test that detects as few as 1 MPN of total coliform and *E. coli* bacteria per 100mL water sample. Results can be read any time between 16 and 48 hours. Generally water is not considered potable if there are more than 1 MPN/100mL (or CFU/100mL) E.coli in a water sample

	Total coliforms	*E. coli*
USUSA BH	no	no
USUSA SPRING	yes	yes
KENYANYA BH	yes	yes
KYENYANYA SPRING	yes	yes
BUSIGI BH	yes	no
BUSIGI SPRING	yes	yes
KIINA	no	no
GRAVITY FLOW-KIINA	yes	yes
KACUMDE SPRING	yes	yes
LAKE-KACUMDE	yes	yes
LAKE-JETTY	yes	yes
LAKE-JETTY DUP	yes	yes
KYABASAMBU STREAM	yes	yes
Along the pipeline		
KABALE 1	no	no
KABALE 2	no	no
KABALE 3	yes	yes
KISOBA 1-STREAM (NYANKEREBE)	yes	yes
KISOBA 2	yes	yes
KISOBA 3	yes	yes
HOHWA	yes	yes
KABEGARAMIRE 1	yes	yes
KYARUSHESHA	yes	yes
KASOGA 1-SPRING	yes	yes
KASOGA 2	yes	yes
KYARUJUMBA	no	no
HANGA 2A	no	no
HANGA2B	yes	yes
KYANGWALI –NYAKATEHE I	no	no

From the results it can be seen that from the surface water samples tested that 100% tested positive for total Coliforms and *E.coli*. The boreholes on the Buhuka flats and lake front villages had a 71% positive result. Similarly, the escarpment villages along the pipeline had a 72% positive result. This shows that the majority of the water sources utilised by communities for domestic use in both areas are not fit for use. The water quality is negatively influenced by poor or non-existing sanitation practices.

5.4.4 Hydrogeological Conceptual Model

The groundwater resources at the Kingfisher Project site and associated pipeline infrastructure can be summarised as followed:

- On the Buhuka flat and lake front villages the groundwater is utilised as a source of domestic water through shallow wells and deeper installed wells. Most are equipped with hand pumps and sealed at surface;
- The groundwater is assumed to be associated with the bedrock formations consisting of granite, gneiss or quartzite formations on the escarpment and with sediments such as sandstone down at the lake front. All geological information was limited to National database information and no ground truthing through drilling was done;
- In general, on the flats next to the lake, the first 50 m below ground is dominated by sand, increasingly interbedded with clay layers at depth, but the sequence of sands and clays is not laterally continuous. Hydrogeologically, the sand deposits can provide reasonably productive aquifers. Rivers crossing the area typically lose water, demonstrating infiltration into the permeable sandy deposits. However, the frequent interbedded clay layers break the sand deposits up into hydraulically isolated units. Borehole yields are highly variable, and even when yields are good, the boreholes would not support sustained abstraction at high rates (Figure 11).
- Water level elevations were interpolated for the area, and static water levels showed great variation between 1m to 63m below ground level. The variability in water levels confirms the fractured and thus heterogeneous character of the aquifers;
- Groundwater levels are about 10 m below ground level (mbgl) near the lake shore, with depth to water increasing inland as the topography rises. Correcting the groundwater levels into metres above datum, a hydraulic gradient is revealed, driving groundwater flow towards the lake, in a similar pattern to surface water. Groundwater levels just inland from the lake appear to be below lake level; this could just be because datum levels are inaccurate, or it could represent a groundwater discharge zone.
- Water quality on the Buhuka flats are very poor and characterised by very high salinity (and corrosive character) caused by accumulation of salts from evapotranspiration and seasonal water fluctuations;
- Water quality along the escarpment villages was generally acceptable with some trace metals exceeding the drinking water guidelines;
- No organic (petroleum) hydrocarbons were detected in any of the samples; and
- Microbial water quality was very poor and most of the water sources including the lake water tested positive for Coliforms and E.coli. The cause of this is most likely due to poor or non-existing sanitation practices.

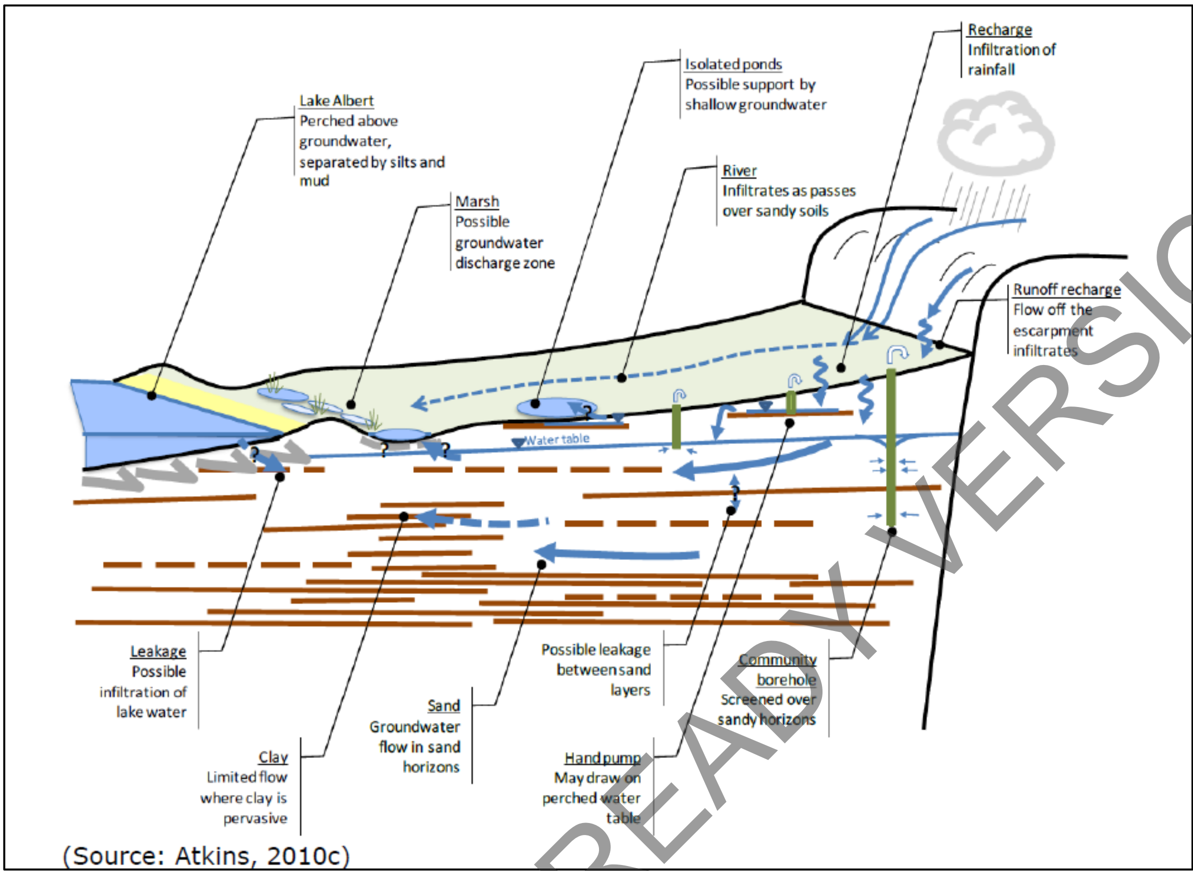

Figure 11: Site hydrogeological conceptualisation from Atkins, 2010

6.0 IMPACT ASSESSMENT

6.1 Impact Assessment Rating of Potential Impacts

The methodology and approach followed during impact assessment in the detailed ESIS is described below.

Potential impacts during the construction, operational and decommissioning/restoration phases of the project are considered separately in the ESIA.

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 significance of the potential impact can be determined. The determination of significance of an impact is largely subjective and primarily based on professional judgment.

The types of potential Project impacts considered appropriate for the groundwater assessment are summarised in Table 11.

Table 11: Types of Potential Groundwater Impacts

Direct Impact	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors
Cumulative impact	Impacts that act together or combine with other impacts (including those from concurrent or planned activities) to affect the same resources and/or receptors of the Project.

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 (Table 12). The significance of impact is then indicated by the product (multiplication) 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 12: Determination of impact significance

			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 13: 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.

6.2 Construction Phase Impacts

From a hydrogeological perspective, the following section summarises the potential impacts that are related to the construction phase of Kingfisher Well Field Development, and provides a significance rating for each impact before and after mitigation (Table 14). The construction phase activities that could potentially impact on the groundwater resource include the materials handling, water demand, and waste generation associated with the following elements:

- Residential, ablution, kitchen and administration facilities for Contractors and CNOOC workers;
- Drilling of oil production wells and the water injection wells from the five well site locations adjacent to the banks of Lake Albert;
- Construction of a 40,000 bopd design capacity CPF on the Lake Albert Buhuka Plain;
- Linking of the well sites to the CPF by buried, heated and insulated production flow lines, water injection lines, electrical cables, and fibre optic cables;
- Construction of a water intake and water extraction pump station on the shore of Lake Albert to the beach, a water extraction pump station on the beach, and a buried water transfer pipeline to the CPF;
- Construction of permanent operators' accommodation near the CPF;
- Construction of a power station at the CPF fuelled by produced gas from the CPF during initial years of production and by crude oil during the later years of production;
- Construction of a pump station at the CPF and a heated, insulated, ~50km crude oil transmission pipeline from the CPF to Kabaale; and
- Construction of a buried high voltage electrical transmission line from the CPF to Kabaale to power pipeline heating stations and block valve stations.

Currently, there is an existing Bugoma drilling camp in Kingfisher that accommodates the crews undertaking field planning and rehabilitation of some field infrastructure ahead of the anticipated field development program. Kingfisher field construction and the production phase will however necessitate a number of various crews that will undertake among other activities, the construction and upgrade of the necessary infrastructure (pipeline, CPF, well sites among others), drilling, production and processing, management of crude export along the pipeline and other support service contractors. These activities are intensive and necessitate resident specialized crews to be accommodated in close proximity to their work stations. Since however, the temporal occupation of the various crews is not uniform and only dependent on the lifespan of the particular project component, there is a consideration to have more than one camp for the project to include:

- The drilling crew camp (drilling camp) – which is the existent current Bugoma camp and can accommodate a maximum of about 250 people.
- Two temporary construction camps will be required: One is dedicated to the CPF and in-field facilities and the other is associated with the crude oil pipeline construction. The CPF and In-field Construction camp would be located on the Buhuka flats north of the CPF. The camp will comprise accommodation, messing and welfare facilities for the labour force undertaking the construction and commissioning work. The construction camp dedicated to the construction of the export pipeline from Kingfisher CPF to Kabaale would be significantly smaller than the main Kingfisher Construction camp and would be fully self-sufficient comprising power generation, water treatment and sewage and waste disposal.

6.2.1 Abstraction of groundwater for potable use

Groundwater on the Buhuka flats is not seen as a sustainable or potable source of water. The main water supply for the Project will be from Lake Albert and therefore abstraction of groundwater is not considered to be an associated impact of the Project. However, should later investigations prove that groundwater abstracted from deeper aquifers (not yet explored) is an option for water supply, the abstraction and associated impacts on the groundwater system will have to be reassessed, defined, and quantified.

6.2.2 Generation of domestic waste water discharge

Domestic waste water from the construction camp kitchen, bathrooms, residential block, and administration areas will be discharged in subsurface drains, until the permanent waste water treatment plant is completed. There is no current detail information on the expected volumes of domestic waste water that will be generated and the design of the systems. The impact description is therefore based on experiences from similar projects.

The presence of the additional workers on site during construction will increase the pressure on the sewage water systems and potential for overloading the existing waste water treatment systems is possible. This could result in spillages and malfunctioning of drain systems, which can lead to shallow groundwater pollution.

The impact for this activity (i.e. potential for groundwater pollution) is rated at **moderate** (9) before mitigation, because of the medium sensitivity and magnitude of the impact expected without mitigation. Post mitigation the impact will be **minor** (4).

Mitigation measures include:

- Adequate design and management to handle the expected volumes of effluent and allow drainage in order not to cause flooding or over saturation of the subsurface.
- Downstream groundwater monitoring of the systems is recommended especially in the case where groundwater may be used for domestic supply.
- Solid and liquid waste must remain contained and quarantined, and be disposed of at an appropriately licenced facility (a register containing safe disposal receipts should be maintained on site);
- Bins must be provided on site for both contractors and security personnel. Litter must be removed from site and disposed of correctly; and

6.2.3 Generation of sanitation waste– well pads and pipeline construction

During the construction phase of the well pads and pipeline (located away from the Construction camp), sanitation waste will be generated by workers. There are no permanent ablution facilities associated with these construction sites, and the workers will have to be provided with adequate sanitation solutions on site to prevent the disposal of waste in unsanitary manners. The informal disposal of these wastes can lead to pollution of the groundwater resources at the construction sites.

The impact from this activity can potentially be **moderate** (9) if local communities along the pipeline route's groundwater resources are polluted from the waste disposal which can cause the outbreak of waterborne diseases such as cholera. The impact can however be reduced to **minor** (4) if adequate mitigation measures are put in place.

Mitigation will typically be the provision of clean water or hand washing and provision of portable toilets at the construction sites. These portable toilets need to be managed and maintained in a manner that will protect the environment.

6.2.4 Waste generated during the maintenance of equipment and machinery

Hazardous waste materials will be generated during the construction phase ranging from used solvents, used oil and grease, etc. The magnitude of the groundwater impact of the generation of hazardous waste before mitigation is expected to be **major** (12), because of high sensitivity of groundwater.

Mitigation measures include:

- Vehicles/ machinery must be maintained and serviced when necessary to prevent leaks and breakdowns. As a minimum, the following must be done:
  - Avoid overfilling of tanks;
  - Ensure correct disposal of hydrocarbons such as lubricants and oils.
  - Toxic chemicals (e.g. fuel, lubricants and oils) must be kept within an appropriate bund;
  - Vehicles must be parked in a designated place with drip trays and spill kits readily available;
  - All vehicles must be regularly services and in good working order.
  - Ensure an appropriately trained person is on site at all times to quickly deal with spills.
- Vehicles/ machinery must be kept at least 100m from water resources;

After the implementation of mitigation measures, the magnitude can be reduced to **minor** (4) and the potential impact will be of short term and limited to the directly affected site.

6.2.5 Accidental spills of materials stored and handled

It is expected that large volumes of potential hazardous materials will be stored and handled at the CPF construction site. The risk for a spill has to be considered as a potential impact. The magnitude of the impact is considered to be **major** (12) before mitigation measures are adopted.

Mitigation of these types of impacts will include the setup of site specific risk assessments and materials handling procedures by construction workers. All chemicals (e.g. fuel, lubricants and oils) must be kept within an appropriate bunded areas. All workers should be made aware of the risks associated with handling these hazardous materials and spill prevention and clean-up measures. With these applied mitigation measures the impact on the groundwater can be reduced to **minor** (4).

6.2.6 Domestic Waste generation

The influx of construction workers and permanent staff on the flats will cause the generation of domestic waste from the residential and construction camp. The wastes generated will typically constitute food packaging, food waste, plastic bags, and bottles, etc.

Potentially if the domestic waste is not properly disposed of or managed it can lead to groundwater pollution at the waste disposal site. A formal waste management plan that includes re-use and recycling will be required to reduce the impact from this activity on the groundwater source.

The EPC contractor will be required to comply with Ugandan Waste Regulations and IFC waste management guidelines, which encompass the principles of the waste hierarchy. Waste generation and waste disposed to landfill will be minimised. All re-usable and recyclable waste will be separated at source from waste destined for disposal to landfill. Waste will be labelled and stored in covered temporary storage areas, for collection.

The impact is therefore rated as **moderate** (9) before mitigation and after mitigation can reduce to **minor** (4).

6.2.7 Well drilling

All 40 wells are proposed to be drilled from five onshore well pads: Pad 1, Pad 2, Pad 3, Pad 4-2 and Pad 5. Amongst those well pads, Pad 1, Pad 2 and Pad 3 are already existing pads. A typical pad for drilling will be approximately 200m by 100m in size. These will be fenced facilities.

During the drilling phase, a typical well pad will include a rig and auxiliary facilities, drill waste pits, fuel tank storage area, drilling fluids preparation area and mud tank, flare pits for emergency use, control rooms, fence among others. All five well pads including three existing well pads will be constructed and/or upgraded to meet development well drilling requirements. It should be noted that drilling operations of development wells shall continue after the onset of the first oil production. Therefore, the construction phase and operation phase will overlap for this task.

The potential impacts on the groundwater resource from drilling are caused by:

- Drill fluids management and disposal;
- Mud cuttings disposal;
- Materials handling; and
- Well blow-out.

There will be two types of drill fluids to be used at Kingfisher Project: Water Based Mud (WBM) and Synthetic Based Drilling Mud (SBM). WBM will be used to drill the upper portions of the well (26" hole section) only and is designed to be environmentally friendly and its constituents will typically include:

- Water, from Lake Albert
- Bentonite (naturally occurring montmorillonite clays)

It is known that the WBM with constituents listed above pose little or no ecological risk. "Saraline 185V" as the base product for SBM has been selected based primarily on its acceptability in the drilling environment and extensive testing on the fluid to determine its impact on the environment. Extensive testing has been conducted over a number of years to validate its non-toxicity in the water column and biodegradability.

The main concern for use of SBMs is safe disposal of SBM associated drill cuttings. Drilled cuttings removed from the wellbore are typically the largest waste streams generated during oil and gas drilling activities. The impacts on the groundwater from drilling fluids will thus be related to improper handling and disposal of the drill fluids and cuttings that can cause groundwater pollution. However, to the use of the selected drill fluids the impact is rated as **moderate** (9) before mitigation and reduce to **moderate** (6), with a lower sensitivity, after considering the mitigation measures in place to safely handle and store drill fluids.

A well blow-out is the uncontrolled release of crude oil from a well, resulting in the release of hydrocarbons, water-based mud and/or water. Blow-outs can occur during exploration or development drilling. They can also occur in the production stage, for instance during maintenance work on a well or due to escalation of a collision or a fire or explosion on the platform. The risk of a blow-out is minimal and not all blow-outs have significant environmental impacts. A blow-out will last until the well is under control again. This may take anywhere from a few hours if control can be regained using the safety systems, up to several months if an additional well needs to be drilled to regain control over the first well. Experience has shown that control over wells can be regained in one or a few days if a blow-out should occur.

The crude oil mixture released during a blow-out, will have a detrimental effect on groundwater systems if not brought under control timeously; and is potentially the most severe and long-term environmental impact associated with oil and gas projects. However, blow out incidents are limited by the use of technology advances in drilling techniques and fluid management. The impact is listed here as **Major** (16) based on the potential to cause detrimental damage to aquifers and other water sources in the case of a blow-out. The mitigation measures reduce the impact to **moderate (9)** based on the low likelihood of such an incident occurring.

Table 14: Construction Phase Impacts

			Pre-mitigation			Post-mitigation		
Receptor	**Description**	**Type of Impact**	**Sensitivity**	**Magnitude of Impact**	**Impact Significance**	**Sensitivity**	**Magnitude of Impact**	**Impact Significance**
Groundwater	Pollution from domestic waste water discharge	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from sanitation waste - well pads and pipeline construction	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from accidental spills from materials handling	Direct	High	Medium	12 Major	Low	Low	4 Minor
Groundwater	Pollution from waste generated during vehicle maintenance	Direct	High	Medium	12 Major	Low	Low	4 Minor
Groundwater	Pollution from domestic waste disposal	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from drill wastes - management and disposal	Direct	Medium	Medium	9 Moderate	Low	Medium	6 Moderate
Groundwater	Pollution from well blow-out	Direct	High	High	16 Major	Medium	Medium	9 Moderate

6.3 Operational Phase Impacts

The operational phase of the Kingfisher project will include a number of activities that could potentially impact on the groundwater resources. The Project surface facilities shall cover the Kingfisher production and transmission system from outlet of the well Christmas choke valves; to inlet flange of delivery point and include the following elements:

- Operational Well pads;
- Flowlines;
- Central Process Facilities (CPF);
- Crude oil Pipeline;
- Lake Water Extracting Station; and
- Infrastructure (camps, roads, buildings, etc.).

The well-fluids from the Kingfisher field will be sent to a CPF on the Buhuka flats. In general, 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 treatment plant
- Fire water and pumps
- Plant Utilities area
- Control room and administrative buildings
- Maintenance workshop
- Gatehouse
- Perimeter fencing, lighting and internal access road system

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 of oil.

Associated gas will be separated at the CPF and utilized in priority for field requirements such as fuel gas for power generation, heating system and other utilities.

Produced water from separators is required to be treated in three stages of separation to achieve the injection water specifications. 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.

After well completion, the rig and the auxiliary facilities will be removed, and feeder field pipeline will be installed to conduit the crude from the well to CPF. Some minor adjustments in the well configuration design may be adopted to factor in the infrastructural changes. Normally, each well pad comprises:

- Production well heads and manifolds
- Water injection wells and manifolds (described in more detail in Section xx);
- 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 etc.

The well pads will be security fenced, with a 24-hour security guard, but will not otherwise be manned. All normal monitoring and operational requirements will be managed from the CPF control room.

A production manifold shall be installed at each well site to gather produced fluids from the production choke valve on each Christmas tree (well head) via the individual well flowline. A test manifold shall also be provided to allow well testing to occur without interrupting production. The individual well flowlines shall be provided with manual block valves to divert produced fluids from production to test manifolds.

A water injection manifold shall be installed at each well site to deliver high pressure water for injection to the water injection choke valve on the Christmas tree via individual well flowlines. The individual well flowlines shall be provided with a manual block valve and a flowmeter.

The well-fluids (mixture of gas, crude and water, etc.) from the Kingfisher Field will be sent to the CPF (as described above) via infield flowlines from individual well pads. All individual well flowlines and manifolds shall be heat traced and insulated for heat conservation. Its design shall allow for drilling rig to move between different slots without shutting down production from the well pad. The well pads are designed as normally unmanned. Firefighting philosophy will also be defined for drilling and completion operations and workover operations and normal production on the well pads.

A buried crude oil pipeline about 50km long with a width of approximately 12”~14” (and requiring a servitude of approximately 30m) with Block Valve Station (BVS) on the escarpment is proposed for the oil export from CPF to the delivery point. Electricity shall be generated at the Kingfisher CPF. A high voltage transmission cable (buried and installed in the same trench as the oil export pipeline) routes from Kingfisher CPF to Kingfisher Block Valve Station and on to Kabaale, with connections to each intermediate heating station and isolating block valve station along the route of the export pipeline. Each connection shall include a local transformer and switchgear.

6.3.1 Generation of domestic waste water discharge

The permanent operators’ accommodation Camp (production camp) would be sized for around 220 personnel (approximately 200m x 150m) and would include operational, maintenance, support, security and Well Workover personnel.

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, discharge into an artificial wetland and other possibilities to be considered in the ESIA. Injection with produced water is not feasible due to the risk of bacterial contamination in the reinjection wells.

There may be potential for groundwater pollution as a result of spillages and malfunctioning of the WWTP system, as well as from seepage from drains, which can lead to shallow groundwater pollution. The impact for this activity which is the potential for groundwater pollution is rated at **moderate** (9) before mitigation, because of the medium sensitivity and magnitude of the impact expected without mitigation.

Mitigation measures include adequate design of the WWTP and management to handle the expected volumes of effluent and treated effluent discharge. Downstream groundwater monitoring of the systems is recommended especially in the case where groundwater may be used for domestic supply. Post mitigation the impact will be **minor** (4).

6.3.2 Solid Waste Generation

Domestic waste generation is common to both the construction and operational phase. As discussed in section 6.2.6 above, the influx of workers on the flats will generate domestic waste at the residential and operational areas. Waste will typically comprise of food packaging, food waste, plastic bags and bottles, etc. A formal waste management plan that includes re-use and recycling will be required to reduce the impact from this activity on the groundwater source and a formal waste handling/disposal site will have to be developed.

The Project will comply with the Ugandan National Environment (Waste Management) Regulations, S.I. No 52/1999. Reference will also be made the OGP (International Association of Oil & Gas Producers), Guidelines for Waste Management with special focus on areas with limited infrastructure (updated March 2009) as a best practice reference.

The management of solid wastes generated at the CPF is described below. Further details of solid waste management are provided in the CNOOC Waste Management Philosophy (KF-FS-RPT-CPF-SA-0002) and in the Waste Management specialist study undertaken as a part of the ESIA.

The Ugandan Waste Management Regulations prohibit the ‘treatment’ of petroleum waste by the operator.

CNOOC’s Waste Management Design Philosophy (2016) commits the company to comply with the key principles underpinning the waste hierarchy, which are, wherever possible, to avoid or reduce the generation of waste (or waste toxicity) at source, and/or to re-use or recycle the waste, before considering disposal options. This philosophy is also enshrined in the Ugandan Waste Management Regulations and in most international waste management standards and guidelines, including those of the IFC/World Bank.

Wastes will be segregated and stored temporarily at designated Waste Collection Points (WCPs) which will operate at the CPF. The WCPs will typically comprise of concrete hardstands, storage containers, secondary containment for hazardous liquid wastes (oil etc.), and provisions to prevent ingress of rain and sunlight, as well as protection measures from fire. Space will be reserved for separate storage containers to store prime recyclables (paper, cardboard, scrap, metal), domestic waste and hazardous waste which require segregation. A Waste Storage Area (WSA) will be determined as the central collection area for all stored waste generated at the CPF and as the transit station for collection by waste contractors for disposal.

Waste streams will be divided into three broad groups:

- recyclable / recoverable;
- general (non-hazardous); and

- hazardous.

Waste will be segregated at source. Once the waste is segregated, the labelled containers will be stored in the WCP area with secondary containment, where necessary. The waste management area will be concrete floored, bunded and roofed to prevent rainfall ingress. The temporary storage area for hazardous wastes will be secured to prevent unauthorized access.

Hazardous waste materials will be generated during the operation phase ranging from used solvents, used oil and grease, etc. The magnitude of the groundwater impact of the generation of waste before mitigation is expected to be **major** (12). After the implementation of mitigation measures, such as the waste management plan, the magnitude can further be reduced to **moderate** (6) and the potential impact will be of short term and limited to the directly affected site.

6.3.3 Accidental spills of materials stored and handled

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.

It is expected that large volumes of potential hazardous materials will be stored and handled at the CPF site. The risk for a spill has to be considered as a potential impact. The magnitude of the impact is considered to be **major** (16) before mitigation measures are adopted. Mitigation of these types of impacts will include the setup of site specific risk assessments and materials handling procedures by construction workers. All workers should be made aware of the risks associated with handling these hazardous materials and spill prevention and clean-up measures. With these applied mitigation measures the impact on the groundwater can be reduced to **moderate** (8).

6.3.4 Waste generated during flow line and CPF maintenance activities

Operational activities consider routine maintenance such as welding, pigging of flowlines and, testing. Impacts are spillages of solid or pigging waste or, of hydro-test water. Potentially hydrocarbon contaminated drainage including pigging waste need to be collected in sumps for drumming and disposal at the CPF. The drums should be protected from rain water ingress. Hydro-testing should be carried out with a minimum of chemical additives and hydro-test water will be kept in lined ponds until tested and if necessary treated to remove contaminants prior to release through distribution to the surrounding environment. Adopting the correct mitigation measures reduces the magnitude of the impact from **moderate** (9) to **moderate** (6).

6.3.5 Inadequate drainage/stormwater management

Potentially Oil Contaminated (POC) stormwater 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 stormwater runoff value of 120 m^3 (equivalent to runoff of 478 m^3/hr) is provided for. The balance of any stormwater will be captured in a stormwater pond, tested and released into the environment, if it meets the discharge specification. All stormwater from designated non-hazardous areas of the plant will be released directly from the open drains, without testing.

The design and application of drainage/stormwater management ensures that contamination of groundwater and other receptors is avoided. The system will require permanent maintenance in order to ensure it has the capacity to handle the required volumes. A potential impact is associated with the failure of the drainage system to function to its capacity. The magnitude of the impact is determined to be **moderate** (9) after mitigation, which should include upgrading and continually managing the drainage systems on site, the magnitude is lowered to **minor** (3).

6.3.6 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.

Management and mitigation can reduce the potential impact on the groundwater from these waste sources from an impact rating of **moderate** (9) to **minor** (4).

6.3.7 Produced Water Injection

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.

Injection water will consist of a combination of produced water, water from POC areas at the CPF and make up water from Lake Albert. All injection water will be treated to meet the injection water specification. The stringent requirement to remove oil from the produced water (Table 15) 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 15: 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	$< n \times 10^3$ ($1<n<10$)
Metatrophic bacteria	unit/ml	$< n \times 10^3$ ($1<n<10$)

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.

Maximum water injection pressure will be 199.8 bar (a typical car tyre is pressurised to around 2.5 bar). Pressure will be provided by pumps located at the CPF. Produced water injection temperature at the well head will be 75ºC. Produced water will be heated at the CPF and transmitted along the injection flowlines to the injector wells. Sixty three percent of the oilfield thermal load (heating requirement) will be for produced water injection, the balance being heating required for maintenance of minimum required oil temperatures. 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. CNOOC proposes to test polymer flooding after first oil, which is a method of adding a polymer to the injection water that increases its viscosity and improves oil recovery performance from the reservoir.

There are various chemical constituents that could be present in the Produced water. These chemicals, individually or collectively, could have significant impact on the environment if releases through accidents, leakage from the wells, or spillages. The severity of an uncontrolled release of produced water impact is therefore rated as **major** (16) but can be reduced to **moderate** (9) after mitigation.

6.3.8 Pipeline or Flowline Failure

The processes utilised at the CPF and pipelines are complex and, in many instances, involve high pressures. Potential failures of materials and equipment could result in the accidental release of hazardous materials and severe groundwater pollution if not brought under control. The main pipeline to Kabaale will follow a route through several communities that are dependent on groundwater as the main water supply. The associated impact is therefore determined as **major** (16) before mitigation. Mitigation will involve hazardous materials management plan including: equipment audits, flow line testing, inspections programs; as well as application of Standard Operating Procedures (SOPs). The probability of such an event taking place over the life time of the plant and pipeline is high before the mitigation but the impact rating is lowered to **moderate** (9) following mitigation.

6.3.9 Well Failure or Blow-out

A well blow-out is the uncontrolled release of crude oil from a well, resulting in the release of hydrocarbons, water-based mud and/or water. Blow-outs can occur during exploration or development drilling. They can also occur in the production stage, for instance during maintenance work on a well or due to escalation of a collision or a fire or explosion on the platform. The risk of a blow-out is minimal and not all blow-outs have significant environmental impacts. A blow-out will last until the well is under control again. This may take anywhere from a few hours if control can be regained using the safety systems, up to several months if an additional well needs to be drilled to regain control over the first well. Experience has shown that control over wells can be regained in one or a few days if a blow-out should occur.

The crude oil mixture released during a blow-out, will have a detrimental effect on groundwater systems if not brought under control timeously; and is potentially the most severe and long-term environmental impact associated with oil and gas projects. However, blow out incidents are limited by the use of technology advances in drilling techniques and fluid management. The impact is listed here as **Major** (16) based on the potential to cause detrimental damage to aquifers and other water sources in the case of a blow-out. The mitigation measures reduce the impact to **moderate (9)** based on the low likelihood of such an incident occurring.

Table 16: Operation Phase Impacts

			Pre-mitigation			Post-mitigation		
Receptor	**Description**	**Type of Impact**	**Sensitivity**	**Magnitude of Impact**	**Impact Severity**	**Sensitivity**	**Magnitude of Impact**	**Impact Severity**
Groundwater	Pollution from domestic waste water discharge	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from accidental spills from materials handling	Direct	High	High	16 Major	High	Low	8 Moderate
Groundwater	Pollution from waste generated during flow line and CPF maintenance activities	Direct	Medium	Medium	9 Moderate	Medium	Low	6 Moderate
Groundwater	Inadequate drainage/stormwater management	Indirect	Medium	Medium	9 Moderate	Medium	Very Low	3 Minor
Groundwater	Pollution from solid waste generation	Direct	High	Medium	12 Major	Medium	Low	6 Moderate
Groundwater	Production Waste Generated on the Well pad	Direct	Medium	Medium	9 Moderate	Low	Low	4 Minor
Groundwater	Pollution from Produced Water Injection	Direct	High	High	16 Major	Medium	Medium	9 Moderate
Groundwater	Pollution from pipeline/flowline failure	Direct	High	High	16	Medium	Medium	9 Moderate

			Pre-mitigation			Post-mitigation		
Receptor	**Description**	**Type of Impact**	**Sensitivity**	**Magnitude of Impact**	**Impact Severity**	**Sensitivity**	**Magnitude of Impact**	**Impact Severity**
Groundwater	Pollution from well blow-out	Direct	High	High	16 Major	Medium	Medium	9 Moderate

6.4 Cumulative Impacts

Cumulative impacts can be described as the impacts on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future activities at a project site. Cumulative impacts can therefore result from individually minor but collectively significant actions taking place over a period of time.

All the “past, present, and future activities” associated with the oil field development in the Albertine Graben is located outside of the Kingfisher and Block EA 3A areas operated by CNOOC. The potential groundwater impacts discussed and identified in the previous sections related to materials, waste, and effluent handling. The groundwater pollution resulting from these activities will be localised to the site of occurrence and will affect the resource (groundwater and surface water) directly downstream. It is not foreseen that the impacts will be affecting the resources in an area more than 1km from the impact site – unless in the case of an unlikely catastrophic well blow out or pipeline failure.

It is therefore concluded that there will be *no cumulative impacts on the groundwater resource* as a result of adjacent oil field development

6.5 Residual impacts

Residual impacts on groundwater would depend on the success of implementation of mitigation measures to prevent the contamination of groundwater resources by activities of all phases of the project lifecycle. Ongoing groundwater monitoring would indicate if residual impacts could occur and should be managed accordingly.

7.0 MITIGATION MEASURES

7.1 Construction Phase Mitigation

Performance Standard 1 of the IFC Standards (Assessment and Management of Social and Environmental Risks) establishes the overarching process of managing social and environmental risks and impacts throughout the life of the project. The major objectives are to identify and evaluate these social and environmental risks; to adopt a mitigation hierarchy that responds to these risks; to ensure communications with external stakeholders are appropriately managed and promoted; and to provide a means for the adequate engagement of affected communities. All mitigation measures discussed here thus takes cognisance of the IFC Standards, together with the relevant Ugandan legislative requirements, CNOOC’s in-house environmental specifications and acceptable industry best practice.

The impacts expected on groundwater resources are discussed in the previous sections touched on mitigation measures that could be applied to minimise the impacts and reduce impact severity. Impacts are mostly related to waste water and solid waste generation during the construction phase and mitigation measures typically consist of management plans to handle hazardous materials, waste and waste water to reduce the impacts.

Sewage waste from workers camps etc. should be treated and disposed of in accordance with (i) the National Environment (Standards for Discharge of Effluent into Water or on Land) Regulations, S.I. No 5/1999; (ii) The IFC General EHS Guidelines for environmental Waste water and ambient water ; and (iii) the Company requirements as stated in Water Management Specification (2148-QHSE) Table 20:

Table 17: Standards for Discharge of Effluent

Parameter	Unit	Uganda	IFC	Company requirement
pH	pH	6 – 8	6 – 9	6 – 8
BOD	mg/l	50	30	30
COD	mg/l	100	125	100

Parameter	Unit	Uganda	IFC	Company requirement
Total nitrogen	mg/l	10	10	10
Total phosphorus	mg/l	10	2	2
Oil and grease	mg/l	10	10	10
Total suspended solids	mg/l	100	50	50

CNOOC's Waste Management Design Philosophy (2016) commits the company to comply with the key principles underpinning the waste hierarchy, which are, wherever possible, to avoid or reduce the generation of waste (or waste toxicity) at source, and/or to re-use or recycle the waste, before considering disposal options. This philosophy is also enshrined in the Ugandan Waste Management Regulations and in most international waste management standards and guidelines, including those of the IFC/World Bank.

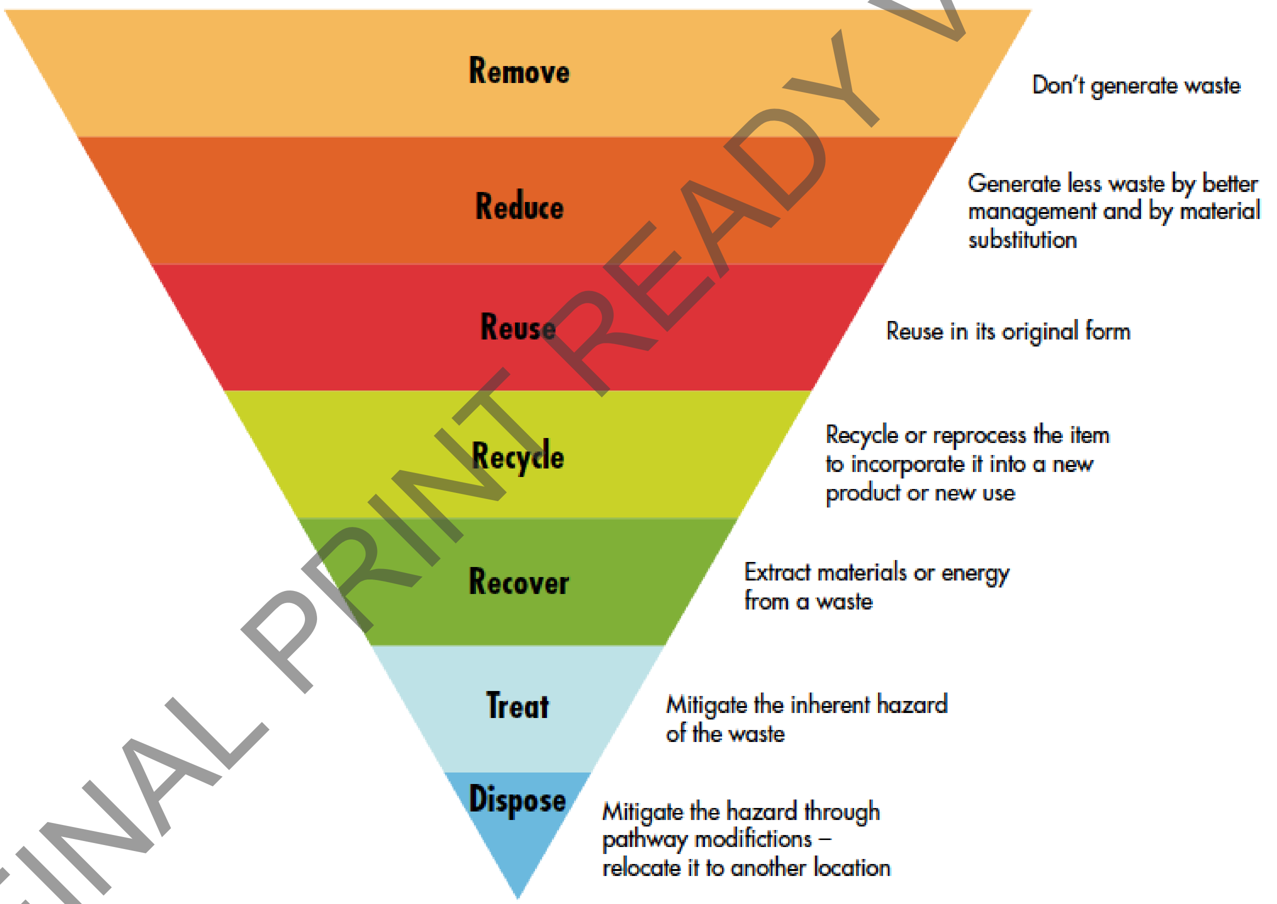

Figure 12: The solid waste management hierarchy

Wastes will be segregated and stored temporarily at designated Waste Collection Points (WCPs) which will operate at the CPF. The WCPs will typically comprise of concrete hardstands, storage containers, secondary containment for hazardous liquid wastes (oil etc), and provisions to prevent ingress of rain and sunlight, as well as protection measures from fire. Space will be reserved for separate storage containers to store prime recyclables (paper, cardboard, scrap, metal), domestic waste and hazardous waste which require segregation. A Waste Storage Area (WSA) will be determined as the central collection area for all stored waste generated at the CPF and as the transit station for collection by waste contractors for disposal.

Groundwater monitoring wells should be installed up and down-stream from any waste disposal and or storage areas. These monitoring wells should form part of the overall groundwater monitoring programme of the Project. Similarly, if the waste discharge effluent disposal is done by means of subsurface drains, these facilities should be monitored through installation of downstream monitoring wells.

Table 18 describes the waste streams, estimated quantities and disposal options for drilling and other wastes from the well pad during the drilling of wells (further details and hazard classification are to be provided in the Waste impact study undertaken for the ESIA). CNOOC will meet the requirements of the Ugandan National Environment (Waste Management) Regulations, S.I. No 52/1999. Where specific Ugandan environmental standards are not available, international guidelines will apply. In particular, CNOOC waste management practices will be aligned with the International Association of Oil and Gas Producers (OGP) guidelines as a measure of international best practice (OGP, 2008: Guidelines for Waste Management with Special Focus on Areas with Limited Infrastructure. Report 413, Rev. 1.1; and with IFC Health and Safety Guidelines for Onshore Oil and Gas Development, April 4th, 2017).

The bulk of the waste generated on the well pads will consist of drilling cuttings and clear liquids. While there will be some variability between the wells, and the quantity of drilling waste will depend on final decisions about dewatering equipment, typical cuttings volumes will be in the order of 600 m^3/well, with one third water based mud cuttings and the balance synthetic mud cuttings. Liquids for disposal are expected to be in the order of 1,000 m^3 per well, dependent on how much is evaporated from the evaporation ponds.

Table 18: Wastes generated on the Kingfisher well pads during the drilling phase

Waste Stream	Estimated quantity (total per well)	Waste Management Options
Hazardous Solids (used chemical containers, fuel storage containers, oil-contaminated rags, used batteries, used filters, fluorescent tubes, power unit/transport maintenance wastes, paint waste,)	0.1 t	Options include recovery / recycling, disposal (with or without pre-treatment) to landfill licensed to receive hazardous waste.
Hazardous solids (potentially contaminated cement slurry)	4 t	Disposed to landfill licensed to receive hazardous waste.
Hazardous Liquids (used oil, waste chemicals, rinsate, thinners, viscofiers, solvents, acids, treating chemicals, other used chemicals in drums)	0.07 t	Options include recovery / recycling, disposal (with or without pre-treatment) to landfill licensed to receive hazardous waste.
Non Hazardous Liquids (sewage effluent, grey water)		Conservancy tanks. Domestic effluent removed by tanker to the sewage treatment plant at the drilling camp
Non Hazardous Solids (construction materials, packaging wastes, paper, scrap metal, plastics, glass)		Waste minimization, separation, re-use and recycling where possible. Domestic refuse disposed to landfill licensed to receive domestic waste.
Drilling Cuttings (solids), coarse and fine particles - aqueous (water based)	205 m^3	Separation from drilling fluids in varying degrees, depending on dewatering equipment installed on the well pad. Disposal to landfill licensed to receive the waste by a certified waste contractor. Landfill site options to be assessed in the ESIA. Landfills include: 1. Enviroserv Uganda Ltd. 2. White Nile Consultants Ltd. 3. ??
Drilling Cuttings (solids), coarse and fine particles - synthetic	402 m^3	
Drilling Liquids (including clear liquids from dewatering of aqueous drill cuttings)	500 m^3	Recycled as much as possible. May also be reduced by evaporation ponds. Disposal to landfill licensed to receive the waste. Quantity will depend on extent of evaporation in evaporation ponds. Landfill site options to be assessed in the ESIA (see above).
Completion Fluids (solids, residual drilling fluids, hydrocarbons, acids, glycol, methanol, other)		Pre-treatment and/or disposal to landfill licensed to receive the waste. Preferred landfill site to be determined by the ESIA (see above).

Note: there will be a total of 31 wells drilled (production and injection) in 5 years

Figure 13 provides an organogram of a typical drilling circuit, showing the two main waste streams (cuttings and clear liquids). Quantities are estimates and will depend on a number of factors, including the extent to which dewatering equipment is used on site and liquids are recycled. A rule of thumb is roughly 0,5 m^3 of drilling mud per metre of well drilled.

The drilling waste management system will operate in a ‘Zero discharge’ principle. Facilities will always be available to deal with discharge requirements and react quickly to changing conditions. The main principle is solid-liquid separation and water-oil separation, solid, water process. Typical drilling waste process and recycle flow chart is shown in Figure 13.

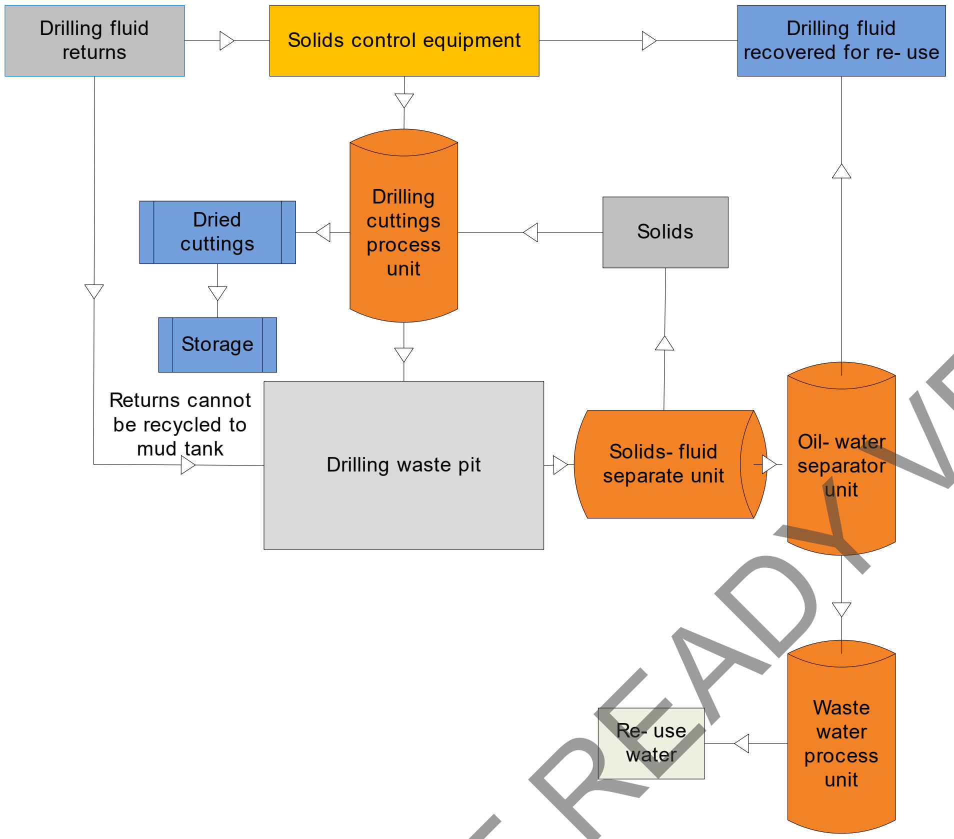

Figure 13: Drilling waste process and recycle flow chart.

On the rig site drilling fluid that returns from the drill hole will be transferred to solid control equipment for primary processing. The fluid will be recovered for re-use and the cuttings will be transferred to the drilling cuttings process unit for secondary processing. The majority of drill cuttings will be processed to dried cuttings with oil content below 5%. These cuttings will be stored in specific containers. The remaining fluid and tiny solid particles will be discharged to the drilling waste pit. Returned drilling fluid that cannot be recycled to the mud tank (such as waste fluid after cementing) will be discharged to the drilling waste pit. These wastes will be pumped to the solids-fluid separate unit for separating. Solids will be transferred to the drilling cuttings process unit for further processing and the fluid will be transferred to the oil-water separator (to recover oil for re-use), and the waste water processing unit (to recover water for re-use).

If drill cuttings will be stored and/or disposed in pits, the following mitigation measures must apply:

- Pits should be lined and tested for integrity prior to use;
- Bottom of pits should be higher than 5 m above the seasonal high water table;
- Prevention of natural surface drainage entering the pits during rains;
- Installation of a perimeter fence around the pits or installation of a screen to prevent access by wildlife (including birds), livestock, and people;
- Pit closure should be completed as soon as practical, but no longer than 12 months, after the end of operations; and
- If the drilling waste is to be buried, the Mix-Bury-Cover disposal method should be used.

The drilling fluid is the primary safeguard against blow-out of hydrocarbons from a well and its density can be controlled to balance any anticipated formation pressures. The drilling mud will be tested from time-to-time during the drilling process and its composition adjusted to account for any changing down-hole conditions. The mud density will be adjusted as required by an on-site chemist. The likelihood of a blow-out will be further minimized by using a specially designed blow-out preventer (BOP). When installed on top of the well-bore, a BOP will close the well automatically in case of a blowout.

The most important mitigation measure for potential impacts to groundwater will be monitoring of the groundwater systems. This will only be accomplished by installation of dedicated groundwater monitoring wells. The monitoring network should be concentrated at the KP area and should include community wells. The installation of the network should be done during the construction phase of the project.

The spatial distribution, depth, and construction of the wells will be dependent on the identified waste sources and final infrastructure distribution. The monitoring system needs to be designed to monitor all identified potential sources of groundwater contamination on the Kingfisher Project area (CPF, well pads, flow lines and accommodation camps). This will ideally include the installation of monitoring wells up- and down-gradient of all activities/sources that could result in potential groundwater pollution. Frequencies of sampling and required analytical parameters need to be discussed with the relevant Regulatory Authority. It is recommended, based on similar project experience, to sample wells quarterly, and to analyse for all the parameters included in the hydrochemical evaluation of this report (See Section 5.4.3).

Table 19: Mitigation Summary - Construction Phase

Groundwater Impacts During Construction Phase				
Management Objectives: Protect groundwater resource **Overall Significance before mitigation: Major/Moderate** **Overall Significance after mitigation: Minor**				
Mitigation Measures	**Monitoring Indicators**	**Monitoring Frequency**	**Responsible Entity**	**Training Necessary**
Design waste water discharge systems according to the volumes expected based on the number of workers on site and to allow adequate draining, to avoid any flooding	Flow volumes	Monthly	CNOOC	
Provision of portable toilets along construction routes (pipeline) and at the well pads.	Maintenance and disposal of effluent	Weekly	CNOOC and Contractors	
Waste Management Plan	Waste management regulations		CNOOC	
Installation of groundwater monitoring boreholes and water sampling	As required by Regulatory Authority	Quarterly	CNOOC	Microbial indicators need to be done on-site
Monitoring of effluent discharge	As per effluent discharge regulations (Table 20)	Monthly	CNOOC	Microbial indicators need to be done on-site
Drilling fluid testing and installation of blow-out preventer	Drilling mud properties and pressure testing	Daily?	CNOOC	

7.2 Operational Phase Mitigation

During operation of the Project there will be many mitigation and monitoring measures that will be required to minimise any potential impacts from the Project sites.

The most important mitigation measure for the protection of the groundwater systems will be the ongoing monitoring of groundwater with the monitoring programme established during the Construction phase of the project (see previous Section). Monitoring of the groundwater at the CPF, well pads and local communities on the Buhuka Flats needs to take precedence.

Leak detection and regular testing of the pipeline will be part of the operational procedures for the pipeline, and therefore the installation of monitoring wells along the pipeline should not be required, unless an incident occurs along the route. It is however, recommended that the local community wells less than 1km from the pipeline need to be considered as part of the monitoring programme.

Pipeline failures can be prevented by choosing the right materials suited to the product transported, equipment and appropriate maintenance and testing of the pipeline. Hydrostatic testing by which the pipeline is subjected to pressure above the operating pressure, to blow out defects before they reach a critical size in service should also be used to detect corroded pipe before it fails in service. A pipeline integrity strategy should be compiled; to guide inspection and preventive maintenance to ensure the integrity of the pipeline. In order to prevent a catastrophic pipeline failure, a management plan should be developed and measures put in place to clean-up soils and groundwater.

Stormwater management should be done in accordance with the recommendations in the surface water specialist report to prevent potential groundwater pollution. Storm water should be separated from process and sanitary wastewater streams wherever possible in order to reduce the volume of wastewater to be treated prior to discharge. Storm water from clean areas such as building roofs or roads shall be allowed to soak-away or be reused as a resource where possible. Good engineering practice need to be employed in the drainage design to ensure that contamination of water and waste by undesirable elements (e.g. oil and heavy metals) is kept to a minimum, and below legislated requirements.

A 'hazardous area open drains' system should be designed to collect water run-off (storm water, fire water, wash-down and any chemical spillages) from hazardous paved areas that are not normally contaminated by hydrocarbons, and hydrocarbon contaminated oily water from designated hazardous areas. The oily water collection system which gathers the above mentioned drainage can be through buried pipes with first flush sumps connected to oil-water interceptors. Storm water runoff should be treated through an oil/water separation system to achieve an oil & grease concentration of <10 mg/L.

To control leaks from storage tanks, secondary containment must be used in the design of the facilities to control the accidental release of liquids to the environment. Secondary containment shall consist of berms, dykes or walls capable of containing 110 percent of the largest tank or 25 % of an areas combined tank volume (i.e. where above-ground tanks have a total storage volume => 1,000 litres). Such structures must be made of impervious, chemically resistant material.

Necessary measures must be considered and provided to prevent oil spillage and discharge of site If discharge of site is needed, it should be treated to meet the discharge limits and the oil concentration must be less than 10 mg/L.

Sewage waste from the Permanent workers camp and CPF should be treated and disposed of in accordance with (i) the National Environment (Standards for Discharge of Effluent into Water or on Land) Regulations, S.I. No 5/1999; (ii) The IFC General EHS Guidelines for environmental Waste water and ambient water ; and (iii) the Company requirements as stated in Water Management Specification (2148-QHSE) and shown in Table 20 below:

Table 20: Standards for Discharge of Effluent

Parameter	Unit	Uganda	IFC	Company requirement
pH	pH	6 – 8	6 – 9	6 – 8
BOD	mg/l	50	30	30
COD	mg/l	100	125	100
Total nitrogen	mg/l	10	10	10
Total phosphorus	mg/l	10	2	2
Oil and grease	mg/l	10	10	10
Total suspended solids	mg/l	100	50	50

The Project should comply with the Ugandan National Environment (Waste Management) Regulations, S.I. No 52/1999. Reference will also be made the OGP (International Association of Oil & Gas Producers), Guidelines for Waste Management with special focus on areas with limited infrastructures (updated March 2009) as indicators of best international practice. See KF-FS-RPT-CPF-SA-0002 Waste Management Philosophy for more details.

Waste will be segregated at source. Once the waste is segregated, the labelled containers will be stored in the WCP area with secondary containment, where necessary. The waste management area will be concrete floored, bunded and roofed to prevent rainfall ingress. The temporary storage area for hazardous wastes will be secured to prevent unauthorized access.

A description of typical wastes and their quantities expected at the CPF is included in Table 21.

Table 21: Hazardous production wastes generated at the CPF during the operational phase

Waste Type	Activity / Source	Potential Contaminants	Mass per year (t)
Contaminated soil/hydrocarbon bearing soil	Spill/leaks	Hydrocarbons, heavy metals, salts, treating chemicals	5 t
Pigging sludge	Pipeline cleaning operations	Hydrocarbons, solids, production chemicals, phenols, aromatics	10 t
Waste oil sludge (from produced water treatment)	Produced water treatment system	Hydrocarbons	200 t
Produced sand	Removal from well fluids	Hydrocarbons	145 t
Pipe scale, hydrocarbon solids, hydrates, and other deposits	Cleaning piping and equipment	Hydrocarbons, heavy metals	20 t
Solid wastes generated by crude oil and tank bottom reclaimers	Separation tank sediments	Hydrocarbons，solids, production chemicals, phenols, aromatics	5 t
Empty chemical drums, drum rinsate and containers	Chemical injection, water treatment, cleaning agents	Heavy hydrocarbons, solvent	65 t
Cement slurries	Cement slurries	Heavy metals, thinners, viscosifiers, pH, salts	5 t
Paint materials	Unused paints, used thinners	Heavy metals, solvent, hydrocarbons	0.5 t
Maintenance wastes	Sandblast (grits)，greases, fuel oils，filters, paint scale	Heavy metals, hydrocarbons, solids, solvents	5 t
Industrial waste	Batteries，transformers，Capacitors	Acid, alkali, heavy metals, PCBs	3 t
Scrap metals	Used piping，cables, drums, casing etc.	Heavy metals, scales	2 t
Sewage sludge	Domestic water treatment	Pathogens	???

Table 22: Non-hazardous waste generated at the CPF during the operational phase (including wastes from the permanent camp)

Waste Type	Activity (Source)	Mass per year (t)	Recycling / Disposal
Plastic	Bottles, waste packings		Mostly recycled

Waste Type	Activity (Source)	Mass per year (t)	Recycling / Disposal
Paper / packaging	Packaging, office paper waste		Recycled
Wood	Packaging		Recycled
Rubber	Vehicle tyres		Recycled
Glass	Bottles		Recycled
Food and vegetable waste	Kitchens		Composted
Metal	Cold drink cans, processed food, other non-hazardous products, electrical metal scrap		Steel disposed to landfill. Aluminium recycled. Copper recycled
Miscellaneous	General office and personnel camp scrap		Disposed to landfill

As mentioned above, mitigation will involve a hazardous materials management plan encompassing: equipment audits, flow line testing, inspections programs; and application of Standard Operating Procedures (SOPs).

Pipeline failures can be prevented by choosing the right materials suited to the product transported, equipment and appropriate maintenance and testing of the pipeline. Hydrostatic testing by which the pipeline is subjected to pressure above the operating pressure, to blow out defects before they reach a critical size in service should also be used to detect corroded pipe before it fails in service. A pipeline integrity strategy should be compiled; to guide inspection and preventive maintenance to ensure the integrity of the pipeline

The drilling fluid is the primary safeguard against blow-out of hydrocarbons from a well and its density can be controlled to balance any anticipated formation pressures. The drilling mud will be tested from time-to-time during the drilling process and its composition adjusted to account for any changing down-hole conditions. The mud density will be adjusted as required by an on-site chemist. The likelihood of a blow-out will be further minimized by using a specially designed blow-out preventer (BOP). When installed on top of the well-bore, a BOP will close the well automatically in case of a blowout.

A management plan needs to be in place in case of a catastrophic well blow-out and or pipeline failure. Such a management plan needs to include measures to clean-up soils and groundwater.

Table 23: Mitigation Summary - Operation Phase

Groundwater Impacts During Operation Phase				
Management Objectives: Protect groundwater resource **Overall Significance before mitigation: Major/Moderate** **Overall Significance after mitigation: Minor/Moderate**				
Mitigation Measures	**Monitoring Indicators**	**Monitoring Frequency**	**Responsible Entity**	**Training Necessary**
Design and installation of groundwater monitoring network	Water quality parameters	Monthly/ quarterly	CNOOC	Microbial indicators need to be done on-site
Design waste water treatment systems according to the volumes expected based on the number of workers on site and to allow adequate draining, to avoid any flooding	Flow volumes	Monthly	CNOOC	
Storm water drainage system, clean and dirty water separation				
Waste Management Plan	Waste management regulations		CNOOC	
Engineering design to prevent accidents and spillages at storage areas – Secondary containment			CNOOC	
Monitoring of waste water discharge	As require per regulations (Table 20)	Monthly	CNOOC	Microbial indicators need to be done on-site
Pipeline integrity strategy	Corrosion, leak detection, failure indicators	Weekly?	CNOOC	
Drilling fluid and blow-out preventer	Drilling mud properties and pressure testing	Daily?	CNOOC	
Management plan in case of catastrophic well blow-out and or pipeline failure	Groundwater parameters, clean-up standards		CNOOC	

8.0 CLOSURE

This report had the objectives of establishing a groundwater baseline and groundwater impact assessment for the CNOOC's Uganda's, Kingfisher Oil Field Development in the Albertine Rift Valley in Western Uganda.

The baseline was established through review of existing groundwater information, a field investigation that included an extensive hydrocensus and sampling of groundwater. The groundwater systems has been characterised based on aquifer properties and water quality.

It was established that at the Kingfisher Project site on the Buhuka flats the groundwater is not considered as a viable source of water supply. However, along the pipeline route and other lake front villages, groundwater from wells is the only supply of potable water for many communities. Therefore, the groundwater systems need to be considered as an important element of the environment that needs to be protected against any potential negative impacts.

Potential impacts and risk factors to the groundwater from the Project during the construction phase are mainly limited to materials handling in conjunction with waste water and solid waste management. Most of the impacts are rated as high or moderate, and in all cases can be reduced to minor through mitigation and management measures. Impacts related to the operational phase include construction impacts (i.e. materials handling, as well as waste water and solid waste management) but also extend to storage of liquid waste, solid waste, drainage, and storm water management, at the CPF and accommodation camps.

The potential impacts associated with oil well drilling and operation is relevant to both the construction and operational phases of the Project and poses the most severe risks to the groundwater systems. However, by utilising technology, monitoring and management measures the impacts can be reduced to minor in all cases. Pipeline failure can also result in severe negative impacts of the groundwater systems but can be mitigated and managed through comprehensive operational practices.

Groundwater monitoring networks need to be established to monitor all potential sources of pollution to groundwater at the CPF and well pads. Community wells should be included in the monitoring networks where infrastructure failure can pose a risk to the groundwater.

9.0 ASSUMPTIONS AND LIMITATIONS

Assumptions and limitations pertaining to the Groundwater study include:

- No dedicated monitoring groundwater wells were available for the study; all samples were taken from community wells.
- The lithological description of the aquifer formations are based on public available information and no ground truthing were done to confirm the lithology of the formations that will constitute the aquifers for the project site.
- The mitigation measures recommended for the waste, waste water, and stormwater management need to be read and applied together with the Waste and Surface Water Specialist study reports.
- There is limited evidence that the groundwater resource and the surface water bodies are linked, such that the groundwater and surface water interaction for the project area is assumed to be insignificant.

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GOLDER ASSOCIATES AFRICA (PTY) LTD.

Jennifer Pretorius
Senior Hydrogeologist

Gerhard van der Linder
Senior Hydrogeologist

JenP/NS/jenp

Reg. No. 2002/007104/07
Directors: SAP Brown, L Greyling, RGM Heath

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APPENDIX A

Document Limitations

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APPENDIX B

Chemical Analytical Results

Form A

Republic of Uganda

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

Certificate of Analysis

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

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

Source Name		Kyabasambu stream	Kyenyanja BH	Busigi BH	Busigi stream	Ususa spring	Kina BH	Kina shores	US 201 DRINKING POTABLE WATER SPECIFICATION CLASS II
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	
Conductivity	µs/cm	351	671	1766	543	667	4400	634	2500
pH	--	10	10.1	10.2	10.1	9.3	7.75	10.1	6.5-8.5
Alkalinity	mg/L	76	88	100	80	76	48	84	500
Total Dissolved Solids	mg/L	284	906	307	335	197.5	20100	326	1200
Total Suspended Solids	mg/L	1	0	0	3	4	24	0	0
Turbidity	NTU	1	1	1	1	2	1	0	10
Calcium: Ca^{2+}	mg/L	48	56	56	48	72	2000	32	75
Magnesium: Mg^{2+}	mg/L	19.2	33.6	33.6	110.4	28.8	186	43.2	50
Iron: Total	mg/L	0.05	0	0	0.01	0.01	0.06	0.01	1
Fluoride: F^-	mg/L	1.2	1	1.2	1.2	1	1.1	0.9	1.5
Chloride: Cl^-	mg/L	0.03	0.03	0.03	0.03	0.03	3.3	0.03	500
Nitrate	mg/L	1.3	0.43	1.33	1.49	0.03	1.64	4.4	5
Ammonia	mg/L	0.5	0	0	0	0.2	0	0	1
Total Phosphorus	mg/L	0.07	0.55	0.17	0.26	0.15	0.04	0.05	10
Total Nitrogen	mg/L	0.13	0.42	2.45	0.057	0.29	1.18	0.37	10

NOTE:

1. S.D = Standard Deviation; AQC = Analytical Quality Control; NR = not Required; ND = Not Done
2. S. D. values have been quoted only form methods that have been validated in our laboratory.
3. The type of sample container and sample holding time affect the integrity of the sample and hence the results of analysis

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Date: 26/03/2014

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Principal Analyst
Date:

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26 MAR 2014
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Sign:

Directorate of Water Resources Management Department
P.O Box 19, Entebbe
Tel: 041-321342
Fax: 041-321368

Form A

Republic of Uganda

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

Certificate of Analysis

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

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

Source Name		CNOOC SW1	CNOOC SW2	CNOOC SW4	CNOOC SW6	CNOOC SW9	US 201 DRINKING POTABLE WATER SPECIFICATION CLASS II
Source location/GPS	Northings	N01°15'53.6"	N01°15'50.6"	N01°15'16.4"	N01°14'24.9"	N01°13'40.9"	
	Eastings	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	
Conductivity	µs/cm	984	711	488	445	227	**2500**
pH	--	8.63	9.29	9.11	9.25	9.03	**6.5-8.5**
Alkalinity	mg/L	76	88	100	80	76	**500**
Total Dissolved Solids	mg/L	284	906	307	335	197.5	**1200**
Total Suspended Solids	mg/L	1	0	0	3	4	**0**
Turbidity	NTU	1	1	1	1	2	**10**
Calcium: Ca^{2+}	mg/L	48	56	56	48	72	**75**
Magnesium: Mg^{2+}	mg/L	19.2	33.6	33.6	110.4	28.8	**50**
Iron: Total	mg/L	0.05	0	0	0.01	0.01	**1**
Fluoride: F^-	mg/L	1.2	1	1.2	1.2	1	**1.5**
Chloride: Cl^-	mg/L	0.03	0.03	0.03	0.03	0.03	**500**
Nitrate	mg/L	0.13	0.11	0.04	0.17	0.15	**5**
Ammonia	mg/L	0	0	0	0	0	**1**
Total Phosphorus	mg/L	0.23	0.14	0.08	0.12	0.05	**10**
Total Nitrogen	mg/L	0.21	0.21	0.28	0.07	0.16	**10**

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Fax: 041-321368

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Republic of Uganda

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

Certificate of Analysis

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

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

Source Name		CNOOC SW12	CNOOC SW14	CNOOC GW1	CNOOC GW2	US 201 DRINKING POTABLE WATER SPECIFICATION CLASS II
Source location/GPS	Northings	N01°14'51.3"	N01°13'13.9"	N01°14'31.6"	N01°13'56.1"	
	Eastings	E30°44'21.0"	E30°43'23.1"	E30°44'17.4"	E30°43'38.8"	
Parameters	**Units/Lab No.**	E22166	E22167	E22168	E22169	
Conductivity	µs/cm	1229	250	10540	7060	**2500**
pH	--	8.24	8.53	7.43	7.82	**6.5-8.5**
Alkalinity	mg/L	48	84	80	36	**500**
Total Dissolved Solids	mg/L	20100	326	249	470	**1200**
Total Suspended Solids	mg/L	24	0	2	5	**0**
Turbidity	NTU	1	0	1	2	**10**
Calcium: Ca^{2+}	mg/L	2000	32	40	112	**75**
Magnesium: Mg^{2+}	mg/L	186	43.2	19.2	24	**50**
Iron: Total	mg/L	0.06	0.01	0.02	0.04	**1**
Fluoride: F^-	mg/L	1.1	0.9	1	0.7	**1.5**
Chloride: Cl^-	mg/L	3.3	0.03	0.03	0.03	**500**
Nitrate	mg/L	0.37	0.13	0.11	0.13	**5**
Ammonia	mg/L	0.4	0	0	0	**1**
Total Phosphorus	mg/L	0.11	0.06	0.056	0.092	**10**
Total Nitrogen	mg/L	0.53	0.17	0.273	0.247	**10**

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Fax: 041-321368

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NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

Certificate of Analysis

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

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

Source Name		Kachunde stream	Ususa BH (shallow well)	L. Albert	Senjojo stream	Nsonga shorelines	US 201 DRINKING POTABLE WATER SPECIFICATION CLASS II
Source Location/GPS	Eastings	245312	257853	244514	243427	248343	
	Northings	130206	148016	130739	127536	138448	
Parameters	**Units/Lab No.**	E22156	E22154	E22149	E22153	E22150	
Conductivity	µs/cm	440	850	576	293	589	2500
pH	--	9.95	9.38	9.96	9.68	10.03	6.5-8.5
Alkalinity	mg/L	80	36	48	36	88	500
Total Dissolved Solids	mg/L	249	470	390.4	373.8	387.8	1200
Total Suspended Solids	mg/L	2	5	0	3	9	0
Turbidity	NTU	1	2	1	2	6	10
Calcium: Ca^{2+}	mg/L	40	112	27.2	136	16	75
Magnesium: Mg^{2+}	mg/L	19.2	24	34.6		48	50
Iron: Total	mg/L	0.02	0.04	0.02	0.01	0.04	1
Fluoride: F^-	mg/L	1	0.7	0.9	1	0.9	1.5
Chloride: Cl^-	mg/L	0.03	0.03	0.03	0.03	0.03	500
Nitrate	mg/L	0.03	1.43	0.04	0.03	0.11	5
Ammonia	mg/L	0	0	0	0	0	1
Total Phosphorus	mg/L	0.1	0.17	0.05	0.05	0.15	10
Total Nitrogen	mg/L	0.28	2.67	0.27	0.31	0.12	10

NOTE:

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Tel: 041-321342
Fax: 041-321368

Republic of Uganda

Form C

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

CERTIFICATE OF ANALYSIS

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

Sampled by: Eco & Partner and Golder Associates
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

Checked:
Laboratory Manager
Date 26/03/2014

LABORATORY MANAGER CHECKED DATE

PRINCIPAL ANALYST LABORATORIES
Issued 26 MAR 2014
Principal Analyst
Date:
NATIONAL WATER QUALITY REFERENCE LABORATORY – ENTEBBE
Sign:...........

Directorate of Water Resources Management Department
P.O Box 19, Entebbe
Tel: 041-321342
Fax: 041-321368

Republic of Uganda

Form C

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

CERTIFICATE OF ANALYSIS

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

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

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:

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

Checked:
Laboratory Manager
Date:

LABORATORY MANAGER
CHECKED
DATE 26/03/2014

PRINCIPAL ANALYST LABORATORIES
Issued
Principal Analyst
Date: 26 MAR 2014
NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE
Sign:.....................

Directorate of Water Resources Management Department
P.O Box 19, Entebbe
Tel: 041-321342
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Republic of Uganda

Form C

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

CERTIFICATE OF ANALYSIS

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

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

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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3. DL stands for Detection Limit

Checked:
Laboratory Manager
Date:

LABORATORY MANAGER CHECKED DATE 26/02/2014

PRINCIPAL ANALYST LABORATORIES
Issued
Principal Analyst 26 MAR 2014
Date:
NATIONAL WATER QUALITY REFERENCE LABORATORY – ENTEBBE
Sign:..................................

Directorate of Water Resources Management Department
P.O Box 19, Entebbe
Tel: 041-321342
Fax: 041-321368

Form C

Republic of Uganda

NATIONAL WATER QUALITY REFERENCE LABORATORY - ENTEBBE

CERTIFICATE OF ANALYSIS

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

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

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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3. DL stands for Detection Limit

Checked:
Laboratory Manager
Date: 26/03/2014

LABORATORY MANAGER CHECKED DATE

PRINCIPAL ANALYST LABORATORIES
Issued
Principal Analyst
Date: 26 MAR 2014
NATIONAL WATER QUALITY REFERENCE LABORATORY – ENTEBBE
Sign:.............................

Directorate of Water Resources Management Department
P.O Box 19, Entebbe
Tel: 041-321342
Fax: 041-321368

APPENDIX C

Microbial Results

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
CH5 2UA

Tel: +44 (0) 1244 833780
Fax: +44 (0) 1244 833781

Golder Associates Africa Ltd
12 Steven Street
Universitas
Bloemfontein
Free State
9301
South Africa

UKAS TESTING 4225

Attention :	Jennifer Pretorius
Date :	13th March, 2014
Your reference :	CNOOC 12614848
Our reference :	Test Report 14/3564 Batch 1
Location :	Kingfisher
Date samples received :	6th March, 2014
Status :	Final report
Issue :	1

Five samples were received for analysis on 6th 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: CNOOC 12614848
Location: Kingfisher
Contact: Jennifer Pretorius
JE Job No.: 14/3564

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.	1-7	8-14	15-21	22-28	29-35								
Sample ID	UNSUNSA	CPFI	KYENYANJA	KIINA	KYANGWALI HQ								
Depth													
COC No / misc													
Containers	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G								
Sample Date	28/02/2014	27/02/2014	28/02/2014	28/02/2014	01/03/2014								
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water								
Batch Number	1	1	1	1	1						LOD	Units	Method No.
Date of Receipt	06/03/2014	06/03/2014	06/03/2014	06/03/2014	06/03/2014								
Dissolved Aluminium #	165	<20	48	<20	71						<20	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	<2.5	<2.5	<2.5						<2.5	ug/l	TM30/PM14
Dissolved Barium #	186	3048	94	100	111						<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5						<0.5	ug/l	TM30/PM14
Dissolved Cadmium #	<0.5	<0.5	<0.5	<0.5	<0.5						<0.5	ug/l	TM30/PM14
Dissolved Calcium #	57.6	262.4	21.8	1587.0	19.9						<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	<1.5	<1.5	<1.5	<1.5						<1.5	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7						<7	ug/l	TM30/PM14
Total Dissolved Iron #	<20	44	<20	218	457						<20	ug/l	TM30/PM14
Dissolved Lead #	14	15	<5	18	45						<5	ug/l	TM30/PM14
Dissolved Magnesium #	24.4	168.0	28.0	948.7	5.5						<0.1	mg/l	TM30/PM14
Dissolved Manganese #	598	1539	14	38	2						<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1						<1	ug/l	TM30/PM14
Dissolved Nickel #	<2	<2	<2	2	<2						<2	ug/l	TM30/PM14
Dissolved Potassium #	8.4	4.2	49.0	16.8	2.8						<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3						<3	ug/l	TM30/PM14
Dissolved Sodium #	81.0	858.9	87.4	5845.0	8.3						<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	17.2	<1.5	20.9	<1.5	1.7						<1.5	ug/l	TM30/PM14
Dissolved Zinc #	63	187	22	200	2481						<3	ug/l	TM30/PM14
Total Hardness Dissolved (as CaCO3)	246	1362	172	7952	73						<1	mg/l	TM30/PM14
PAH MS													
Naphthalene #	<0.014	<0.014	<0.014	<0.014	<0.014						<0.014	ug/l	TM4/PM30
Acenaphthylene #	<0.013	<0.013	<0.013	<0.013	<0.013						<0.013	ug/l	TM4/PM30
Acenaphthene #	<0.013	<0.013	<0.013	<0.013	<0.013						<0.013	ug/l	TM4/PM30
Fluorene #	<0.014	<0.014	<0.014	<0.014	<0.014						<0.014	ug/l	TM4/PM30
Phenanthrene #	<0.011	<0.011	<0.011	<0.011	<0.011						<0.011	ug/l	TM4/PM30
Anthracene #	<0.013	<0.013	<0.013	<0.013	<0.013						<0.013	ug/l	TM4/PM30
Fluoranthene #	<0.012	<0.012	<0.012	<0.012	<0.012						<0.012	ug/l	TM4/PM30
Pyrene #	<0.013	<0.013	<0.013	<0.013	<0.013						<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.015	<0.015	<0.015	<0.015	<0.015						<0.015	ug/l	TM4/PM30
Chrysene #	<0.011	<0.011	<0.011	<0.011	<0.011						<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<0.018	<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	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<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	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.011	<0.011	<0.011	<0.011	<0.011						<0.011	ug/l	TM4/PM30
PAH 16 Total #	<0.195	<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						<0.01	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01						<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	86	88	82	90	90						<0	%	TM4/PM30
EPH (C8-C40) #	<10	<10	<10	<10	<10						<10	ug/l	TM5/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name: Golder Associates Africa Ltd
Reference: CNOOC 12614848
Location: Kingfisher
Contact: Jennifer Pretorius
JE Job No.: 14/3564

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.	1-7	8-14	15-21	22-28	29-35			
Sample ID	UNSUNSA	CPFI	KYENYANJA	KIINA	KYANGWALI HQ			
Depth								
COC No / misc								
Containers	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G			
Sample Date	28/02/2014	27/02/2014	28/02/2014	28/02/2014	01/03/2014			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	LOD	Units	Method No.
Date of Receipt	06/03/2014	06/03/2014	06/03/2014	06/03/2014	06/03/2014			
GRO (>C4-C8)#	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
GRO (>C8-C12)#	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
GRO (>C4-C12)#	<10	<10	<10	<10	<10	<10	ug/l	TM36/PM12
Fluoride	0.3	0.3	0.8	<0.3	0.4	<0.3	mg/l	TM27/PM0
Sulphate#	47.90	<0.05	19.12	692.33	10.34	<0.05	mg/l	TM38/PM0
Chloride#	81.3	2420.9	56.6	14979.4	16.0	<0.3	mg/l	TM38/PM0
Ortho Phosphate as PO4#	1.35	<0.06	2.48	<0.06	0.06	<0.06	mg/l	TM38/PM0
Nitrate as N#	30.15	0.50	4.49	3.31	0.52	<0.05	mg/l	TM38/PM0
Ammoniacal Nitrogen as N#	0.22	0.43	0.36	0.61	0.16	<0.03	mg/l	TM38/PM0
Total Alkalinity as CaCO3#	222	304	290	258	56	<1	mg/l	TM75/PM0
Electrical Conductivity @25C#	979	7193	820	38267	199	<2	uS/cm	TM76/PM0
pH#	7.23	7.13	8.00	6.89	5.99	<0.01	pH units	TM73/PM0
Silica	27.40	34.10	6.20	42.10	55.60	<0.01	mg/l	TM52/PM0
Total Dissolved Solids	903	4776	916	4477	1406	<10	mg/l	TM20/PM0

All solid results are expressed on a dry weight basis unless stated otherwise.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 14/3564

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 accredited when all the requirements of our Quality System have been met. In certain circumstances where the requirements have not been met, the laboratory may issue the data in an interim report but will remove the accreditation, in this instance results should be considered indicative only. Where possible samples will be re-extracted and a final 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

JE Job No: 14/3564

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: 14/3564

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			

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
CH5 2UA

Tel: +44 (0) 1244 833780
Fax: +44 (0) 1244 833781

Golder Associates Africa Ltd
12 Steven Street
Universitas
Bloemfontein
Free State
9301
South Africa

Attention :	Jennifer Pretorius
Date :	14th March, 2014
Your reference :	CNOOC 12614848
Our reference :	Test Report 14/3628 Batch 1
Location :	
Date samples received :	7th March, 2014
Status :	Final report
Issue :	1

Fourteen samples were received for analysis on 7th 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: CNOOC 12614848
Location:
Contact: Jennifer Pretorius
JE Job No.: 14/3628

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.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70	LOD	Units	Method No.
Sample ID	KABALE 1	KABALE 2	KABALE 3	KISOBA 1	KISOBA 2	KISOBA 3	HOHWA 1	KABEGARAIRE 1	KYARUSHESHA 1	KASOGA 1			
Depth													
COC No / misc													
Containers	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G			
Sample Date	02/03/2014	02/03/2014	02/03/2014	02/03/2014	02/03/2014	02/03/2014	02/03/2014	03/03/2014	03/03/2014	03/03/2014			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1			
Date of Receipt	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014			
Dissolved Aluminium #	<20	1098	<20	<20	<20	<20	<20	<20	267	<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 #	93	79	175	138	168	156	137	35	56	201	<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 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 #	34.1	12.4	33.8	21.7	39.7	21.7	35.2	30.0	18.2	61.4	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Copper #	<7	11	<7	14	40	<7	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	655	940	217	846	145	32	<20	2058	317	984	<20	ug/l	TM30/PM14
Dissolved Lead #	15	20	12	15	14	13	13	18	12	14	<5	ug/l	TM30/PM14
Dissolved Magnesium #	18.7	5.8	20.0	11.4	20.0	10.2	37.2	24.6	9.4	17.5	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	10	56	130	30	125	33	50	103	82	351	<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 #	2.7	1.5	1.0	2.1	2.5	2.7	1.2	2.8	2.1	2.8	<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 #	29.7	27.4	30.2	17.6	19.9	12.0	52.5	12.3	22.2	16.5	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	7.3	2.5	<1.5	3.2	<1.5	<1.5	11.1	<1.5	8.3	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	73	26	48	42	69	174	33	132	16	11	<3	ug/l	TM30/PM14
Total Hardness Dissolved (as CaCO3)	164	55	169	102	183	97	244	178	85	227	<1	mg/l	TM30/PM14
PAH MS													
Naphthalene #	<0.014	<0.014	<0.014	<0.014	<0.014	0.020	<0.014	<0.014	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Acenaphthylene #	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Acenaphthene #	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluorene #	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Phenanthrene #	<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
Anthracene #	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluoranthene #	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	ug/l	TM4/PM30
Pyrene #	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	ug/l	TM4/PM30
Chrysene #	<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
Benzo(bk)fluoranthene #	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	<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	<0.195	<0.195	<0.195	<0.195	<0.195	<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	<0.01	<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	107	104	101	92	80	107	102	87	108	87	<0	%	TM4/PM30
EPH (C8-C40) #	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	ug/l	TM5/PM30

Client Name: Golder Associates Africa Ltd
Reference: CNOOC 12614848
Location:
Contact: Jennifer Pretorius
JE Job No.: 14/3628

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.	1-7	8-14	15-21	22-28	29-35	36-42	43-49	50-56	57-63	64-70			
Sample ID	KABALE 1	KABALE 2	KABALE 3	KISOBA 1	KISOBA 2	KISOBA 3	HOHWA 1	KABEGARAIRE 1	KYARUSHESHA 1	KASOGA 1			
Depth													
COC No / misc													
Containers	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G	V H HN P G			
Sample Date	02/03/2014	02/03/2014	02/03/2014	02/03/2014	02/03/2014	02/03/2014	02/03/2014	03/03/2014	03/03/2014	03/03/2014			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD	Units	Method No.
Date of Receipt	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014	07/03/2014			
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	<0.3	<0.3	0.5	1.0	1.3	0.6	2.7	0.3	<0.3	1.7	<0.3	mg/l	TM27/PM0
Sulphate #	40.26	5.12	17.08	6.24	17.41	6.99	14.32	24.90	36.38	18.04	<0.05	mg/l	TM38/PM0
Chloride #	5.3	0.7	3.0	1.0	15.6	0.5	3.5	2.4	1.7	1.4	<0.3	mg/l	TM38/PM0
Ortho Phosphate as PO4 #	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	mg/l	TM38/PM0
Nitrate as N #	0.23	0.49	0.26	0.97	0.17	0.46	1.93	0.15	1.33	0.17	<0.05	mg/l	TM38/PM0
Ammoniacal Nitrogen as N #	0.15	0.19	0.18	0.71	0.31	0.30	0.22	0.25	0.33	0.34	<0.03	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	198	114	218	146	206	118	336	186	100	252	<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	444	233	433	298	448	247	643	391	277	475	<2	uS/cm	TM76/PM0
pH #	6.74	6.60	6.99	6.83	7.07	6.64	7.53	7.13	6.96	7.36	<0.01	pH units	TM73/PM0
Silica	53.10	61.80	25.90	37.60	36.70	32.20	33.90	33.40	36.00	46.90	<0.01	mg/l	TM52/PM0
Total Dissolved Solids	312	237	284	236	301	183	554	292	222	341	<10	mg/l	TM20/PM0

All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name:	Golder Associates Africa Ltd	**Report :**	**Liquid**
Reference:	CNOOC 12614848		
Location:			
Contact:	Jennifer Pretorius	**Liquids/products:**	V=40ml vial, G=glass bottle, P=plastic bottle
JE Job No.:	14/3628		$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	71-77	78-83	84-90	91-97			
Sample ID	KASOGA 2	KYARUJUMBA	HANGA 2B	HANGA 2A			
Depth							
COC No / misc							
Containers	V H HN P G	V H HN P G	V H HN P G	V H HN P G			
Sample Date	03/03/2014	03/03/2014	03/03/2014	03/03/2014			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	1	1	1	1			
Date of Receipt	07/03/2014	07/03/2014	07/03/2014	07/03/2014	LOD	Units	Method No.
Dissolved Aluminium #	208	<20	<20	<20	<20	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	<2.5	<2.5	<2.5	ug/l	TM30/PM14
Dissolved Barium #	84	123	127	125	<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Cadmium #	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Calcium #	13.9	13.5	58.5	24.8	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	<1.5	8.6	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	1086	820	996	1026	<20	ug/l	TM30/PM14
Dissolved Lead #	9	17	10	16	<5	ug/l	TM30/PM14
Dissolved Magnesium #	5.4	6.0	18.8	12.4	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	46	8	305	99	<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1	ug/l	TM30/PM14
Dissolved Nickel #	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Potassium #	0.5	2.7	3.0	1.8	<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3	ug/l	TM30/PM14
Dissolved Sodium #	13.7	14.1	35.3	31.7	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	1.8	4.8	<1.5	4.0	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	59	94	50	25	<3	ug/l	TM30/PM14
Total Hardness Dissolved (as CaCO3)	57	59	225	114	<1	mg/l	TM30/PM14
PAH MS							
Naphthalene #	<0.014	<0.014	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Acenaphthylene #	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Acenaphthene #	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluorene #	<0.014	<0.014	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Phenanthrene #	<0.011	<0.011	<0.011	<0.011	<0.011	ug/l	TM4/PM30
Anthracene #	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluoranthene #	<0.012	<0.012	<0.012	<0.012	<0.012	ug/l	TM4/PM30
Pyrene #	<0.013	<0.013	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.015	<0.015	<0.015	<0.015	<0.015	ug/l	TM4/PM30
Chrysene #	<0.011	<0.011	<0.011	<0.011	<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<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	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<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	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.011	<0.011	<0.011	<0.011	<0.011	ug/l	TM4/PM30
PAH 16 Total #	<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	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	91	87	92	95	<0	%	TM4/PM30
EPH (C8-C40) #	<10	<10	<10	<10	<10	ug/l	TM5/PM30

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: CNOOC 12614848
Location:
Contact: Jennifer Pretorius
JE Job No.: 14/3628

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.	71-77	78-83	84-90	91-97							LOD	Units	Method No.
Sample ID	KASOGA 2	KYARUJUMBA	HANGA 2B	HANGA 2A									
Depth													
COC No / misc													
Containers	V H HN P G	V H HN P G	V H HN P G	V H HN P G									
Sample Date	03/03/2014	03/03/2014	03/03/2014	03/03/2014									
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water									
Batch Number	1	1	1	1									
Date of Receipt	07/03/2014	07/03/2014	07/03/2014	07/03/2014									
GRO (>C4-C8) #	<10	<10	<10	<10							<10	ug/l	TM36/PM12
GRO (>C8-C12) #	<10	<10	<10	<10							<10	ug/l	TM36/PM12
GRO (>C4-C12) #	<10	<10	<10	<10							<10	ug/l	TM36/PM12
Fluoride	0.3	0.5	1.4	1.1							<0.3	mg/l	TM27/PM0
Sulphate #	0.32	6.18	31.18	16.41							<0.05	mg/l	TM38/PM0
Chloride #	0.7	0.5	18.0	9.0							<0.3	mg/l	TM38/PM0
Ortho Phosphate as PO4 #	<0.06	0.19	<0.06	<0.06							<0.06	mg/l	TM38/PM0
Nitrate as N #	0.17	0.50	0.14	0.53							<0.05	mg/l	TM38/PM0
Ammoniacal Nitrogen as N #	0.33	0.38	0.33	0.12							<0.03	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	90	86	266	152							<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	174	191	580	359							<2	uS/cm	TM76/PM0
pH #	6.57	6.62	7.22	6.74							<0.01	pH units	TM73/PM0
Silica	32.20	36.60	38.50	49.40							<0.01	mg/l	TM52/PM0
Total Dissolved Solids	150	181	388	267							<10	mg/l	TM20/PM0

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

JE Job No.: 14/3628

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 accredited when all the requirements of our Quality System have been met. In certain circumstances where the requirements have not been met, the laboratory may issue the data in an interim report but will remove the accreditation, in this instance results should be considered indicative only. Where possible samples will be re-extracted and a final 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

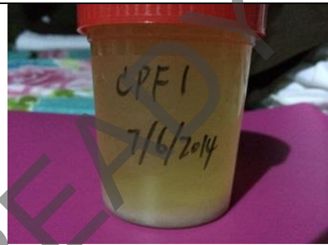
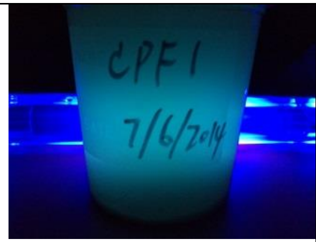
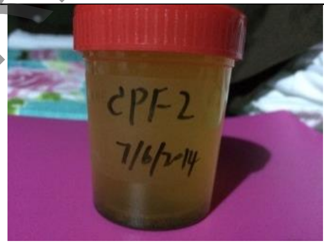
#	UKAS accredited.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance.
SV	Surrogate 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

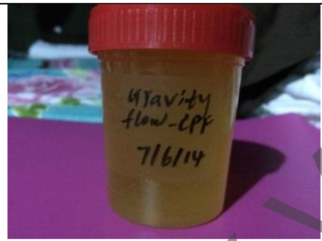
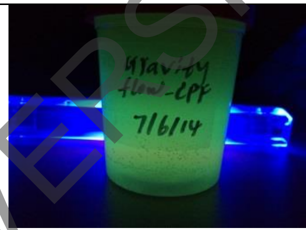
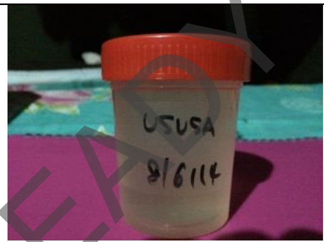
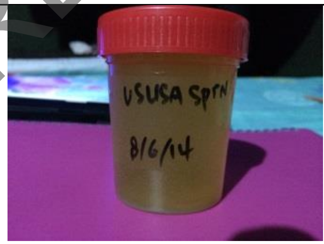
JE Job No: 14/3628

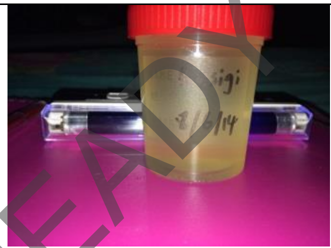
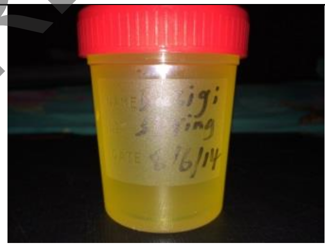
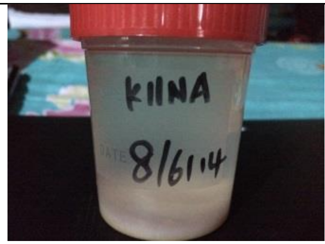
Test Method No.	Description	Prep Method No. (if appropriate)	Description	UKAS	MCERTS (soils only)	Analysis done on As Received (AR) or Air Dried (AD)	Reported on dry weight basis
TM4	16 PAH by GC-MS, modified USEPA 8270	PM30	In-house method based on USEPA 3510. Liquid samples are mixed with solvent and 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.				

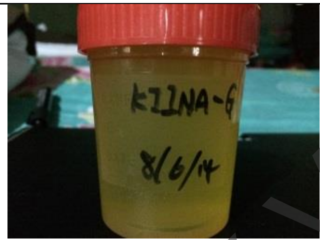
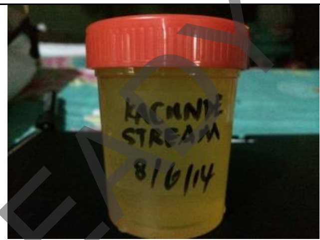
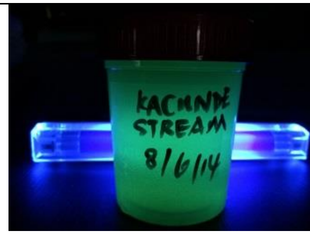
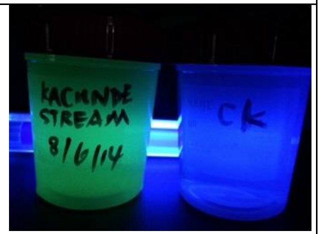
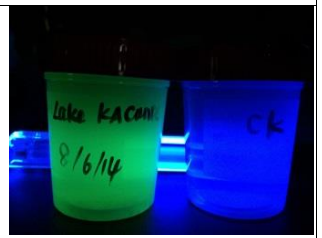
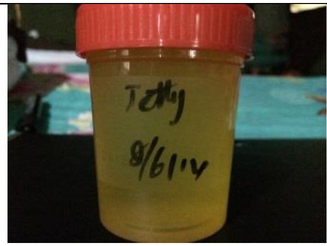
JE Job No: 14/3628

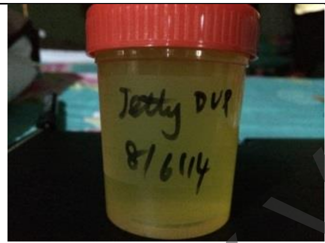
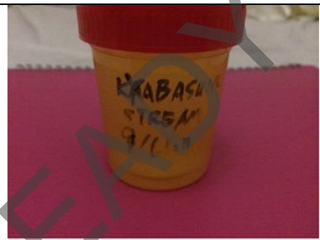
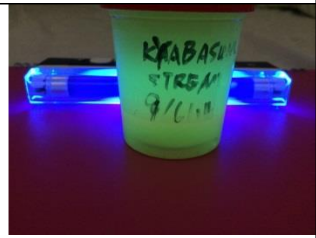
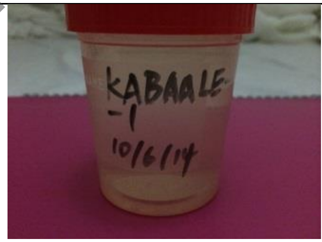
Test Method No.	Description	Prep Method No. (if appropriate)	Description	UKAS	MCERTS (soils only)	Analysis done on As Received (AR) or Air Dried (AD)	Reported on dry weight basis
TM73	pH in by Metrohm	PM0	No preparation is required.	Yes			
TM75	Alkalinity by Metrohm	PM0	No preparation is required.	Yes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

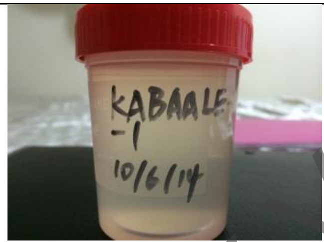
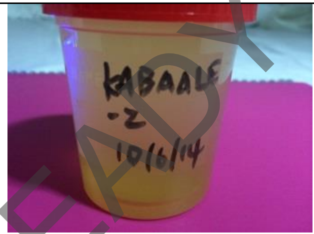
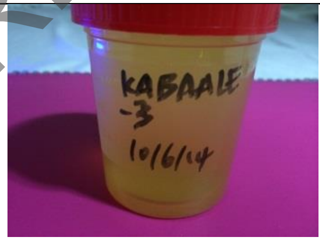
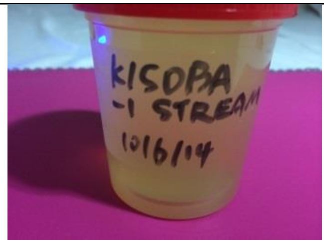
No.	I.D.	Coordinate East / North	Pic of sampling location	Incubate duration /hrs (result)	Exposure to natural light	Exposure to UV light	Compared with CK under UV light
Kingfisher (Buhuka Flat)							
1	KYABASA MBU-CPF 1	249035 138588		12 + *E. coli*			
2	NSONGA-CPF2 (KISONGA-CPF2)	247651 136606		12 + *E. coli*			
3	LAKE-JETTY	**248405(1)** **138059(1)**		12 + *E. coli*			

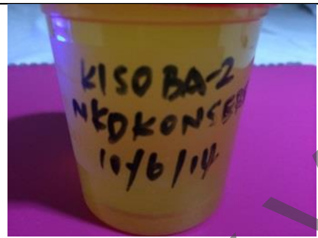
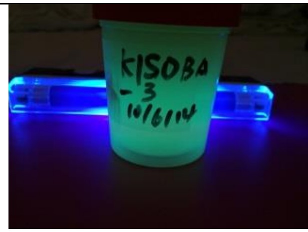
4	GRAVITY FLOW-CPF	**249666[1]** **136798[1]**		12 + *E. coli*			
5	USUSA (Light Yellow)	257849 147984		10 -coli			
6	USUSA SPRING	**258083[1]** **147372[1]**		10 + *E. coli*			
7	KENYANY A	253942 145068		10 + *E. coli*			

8	KYENYANYA SPRING	254092[1] 144666[1]		10 + *E. coli*				
9	BUSIGI (Light Yellow)	252524 142802		10 + *E. coli*				
10	BUSIGI SPRING	252752[1] 142487[1]		10 + *E. coli*				
11	KIINA (White)	246304 133757		9 -coli				

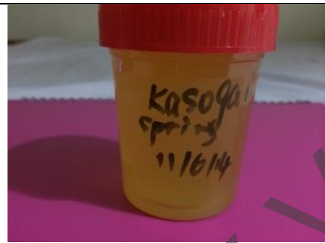
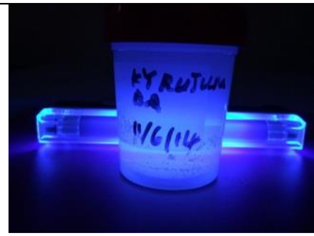
12	GRAVITY FLOW-KIINA	246585(1) 133720(1)		9 + *E. coli*			
13	KACUMDE SPRING	245726(1) 129768(1)		9 + *E. coli*			
14	LAKE-KACUMDE	245333(1) 130246(1)		9 + *E. coli*			
15	LAKE-JETTY			9 + *E. coli*			

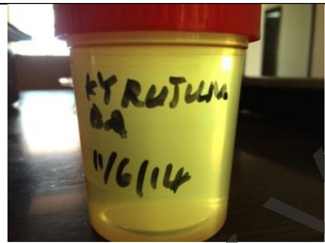
16	LAKE-JETTY DUP			9 + *E. coli*			
17	KYABASAMBU STREAM	**250461(1)** **137197(1)**		13 + *E. coli*			
Along the pipeline							
18	KABALE 1	283358 159091		8			

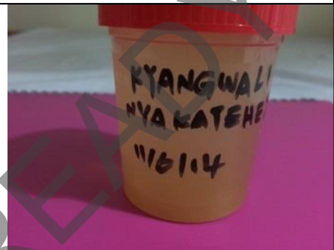
				29 -coli			
19	KABALE 2	282989 156593		8 + *E. coli*			
20	KABALE 3	282372 158165		8 + *E. coli*			
21	KISOBA 1-STREAM (NYANKEREBE)	**276477**[1] **150690**[1]		8 + *E. coli*			

22	KISOBA 2	**277189**[1] **151949**[1]		8 + *E. coli*			
23	KISOBA 3	276408 150977		8			
				19 + *E. coli*			
24	HOHWA	274363 151941		9 + *E. coli*			

25	KABEGAR AMIRE 1	168722 146184		9 + *E. coli*			
				21 + *E. coli*			
26	KYARUSH ESHA	265845 145814		21 + *E. coli*			

27	KASOGA 1-SPRING	**261901**(1) **144509**(1)		11 + *E. coli*			
28	KASOGA 2	261178 141699		11 + *E. coli*			
29	KYARUJU MBA	258094 141404		11 + *E. coli*			

				63(2)			
30	HANGA 2A	253800 139101		11			
				63(2) -coli			
31	HANGA2B	253941 140082		11			

				63[2] + *E. coli*			
32	KYANGWALI – NYAKATEHE I	256443[1] 135999[1]		11 + *E. coli*			

Note :

[1]-- Coordinate for the new sampling location

[2]—incubated in natural temperature after 11hrs' incubation under 35°C

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Africa (Pty) Ltd.
P.O. Box 29391
Maytime, 3624
Block C, Bellevue Campus
5 Bellevue Road
Kloof
Durban, 3610
South Africa
T: [+27] (31) 717 2790

Golder Associates