

## TERMS OF REFERENCE

### GEOPHYSICAL SURVEY IN IKYOGEN AND UKENDE REFUGEE SETTLEMENTS (BENUE AND CROSS RIVER STATES, NIGERIA)

#### 1. BACKGROUND

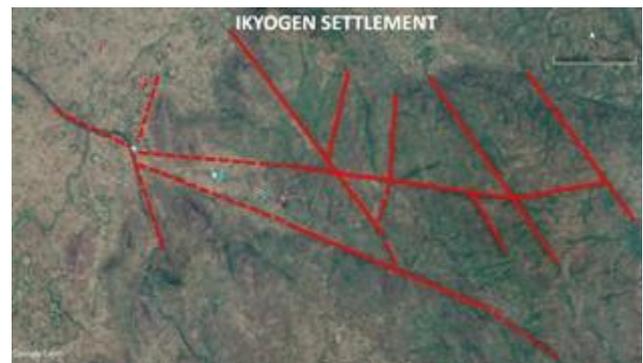
##### IKYOGEN REFUGEE SETTLEMENT

The Ikyogen settlement is located in Benue State and is hosting about 10,000 refugees coming from neighbouring Cameroon. The settlement has been established in 2019 and its water provision essentially rely on the treatment of river water coming from the nearby Amile River. The existing water system requires high operation costs related to the purchase of water treatment products and the operation of fuel feed motor pumps. It also requires to the presence of quite of large technical team in charge of the daily water treatment and distribution procedures. Additionally, several boreholes have been drilled in villages and schools located close to the settlement, but all boreholes show very limited yield (<1 m<sup>3</sup>/h) despite reaching great depths (>100 m). Regarding geology, the settlement area lays in the Precambrian basement complex which is essentially represented by poorly weathered metamorphic rocks. Such hard and sound rock formations explain the low potential for groundwater. However, it is well noticeable that the settlement area is affected by large fractures (Figure 1 and 2) mostly oriented NW-SE and W-E (or WNW-ESE). It is likely than such fractures could represent water-bearing formations particularly when they are in direct contact with perennial rivers or streams and their drainage system. Intersecting fractures could also represent areas of higher underground water potential. Identifying such fractured zones would significantly increase the chance of drilling productive and potentially high-yield boreholes.

*Figure 1. Ikyogen settlement area*



*Figure 2. Ikyogen settlement area with main interpreted fractures*



##### UKENDE SETTLEMENT

The Ukende settlement is located in Cross River State near the town of Ogoja. It is hosting about 4,000 Cameroonian refugees. The settlement has been established in 2019 and its water provision rely exclusively on boreholes equipped with handpumps or small solar systems. However, it seems that the borehole yields are limited ( $<1 \text{ m}^3/\text{h}$ ) despite reaching great depths ( $>100 \text{ m}$ ). Additionally, water quality is highly heterogeneous with electric conductivity ranging from 600 to 2,000  $\mu\text{S}/\text{cm}$ . Hence, many refugees don't drink water coming from the settlement water infrastructures but prefer to purchase it outside. Regarding geology, the settlement area most likely lays in Cretaceous shales representing the edge of the Lower Benue Trough. Such formations are likely to show a low potential for underground water which can also be locally mineralized. Such a situation is not in favour of identifying deep underground water resource, but rather in favour of investing shallower options, which may in direct hydraulic connexion with surface water. The Ukende settlement lays about 500 m to the southern bank of the Aya River. From Google Earth images is likely that the river main channel has changed over the past centuries and millennia forming ancient menders that are well recognizable. Such features are filled by water-bearing interbedded sedimentary deposits, and it is possible that a shallow aquifer may extend into the shale basement where weathering and/or fracturing are locally more important. Identifying river deposits and/or weathered basement areas would significantly increase the chance of drilling productive and potentially high-yield boreholes.

Figure 3. Ikyogen settlement area



Figure 4. Ikyogen settlement area with main interpreted ancient members of the Aya River



## 2. OBJECTIVE OF THE SURVEY

In order to assess the groundwater potential of some potentially fractured zone in Ikyogen settlement and some river deposits and associated weathered basement in Ukende settlement, UNHCR intends to engage the services of a Consultant to carry out a geophysical survey using the Electrical resistivity tomography (ERT) method.

The Consultant will thus realize a total of 9 ERT profiles representing a cumulative length of 3,750 m.

By interpreting the collected data, the Consultant will propose the 5 best drilling options for each settlement (10 drilling options in total) and guide UNHCR in defining its exploratory strategy.

## 3. GEOPHYSICAL SURVEY

## ERT

Electrical resistivity tomography (ERT) is a geophysical method that allows for imaging 2D or 3D variations of electrical resistivity of subsurface geological materials. This resistivity is calculated from the measurement of the potential difference between two electrodes after the injection of a weak electric current (<1A) by another pair of electrodes (quadropole). The tomographic technique consists in varying the position and spacing of a large number of these quadropole electrodes in order to obtain apparent resistivity values corresponding to different positions and depths. Inversion modelling is necessary to obtain a usable image of the apparent resistivity distribution at each measurement point. This processing is carried out using dedicated software.

## IKYOGEN REFUGEE SETTLEMENT

4 ERT profiles will be carried out in Ikyogen. Figure 5 shows the locations of the profiles and Table 1 summarizes their main characteristics.

Figure 5. ERT profiles in Ikyogen

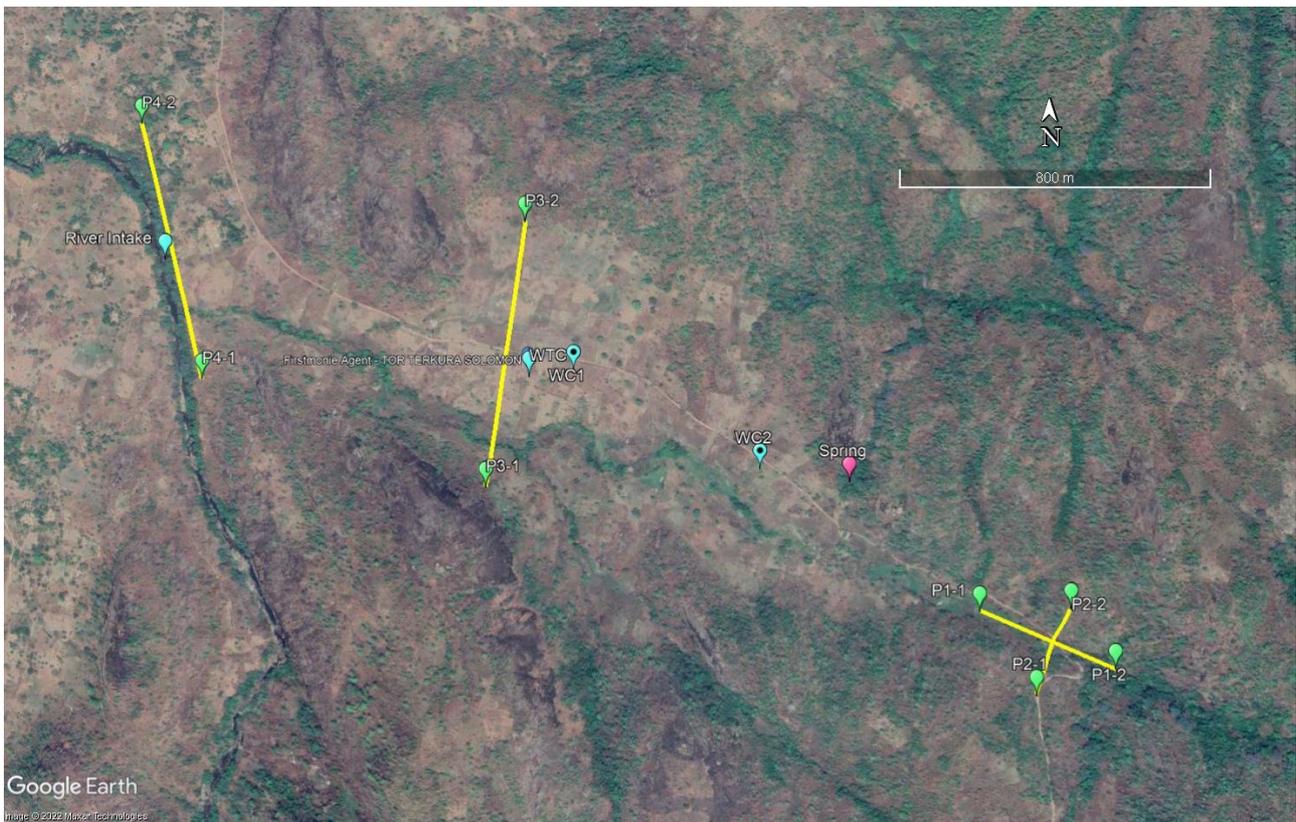


Table 1. Main characteristics of ERT profiles in Ikyogen

Settlement	Profile	Start point		End Point		Profile length	Electrode spacing
		Latitude	Longitude	Latitude	Longitude		
Ikyogen	Profile 1	6.646283°	9.457260°	6.644874°	9.460581°	250 m	5 m
Ikyogen	Profile 2	6.644260°	9.458560°	6.646392°	9.459413°	400 m	5 m
Ikyogen	Profile 3	6.649005°	9.445286°	6.655763°	9.444791°	750 m	5 m
Ikyogen	Profile 4	6.652120°	9.437691°	6.658677°	9.436020°	750 m	5 m
<b>Total</b>						<b>2,150 m</b>	

## UKENDE REFUGEE SETTLEMENT

5 ERT profiles will be carried out in Ukende. Figure 6 shows the locations of the profiles and Table 2 summarizes their main characteristics.

Figure 6. Figure 7. ERT profiles in Ukende

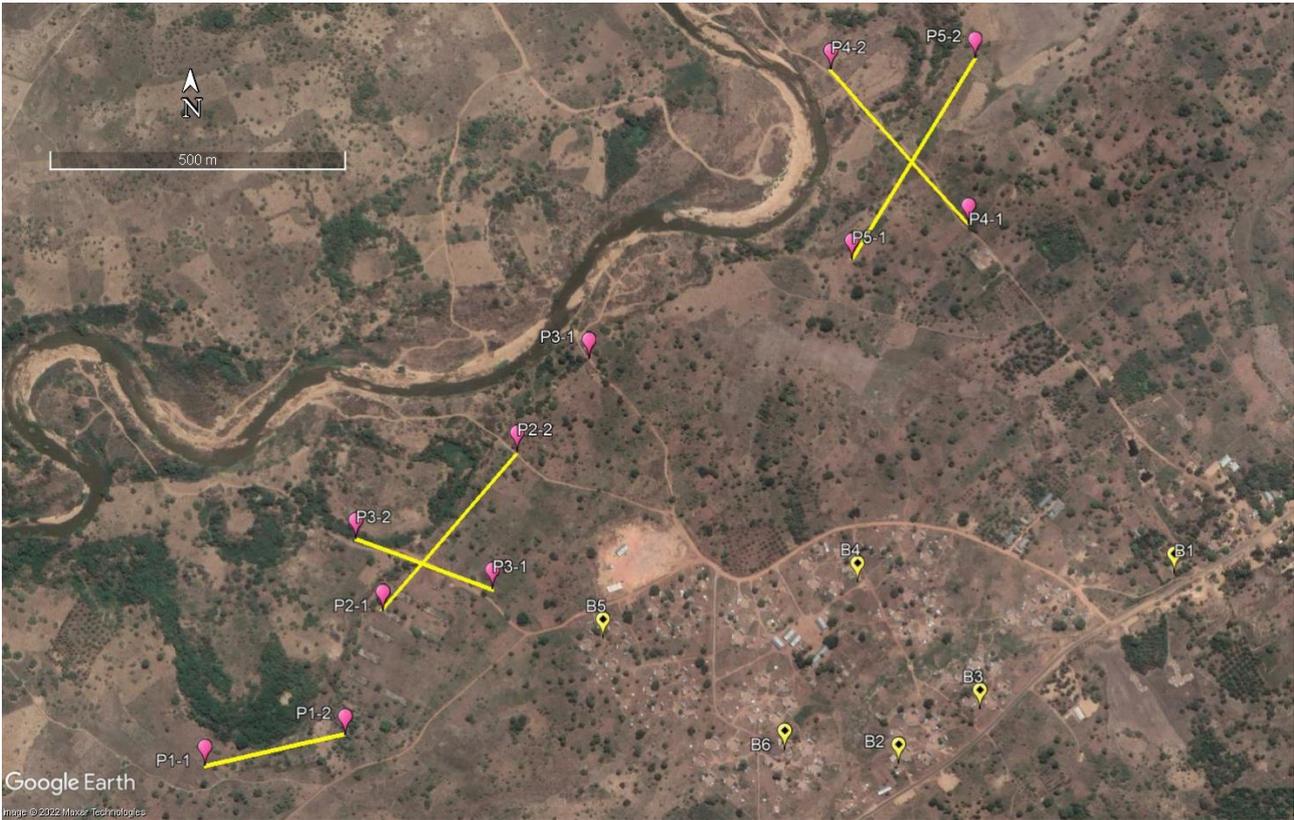


Table 2. Main characteristics of ERT profiles in Ukende

Settlement	Profile	Start point		End Point		Profile length	Electrode spacing
		Latitude	Longitude	Latitude	Longitude		
Ukende	Profile 1	6.616514°	8.748483°	6.616993°	8.750636°	250 m	5 m
Ukende	Profile 2	6.618889°	8.751212°	6.621309°	8.753247°	350 m	5 m
Ukende	Profile 3	6.619227°	8.752880°	6.619973°	8.750781°	250 m	5 m
Ukende	Profile 4	6.624770°	8.760120°	6.627142°	8.758035°	350 m	5 m
Ukende	Profile 5	6.624239°	8.758350°	6.627314°	8.760233°	400 m	5 m
<b>Total</b>						<b>1,600 m</b>	

## 4. TERMS OF REFERENCE FOR THE GEOPHYSICAL (ERT) SURVEY: APPROACH, METHODOLOGY

The geophysical/ERT survey will be carried out in 3 phases:

### **Phase 1: Field visit and exact definition of the profiles' layouts**

A field visit will be made jointly between the contractor and a UNHCR expert in order to determine exactly the routes of the profiles, evaluating the operational feasibility. Once the routes are precisely defined, the coordinates given in Table 1 and 2 are modified accordingly and form the working basis for the contractor.

The contractor will also collect all field (presence of roads, buildings, streams, etc.) and hydrogeological information (electric conductivity, water level, etc.) that could be considered as part of the interpretation (Phase 3).

### **Phase 2: On-site geophysical investigation**

Phase 2 is the actual field investigation, during which the data is acquired using the equipment specified by the contractor in the offer. GPS coordinates (incl. elevation) of all electrodes will also be recorded. The raw data of each profile is shared with the client's on-site expert at the end of each field day, for internal validation by a geophysical expert. In the event that the internal validation demonstrates that the quality of the data is not sufficient due to equipment malfunction or handling to obtain consistent inversion results, the client may require to repeat data acquisition at the contractor's expense.

### **Phase 3: Data inversion and survey reports**

Phase 3 consists of the elaboration of 2 survey reports (one for each settlement) describing field investigation work and methodology, displaying all datasets and interpretation hypothesis and presenting results and related recommendations. The survey reports will indicate the 5 best drilling options in priority order for each location (10 drilling options in total) indicating and justifying borehole sitting coordinates, aquifer targets and proposed drilling depths. The reports will display all inverted and modelled profiles. The reports will also display the same profiles showing the main interpreted figures (contacts and structures) and the best drilling options.

## **5. EQUIPMENT REQUIRED FOR THE SURVEY**

The Consultant shall have available the following equipment and other relevant kits for the survey:

- Hydro (geo) logical equipment
  - 1 EC meter
  - Turbidity meter
  - 1 compass
  - 1 electrical water level dipper: 100 m
  
- Geophysical Equipment:
  - Electric Resistivity Equipment with accessories. The exact specification of the equipment will be specified in the offer
  - Geophysical interpretation software. The exact specification of the equipment will be specified in the offer
  - Any other equipment proposed by the consultant relevant to carry out the survey. The exact specification of the equipment will be specified in the offer
  
- Field Office Equipment:
  - Notebook computers
  - Global Positioning System (GPS) devices
  - Drawing and tracing equipment/computer
  - Digital Cameras

## **6. PROPOSED TIME/ACTIVITY SCHEDULE**

Due to the nature of the proposed work, the geophysical survey field mission is expected to take a maximum of 14 consecutive days including 1 reconnaissance day (phase 1) for each location and 1 transfer day between the 2 locations. Geophysics should take between 3 to 5 days at each location depending on the contractor skills. The draft reports should be submitted within 20 consecutive days after completion of the field work (phase 2). The final reports should be submitted within 7 consecutive days after receiving the client's comments.

The consultant should draw in the offer a detailed time/activity schedule.

## 7. RESPONSIBILITIES

### UNHCR

For the execution of the survey, UNHCR shall ensure that the local authorities are informed of this survey and to obtain all the required authorisations. UNHCR shall inform and update the consultant on the security situation, or changes therein. UNHCR shall also make available the following information and facilities to the consultant:

- Full guidance and supervision during all field work.
- Counterpart staff for necessary support in the field.
- Timely feedback on the submitted survey reports so that, consultant could be finalizing the reports.

### The consultant

- Prepare and deliver consultancy services as per the TOR
- Deliver the key deliverables in time; submit a final report duly approved by UNHCR after full incorporation of views and editions from the client.
- The consultant and its team will make their own arrangements on transport, security, accommodation, and meals during the duration of the assignment.

## 8. KEY DELIVERABLES

- 2 distinct survey reports for each settlement. The consultant will be expected to deliver 3 hard copies of each of the final approved version of the reports. The survey reports will indicate the 5 best drilling options in priority order for each location (10 drilling options in total) indicating and justifying borehole sitting coordinates, aquifer targets and proposed drilling depths. The reports will display all inverted and modelled profiles. The reports will also display the same profiles showing the main interpreted figures (contacts and structures) and the best drilling options.
- A pdf copy on e-mail of the final reports and 2 USB keys with the final reports in word and pdf formats including all Appendices and raw data in accessible (i.e. Excel) formats. Appendices will include GPS coordinates of each electrodes, photos and any relevant information and maps.
- The consultant will also be required to deliver to UNHCR all study materials:
  - Soft copies of all datasets
  - Geophysical interpretation models and graphical plots
  - Any other non-consumable documents/items that will be used in the course of the planned consultancy.

## 9. PRINCIPAL GEOPHYSICIST REQUIREMENTS (QUALIFICATIONS AND EXPERIENCE)



**UNHCR**

United Nations High Commissioner for Refugees  
Haut Commissariat des Nations Unies pour les réfugiés

- A PhD or at least a Master or postgraduate degree in Hydrogeology/Geology/Geophysics
- At least 10 years proven experience in conducting and interpreting hydrogeological/geophysical survey using techniques described in this TOR
- A reliable and effective analyst with extensive experience in conducting analyses and a proven record of delivering professional results
- Excellent computer skills in geophysical interpretation software
- Excellent presentation and report writing skills.

## 10. CONTACTS, COMMUNICATION AND SUPERVISION

The consultant will be under the direct supervision of the UNHCR technical team based in Ogoja Office for the duration of the contract. The consultant will maintain official communication with the UNHCR supply unit.